Reading Skills in Mental Illness:
A Multimodal Analysis

A Thesis Submitted for the Degree of Doctor of Philosophy

by

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Abstract

Reading is a complex process involving multiple skills – i.e., phonological processing, comprehension, and word recognition. It is also a significant predictor of socio-economic status, academic achievement, and has vast importance in everyday functioning. Reading deficits can lead to maladaptive behaviour and consequently increase the risk of incarceration. Severe reading skills deficits are present in schizophrenia, and to some extent in people with psychopathy and forensic populations (Chapter 2 – systematic review and meta-analysis). Considering the overlap between discreet clinical diagnoses and the presence of symptoms and psychopathology-related traits in non-clinical populations, this thesis aimed to examine the behavioural and neurofunctional associations between reading skills and dimensional psychopathology-related traits in the general and clinical populations.

To address these aims, three empirical investigations were carried out: i) behavioural studies (Chapters 4 and 5) investigating the relationship between reading-related skills, as indexed by performance on a lexical decision task (LDT) requiring word-nonword recognition, and a range of psychopathology-related traits (schizotypy, psychopathy, impulsivity, and affective traits) in a general population sample (N = 78), ii) a functional magnetic resonance imaging (fMRI) study (Chapter 6) investigating the neural correlates of this relationship (N = 22), and iii) a preliminary clinical study (Chapter 7) investigating the relationship between reading skills of phonological processing and comprehension, dimensional psychopathology, and cognition (verbal learning and memory, IQ, and executive functioning) in a forensic psychiatric sample (N = 15).

The findings suggest that traits of positive schizotypy (Unusual Experiences), fearless dominance (Meanness) and callous aggression (Boldness) in psychopathy, and motor impulsivity can modulate behavioural responses in word-nonword recognition (LDT performance) in the general population. Higher motor impulsivity was the trait most strongly associated with lower LDT performance accuracy in non-native speakers. At the neural level also, motor impulsivity was most consistently associated with lower activity in some of the brain areas that are crucial for word recognition, namely the fusiform and inferior frontal gyri (IFG). In the forensic psychiatric sample, 13/15 patients were diagnosed with a psychotic disorder and all reading skills were significantly below their age norms and showed some association with executive function and verbal learning. In this sample, Lifestyle psychopathy was significantly associated with poor LDT performance, especially in low-frequency words recognition and Cognitive Perceptual aspect of positive schizotypy with severe deficits in reading comprehension, overall reading ability, and poor low-frequency word recognition.

In conclusion, positive schizotypy and psychosis seem to be associated with poor reading skills. Higher psychopathy and motor impulsivity traits seem to predict of poor reading skills across the general and clinical populations and modulate neural activity during correct word-nonword recognition. These findings provide insight into the relationship between dimensional psychopathology-related traits, their comorbidities, and reading skills in clinical and non-clinical populations, and suggest that poor reading skills in clinical populations should be considered as important treatment targets.

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Thank you all very much again, and I am looking forward to what lies ahead. Although one race may be over, other exciting challenges are awaiting.

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List of Abbreviations

ADHD	Attention Deficit/Hyperactivity Disorder
ANOVA	Analysis of Variance
ASPD	Antisocial Personality Disorder
BA	Brodmann Area
BADS	Behavioural Assessment of the Dysexecutive Syndrome
BDAE	Boston Diagnostic Aphasia Examination
BIS-11	Barratt Impulsiveness Scale
BPD	Borderline Personality Disorder
BPQ	Borderline Personality Questionnaire
CI	Confidence Interval
COVID	Coronavirus Disease
CTOPP	Comprehensive Test of Phonological Processing
DASS-21	Depression, Anxiety and Stress Scale
DRC	Dual Route Cascaded
DSM	Diagnostic and Statistical Manual of Mental Disorders
DSST	Digit Symbol Substitution Test
EEG	Electro-Encephalography
FA	False Alarm
fMRI	Functional Magnetic Resonance Imaging
FWE	Family-Wise Error
FWHM	Full Width at a Half-Maximum
GAD-7	Generalised Anxiety Disorder Assessment
GNG	Go/No-Go
GORT	Gray Oral Reading Test
HC	Healthy Controls
HVLT-R	Hopkins Verbal Learning Test-Revised
ICD	International Classification of Diseases
IFG	Inferior Frontal Gyrus
IRAS	Integrated Research Application System
ITBS	Iowa Test of Basic Skills
ITED	Iowa Test of Educational Development
JDT	Jacobson's Decoding Test
LDT	Lexical Decision Task
LNNB	Luria-Nebraska Neuropsychological Battery

LNST	Letter Number Span Task188
M	Mean
MI	Mental Illness
MMPI-STY	Minnesota Multiphasic Personality Inventory – Schizotypal Disorder Scale
MNI	Montreal Neurological Institute (space)
ms	Milliseconds
MST	Madison's Spelling Test
MSVT	Madison's Standardized, Vocabulary Test
MWDT	Madison's Word Decoding Test
N/n	Number
NARA	Neale Analysis of Reading Ability
NART	National Adult Reading Test
NDRT	Nelson–Denny Reading Test
O-LIFE	Oxford-Liverpool Inventory of Feelings and Experiences
PALPA	Psycholinguistic Assessments of Language Processing in Aphasia
PANSS	Positive and Negative Syndrome Scale
PCL-R	Psychopathy Checklist - Revised
PD	Personality Disorder
PFC	Prefrontal Cortex
PHQ	Patient Health Questionnaire for Depression
PIAT	Peabody Individual Achievement Test
RAN	Rapid Automatised Naming
RCBA	Reading Comprehension Battery for Aphasia
REALM	Rapid Estimate of Adult Literacy in Medicine
RNRT	Roentgen's Nonwords Reading Test
RNST	Roeltgen's Nonwords Spelling Test
RT	Reaction Time
S-UPPS-P	Urgency, Premeditation, Perseverance, Sensation Seeking, Positive Urgency, Impulsive Behavior Scale
SD	Standard Deviation
SPM	Statistical Parametric Mapping
SPQ-BR	Schizotypal Personality Questionnaire - Brief
SPSS	Statistical Package for the Social Sciences
SRP-4-SF	Self-Report Psychopathy Scale-Short Form
SST	Stop-Signal Task
STG	Superior Temporal Gyrus

SVR	Simple View Reading
SZ	Schizophrenia
SZAD	Schizoaffective Disorder
TE	Time to Echo
TMT	Trial Making Test
TOPF	Test of Premorbid Functioning
TOWRE	Test of Word Reading Efficiency
TR	Repetition Time
TriPM	Triarchic Psychopathy Measure
WASI-II	Wechsler Abbreviated Scale of Intelligence–Second Edition
WJTA-III	Woodcock-Johnson III Tests of Achievement
WRAT	Wide Range Achievement Test
WRMT-R	Woodcock Reading Mastery Test-Revised

Chapter 1: Reading Skills: Classification, Assessment, and Importance

1.1. Chapter Aims and Overview

Reading is vitally important for proper everyday functioning, academic and socio-economic achievement (L. Hemphill & Tivnan, 2008). It is not a standalone ability but a process that requires several specific skills and has a close relationship with other cognitive abilities, including memory, speech, and executive processing (G. Cohen, 1972). Reading deficits are found in certain psychopathological groups (Sundheim & Voeller, 2004; Whitford et al., 2018) and have a range of negative outcomes (Maughan, 1995). This chapter aims to introduce the core reading terminology, explain reading as a process with its specific skills, summarise the methods of assessment, describe the synergy with other cognitive abilities, and highlight the importance of good reading skills.

1.2. Reading Skills Taxonomy and Mechanisms

Reading can be defined as a cognitive process of decoding written symbols into verbal information. During reading, individuals extract the meaning from linguistic symbols which covers various actions (or skills) substantially different from each other (G. Cohen, 1972). The most important taxonomic terms often used in the literature on reading skills to understand the key concepts are summarised below in Table 1.1.

Table 1.1. Glossary of reading-related terms.

Discourse	Written (or spoken) communication about a certain topic.
Dyslexia	Learning disability mostly affecting reading. Results in impairment of various reading skills, most frequently in phonology, decoding, spelling.
Lexical	Related to word(s).
Mental lexicon	"Word storage" or a mental vocabulary that includes all the words stored and organised in an individual's memory.
Nonword	A non-existent string of letters or syllables; sometimes can resemble words.
Phoneme	A sound unit that can correspond to one or more letters.
Phonology	System of sounds. In reading, it is related to pronunciation.
Semantics	Related to meaning. System studying the meaning of written information.
Syntax	A sentence structure determined by syntactic rules. Influences the order of words and the sentence meaning.

Word frequency	An indicator of how often a word is used in language and communication expressed by the number of occurrences per million. High-frequency words are most commonly used and are more familiar. Low-frequency words are less used, can be specific to a certain jargon, and can be less familiar.

1.3. Classification of Reading Skills

To understand reading, we need to examine all its components and their interactions. Reading is a complex process that requires the implementation of various skills simultaneously. To begin with, reading requires recognition of the visual information necessary to extract the information from the text (Aghababian & Nazir, 2000). This requires the knowledge of letters and the writing system of the language (orthography).

The core reading skill is phonological processing which involves the recognition of the sound structure of the language, the decoding of written symbols into sounds, and then their maintenance in working memory (Wagner & Torgesen, 1987). Phonological processing is the ability to manipulate sounds, for example, repeating syllables, words, or nonwords, separating certain parts of words, or putting word parts/syllables together. It embodies three subprocesses: i) phonological awareness – the ability to recognise sounds and sound structure of particular language, ii) phonological decoding in lexical (word) access – the ability to connect a symbol(s) with an adequate sound and to recognise familiar written letters or strings (is vital for word-nonword identification), and iii) phonological memory – phonetic decoding in working memory, the ability to remember and combine sounds to form a word (Wagner & Torgesen, 1987). Knowledge of the phonological aspect of language and the ability to manipulate phonological information (processing) facilitates the decoding of the written information. Decoding is the process when a letter or a group of letters is assigned to a particular sound and/or word. It leads to word identification and subsequent extraction of its meaning (Pollatsek et al., 2000). Therefore, phonological processing is the core reading skill because it leads to word identification. Thus a failure to read each word correctly later leads to problems with comprehension (Perfetti, 2001). This means that errors with phonological processing lead to difficulties with comprehension, as comprehension involves the processing of individual letters and words, and then putting them together to form meaning (C. H. Judd & Gray, 1918).

There are also other factors/skills which contribute to the reading process – rate (number of words pronounced per minute), and accuracy (number of mistakes/correctly read words) while both contribute to reading fluency (the ability to read at proper speed with corresponding accuracy and expression). Good fluency is also important for the comprehension of written text. A fluent reader has to accurately identify each word and pronounce it correctly with appropriate cadence and tone as this puts less demand on working memory (Hudson et al., 2005). If a reader inaccurately pronounces a word this might affect its meaning, or if they spend too much time on a single word this can lead to misinterpretations of the text as the previously read text or its parts can be forgotten, or the meaning can be alternated due to working memory lapses. Furthermore, the comprehension of sentences or larger blocks of text requires more than just the extraction of the meaning of each word. In addition to the mechanisms behind the single-word reading described above, sentence reading and comprehension require knowledge of grammar (which involves the rules for pronunciation, spelling and sentence composition) and also are more demanding for short-term memory (Caplan, 2015). Apart from that, sentence comprehension is also influenced by factors like sentence structure (the order and position of words), the frequency of certain word combinations, and the sentence context (Clifton, 2001). Context is a combination of general information of text features such as discourse, syntax, and structure of words and sentences, and also the background knowledge (Nation & Coady, 1988).

In sum, reading includes several core processes – phonological processing and decoding, single-word reading, comprehension, rate, accuracy, and fluency, but is also dependent on other knowledge and skills (e.g., context, orthography, grammar). Therefore, it is important to understand the impact of other reading-related skills and factors which help to determine a good reading.

1.4. Reading-Related Skills

Successful reading requires appropriate knowledge of other reading-related skills: i) orthography/spelling, ii) vocabulary, and iii) grammar to support the reading processes mentioned earlier. Orthography is the knowledge of letters, their meaning, and the writing system in general and spelling is the ability to use the orthographic knowledge appropriately during reading. Orthography itself is one of the first skills people acquire when learning to read and the early orthography-phonology integration is crucial in making reading automatic (Kaefer, 2016). Orthographic patterns are specific to different languages and essential to learn from early on. They represent existent and used letter combinations in a certain language, and can also represent various functions (e.g. prefix, suffix). Orthographical knowledge and phonological processing are two mechanisms that constantly interact during reading. Familiar orthographic patterns lead to automatic word identification whereas unfamiliar orthographic representations lead to decoding of an unknown word (Perfetti, 2001). Therefore, a good knowledge of orthographic patterns or combinations and appropriate use of this skill can significantly positively influence word recognition, leading to better text reading fluency and higher reading speed (Barker et al., 1992).

Vocabulary is the knowledge of words, their meanings, and how we use them in a particular language. It is essential for reading, especially at the early stages, and is closely related to comprehension and context in a bidirectional connection (Perfetti et al., 2010). New readers rely on their vocabulary knowledge to understand the text while the text they read helps them to build their vocabulary (Hsueh-Chao & Nation, 2000). Vocabulary also helps to create background knowledge about the text (context) and make predictions on the type of words that can appear further on within the text (Nation & Coady, 1988). Decoding also has a significant influence on vocabulary. Firstly, readers learn how to read by decoding letters and syllables and put them together to form words. This helps to build their knowledge of different word parts as prefixes and suffixes and their roles in changing word meaning. Readers with poor decoding skills tend to have also poorer vocabulary as although they are able to recognise certain words automatically (e.g. *add*), they may struggle to identify words that are not in their vocabulary yet, but are derived from a familiar word (e.g. *adding*) (T. G. White et al., 1990). This means that good decoding skills help with the acquisition of new words for the vocabulary, which makes the process of word recognition faster and automatic and eventually leads to more accurate and faster reading.

There is no doubt that the knowledge of individual words is especially important for good reading comprehension. However, the knowledge of the grammatical rules and how the words are combined to form sentences is crucial to be able to determine the context (O'Donnell, 1962). Grammar is the set of rules that determine the order of words in a sentence and the way these can be combined. The knowledge of grammar is useful in understanding ambiguities in word meanings by determining the place and function of these ambiguous words within the sentence and their function in the grammatical structure (Weber, 1968). One of the important elements of grammar is syntactic knowledge, which is the rules of sentence structure and word order. Together with vocabulary, it has an influential impact on the overall comprehension of a text. Syntax and vocabulary constantly work together in a synergic way during reading, and both are considered significant predictors of reading comprehension (Mokhtari & Niederhauser, 2012).

This being said, good orthography skills and appropriate knowledge of vocabulary significantly contribute to the overall reading process mostly by facilitating the word recognition process which improves comprehension, reading speed and fluency. The knowledge of grammatical rules and structures is important for determining the context and meanings of particular words. However, it is also important to acknowledge that neither of these skills operates as an isolated process; rather these skills co-operate and influence the reading outcome together in a reciprocal way. This indicates that reading as an outcome is dependent on the proper functioning of all its specific skills and can be easily negatively influenced by any disruption in any of these skills.

As a process consisting of the various skills mentioned above, reading does not occur as a linear sequence of these skills, but rather as cooperation within a complex mechanism that has its own structure and sequence. The mechanism of operation of the various reading skills and other processes involved can be described by various theoretical models.

1.4.1. Models of Reading – from Letters to Words to Comprehension

Currently, there is no single theory or an integrative model of reading which could explain reading as a complex process with all of its components. Several different theories are explaining the involvement of the different aspects and processes of reading and their interactions.

One of the first models of reading was the Simple View of Reading (SVR) model, proposed by Gough and Tunmer in 1986, which described successful reading as a result of two components: decoding and comprehension (Gough & Tunmer, 1986). The decoding component is determined by knowledge of the letter-sound structure of the language and enables the transformation of letters into sounds. This knowledge facilitates the recognition of words but also the ability to pronounce and recognise nonwords. Consequently, for one to be successful in reading, comprehension of the lexical information comprised of words and sentences is necessary. However, this theory is not a comprehensive model of reading as decoding and comprehension can be further broken down into other components (memory of words, knowledge of sentence structure – syntax, and the ability to understand the context) (Tunmer & Chapman, 2012).

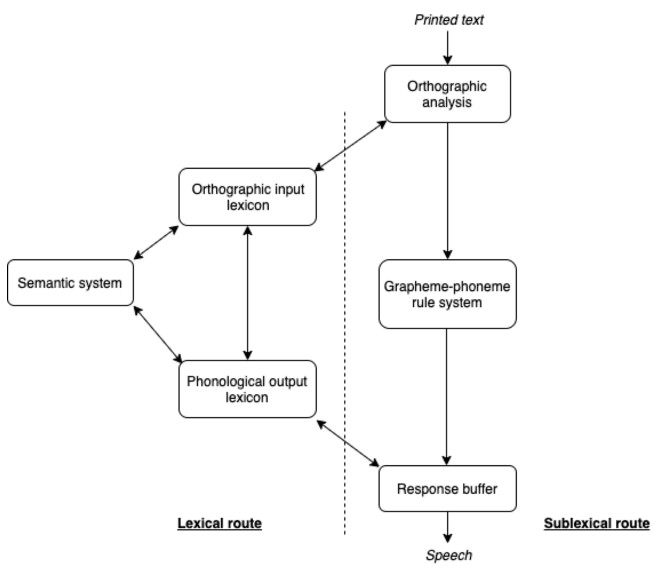
More recently, several models have been proposed explaining the different stages of reading as a process. These could be categorised as: i) word recognition models (Dual Route Cascaded – DRC model, Triangle model are the most influential), ii) sentence-level processing models (Garden-path vs Constraint models), and iii) models of text comprehension (Rayner & Reichle, 2010).

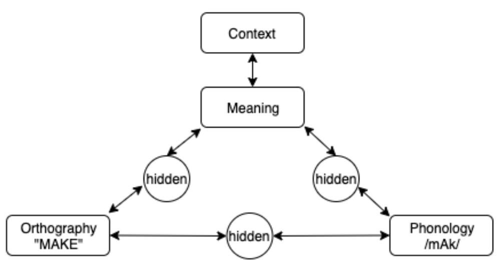
1.4.1.1. Word Recognition Models

In both, the DRC and the Triangle models, word recognition occurs when information from the phonological (letters are translated into sounds) and semantic (word meaning) systems are linked (James & Oberle, 2012). The DRC (Coltheart et al., 2001) is the most recognised word recognition model where the individual words are represented as separate instances (Norris, 2013). The model proposes the existence of two routes that mediate word recognition and reading: lexical and sublexical. In the lexical route, the word is recognised as a whole which triggers its mental representation and this automatically activates the correct pronunciation, whereas the sublexical route generates the pronunciation by following the letter-sound decoding, where each letter or group of letters are recognised and represent a specific sound(s) which are later combined to form the word (Balota & Yap, 2006; Coltheart et al., 2001). According to this model, high-frequency words are pronounced following the lexical route whereas low-frequency words follow the sublexical route (Balota & Yap, 2006; Coltheart et al., 2001).

In contrast to the DRC, in the Triangle connectionist model (Seidenberg & McClelland, 1989), different words are represented as an activation of the separate letters (Norris, 2013). The so-called "hidden layers" in this model represent information acquired by learning from experience which mediates and facilitates the process between two representations (Rueckl, 2010). According to this model, the reader learns how to associate the different letters and their combinations with sounds. This also permits the reading of nonwords (Seidenberg, 1995), the strings without a lexical representation in memory. This is the main characteristic that differentiates the Triangle model from the DRC. The DRC model does not explain nonwords reading as, in this model, the sublexical route always leads to the pronunciation of a real word and its recognition in the mental lexicon. However, both models illustrate the process of word recognition which is crucial for reading and can be evaluated by standardised tests or experimentally with a lexical decision task (LDT) (Figure 1.1.).

Figure 1.1. The DRC (Coltheart et al., 2001; diagram on the left) and the Triangle (Seidenberg & McClelland, 1989; on the right) models of word recognition. A side-by-side comparison.





1.4.1.2. Sentence-Level Processing Models

Models investigating comprehension of sentences focus on two main processes: syntactic parsing and ambiguity resolution. Syntactic parsing can be defined as a process of analysing the structure of a sentence. During this process, the reader identifies the elements of a sentence which eventually once put together form the meaning of the sentence. Syntactic parsing contributes to ambiguity resolution. This means that a sentence can have more than one meaning until all its components are correctly identified. There are two main types of syntactic parsing models: "*Garden-path*" and "*Constraint*" models.

The Garden-path model was proposed and described by Frazier (Frazier, 1987). This model posits that the reader, initially, works with only one syntactic structure or explanation and this structure is revised once all the other components in the sentence are identified (word meanings and their frequencies, whole sentence structure). If the information from other components is not following the initial syntactic structure, the reader adopts a new syntactic structure to resolve the sentence ambiguity (Van Gompel & Pickering, 2012). In other words, once the reader reads the whole sentence and identifies all word meanings and their positions, functions, and frequencies, this information is put together with the initial assumption on the syntactic structure. If the components do not fit the initial assumption, then the reader has to adopt a new explanation of the sentence meaning. According to this model, the reason why the reader does not take into account all the sentence components and initial syntactic structure all at once is that these components are too complex and this could take too much time to implement from the start (MacDonald & Sussman, 2009).

A different approach in sentence processing is offered by Constraint models. In this type of models, all sentence components are analysed simultaneously and the syntactic component does not have priority over other components as it is in the Garden-path model (Rayner & Reichle, 2010). These models assume that various versions of the syntactic structure exist at the same time and when more components are identified during reading these support either alternative (Van Gompel & Pickering, 2012) Therefore, this process is parallel rather than serial. This is in contrast with the Garden-path model which operates serially as a sequence of components. It means that syntactic parsing is alternated with the analysis of meaning or context (Tanenhaus & Trueswell, 1995). This group of models was actualised throughout the time to determine the best prediction model for reading speed while accounting for syntactic and semantic ambiguities, and violations to grammatic rules (Tabor & Tanenhaus, 1999). This suggests that reading speed could be a good (theoretical) indicator of impaired sentence processing and comprehension.

1.4.1.3. Text Comprehension Models

The models of text comprehension work on the bottom-up principle. The overall text meaning is constructed over time from smaller components – word identification and sentence processing, and are not contrasting as it is in the previously mentioned models (Rayner & Reichle, 2010). This means that the reader to be able to understand the discourse has to process all the partial components of the text. One of the most influential models, a construction-integration model by Kintsch & van Dijk, assumes that discourse comprehension is a result of micro and macro processes and is limited by working memory (Kintsch & van Dijk, 1978). In the model, the microstructure represents the individual words, phrases and sentences and their individual meanings whereas the macrostructure represents the overall discourse. Following the bottom-up principle, the reader first identifies all individual components with their meanings and syntactic organisation and creates a basic assumption on the content. Later, as the reading of the text continues, these assumptions are either supported or not by following statements and clarify the ambiguities in text comprehension (Kintsch & van Dijk, 1978; Rayner & Reichle, 2010). In other words, if any of the components is ambiguous (e.g., in a sentence it is not clear who is the executor of action) it can be clarified from the context of the following sentences. The reader extracts important information about the meaning, stores it in their working memory, and updates this meaning as the reading continues.

The above-mentioned models of reading illustrate the main processes that take place on the way of reading and integrate the previously described reading skills. These models show how complex the process of reading truly is. Therefore, in deficient reading, to be able to identify the core of the problem, it is necessary to use methods developed to assess each reading skill separately.

1.5. Standardised Reading Skills Assessments

The reading skills have been assessed in several healthy and clinical adult samples using a range of standardised tests (detailed in Table 1.2.). Some tests are specific assessments of one single reading skill whereas others work as complex batteries with various subtests with each assessing a particular skill. This section presents an overview of major reading skills assessments previously used in various MIs.

Tests of phonological processing assess the ability to manipulate sounds and, therefore, they usually require the repetition of sounds, for example by putting sounds together or reading nonwords. Decoding normally includes recognising words from a chain of characters and requires marking the space between them (e.g. doyouseethedogg), as it is in the Word-chains test (Jacobson, 2001). The Comprehensive

Test of Phonological Processing (CTOPP) (Wagner et al., 1999) is a widely used complex battery specific to assess phonological aspects of reading. It consists of several subtests that focus on different components of phonological processing – i) phonological awareness (e.g. put separate sounds together to form a word: pen – cil; or find a word which rhymes with another word), ii) phonological memory (e.g. repeat nonwords or numbers), both for words and nonwords, and iii) rapid naming skills – the ability to quickly read familiar items (i.e. numbers, letters, colours, or objects) which reflect on executive functions, processing speed and the ability to access phonological units (da Silva et al., 2020). Rapid naming skills can directly impact reading speed and together with phonological awareness are strong indicators of overall reading achievement (literacy) (Vander Stappen & Reybroeck, 2018). The Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) (Castro et al., 2007) is another complex reading battery that includes subtests to assess phonology: nonword judgements and phonological segmentation – when each sound (phoneme) in a word/nonword is pronounced separately. In this battery, phonological processing is assessed for verbally presented words, written words, and pseudowords (a type of nonwords).

Table 1.2. Tests and measures frequently used in reading skills assessments in adults with or without MIs.

Measures (test - subtest name)	Measure description
	PHONOLOGICAL PROCESSING AND DECODING
Auditory Blending Test (Walder et al., 2006)	*Pronounce sounds separately and put them together to form a word.*
CTOPP-PA (Wagner et al., 1999)	*Manipulate with sounds, distinguish, pronounce, and synthesize sounds to create words.*
CTOPP-PM (Wagner et al., 1999)	*Remember and reproduce digits and pronounce nonwords.*
CTOPP-RN (Wagner et al., 1999)	*Name objects and colours as quickly as possible.*
CTOPP-APA (Wagner et al., 1999)	*Manipulate with sounds, distinguish, pronounce and synthesize sounds to create nonwords.*
CTOPP-ARN (Wagner et al., 1999)	*Name letters and numbers as quickly as possible.*
JDT (Word-chains) (Jacobson, 2001)	*Decode words from a group of letters and mark a space between them (e.g. girl/chair/meet).*
MWDT (Madison, 2001)	*Read specific words.*
PALPA (Castro et al., 2007)	*Make nonword judgements or segment words/nonwords.*
Phonological Choice (Olofsson, 1994)	*Decide which nonword in a pair sounds like a real word.*
RAN (Katz et al., 1992)	*Name the letters, numbers, colours, or pictures presented on cards.*
RNRT, RNST (Roeltgen, 1992)	*Read or spell a list of nonwords and identify words read to the subject each syllable separately.*
The Pidgeon (Lundberg & Wolff, 2003)	*Five tasks: Self-reported dyslexic problems, Working memory, Vocabulary, Reversed spoonerism, Phonological choice and Orthographic choice.*
WJTA-III (Mather & Wendling, 2010)	*Read or spell a list of nonwords.*
WRMT-R (Word attack) (Woodcock, 1998)	*Read as many nonwords as possible in one minute.*
	COMPREHENSION
BDAE (Goodglass & Kaplan, 1972)	*Answer questions (multiple-choice) about a text.*
GORT-4 (Wiederholt & Bryant, 2001)	*Respond to questions about the block of text read.*
ITBS (Hoover et al., 1996), ITED (Forsyth et al., 2001)	*Comprehension of fiction and non-fiction text.*
Israeli language skills test (Gal, 1986)	*Comprehension of ideas presented in a block of text of increasing difficulty.*

NARA-III (Neale, 1999)	*Respond to open questions about the block of text read.*
NDRT (Brown et al., 1993)	*Respond to questions about the block of text read.*
PIAT (Dunn & Markwardt, 1970)	*Use pictures to describe the meaning of a sentence.*
PALPA	*Choose a picture that fits the meaning of a sentence or a word.*
RAN	*Reproduce letters and digits.*
RCBA (LaPointe & Horner, 1979), RCBA-2 (LaPointe & Horner, 1998)	*Ten subscales (I-X). Answer questions (multiple-choice, silent reading) about single words, sentences, paragraphs, functional information, synonyms.*
"Summer with Monika" (Madison, 1993)	*"Fill in the blank" response about a text.*
"The Hedgehog" (Madison, 1985)	*Underline a salient word in a text.*
WJTA-III	*"Fill in the blank" response about a text.*
WRAT-IV (Wilkinson & Robertson, 2006)	*Complete a sentence with an appropriate word.*
WRMT-R	*Text passages followed by a blank line to orally fill in a word that fits the passage.*
Paragraph reading (Disimoni et al., 1973)	*Answer questions (Yes/No, and multiple choice) about a block of text.*
SINGLE-WORD READING	
LNNB (A. L. Christensen, 1975)	*A comprehensive battery assesses various neuropsychological functions, including reading.*
MWDT	*Read specific words out loud.*
PALPA	*Read letters, syllables, words and sentences out loud.*
PIAT	*Read individual words out loud.*
REALM (Davis et al., 1991)	*Pronounce words commonly used in medicine. A scale from 3rd grade and up to secondary school reading.*
TOWRE (Torgesen et al., 1999)	*Read individual words out loud.*
WJTA-III	*Read individual words out loud.*
WRAT (Jastak & Jastak, 1978)	*Read individual words out loud.*
WRMT-R	*Read individual words/nonwords out loud.*
RATE	
Alouette	*Total number of words correctly read.*
GORT-4	*Time taken to read a block of text.*
NARA-III	*Number of words read per minute.*
NDRT	*Number of words read in the first minute.*

	SPEED
Alouette (Lefavrais, 2006)	*Overall reading time (max. 180s.).*
"Summer with Monika"	*Overall reading time of the text.*
"The Hedgehog"	*Overall reading time of the text.*
RCBA-2	*Overall completion time of 10 tasks.*
	ACCURACY
Alouette	*Number of words correctly read in 180s. limit.*
GORT-4	*Number of correctly/incorrectly read words.*
NARA-III	*Number of errors made when reading a block of text.*
	FLUENCY
GORT-4	*Sum of rate and accuracy scores.*
"Arthur the Young Rat" (Halpern et al., 1989)	
"Grandfather" (Halpern et al., 1989)	
BDAE	*Number of non-fluencies in the reading of a text (i.e., repetitions of a sound, syllable, word or phrase).*
Fisher-Logermann (Fisher & Logemann, 1971)	
WJTA-III	*Time taken to read a block of text followed by questions.*
	VOCABULARY
ITBS, ITED	*Select a word or phrase synonymous with the target word.*
NDRT	*Answer multiple-choice questions about words.*
MSVT (Madison, 1985)	*Find word's synonym among five options.*
	SPELLING
ITBS, ITED	*Spelling of real word by writing.*
MST (Madison, 1985)	*Spelling of real word by writing.*
Orthographic Choice (Olofsson, 1994)	*Decide which of the two words presented is correctly spelt.*
WJTA-III	*Spelling of real words out loud or by writing.*
	GRAMMAR
Caplan and Hildebrandt (Caplan & Hildebrandt, 1992)	*Identify the subject and object of the actions of phrases.*

ORTHOGRAPHY	
Pseudo-homophone Discrimination, Animal Word Cross-out Test, Onset Judgement Test (Zou et al., 2012)	*Mark particular words/nonwords within a time limit.*

Note: BDAE - Boston Diagnostic Aphasia Examination, CTOPP - Comprehensive Test of Phonological Processing (PA - Phonological Awareness, PM - Phonological Memory, RN - Rapid Naming, APA - Alternative Phonological Awareness, ARN - Alternative Rapid Naming), GORT - Gray Oral Reading Test, ITBS - Iowa Test of Basic Skills, ITED - Iowa Test of Educational Development, JDT - Jacobson's Decoding Test, LNNB - Luria-Nebraska Neuropsychological Battery, MST - Madison's Spelling Test, MSVT - Madison's Standardized, Vocabulary Test, MWDT - Madison's Word Decoding Test, NARA - Neale Analysis of Reading Ability, NDRT - Nelson–Denny Reading Test, PALPA - Psycholinguistic Assessments of Language Processing in Aphasia, PIAT - Peabody Individual Achievement Test, RAN - Rapid Automatised Naming, RCBA - Reading Comprehension Battery for Aphasia, REALM - Rapid Estimate of Adult Literacy in Medicine, RNRT - Roentgen’s Nonwords Reading Test, RNST – Roeltgen’s Nonwords Spelling Test, TOWRE - Test of Word Reading Efficiency, WJTA-III - Woodcock–Johnson III Tests of Achievement (BR - Broad Reading, BRS - Basic Reading Skills, RC - Reading Comprehension, PGK - Phoneme-Grapheme Knowledge), WRAT - Wide Range Achievement Test, WRMT-R - Woodcock Reading Mastery Test — Revised (BS - Basic Skills, PC - Passage Comprehension, PGK - Phoneme-Grapheme Knowledge)

Word recognition can be assessed by single-word reading tests which require reading of standalone words out loud and this ability depends on familiarity (previous encounter with the word) and is influenced by the educational experience (Gathercole et al., 1992). The early acquisition of word recognition within the schooling process is especially important to mention in relation to the impact of psychopathology symptoms on reading. Single-word reading is usually acquired at an early age before the onset of mental illness (MI) and thus is not affected by the psychopathology symptoms (Reichenberg et al., 2002). This is also the reason that single-word reading tests are used to test premorbid IQ because the skill is considered resistant to the gradual cognitive decline (Franzen, 1997). For example, the basic versions of the National Adult Reading Test (NART) (Blair & Spreen, 1989) and the Wide Range Achievement Test (WRAT) (Jastak & Jastak, 1978) tests assess reading and pronunciation via a list of phonetically irregular words that participants are asked to read aloud. Other single-word reading tests work on the same principle and most of the complex reading batteries include their own list of stand-alone words. The Rapid Estimate of Adult Literacy in Medicine (REALM) (Davis et al., 1991) is a specific test as it measures literacy by counting the correctly pronounced words commonly used in medicine. However, REALM is a measure of word recognition. It scores participants capacity on a scale from 3rd grade of school and below, up to the secondary school reading performance.

In comprehension assessments, participants are usually asked to read a sentence or a block of text out loud and are asked questions about its content. The questions can be open-answer or multiple-choice. Sometimes the comprehension is assessed by filling an empty space in a sentence with an appropriate word or indicating the meaning with an appropriate picture. The Gray Oral Reading Test (GORT) (Wiederholt & Bryant, 2001) is a thorough test of reading comprehension using independent stories of increasing length, difficulty, and complexity and asks participants open questions. This is similar to all other major reading batteries and their comprehension subtests: Woodcock-Johnson Test (WJ) (Mather & Wendling, 2010), Peabody Individual Achievement Test (PIAT) (Dunn & Markwardt, 1970), PALPA, (all single sentence tests), or Nelson-Deny Reading Test (NDRT) (Brown et al., 1993). These tests incorporate a range of reading skills – decoding, word recognition and comprehension. Although all these tests measure comprehension, some differences exist, especially in the form of answering the questions which put different demands on each reading component. For example, the GORT puts less demand on word recognition than the PIAT or WJ because it presents a broader context and is not highly dependent on correct recognition of the clue word which leads to the meaning in standalone sentences (Keenan et al., 2008). In other words, in a block of text, participants have more space to understand the meaning from the context of the sentences, compared to single sentence comprehension tests where the meaning is often dependent on a single word that carries the meaning.

Reading a block of text can help to indicate other aspects of reading such as rate, accuracy, and fluency. The GORT comprises all three of those scores by timing each text read and marking mistakes in pronunciation, hesitations, and pauses and, therefore, allows a complex view on reading comprehension. Assessing these aspects of text reading is important in determining the overall reading proficiency (Hudson et al., 2005).

Most of the complex reading batteries are standardised and present norms for each reading skill indicating the reading age or schooling years equivalents based on the scores achieved. This is important to know especially in people with MI where the schooling process is often disrupted by the onset of symptoms (Fuller et al., 2002). The ability to compare their acquired years of education with their actual reading age and the severity of reading impairments in different diagnoses can clarify how much each psychopathology impacts reading skills.

1.6. Experimental Assessments of Reading

Many of the reading skills mentioned earlier have been examined experimentally using one or more of the following methods: i) self-paced reading – records participants responses by button press after each word or segment is read, ii) eye-tracking – detects the fixation time of each word and the fluency of eye movements forward and backward, and iii) EEG – records brain activity during reading in event-related components to reflect on the psychophysiological components of reading (Keating & Jegerski, 2015).

A number of experimental paradigms have been used to assess specific reading skills. The experimental paradigms of phonological processing include: i) discrimination – distinguish two different sounds (phonemes, words, nonwords) as the same or different, ii) ABX discrimination – recognise the similarity between three sounds, say if the third sound is similar to the first or second one, iii) go-no-go – indicate when a sound presented is the same as the sample one, iv) temporal processing – replicate the sound sequence presented, v) identification – reproduce the sound presented (McBride-Chang, 1995). In the frequently used experimental paradigms, participants are asked to match two different pseudowords, rhyme (identify words/nonwords which rhyme based on the last three letters/phonemes), or identify a single phoneme (Dębska et al., 2019).

Experimental paradigms to assess single-word reading experiments include alterations to the lexical decision task (LDT) when participants have to decide whether a presented stimulus is a word (a word/nonword judgment task) or decide on its meaning or category (e.g. whether a presented word represents a living thing) (semantic judgment task) (Hauk et al., 2012). The stimuli can be presented alone or in pairs, can include words with different emotional valence (e.g. positive, negative, neutral), or can include primed conditions. The semantic judgment task assesses the representation of the word meaning in the memory and usually, presents two or more words when the participant has to indicate whether they belong to the same category (e.g. animals), or whether a presented word is related to a sample word (Chee et al., 2002; Mathews et al., 1981). The LDT and its mechanisms are described further in Chapter 4.

The comprehension of words and sentences is usually assessed in the context of other statements (segments, sentences, or a block of text). The experimental designs include assessment of one of the three basic paradigms: i) *anomaly detection* – the ability to distinguish grammatically correct/incorrect statements or sentences with inconsistencies in meaning or context, ii) *ambiguity resolution* – aspects of reading ambiguous/unambiguous statements, or iii) *syntactic dependency* – the ability to link words and sentences to form meaning (Keating & Jegerski, 2015). More specifically, participants can be asked to silently read sentences and say whether these are correct or incorrect, identify their meaning, answer questions about the sentence, match the sentence with a picture, or identify a word that best fits in the context of the sentence. Participants can be also presented with sentences that end with or include words congruent or incongruent with the previous context and are asked to say if those sentences make sense or not.

1.6.1. Lexical Decision Task

1.6.1.1. The Role of Lexical Decision in Reading

A mental lexicon can be described as a "word storage" or mental vocabulary that includes all the words stored and organised in an individual's memory. This storage is large, complex, and easily accessible for retrieval in a split second (Aitchison, 2012). The process of identification of words that are ready in the mental lexicon is called lexical retrieval or lexical decision making. As a key process in word recognition, the lexical decision is especially important in reading aloud based on the DRC model (Norris, 2013). This process is dependent on the correct recognition of a pattern of letters (word recognition) and is important in reading (Balota et al., 2006). As described above, word recognition requires the decoding of written information (orthographic patterns) into sounds. This identification of letter-sound relationships leads to the automatic identification of familiar words and their differentiation from unfamiliar words or letter sequences (Tunmer & Chapman, 2012). However, skilled readers do not read every single letter separately, then decode the individual sounds and put them together. Rather, they can recognise familiar words automatically by accessing them in their mental vocabulary and they use phonological decoding more for unfamiliar words (Wagner & Torgesen, 1987). Although phonological processing is still involved very early in the recognition of even familiar words in skilled readers (Schotter et al., 2016). Word recognition is also dependent on other factors such as context, word familiarity, and word complexity (Jacobs & Ziegler, 2015). This means that word recognition and phonological processing and decoding are interconnected, which facilitates the lexical decision process. Among other factors affecting the lexical decision process is also the size of an individual's mental lexicon. This indicates that skilled readers differ from less-skilled ones by their ability to recognise more low-frequency words with higher accuracy in shorter periods of time. In summary, better access and execution of the lexical decision process contribute to good overall reading.

1.6.1.2. Overview of Task Mechanisms

Word recognition is typically evaluated by the LDT when a participant is asked to decide whether a presented string is an actual word or a nonword. Participants are usually presented with words of different frequencies and lengths. Word frequency indicates how often a word is used in language and communication, which is expressed by the number of occurrences per million. High-frequency words are most commonly used, and participants are more familiar with them. Low-frequency words are less used and can be specific to a certain jargon (special words used by a profession or group e.g., the word "tumour" is used in medicine) which means that participants are less familiar with them. Word frequency plays a significant role in word identification. High-frequency words are easier to identify, which results in a higher number of correct responses with faster RTs than in low-frequency words (Moreno & van Orden, 2001; Rice & Robinson, 1975). This word frequency effect appears to be more noticeable in the one-choice variant of LDT in comparison to the two-choice variant (Perea et al., 2003). The task is usually presented as a two-choice variant when a participant is required to choose between two options (pressing one of two buttons) – word or nonword. It can also be presented as a one-choice variant – a Go/No-Go task (GNG), where a participant presses a button only when a word (or a nonword) appears and withdraws the response for the other one. The one-choice variant of LDT has some advantages over the usual two-choice variant: faster RTs, higher accuracy, and lower demand on processing (Perea et al., 2002). Word length also influences quick and efficient word identification. Shorter words are easier to identify because of the limited capacity of short-term memory (Baddeley et al., 1975). Words length directly affects RTs and accuracy in LDT (Ferrand et al., 2011), and thus, medium-sized words (5-6 letters) are most commonly used in this experiment as they have less of a response latency effect (Balota et al., 2007). In contrast to the words, pronounceable non-existent strings of letters or syllables – nonwords – are presented. Pseudohomophones are a type of nonword which resemble real words and can be easily mistaken for real words. Real nonwords are non-existent strings that lack any meaning and do not resemble any existing words. Due to the lack of similarities between real nonwords and actual words, these are easier to identify than pseudohomophones which results in a higher number of correct responses and shorter RTs for real nonwords (Martin, 1982; Pexman et al., 2001).

1.7. Reading Skills and Other Cognitive Abilities

Each of the specific reading skills described earlier in this chapter interacts with various other cognitive skills that support the proper execution of all reading processes. As mentioned earlier, according to the SVR model (Gough & Tunmer, 1986), reading consists of two major processes – decoding and comprehension and both processes pose various cognitive demands. Decoding is described as a lower-level cognitive process that puts a demand on attention and working memory, whereas comprehension includes more higher-level processes: i) inference making (the ability to extract hidden meaning), ii) attention-allocation (adaptation of attention resources accordingly to the demands), and iii) executive functioning (planning, working memory, inhibitory control) (Kendeou et al., 2014).

Working memory is one of the key cognitive abilities necessary for successful reading. It facilitates simultaneous use of other cognitive abilities, decoding of new words, accessing semantic information, accessing previously read information, and anticipating the reading context (Sesma et al., 2009). Its primary function is to facilitate a quick manipulation of decoded information. Poor readers with a general reading deficit demonstrate difficulties in maintaining phonologically decoded information in working memory which leads to poorer context identification and this results in comprehension problems (Lesaux et al., 2006; Stanovich, 1982). Also, individuals deficient in comprehension skills solely, with intact decoding and word recognition (low-level processes), can show deficits in the higher-level processes, especially in working memory (Lesaux et al., 2006). This indicates that although word recognition driven by proper decoding is important for reading comprehension, the deficit in the comprehension domain can be caused by problems with working memory and other executive functions in general. However, working memory can be intact and the comprehension deficient when it gets overwhelmed by demands from reading fluency (Sesma et al., 2009). Deficits in fluency can put excessive demand on working memory when the information is not being read quickly and accurately enough and working memory has to operate with inaccurate information and maintain it for a longer time. This illustrates its dominant impact on reading among other cognitive abilities.

Long-term memory is important for storing information about vocabulary which can supplement gaps in working memory during reading (McDougall & Donohoe, 2002). Good readers are also able to efficiently access the information in long-term memory in order to comprehend the larger context of the information read (Lorch, Jr. & van den Broek, 1997). Therefore, long-term memory can facilitate reading by storing information for a long time about vocabulary that can be relevant for the context of the currently read text.

Executive functioning is particularly important for comprehension as it facilitates a smooth use and transition of all reading processes – from decoding letters into sounds to merging word parts, and identifying syntax and context, and thus, it has an impact on successful reading (Cartwright, 2012). Moreover, reading comprehension of sentences is a more complex process than word identification, therefore, the executive functioning is a strong predictor of comprehension but not of word recognition (Sesma et al., 2009). In addition to this, inhibitory control as a component of executive functioning helps to suppress irrelevant interpretations of word or sentence meaning and to identify appropriate context, which puts a less load on working memory and leads to more efficient comprehension (Chang, 2020). This indicates that individuals with poor comprehension have problems suppressing irrelevant interpretations, which originates in their deficient active inhibition (Borella et al., 2010). In reading, inhibition directs the attention to relevant and most important aspects of the written information and inhibitory impairment is a strong predictor of poor reading skills and developmental dyslexia (Doyle et al., 2018). Although inhibitory control impairment is not always present in dyslexia, the ability to suppress irrelevant responses or interpretations in reading has a strong impact on the retrieval of phonological information from long-term memory (Bexkens et al., 2015).

From a neurophysiological perspective, cognition can also have an indirect impact on eye movement during reading. There are three types of eye movements during reading: i) saccades (short forward movements from one word to another), ii) anti-saccades (larger backward leaps), and iii) fixations (pauses for information processing) (Ciuffreda et al., 1976). If the reader has problems with processing the meaning of a text, the saccadic eye movements can slow down or can be implicitly adjusted based on the comprehension speed (McConkie & Yang, 2003). Therefore the inability to understand the meaning of a particular word prolongs the fixation durations and these are usually longer for verbs, which indicates the action word as the most important semantic information (Rayner, 1977). Thus, poor readers can also have problems in processing all types of semantic information, which makes their eye fixations longer and results in slower reading speed. This statement is also supported by findings from studies in dyslexia, which show lower cortical activation during semantic processing (L. Liu et al., 2012; Schulz et al., 2008) and its negative influence on reading fluency, resulting in lower accuracy and longer reading times (Christodoulou et al., 2014).

Understanding the impact of cognitive abilities on reading and their relationship with eye movement is important in drawing the overall picture of reading as a process. The influences of cognition and neurophysiology on reading are also directly related to the research of the neural correlates as these are directly related to the specific patterns of brain activity observed during reading.

1.8. Neural Correlates of Reading

The neural correlates of reading are generalised into three main brain regions: i) left basal temporal cortex, specifically fusiform gyrus (orthographic and lexical representations, word meanings), ii) left inferior frontal cortex (controlled phonological processing and output, pseudoword reading), and iii) left temporoparietal cortex (automatic phonological processing, word reading) (Fiez, 2001). All three regions are involved in various stages of reading words. In the first step, which is the conversion of orthographic information into phonological representation, the inferior frontal cortex is activated, followed by the superior temporal gyrus and fusiform gyrus with additional activation of parietal regions in semantic activations (Mathur et al., 2020). The left temporoparietal cortex in phonological awareness and left occipitotemporal cortex in orthography to phonology conversion are activated in both, alphabetical (English) and non-alphabetical languages (Chinese) (Xia et al., 2018).

To a certain extent, in sentence reading, a different pattern of brain activity is seen relative to that seen in single-word reading. When reading a block of text, the fusiform gyrus bilaterally, especially the anterior part, is mainly activated during comprehension, but this activation also reflects the fluency of reading (Houston et al., 2014; Langer et al., 2015). The influence of fluency on comprehension was also established behaviourally with the main activation in left parahippocampal regions during sentence comprehension (Xia et al., 2018). In summary, the left fusiform gyrus and the left inferior parietal cortex are mostly activated in single-word reading, and the parahippocampus and fusiform gyrus are activated in sentence comprehension processes, and these regions form a reading neural network.

Differences in neural activation during the involvement of the individual reading skills are present in less-skilled readers and in those with dyslexia. Skilled readers show greater activation in reading specific areas (left anterior, ventral, and middle temporal lobe) and less activation in areas associated with executive functioning in comparison to less efficient readers, which reflects their ability to automatically involve correspondent neural networks (Wang et al., 2019). In dyslexia, the standard deficit model highlights the hypoactivation in the left temporoparietal area, which is responsible for poor phonological processing (Richlan et al., 2009). However, different meta-analytic evidence also suggests that poor activation in the occipitotemporal area in dyslexics results in the inability to connect visual input with its phonological representation (Richlan, 2012). A complex analysis of neuroimaging results in dyslexia also showed that hypoactivation can be found in all main regions associated with reading and the functional decline together with structural abnormalities present in the grey matter (Elnakib et al., 2014).

1.9. Importance of Good Reading Skills

In modern societies, reading skills are of enormous significance for a range of socioeconomic outcomes including success in academic performance, income and occupational achievement, socioeconomic status, and family and social relationships (Duncan et al., 2007; Ritchie & Bates, 2013). Reading skills are a part of speech and language development, and the relationship between their impairment and certain psychopathologies is bidirectional. Language impairments, including reading, are more often reported in people with MIs (e.g. depression, anxiety, antisocial personality disorder – ASPD, ADHD), while some psychopathology symptoms occurred more frequently in speech and language impairments (Sundheim & Voeller, 2004).

Furthermore, poor reading skills in children have been associated with increased antisocial behaviour (Maughan et al., 1996; Trzesniewski et al., 2006). Poor reading skills and traits of dyslexia have been associated with increased anxiety and poor socialisation, which in turn might explain antisocial behaviour, impulsivity, and violence (Baker & Ireland, 2007; Jensen et al., 1999). Undiagnosed reading deficits can lead to various negative outcomes. Firstly, undiagnosed reading deficits and dyslexia can result in scholastic failure, which can raise the risk for mood problems (Maughan et al., 2003) and future criminal behaviour (Daderman et al., 2004). Secondly, they pose a serious challenge to mental health interventions and their accessibility (Sentell & Shumway, 2003). This can be for a variety of reasons, including understanding information related to medical and clinical appointments, prescription labels, consent forms, therapy, and related assignments.

Given that reading deficits are generally associated with a range of negative outcomes, there is a need to consider them as a therapeutic target and address them, for example, with interventions used for treating or managing dyslexia (Law et al., 2015; Whitford et al., 2018). Moreover, considering the associations between reading impairments and MI, these populations can be more vulnerable and worse affected by undiagnosed and neglected reading deficits. A thorough understanding of the pattern and magnitude of reading deficits in people with specific MIs is an important first step towards amelioration of their deficient reading skills using targeted interventions.

1.10. Chapter Summary

Reading is a complex process that can be subdivided into the following skills: phonological processing and decoding, word recognition, and comprehension, and includes other related factors: reading speed, rate, accuracy, and fluency, together with reading-related skills – orthography, vocabulary, and grammar. All these skills can be viewed as independent processes which interact and influence each other. This indicates that reading follows both – bottom-up and top-down principles. The bottom-up principle can be seen in the identification of individual phonemes, words, and in building up sentence meaning, whereas syntactic parsing and ambiguity resolution are based on top-down processes. Reading skills can be assessed by a range of standardised and experimental measures. This is particularly important as good reading skills play a crucial role in everyday life and in achieving a good education and socioeconomic status.

The next chapter will review the use of standardised reading assessments in different psychopathologies in non-forensic and forensic populations, and thoroughly examine the pattern and magnitude of reading deficits in people with specific MIs.

Chapter 2: Reading Skills Deficits in People with Mental Illness: A Systematic Review and Meta-analysis

This chapter is an extended version of an article published as:
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2.1. Chapter Aims and Overview

Good reading skills are important for appropriate functioning in everyday life, scholastic performance, and the chances of acquiring a higher socio-economic status. This chapter contains the results from a systematic review and meta-analysis to quantify possible deficits in specific reading skills in people with a variety of mental illnesses (MIs).

2.2. Introduction

Reading is a complex process that requires the implementation of various skills simultaneously. To begin with, it requires recognition of the visual information necessary to extract the information from the text (Aghababian & Nazir, 2000). The core reading skill is phonological processing which involves recognition of the sound structure of the language, the decoding of written symbols into sounds (phonological awareness), and then their maintenance in working memory (phonological memory) (Wagner & Torgesen, 1987). Phonological processing facilitates the decoding of written information which leads to word identification and subsequent extraction of meaning (Pollatsek et al., 2000). A failure to read each word correctly leads to problems with comprehension (Perfetti, 2001) as comprehension involves the processing of individual letters and words, and then putting them together to form meaning (Judd & Gray, 1918). When one or more of these reading skills are impaired, and this impairment cannot be explained by general cognitive dysfunction or intelligence, this is referred to as dyslexia (Lyon et al., 2003). Overlaps between dyslexia and schizophrenia (SZ) have been suggested, based on previous findings of disruption in the processes that support skilled reading (e.g., deficits in language, auditory and visual perception, oculomotor control) in both disorders (Whitford et al., 2018) but the nature and severity of reading skills deficits in SZ and other severe mental illnesses (MIs) remain unclear at present.

Reading skills are of enormous significance for a range of socioeconomic outcomes in modern societies including academic performance, occupational achievement, and family and social relationships (Duncan et al., 2007; Ritchie & Bates, 2013). Furthermore, poor reading skills in children have been associated with increased antisocial behaviour (Maughan et al., 1996; Trzesniewski et al., 2006). Likewise, in forensic populations, poor reading skills and dyslexia traits have been associated with increased anxiety and poor socialisation, which in turn might explain their antisocial behaviour (Baker & Ireland, 2007; Jensen et al., 1999). In people with various MIs, undiagnosed reading problems and dyslexia result in scholastic failure, in turn raising the risk for mood problems (Maughan et al., 2003) and future criminal behaviour (Daderman et al., 2004). Poor reading skills also pose a challenge for accessibility of mental health interventions (Sentell & Shumway, 2003) and predict poor psychosocial outcomes (Dondé et al., 2019; Revheim et al., 2014). There is thus a need to consider reading deficits as a therapeutic target and address them, for example, with interventions used for dyslexia (Law et al., 2015; Whitford et al., 2018). A thorough understanding of the pattern and magnitude of reading deficits in people with specific MIs is an important first step towards this goal.

The main aim of this systematic and meta-analytic review was to conduct a comprehensive analysis to delineate the nature and magnitude of reading impairments based on data from studies that employed standardised tools to assess reading skills in people with SZ, bipolar disorder, affective disorders (major depression, anxiety, mania), personality disorders [PDs; borderline personality disorder (BPD), antisocial personality disorder (ASPD), psychopathy], and general MIs (across diagnoses/not-specified). Our secondary aims were to examine whether: i) particular reading skill deficits were more strongly present when assessed with some tests compared to others, given that reading skills in different studies have been quantified using a variety of tests and batteries, and ii) groups with MIs and a forensic history show more pronounced deficits relative to those from non-forensic settings.

2.3. Methods

This systematic literature review and meta-analysis followed PRISMA guidelines (Liberati et al., 2009). An exploratory search of databases and an internet search engine (Google Scholar) identified the key terms and articles. We then searched Academic Search Complete, CINAHL Plus, PsycINFO, PsycARTICLES, SocINDEX, MEDLINE via EBSCO Host and PubMed (up to February 2020) for all studies including reading assessment(s) in MIs (see Table 2.1. for the full search strategy and eligibility criteria). Manual searches were conducted using relevant literature (Revheim et al., 2006, 2014; Whitford et al., 2018).

Table 2.1. Full search strategy per database and eligibility criteria.

EBSCO search: *Academic Search Complete, CINAHL Plus, PsycINFO, PsycARTICLES, SocINDEX, MEDLINE*	PubMed
(Reading* OR literacy OR scholastic) AND (schizophren* OR "schizoaffective disorder" OR psychosis OR psychotic OR bipolar OR psychopathy OR "personality disorder" OR "antisocial personality disorder" OR "mental disorder" OR "mental ill*" OR "mood disorder" OR "anxiety" OR depress*) AND adult* (Dyslexia OR "learning disability" OR "reading disorder" OR "reading dysfunction" OR "reading deficit") AND (schizophren* OR "schizoaffective disorder" OR psychosis OR psychotic OR bipolar OR psychopathy OR "personality disorder" OR "antisocial personality disorder" OR "mental disorder" OR "mental ill*" OR "mood disorder" OR "anxiety" OR depress*) AND adult* **Related words and related subjects, only peer-reviewed.*	((((((("Mental Disorders"[Mesh]) OR ("Schizophrenia"[Mesh] OR "Schizophrenia Spectrum and Other Psychotic Disorders"[Mesh] OR "Schizophrenia, Paranoid"[Mesh] OR "Schizophrenia, Disorganized"[Mesh] OR "Schizophrenia, Catatonic"[Mesh] OR "Schizotypal Personality Disorder"[Mesh])) OR "Psychotic Disorders"[Mesh]) OR ("Bipolar Disorder"[Mesh] OR "Depressive Disorder, Major"[Mesh] OR "Major Affective Disorder 1" [Supplementary Concept] OR "Major Affective Disorder 2" [Supplementary Concept])) OR "Antisocial Personality Disorder"[Mesh]) OR ("Personality Disorders"[Mesh] OR "Schizoid Personality Disorder"[Mesh] OR "Passive-Aggressive Personality Disorder"[Mesh] OR "Paranoid Personality Disorder"[Mesh] OR "Multiple Personality Disorder"[Mesh] OR "Histrionic Personality Disorder"[Mesh] OR "Dependent Personality Disorder"[Mesh] OR "Compulsive Personality Disorder"[Mesh] OR "Borderline Personality Disorder"[Mesh])) AND ("Reading"[Mesh] OR "Dyslexia"[Mesh] OR "Dyslexia, Acquired"[Mesh])) AND ("Adult"[Mesh] OR "Young Adult"[Mesh]) ((("mood disorders"[MeSH Terms] OR ("mood"[All Fields] AND "disorders"[All Fields]) OR "mood disorders"[All Fields] OR ("mood"[All Fields] AND "disorder"[All Fields]) OR "mood disorder"[All Fields]) OR ("anxiety"[MeSH Terms] OR "anxiety"[All Fields])) AND ("Reading"[Mesh] OR "Dyslexia"[Mesh] OR "Dyslexia, Acquired"[Mesh])) AND ("Adult"[Mesh] OR "Young Adult"[Mesh])

2.3.1. Eligibility Criteria

Studies were included if they met the following criteria:

- Case-control, cohort and cross-sectional studies reporting measures assessing reading abilities in adults with psychosis, depression, anxiety, personality disorders, antisocial personality disorder, psychopathy, and/or general mental illness
- Studies using standardised tests and/or translated versions of these into their national language

- Quantitative studies published in peer-reviewed journals in English, without publication date restrictions
- Abstract and full-text available

Non-peer reviewed articles, case studies, theses, books, editorial letters, descriptive articles, conference papers, personal opinions, and protocols were excluded. Studies using experimental methods to assess reading in people with MI without reporting scores from standardised tests or using single-word reading tests only to assess premorbid IQ were excluded. However, studies that used the Wide Range Achievement Test (WRAT) (Jastak & Jastak, 1978), WRAT-R (Jastak & Wilkinson, 1984), WRAT-III (Wilkinson, 1993), WRAT-IV (Wilkinson & Robertson, 2006) or WRAT-V (Robertson & Wilkinson, 2017) and reported the scores for different subscales (single-word reading, comprehension, arithmetic) were included. Similarly, other single-word reading tests when used to assess reading or literacy were included [e.g. Rapid Estimate of Adult Literacy in Medicine (REALM) (Davis et al., 1991)].

Firstly, studies were identified based on title and abstract. Secondly, the full-texts of these studies were accessed and reviewed for eligibility. Included studies were subject to data extraction. The data was extracted from full-texts and reviewed for inconsistencies. Extracted data included tests and measures as well as participant characteristics, main findings, the language of assessment, and country (Table 2.2.).

Studies that reported means and standard deviations (SD) for patient and healthy control (HC) groups to permit the calculation of effect sizes were included in the meta-analysis (effect sizes were also presented where only one study was available). The remaining studies contributed only to the narrative synthesis (see Table 2.2. for details). Studies assessing individuals with conditions primarily classified as neurodevelopmental (ADHD, autism, learning difficulties, and intellectual disabilities) (American Psychiatric Association, 2013) were excluded.

2.3.2. Statistical Analysis

The meta-analysis was conducted using Review Manager 5.3 Software – RevMan (The Cochrane Collaboration, 2014). For eligible studies, effect sizes were calculated as *Hedge's g* (standardised mean difference). A random-effects model was used as a more conservative approach. Heterogeneity was calculated as the I^2 measure of consistency for each meta-analytic calculation. Planned analyses included comparing each diagnosis (SZ, bipolar disorder, depression, anxiety, PDs, psychopathy), and unspecified general MI with healthy groups on specific reading skills (phonological processing and decoding; comprehension; single-word reading; rate, speed, accuracy and fluency). For each reading skill, differences between tests to assess deficits in the patient group were calculated by investigating overlaps of confidence intervals of the summary effect sizes for each test. The risk of publication bias (none identified) was formally assessed via Egger's and Begg's tests and with funnel plots.

2.4. Results

Of 34 studies in total (Table 2.2.), 19 studies provided data for meta-analysis (Figure 2.1. *PRISMA flowchart*); five of these studies also presented composite scores (combining two or more measures) that are covered in the narrative synthesis. The remaining 15 studies contributed to the narrative synthesis only. All studies were published between 1973 and 2019. The findings from the non-forensic and forensic samples are presented separately, followed by a direct comparison of forensic and non-forensic groups.

Figure 2.1. PRISMA flowchart.

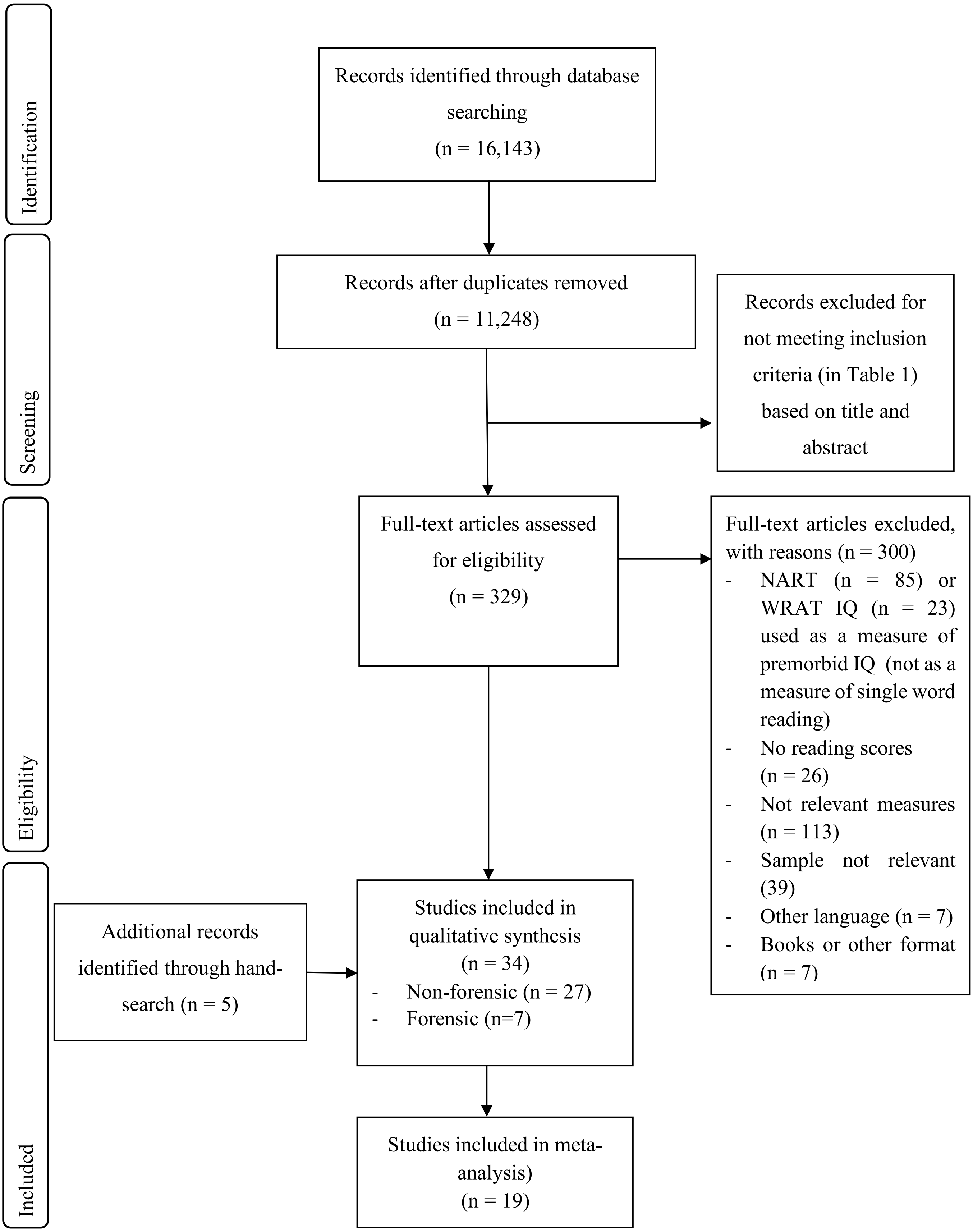


Table 2.2. Summary of key data extracted from selected studies (*n* = 34).

Study	Dg.	Sample (N) (M/F)	Age (Mean, SD)	Medication (mg/day, CPZE)	Education years (Mean, SD)	Tests (subtests)	Variables examined	Reading performance	Symptoms, medication and reading	Cognition, education and reading	Language
2.2.1 PSYCHOSIS											
Disimoni et al. (1973)	**SZ**	SZ=27 (9/18)	SZ= 36.3 (13.2)	NR	SZ=11.3 (2.6)	Language battery: comprehension (3 subtests), naming, writing, arithmetic	comprehension	SZ are impaired in comprehension but less than aphasics. Poorer speaking and listening scores were linked with better reading. This indicated independence of communication skills from reading.	NE	NE	English
Maj, M. (1986) *Meta-analysis*	**SZ, SZAD, DD**	SZAD=16 (7/9); SZ=20 (8/12); DD=16 (7/9); ex SZAD=15 (7/8); **HC=20** (8/12)	SZAD=33.6 (6.1) DD=36.5 (6.9) SZ=31.7 (8.9) HC=33.5 (5.8) exSZAD=36.5 (5.6) HC=37.7 (5.9)	Lithium <1200, antidepressants <75, and/or haloperidol <5 or chlorpromazine <100	NR	LNNB (reading: 13 items)	single-word reading	SZ scored significantly worse than HC in reading. SZ also demonstrated (non-significantly) worse reading skills than the SZAD and the DD.	NE	Means for cognitive domains were reported but the relationship with reading NE. Groups did not differ in years of education.	Italian

Halpern et al. (1989)	**SZ**	SZ=7 (7/0); Atypical Organic Brain Syndrome =1 (1/0)	SZ= 51.5	NR	NR	BDAE (subtest L), Fisher-Logeman n sentences, "Grandfat her" passage, "Arthur the Young Rat"	reading fluency of words, sentences, and paragraphs	No significant number of non-fluencies in reading were found based on location in a sentence, location in the utterance (sound, syllable, word, phrase, and sentence) or symptoms (repetitions, prolongations, hesitations). Significantly more non-fluencies occurred in sentence reading and paragraph reading and, in the middle, and beginning of sentences.	NE	NE	English
Puente et al. (1993)	**SZ**	SZ total=60: SZ-brain damage=20 (15/5); non-brain damage=20 (15/5); acute=20 (11/9); **HC=20** (6/14)	SZ-brain damage= 51.7 (17.8) non-brain damage= 36.1 (11.1) acute= 34.5 (14.2) **HC= 19.5** (2.1)	SZ-brain damage= 405.0 CPZE non-brain damage= 234.8 CPZE acute= 492.2 CPZE	SZ-brain damaged = 9.8 (2.6) Non-brain damaged = 10.7 (2.4) acute= 11.4 (3.1) HC= 12.6 (1.1)	LNNB	single-word reading	No significant differences between SZ and HC.	No significant correlation between medication dosage and LNNB battery. Other relationships NE.	NE	English

Fuller et al. (2002)	**SZ**	SZ=70 (57/13)	SZ= 28.0 (6.9)	NR	NR	ITBS, ITED	comprehension, spelling, language, vocabulary	SZ scores were significantly lower than average general rank between 11th grade and the 4th and 8th grade respectively in reading, vocabulary, language, and other scholastic skills. Reading performance significantly dropped between grades 8 and 11. ITED scores did not predict the age of onset of SZ.	NE	WAIS-R verbal IQ significantly positively correlated with reading, vocabulary and language skills measured by ITED in 11th grade in SZ.	English
Reichenberg et al. (2002)	**SZ, SZAD, BD**	SZ=536 (390/146); SZAD=31 (23/8); BD=68 (38/30); **HC=635** (451/184)	SZ=20.7 (2.0) SZAD= 20.0 (1.5) BD=21.5 (2.8)	NR	NR	Israeli language skills assessment (2 subtests)	comprehension, reading sentences	SZ but not BD had significantly worse scores in reading and reading comprehension in comparison with HC.	NE	NE	Israeli

Hayes & O'Grady (2003) *Meta-analysis*	**SZ**	SZ=30 (26/4); **HC=30** (26/4)	SZ=37.3 (11.20) HC=37.2 (11.85)	NR	NR	RCBA (10 subtests)	single-word comprehension, functional reading, comprehension of synonyms, sentence comprehension, paragraph comprehension, factual comprehension, inferential reading, comprehension with structure variation, reading speed	SZ scored lower in comprehension (9/10 RCBA subtests were significantly lower in SZ) than HC but retained word-recognition skills (NART). Reading time is longer in SZ. Functional reading necessary for real-life functioning was significantly impaired in SZ.	NE	Lower premorbid IQ (NART) correlated with low RCBA scores. Education levels for each group were similar.	English
Ho et al. (2005) *Meta-analysis*	**SZ**	SZ=70 (57/13); comparison subjects =147 **(HC= 36:** Alc=66.7% drug=34.7 % DD=29.9%) (63/84)	NR	NR	NR	ITBS, ITED	comprehension, vocabulary	SZ scored lower in all subtests than comparisons. Reading in SZ was lower than in comparison group in all grades (4th, 8th, and 11th), lowest in 11th grade. Effect sizes were reduced when gender and parental social-economic status were accounted for.	NE	NE	English

Revheim et al. (2006) *Meta-analysis*	**SZ, SZAD**	SZ/SZAD= 19 (18/1); **HC=10** (6/4)	SZ=38.3 (9.6) HC=28.7 (9.0)	1077.7 ±574 CPZE	SZ= 12.4 (2.3) HC= 15.2 (0.85)	GORT-4, CTOPP (12 subtests), WJTA-III (7 subtests), NDRT (3 subtests), WRAT-III	GORT: comprehension, rate, accuracy, fluency, ORQ CTOPP: PA, PM, RN, APA, ARN WJTA-III: (BR) - reading decoding, speed, comprehension/ (BRS) - vocabulary, phonics, structure/ (RC) - comprehension, vocabulary, reasoning/ (PGK) - phonic and orthographic processes NDRT: vocabulary, comprehension and total score WRAT-III: single-word reading	SZ show significantly impaired reading abilities than HC. Patients' reading levels were 3.4 years below their education level. Significant differences between SZ and HC were in all subtests except in CTOPP-RN and NDRT-PGK. No differences between SZ and HC in WRAT scores.	PANSS-Cog negatively correlated with GORT-4 comprehension. Relationship between medication and reading NE.	WAIS-III working memory or processing speed could not predict GORT-4 scores. Groups differed significantly in education. Sz had reading 3.4 years below achieved education years.	English

Walder et al. (2006) *Meta-analysis*	**SZ**	SZ=31 (17/14); **HC=27** (13/14)	SZ=39.1 (7.0)	520±428 CPZE	NR	RNRT, RNST, Auditory blending test, RAN, Caplan and Hildebrandt's task, WRAT-R	RNRT, RNST, auditory blending test & RAN: all phonological processing WRAT-R: single-word reading Caplan and Hildebrandt's task: grammar	Women with SZ had relatively preserved phonology and grammar function when compared with HC women. SZ men generally impaired in language skills in comparison with HC men, especially in phonology and grammar. Men and women with SZ differed most in grammar. Sex and group had a significant effect on phonology and grammar.	No significant differences in chlorpromazine levels. Relationship between symptoms and reading NE.	Attention scores entered as a covariate in the analysis. Relationship between education and reading NE.	English
Nelson et al. (2007)	**SZ**	SZ=100 (72/28)	SZ=38.28 (9.37)	795.80 ±566.16 CPZE	SZ=12.31 (9.10)	WRAT-III	single-word reading	SZ scored M=78.00 (21.01) in WRAT. Relationship between premorbid functioning (WRAT) and social cognition is unclear.	No significant correlation between BPRS scores and WRAT. Relationship between medication and reading NE.	NE	English

Leonard et al. (2008) *Meta-analysis*	**SZ**	SZ=45 (36/9); **HC=39** (36/3)	SZ=41.1 (10) HC=42.0 (10)	NR	NR	WJTA-III (3 subtests)	Word Attack: phonological decoding Letter-Word Identification: single-word reading (word recognition) Passage comprehension: comprehension	SZ scored significantly lower than HC in phonological decoding, comprehension and single-word reading. Anatomical risk index predicted 38% of the variance in verbal ability and 44% of the variance in comprehension.	NE	Broad cognitive ability was significantly lower in SZ, but no correlations with reading skills were reported. Relationship between education and reading NE.	English
Potter & Nestor (2010) *Meta-analysis*	**SZ**	SZ-Preserved =21 (19/2); SZ-Deteriorated=21 (16/5); SZ-Compromised=31 (23/8); **HC=74** (47/27)	SZ-P= 36.31 (11.06) SZ-D= 41.40 (10.42) SZ-C= 38.71 (10.93) HC=40.59 (8.89)	410.70 ±298.76 CPZE	SZ-P= 13.7 (1.809) SZ-D= 13.214 (1.29) SZ-C= 12.18 (1.98) HC= 15.27 (2.029)	WRAT-III	single-word reading	SZ-Compromised scored significantly lower than all other groups. No significant differences between other SZ groups and HC.	NE	Significant differences were found between the SZ IQ subgroups in memory and executive functioning. No correlation with reading was reported. Relationship between education and reading NE.	English

Arnott et al. (2011) *Meta-analysis*	**SZ**	SZ=16 (10/6); **HC=12** (6/6)	SZ=41.19 (13.43) HC=42.17 (15.56)	417.86 ±375.22 CPZE	SZ= 11.88 (1.78) HC= 11.75 (2.18)	NARA-III WRMT-R (3 subtests) RCBA-2 (10 subtests) CTOPP (8 subtests)	NARA-III: comprehension, rate, accuracy WRMT-R: comprehension, word recognition (Basic Skills subscore), RCBA-2: comprehension, total time CTOPP: PA, APA, PM, RN	SZ had impaired comprehension and rate in NARA. Phonological processes were related to symptomatology but only CTOPP-RN was significantly lower in SZ than HC. Reading comprehension measured by RCBA was mostly spared in SZ. Reading words and nonwords was comparable in SZ and HC.	PANSS-N and PANSS-G negatively correlated with CTOPP RN. PANSS-P negatively correlated with CTOPP-PA. Relationship between medication and reading NE.	No significant differences between groups in education. Relationship between cognition and reading NE.	English
Gavilán & Garcia-Albea (2011) *Meta-analysis*	**SZ**	SZ=22 (18/4); **HC=22** (18/4)	SZ=42.82 (10.84) HC=41.95 (10.78)	833.46 CPZE	SZ= 10.18 (2.38) HC= 10.05 (2.44)	PALPA (comprehension of words and sentences) BDAE (paragraph comprehension), experimental test of figurative language comprehension.	PALPA, BDAE: reading comprehension (words, sentences, paragraphs) experimental: comprehension of metaphors, ironies, proverbs	SZ have difficulties in understanding the theory of Mind, which is closely related to the understanding of figurative language. SZ understand proverbs (in isolation) less than ironies and less than metaphors (in context). All figurative language significantly impaired in SZ when compared to HC.	NE	Groups significantly differed in IQ but not premorbid IQ. IQ was a covariate in the analysis. Relationship between education and reading NE.	Spanish

Light et al. (2012) *Meta-analysis*	**SZ**	SZ=341; **HC=205** (all: 247/94)	SZ=45.49 (9.37)	NR	SZ= 11.98 (1.99)	WRAT-III	single-word reading	SZ scored significantly lower in WRAT reading than HC at baseline and after 1 year.	NE	NE	English
Martinez et al. (2012) *Meta-analysis*	**SZ, SZAD**	SZ=21; SZAD=5 (20/5); **HC=17** (15/2)	SZ/SZAD= 39.4 (10.8) HC=32.7 (11.0)	1314.1 ±973.5 CPZE	SZ= 12.4 (2.3) HC= 16.1 (2.4)	GORT-4 WRAT-III	GORT-4: comprehension, fluency (rate + accuracy), ORQ WRAT-III: single-word reading	SZ scored significantly lower than HC in all passage reading measures. These impairments correlated with reduced fMRI activation in low spatial frequency (LSF) regions (dorsal stream visual system). Deficits in comprehension were greater than in single-word reading.	Reading negatively correlated with antipsychotic dosage. Relationship between symptoms and reading NE.	General intelligence did not predict reading scores. Group differences in reading ability remained when cognitive deficits (processing speed and working memory) were accounted for analyses. Reading was at the 6th-grade level despite achieved 12.4 years of education.	English

Whitford et al. (2013) *Meta-analysis*	**SZ**	SZ=20 (16/4); **HC=16** (13/3)	SZ=31.05 (9.08) HC=31.56 (10.08)	443.57 ±277.55 CPZE	SZ= 11.85 (1.99) HC= 13.66 (1.87)	CTOPP (6 subtests), NDRT (2 subtests)	CTOPP: PA, PM, RN NDRT: comprehension, rate	SZ scored significantly lower than HC in all reading measures.	No influence of medication on reading. Relationship between symptoms and reading NE.	Education in years entered as a covariate.	English
Revheim et al. (2014) *Meta-analysis*	**SZ, SZAD**	SZ=37; SZAD=8 (40/5); **HC=24** (17/7)	SZ/SZAD= 37.6 (11.6) HC=39.6 (11.3)	944.3 ±702.7 CPZE	SZ/SZAD = 12.7 (2.2) HC= 14.6 (1.8)	GORT-4, CTOPP (12 subtests), WJTA-III (7 sub-tests), NDRT (2 subtests) WRAT	GORT: rate, accuracy, fluency, comprehension CTOPP: PA, APA, RN, ARN WJTA-III: fluency, spelling, (BR) - reading decoding, speed, comprehension/ (BRS) - vocabulary, phonics, structure/ (RC) - comprehension, vocabulary, reasoning/ (PGK) - phonic and orthographic processes	Reading skills (GORT-4, CTOPP - APA, RN, ARN, and WJTA-III) were significantly reduced in all SZ in comparison with HC, and significantly below than would be expected based on their general cognition. 73% of SZ met criteria for dyslexia. WRAT scores were relatively intact in SZ.	No correlation between PANSS scores and reading. Reading deficits positively correlated with the gap between their and parental socioeconomic status. No correlation between medication and reading.	Passage reading was significantly reduced relative to premorbid IQ measured by WRAT. Reading was significantly below achieved education level.	English

							NDRT: comprehension, vocabulary, total score WRAT: single-word reading				
Patrick et al. (2015) *Meta-analysis*	**SZ**	SZ=29 (26/3); **HC=29** (15/14)	SZ=44.77 (8.24) HC=40.93 (9.02)	NR	SZ= 13.33 (1.75) HC= 15.34 (2.32)	WRAT-IV	comprehension	SZ patients scored significantly lower in comprehension than HC.	NE	NE	English
Wang et al. (2015)	**SZ**	SZ=22 (12/10); **HC=22** (13/9)	SZ=24.36 (4.03) HC=23.14 (1.94)	582.16 CPZE	SZ= 14.77 (1.06) HC= 15.00 (0.01)	Nonword Cross-out test, Onset Judgment test, Animal Word Cross-out test, Pseudo-Homophone Discrimination test	Nonword Cross-out test: orthography Onset Judgment test: orthography-phonology Animal Word Cross-out test: orthography-semantics (comprehension) Pseudo-Homophone Discrimination test: vocabulary	SZ had impaired all orthographic skills in Chinese while their access to the mental lexicon was intact. Reading in Chinese requires also deep orthographic processing which results in impaired reading in Chinese in SZ and this correlated with the severity of psychosis symptoms.	BPRS scores negatively correlated with orthography and orthography-semantics. Relationship between medication and reading NE.	Groups did not differ in achieved education levels. Relationship between cognition and reading NE.	Chinese

Curzietti et al. (2018) *Meta-analysis*	**SZ**	SZ=22 (13/9); **HC=22** (13/9)	SZ=41.0 (8.84) HC=40.03 (8.4)	261 ±144 CPZE	SZ= 12.3 (2.8) HC= 12.5 (2.7)	Alouette	rate, accuracy, speed	No significant differences were found between SZ and HC in neither of the three variables examined.	PANSS overall scores did not correlate with any reading subscores. The hallucination scores correlated significantly with reading efficiency and speed. Relationship between medication and reading NE.	Groups did not differ in achieved education levels. Groups were significantly different in WAIS scores. Relationship between cognition and reading NE.	French
Dondé et al. (2019) *Meta-analysis*	**SZ**	SZ=30 (21/11); **HC=28 (24/6)**	SZ=39.4 (11.2) HC=37.2 (10.2)	NR	SZ= 14.1 (2.5) HC= 14.9 (2.0)	CTOPP (3 subscales), WJTA-III (3 subscales)	CTOPP PA, PM, APA: phonological processing WJTA-III: comprehension, fluency, (BRS) – single-word reading	SZ had impaired phonological awareness for words and nonwords whereas phonological memory was intact. Reading comprehension and fluency were also significantly impaired. Single-word reading was intact in comparison to HC.	NE	MCCB correlations with reading skills were not reported. Groups did not differ in achieved education levels.	English

2.2.2. AFFECTIVE DISORDERS											
Weiss et al. (2006)	**DD**	DD-intervention =38 (22/16); DD-control=32 (17/15)	DD Intervention= 41.4 (14.3) DD Control= 43.7 (15.3)	NR	NR	REALM	single-word reading (literacy)	Only patients with limited literacy (scoring <60) were included. Literacy skills improved in DD intervention group after literacy training, and the depression severity lessened.	No correlation between depression symptoms (PHQ-9) and REALM at baseline. Relationship between medication and reading NE.	NE	English
2.2.3. PERSONALITY DISORDERS / PSYCHOPATHY											
Daderman et al. (2004) ***Forensic** *Meta-analysis*	**PD**	PD=10 (7 dyslexia) (10/0); FC dyslexia=26 (26/0); FC=31 (31/0); **HC=77** (77/0)	PD=38.7 (5.89) FC=35.1 (10.5) HC=31.2 (10.8)	NR	PD=9.8 (2.5) FC dyslexia= 9.1 (1.5) FC= 10.4 (2.1) HC= 11.1 (1.6)	“Summer with Monika”, MST, MWDT, JDT (Word chains)	“Summer with Monika”: reading speed, comprehension MST: spelling MWDT: reading pronunciation JDT: word decoding	Dyslexia remains underdiagnosed in forensic psychiatric patients. 7/10 of forensic participants had dyslexia. Reading speed was slower in PD with dyslexia. Verbal comprehension was normal. PD with dyslexia scored significantly lower than FC without dyslexia and HC on measures of decoding and spelling and significantly poorer	NE	Patients had reading skills below their education levels. Relationship between cognition and reading NE.	Swedish

								than HC in reading out loud. Reading was characterised by distortion and misreading.			
Brites et al. (2015) ***Forensic** *Meta-analysis*	**Psychopathy**	Psychopathy=13; Psychopathy-Forensic =13; FC=25 (51/0); **HC=39**	38.19 (7.67)	NR	M= 9.3 (1.88)	PALPA	phonological processing, reading pronunciation and writing, comprehension of words and images, comprehension of sentences	Phonological processing and single-word reading were similar between psychopaths (forensic + non-forensic) and non-psychopaths (forensic + non-forensic). Phonological processing was lower in imprisoned participants. Comprehension was also intact in psychopaths.	NE	Groups did not differ in achieved education levels. Relationship between cognition and reading NE.	Portuguese
Davidson et al. (2011) ***Forensic**	**ASPD**	ASPD: Research Naive=18 (18/0); Research Experienced=7 (7/0)	Research Naive=38.67 (9.7) Research Experienced=38.86 (8.0)	NR	NR	TOWRE	single-word reading (literacy)	Research experienced participants had higher literacy scores than research naïve ones. Participants with lower literacy prefer shorter wording and answered fewer questions correctly. Understanding of research terms may infer a higher ability to	NE	NE	English

							integrate research information.			
2.2.4. GENERAL MENTAL ILLNESS										
Berg & Hammitt (1980)	**MI**	Alc=53; PD=6; Psychosis =30; Mental Retardation =5; Organic Brain Syndrome= 6 (all: 74/26)	39	NR	M= 9.0	PIAT (2 subtests)	comprehension, single-word reading (word recognition)	Over 50% of the patients scored below 7th grade in comprehension, resulting in being functionally illiterate. Patients scored significantly worse in comprehension than in single-word reading. Therefore, they could have read the text but did not understand it. Formal education was an indicator of word pronunciation but not comprehension. PD and Psychosis groups scored similarly in single-word reading and comprehension. Mental retardation and organic brain syndrome performed significantly lower than PD and Psychosis groups.	NE	Formal education was a good predictor of single-word reading but not for comprehensio n. Relationship between cognition and reading NE.	English

Dalby & Williams (1986) ***Forensic** *Meta-analysis*	**MI**	SZ=30 (29/1); BD Manic=15 (9/6); Alc=28 (26/2); ASPD=17 (17/0); **HC=21** (21/0)	SZ=29.37 (5.94) BP=31.69 (9.37) Alc=39.00 (11.54) ASPD=25.53 (5.59) HC=30.33 (10.31)	NR	SZ= 10.73 (2.60) BP= 11.07 (2.44) Alc= 9.54 (1.53) ASPD= 8.41 (2.12) HC= 10.43 (1.16)	WRAT	single-word reading (word recognition), spelling, arithmetic	Significant differences in reading, spelling and arithmetic between all groups. Reading scores: Mania > SZ > HC > Alc > ASPD>	NE	In HC, IQ correlated with reading and spelling. Reading was significantly better than full-scale IQ in SZ and BD. Reading and spelling were preserved in psychotics despite lowered general IQ. Relationship between education and reading NE.	English
stor et al. (1992) ***Forensic**	**MI**	MI=40: Young=22 (22/0); Old=18 (18/0)	MI Young=19.3 MI Old=41.4	NR	NR	WRAT-R	single-word reading, spelling, arithmetic	Violent patients: MI-Old scored significantly higher in WRAT-R reading subtest than MI-Young, suggesting developmental learning disability. Scores in Spelling were not significantly different. Murder: MI-Old scored significantly higher in reading and spelling than MI-Young.	NE	NE	English

								Learning disability and conduct disorder may increase the probability of violence in MI-Young.			
Christensen & Grace (1999)	**MI**	SZ=7; AfD=27; AdjD=2; Other=9 (all: 32/13)	32	NR	NR	REALM	single-word reading (word recognition and pronunciation)	Over 75% of MI have reading skills on the level of 7th or 8th grade. People with MI are usually unaware of their reading problems. Reading screening recommended in routine evaluations.	NE	NE	English
Ferron et al. (2012)	**MI**	SZ/SZAD=95; Mood disorder=34; Other MI=6 (all: 97/38)	35 (10.0)	NR	NR	WRAT-IV	comprehension	WRAT reading and comprehension on the level of 9th grade of education.	NE	NE	English
Selenius et al. (2015) ***Forensic**	**MI with Psychopathy**	MI=40: violence =29; sexual=8; other=3 (all: 32/8)	36 (10.0)	NR	MI= 10.04 (1.79)	MWDT, MST, The Hedgehog , MSVT (all tests by Madison), “The Pidgeon”, JDT	The Pidgeon: phonological processing MWDT and JDT: word decoding MST: spelling The Hedgehog: reading speed and comprehension	Antisocial traits are not associated with reading. However, affective and interpersonal (Factor 1) traits were significantly related to decoding, reading speed and phonological processing. Phonology, semantics and syntactic skills significantly	Antisocial lifestyle did not correlate with reading skills. Affective and personality traits significantly	NE	Swedish

							MSVT: vocabulary	positively correlated with Superficial traits in psychopaths with MI.	positively correlated with sentence decoding and reading speed. Relationship between medication and reading NE.		
Svensson et al. (2015) ***Forensic**	**MI**	MI=185: Neurodevelopmental disorder =58; DD =40; Psychosis= 57; Anxiety=13 ; PD=12 (all: 133/52)	33 (9.9)	NR	NR	JDT (Word chains), Word Attack, Phonological Choice, Orthographic choice, WRMT (Oral Close), RAN	JDT: decoding Word Attack, Phonological choice: phonological decoding Orthographic Choice: spelling Oral Close, RAN: reading comprehension	Low reading abilities interfere with psychiatric treatment in forensic settings. 16% of patients had a dyslexic profile. Psychosis and anxiety had the lowest general reading skills (phonological processing + comprehension). DD had a significantly better word, non-word reading, and comprehension than psychosis. General reading skills did not predict diagnoses.	NE	NE	Swedish

Note: **Diagnoses:** AfD - Affective Disorder, AdjD - Adjustment Disorder, Alc – Alcoholism, BD - Bipolar Disorder, CPZE – Chlorpromazine equivalents, DD - Depressive Disorder, FC - Forensic Controls (history of violence without MI), HC - Healthy Controls, MI - Mental Illness, PD - Personality Disorder, SZ – Schizophrenia, SZAD - Schizo-Affective Disorder

Measures: BDAE - Boston Diagnostic Aphasia Examination, BPRS – Brief Psychiatric Rating Scale, CTOPP - Comprehensive Test of Phonological Processing (PA - Phonological Awareness, PM - Phonological Memory, RN - Rapid Naming, APA - Alternative Phonological Awareness, ARN - Alternative Rapid Naming), GORT - Gray Oral Reading Test, ITBS - Iowa Test of Basic Skills, ITED - Iowa Test of Educational Development, JDT - Jacobson's Decoding Test, LNNB - Luria-Nebraska Neuropsychological Battery, Mac-CAT-CR - MacArthur Treatment Competence Assessment Tool for Clinical Research, MCCB - MATRICS Consensus Cognitive Battery, MST - Madison's Spelling Test, MSVT - Madison's Standardized Vocabulary Test, MWDT - Madison's Word Decoding Test, NARA - Neale Analysis of Reading Ability, NDRT - Nelson–Denny Reading Test, PALPA - Psycholinguistic Assessments of Language Processing in Aphasia, PANNS – Positive and Negative Syndrome Scale, PIAT - Peabody Individual Achievement Test, RAN - Rapid Automatised Naming, RCBA - Reading Comprehension Battery for Aphasia, REALM - Rapid Estimate of Adult Literacy in Medicine, RNRT - Roentgen's Nonwords Reading Test, RNST - Roeltgen's Nonwords Spelling Test, TOWRE - Test of Word Reading Efficiency, WJTA-III - Woodcock–Johnson III Tests of Achievement (BR - Broad Reading, BRS - Basic Reading Skills, RC - Reading Comprehension, PGK - Phoneme-Grapheme Knowledge), WJCog - Woodcock–Johnson Test of Cognitive Ability, WRAT - Wide Range Achievement Test, WRMT-R - Woodcock Reading Mastery Test — Revised (BS - Basic Skills, PC - Passage Comprehension, PGK - Phoneme-Grapheme Knowledge).

NR – Not Reported, NE – Not Examined

Studies including forensic populations are marked with ***Forensic.** *Studies included in the meta-analysis are marked* "*Meta-analysis*".

2.4.1. Reading Skills in Non-Forensic Populations

2.4.1.1. Schizophrenia

Phonological Processing and Decoding:

Narrative synthesis: Phonological processing in SZ was examined using 10 different measures (Table 2.2., Figure 2.2.1.). The CTOPP was used in five studies (Arnott et al., 2011; Dondé et al., 2019; Revheim et al., 2006, 2014; Whitford et al., 2013) which reported between three and five subscores [Phonological Awareness (PA), Phonological Memory (PM), Rapid Naming (RN), Alternative Phonological Awareness (APA), Alternative Rapid Naming (ARN)].

The Rapid Automatic Naming (RAN) (Katz et al., 1992), Roeltgen's Nonword Reading Test (RNRT) (Roeltgen, 1992), Roeltgen's Nonword Spelling Test (RNST) (Roeltgen, 1992), and an auditory blending test were all used in one study (Walder et al., 2006) which also created a phonology composite score by combining RNRT, RNST with a test of single-word reading (WRAT-R), and a test of fluency (Controlled Oral Word Association Test – COWAT) (Benton, 1976) in their phonological assessment. The composite score showed a significant deficit in SZ patients relative to HC. The Woodcock-Johnson Test of Achievement (WJTA-III) (Mather & Wendling, 2010) was used in three studies (Leonard et al., 2008; Revheim et al., 2006, 2014).

The Word Attack subtest, together with a single-word reading test to create the Basic Reading Skills composite score, was used in two studies (Revheim et al., 2006, 2014). These two studies (Revheim et al., 2006, 2014) also created the Phoneme-Grapheme Knowledge composite score (reflecting phonological processing and orthography) and the Broad Reading composite score (phonological processing, comprehension and speed) and showed different results. Significant differences were reported between SZ and HC in Basic Reading Skills and Phoneme-Grapheme Knowledge in one study (Revheim et al., 2014) while both studies found significantly lower Broad Reading scores in people with SZ, relative to HC.

Meta-analysis: Across seven studies (Figure 2.2.1.), SZ showed significantly poorer phonological processing compared to HC with a large effect size (*Hedge's g* = -.88, df = 24, $p < .00001$, CI = [-1.07, -.70]). There was medium heterogeneity within the data ($p = .001$, $I^2 = 53\%$), with non-significant differences between the tests ($p = .15$, $I^2 = 32.3\%$). The tests assessing RN skills showed the most prominent deficit; CTOPP-ARN (*Hedge's g* = -1.51, df = 1, $p < .0001$, CI = [-2.20, -.81]), CTOPP-RN (*Hedge's g* = -1.07, df = 3, $p < .00001$, CI = [-1.41, -.73]), RAN (*Hedge's g* = -1.38, df = 0, $p < .00001$, CI = [-1.96, -.81]). The WJTA-III (Word Attack subtest) was the least significant in meta-analysis and showed only a low-medium effect (*Hedge's g* = -.44, df = 0, *p* = .05, CI = [-.87, -.00]).

Figure 2.2. Reading deficits in SZ (non-forensic population). Within each specific reading skill, the results are presented for each of the test(s)/measures used, followed by the analysis of differences between tests (last row). Negative values represent a poorer performance of people with SZ in comparison to HC.

Figure 2.2.1. Phonological processing and decoding.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
AUDITORY BLENDING TEST				
Walder et al. 2006	-1.02 [-1.57, -0.47]	4.6%	31/27	p=0.0003
CTOPP-PA				
Arnott et al. 2011	-0.10 [-0.85, 0.65]	3.4%		
Dondé et al. 2019	-0.68 [-1.21, -0.15]	4.7%		
Revheim et al. 2006	-0.67 [-1.46, 0.12]	3.2%		
Revheim et al. 2014	-0.54 [-1.04, -0.03]	4.9%		
Whitford et al. 2013	-1.99 [-2.81, -1.17]	3.1%		
	-0.76 [-1.28, -0.24]	19.3%	130/90	p=0.004
CTOPP-PM				
Arnott et al. 2011	-0.29 [-1.04, 0.47]	3.4%		
Dondé et al. 2019	-0.34 [-0.86, 0.17]	4.8%		
Revheim et al. 2006	-0.96 [-1.77, -0.15]	3.1%		
Revheim et al. 2014	-0.51 [-1.01, 0.00]	4.9%		
Whitford et al. 2013	-1.48 [-2.23, -0.73]	3.4%		
	-0.67 [-1.07, -0.26]	19.5%	130/90	p=0.001
CTOPP-RN				
Arnott et al. 2011	-1.33 [-2.17, -0.49]	3.0%		
Revheim et al. 2006	-0.64 [-1.43, 0.15]	3.2%		
Revheim et al. 2014	-1.12 [-1.65, -0.59]	4.7%		
Whitford et al. 2013	-1.14 [-1.85, -0.42]	3.6%		
	-1.07 [-1.41, -0.73]	14.4%	100/62	p<0.00001
CTOPP-APA				
Arnott et al. 2011	-0.18 [-0.93, 0.57]	3.4%		
Dondé et al. 2019	-0.70 [-1.24, -0.17]	4.7%		
Revheim et al. 2006	-1.19 [-2.02, -0.36]	3.0%		
Revheim et al. 2014	-1.24 [-1.78, -0.70]	4.7%		
	-0.84 [-1.30, -0.39]	15.7%	110/74	p=0.0003
CTOPP-ARN				
Revheim et al. 2006	-1.09 [-1.91, -0.26]	3.0%		
Revheim et al. 2014	-1.81 [-2.39, -1.22]	4.3%		
	-1.51 [-2.20, -0.81]	7.4%	64/34	p<0.0001
RAN				
Walder et al. 2006	-1.38 [-1.96, -0.81]	4.4%	31/27	p<0.00001
RNRT				
Walder et al. 2006	-0.73 [-1.26, -0.20]	4.7%	31/27	p=0.007
RNST				
Walder et al. 2006	-1.04 [-1.59, -0.49]	4.6%	31/27	p=0.0002
WJTA - Word Attack				
Leonard et al. 2008	-0.44 [-0.87, 0.00]	5.4%	45/39	p=0.05
Overall (95% CI):	-0.88 [-1.07, -0.70]	100%	703/497	p<0.00001

Heterogeneity: Tau^2=0.11 Chi^2=51.26 df=24 (p=0.001) I^2=53%

Test differences: Chi^2=13.30 df=9 (p=0.15) I^2=32.3%

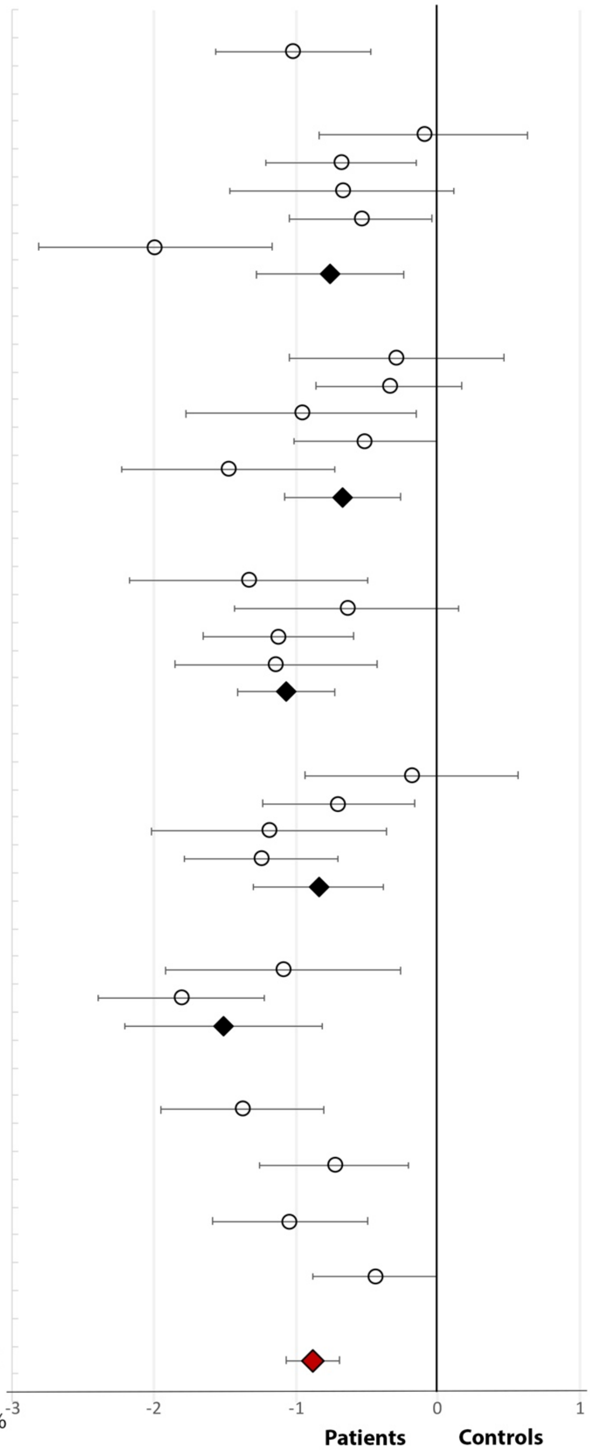


Figure 2.2.2. Comprehension.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
GORT-4				
Martinez et al. 2012	-1.65 [-2.40, -0.90]	2.5%	21/17	
Revheim et al. 2006	-1.03 [-1.85, -0.22]	2.3%	19/10	
Revheim et al. 2014	-1.30 [-1.84, -0.76]	3.1%	45/24	
	-1.33 [-1.72, -0.95]	7.9%	85/51	p<0.00001
WJTA				
Dondé et al. 2019	-0.30 [-0.82, 0.21]	3.2%	30/28	
Leonard et al. 2008	-1.34 [-1.82, -0.87]	3.3%	45/39	
Revheim et al. 2006	-0.76 [-1.56, 0.03]	2.4%	19/10	
Revheim et al. 2014	-1.28 [-1.82, -0.73]	3.1%	45/24	
	-0.94 [-1.46, -0.41]	12.0%	139/101	p=0.0005
NDRT				
Revheim et al. 2006	-1.35 [-2.20, -0.50]	2.2%	19/10	
Revheim et al. 2014	-1.67 [-2.24, -1.10]	3.0%	45/24	
Whitford et al. 2013	-1.93 [-2.74, -1.12]	2.3%	20/16	
	-1.66 [-2.07, -1.25]	7.6%	84/50	p<0.00001
NARA-III				
Arnott et al. 2011	-1.43 [-2.28, -0.58]	2.2%	16/12	p=0.001
WRMT-R				
Arnott et al. 2011	-0.93 [-1.73, -0.14]	2.4%	16/12	p=0.02
WRAT-IV				
Patrick et al. 2015	-1.34 [-1.91, -0.77]	3.0%	29/29	p<0.00001
RCBA (subtests I-X)				
Arnott et al. 2011	-0.48 [-1.24, 0.28]	2.5%	16/12	
Arnott et al. 2011	-0.32 [-1.07, 0.43]	2.5%	16/12	
Arnott et al. 2011	-0.28 [-1.03, 0.47]	2.5%	16/12	
Arnott et al. 2011	-0.42 [-1.18, 0.33]	2.5%	16/12	
Arnott et al. 2011	-0.29 [-1.04, 0.46]	2.5%	16/12	
Arnott et al. 2011	-0.08 [-0.83, 0.66]	2.5%	16/12	
Arnott et al. 2011	-0.30 [-1.05, 0.45]	2.5%	16/12	
Arnott et al. 2011	-0.67 [-1.44, 0.10]	2.4%	16/12	
Arnott et al. 2011	-0.62 [-1.39, 0.15]	2.5%	16/12	
Arnott et al. 2011	-0.60 [-1.37, 0.17]	2.6%	16/12	
Hayes et al. 2003	-1.22 [-1.78, -0.67]	3.1%	30/30	
Hayes et al. 2003	-0.39 [-0.90, 0.12]	3.2%	30/30	
Hayes et al. 2003	-1.06 [-1.61, -0.52]	3.1%	30/30	
Hayes et al. 2003	-0.52 [-1.03, -0.003]	3.2%	30/30	
Hayes et al. 2003	-3.12 [-3.89, -2.35]	2.5%	30/30	
Hayes et al. 2003	-0.96 [-1.49, -0.42]	3.1%	30/30	
Hayes et al. 2003	-1.45 [-2.03, -0.88]	3.0%	30/30	
Hayes et al. 2003	-1.30 [-1.86, -0.74]	3.1%	30/30	
Hayes et al. 2003	-0.90 [-1.43, -0.37]	3.1%	30/30	
Hayes et al. 2003	-0.78 [-1.31, -0.25]	3.2%	30/30	
	-0.80 [-1.06, -0.54]	55.4%	460/420	p<0.00001
BDAE				
Gavilan et al. 2011	-0.99 [-1.62, -0.36]	2.8%	22/22	p=0.002
PALPA				
Gavilan et al. 2011	-1.36 [-2.02, -0.70]	2.8%	22/22	p<0.0001
ITBS, ITED				
Ho et al. 2005	-0.40 [-0.68, -0.11]	3.8%	70/147	p=0.007
Overall (95% CI):	-0.96 [-1.15, -0.78]	100%	943/866	p<0.00001

Heterogeneity: Tau^2=0.21 Chi^2=111.99 df=35 (p<0.00001) I^2=69%

Test differences: Chi^2=35.36 df=9 (p<0.0001) I^2=74.5%

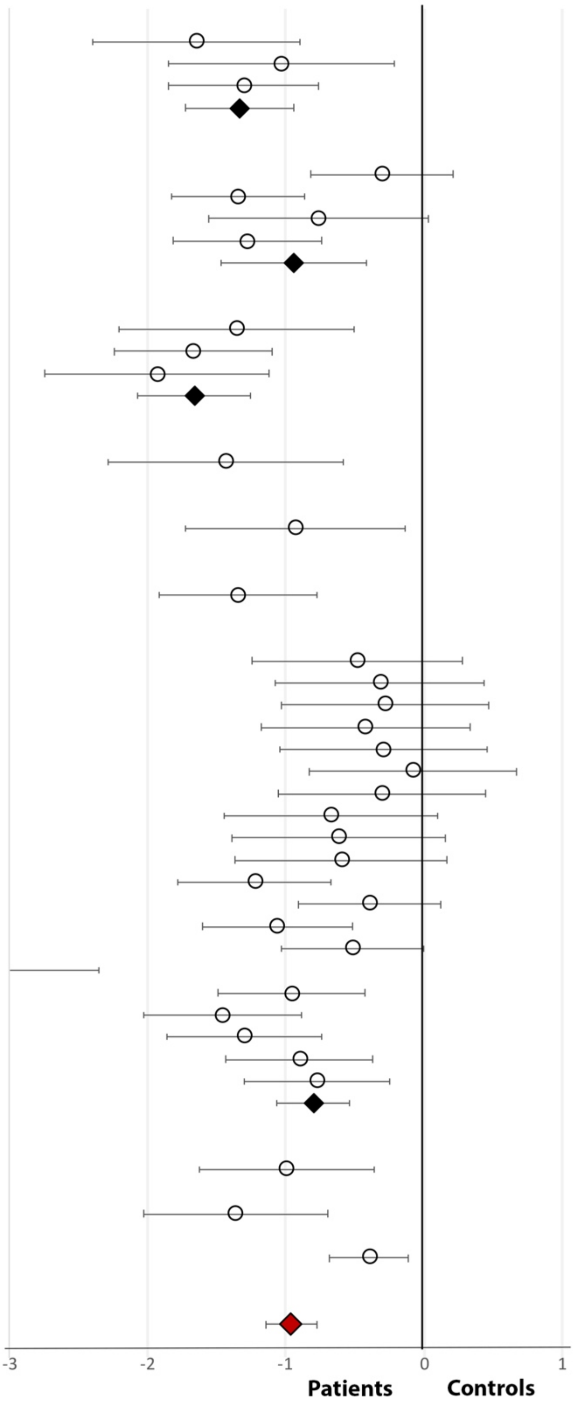


Figure 2.2.3. Single-word reading.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
WJTA				
Dondé et al. 2019	-0.28 [-0.79, 0.24]	9.9%	30/28	
Leonard et al. 2008	-0.78 [-1.23, -0.34]	11.3%	45/39	
	-0.55 [-1.04, -0.05]	21.2%	75/67	p=0.03
WRMT-R				
Arnott et al. 2011	-0.11 [-0.86, 0.64]	6.6%	16/12	p=0.77
WRAT-IV				
Light et al. 2012	-1.15 [-1.46, -0.83]	13.9%	163/58	
Patrick et al. 2015	-1.34 [-1.91, -0.77]	9.0%	29/29	
Potter et al. 2010	-0.56 [-0.89, -0.23]	13.7%	73/74	
Revheim et al. 2006	-0.85 [-1.65, -0.05]	6.1%	19/10	
Revheim et al. 2014	-0.94 [-1.47, -0.42]	9.9%	45/24	
Walder et al. 2006	-0.37 [-0.89, 0.15]	9.9%	31/27	
	-0.86 [-1.17, -0.56]	62.3%	360/222	p<0.00001
LNNB				
Maj 1986	-0.44 [-0.96, 0.08]	9.9%	52/20	p=0.10
Overall (95% CI):	-0.70 [-0.94, -0.46]	100%	503/321	p<0.00001

Heterogeneity: Tau^2=0.08 Chi^2=21.34 df=9 (p=0.01) I^2=58%

Test differences: Chi^2=4.66 df=3 (p=0.20) I^2=35.6%

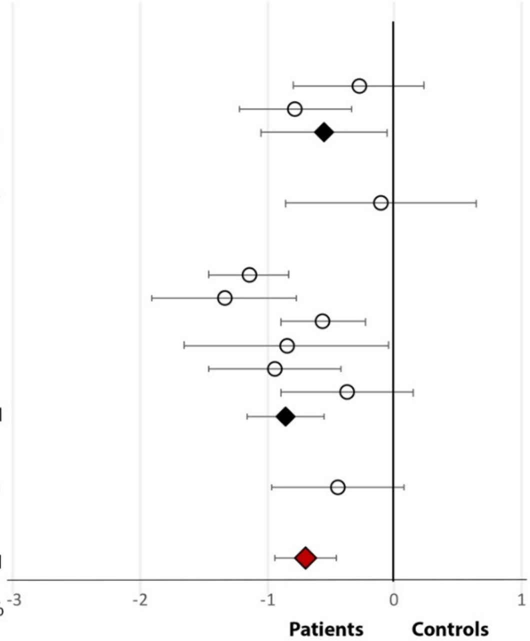


Figure 2.2.4. Rate.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
GORT-4				
Revheim et al. 2006	-1.13 [-1.96, -0.31]	18.9%	19/10	
Revheim et al. 2014	-2.34 [-2.98, -1.70]	20.8%	45/24	
	-1.77 [-2.95, -0.59]	39.7%	64/34	p=0.003
NDRT				
Whitford et al. 2013	-1.38 [-2.12, -0.64]	19.8%	20/16	p=0.0002
NARA-III				
Arnott t al. 2011	-0.99 [-1.79, -0.19]	19.2%	16/12	p=0.02
Alouette				
Curzietti et al. 2018	-0.24 [-0.83, 0.36]	21.2%	22/22	p=0.44
Overall (95% CI):	-1.22 [-1.98, -0.46]	100%	122/84	p=0.002

Heterogeneity: Tau^2=0.62 Chi^2=22.96 df=4 (p=0.0001) I^2=83%

Test differences: Chi^2=8.54 df=3 (p=0.04) I^2=64.9%

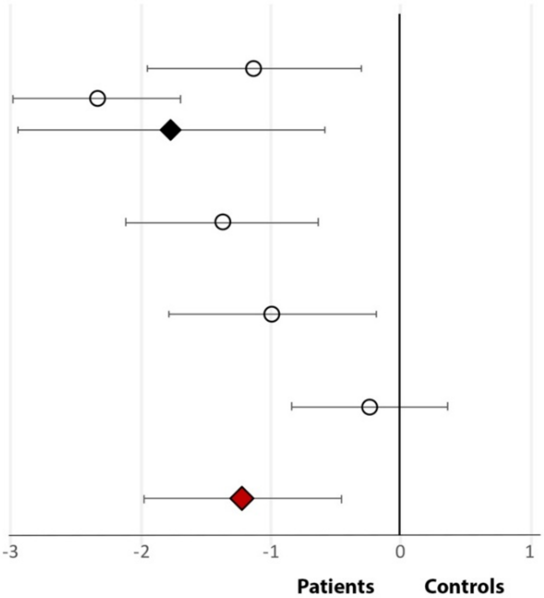


Figure 2.2.5. Accuracy.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
GORT-4				
Revheim et al. 2006	-0.91 [-1.72, -0.10]	23.4%	19/10	
Revheim et al. 2014	-1.67 [-2.24, -1.10]	26.3%	45/24	
	-1.34 [-2.08, -0.61]	49.8%	64/34	p=0.0003
NARA-III				
Arnott et al. 2011	-0.38 [-1.14, 0.37]	24.1%	16/12	p=0.32
Alouette				
Curzietti et al. 2018	0.07 [-0.52, 0.66]	26.1%	22/22	p=0.82
Overall (95% CI):	-0.73 [-1.56, 0.10]	100%	102/68	p=0.09

Heterogeneity: Tau^2=0.59 Chi^2=18.32 df=3 (p=0.0004) I^2=83%

Test differences: Chi^2=8.72 df=2 (p=0.01) I^2=77.1%

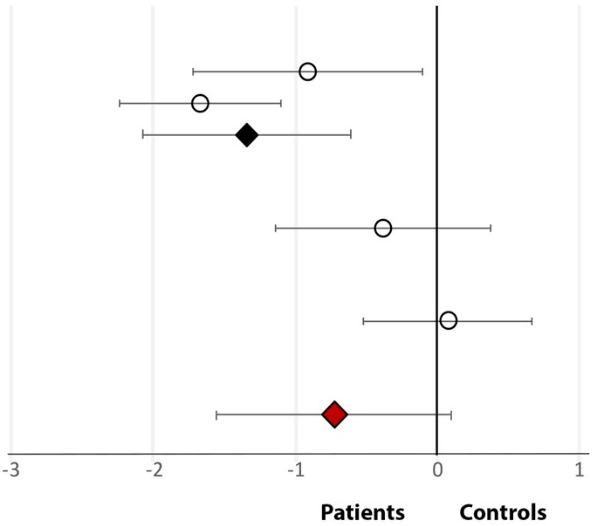


Figure 2.2.6. Fluency.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
GORT-4				
Martinez et al. 2012	-2.86 [-3.79, -1.93]	18.1%	21/17	
Revheim et al. 2006	-1.17 [-2.00, -0.34]	19.1%	19/10	
Revheim et al. 2014	-2.34 [-2.98, -1.70]	21.4%	45/24	
	-1.91 [-2.76, -1.07]	58.5%	85/51	p<0.00001
WJTA				
Dondé et al. 2019	-1.22 [-1.79, -0.66]	21.5%	30/28	
Revheim et al. 2014	-3.22 [-3.96, -2.48]	19.9%	45/24	
	-2.21 [-4.16, -0.25]	41.5%	75/52	p=0.03
Overall (95% CI):	-2.03[-2.82, -1.24]	100%	160/103	p<0.00001

Heterogeneity: Tau^2=0.67 Chi^2=24.83 df=4 (p<0.0001) I^2=84%

Test differences: Chi^2=0.07 df=1 (p=0.79) I^2=0%

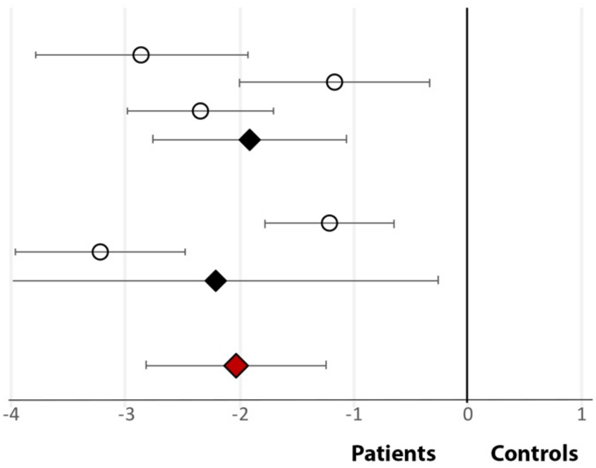
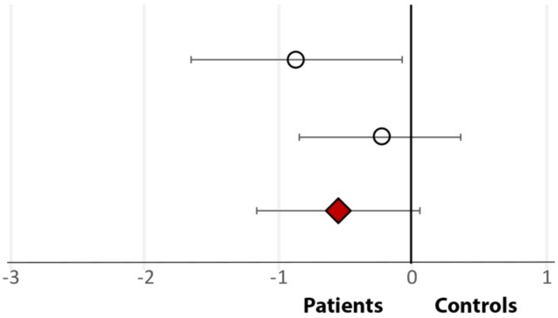


Figure 2.2.7. Speed.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
RCBA-2				
Arnott et al. 2011	-0.87 [-1.66, -0.08]	41.3%	16/12	p=0.03
Alouette				
Curzietti et al. 2018	-0.24 [-0.84, 0.36]	58.7%	22/22	p=0.44
Overall (95% CI):	-0.55 [-1.11, 0.11]	100%	38/34	p=0.11
Heterogeneity: Tau^2=0.07	Chi^2=1.58	df=1 (p=0.21)		I^2=37%
Test differences:	Chi^2=1.58	df=1 (p=0.21)		I^2=36.7%



Note: BDAE – Boston Diagnostic Aphasia Examination, CTOPP – Comprehensive Test of Phonological Processing (PA – Phonological Awareness, PM – Phonological Memory, RN – Rapid Naming, APA – Alternative Phonological Awareness, ARN – Alternative Rapid Naming), GORT – Gray Oral Reading Test, ITBS – Iowa Test of Basic Skills, ITED – Iowa Test of Educational Development, LNNB – Luria-Nebraska Neuropsychological Battery, NARA – Neale Analysis of Reading Ability, NDRT – Nelson–Denny Reading Test, PALPA – Psycholinguistic Assessments of Language Processing in Aphasia, RAN – Rapid Automatised Naming, RCBA – Reading Comprehension Battery for Aphasia, RNRT – Roentgen's Nonwords Reading Test, RNST – Roeltgen's Nonwords Spelling Test, WJTA-III – Woodcock-Johnson III Tests of Achievement Knowledge), WRAT – Wide Range Achievement Test, WRMT-R – Woodcock Reading Mastery Test-Revised.

White circle (○) – effect size for a particular study determining the difference between patients and controls

Black diamond (◆) – pooled effect size for particular test/subtest

Red diamond (◆) – overall effect size for diagnosis for a certain reading skill (e.g., comprehension) including all partial effect sizes

Comprehension

Narrative synthesis: There were 14 studies in SZ (Arnott et al., 2011; Disimoni et al., 1973; Dondé et al., 2019; Fuller et al., 2002; Gavilán & García-Albea, 2011; Hayes & O'Grady, 2003; Ho et al., 2005; Leonard et al., 2008; Martínez et al., 2012; R. E. Patrick et al., 2015; Reichenberg et al., 2002; Revheim et al., 2006, 2014; Whitford et al., 2018) using one or more of the 12 different measures. The WJTA-III, the Nelson-Deny Reading Test (NDRT) (Brown et al., 1993) and GORT-4 (Wiederholt & Bryant, 2001) were the most frequently administered tests, used in three to four studies (Table 2.2.2.). The three studies using GORT-4 (Martínez et al., 2012; Revheim et al., 2006, 2014) also reported the Oral Reading Quotient (ORQ), a composite score that combines comprehension and fluency scores and all found significant deficits in SZ. The Reading Comprehension Battery for Aphasia (RCBA) (LaPointe & Horner, 1979) was used in one study (Hayes & O'Grady, 2003). Another study (Arnott et al., 2011) used the newer version of RCBA [RCBA-2], together with the Woodcock Reading Mastery Tests – Revised (WRMT-R) (Woodcock, 1998), a test similar to the WJTA-III, and the Neale Analysis of Reading Ability, Third Edition (NARA-III) (Neale, 1999). One study (R. E. Patrick et al., 2015) used the comprehension subtest of the WRAT-IV.

One of the earliest studies (Disimoni et al., 1973) used paragraph reading to examine comprehension. Two studies (Fuller et al., 2002; Ho et al., 2005) evaluated the scholastic performance of people who later developed SZ using the Iowa Tests of Basic Skills (ITBS) (Hoover et al., 1996) and the Iowa Tests of Educational Development (ITED) (Forsyth et al., 2001). This retrospective assessment found that those with a current diagnosis demonstrated below the norms in comprehension during the 4^{th} to 11^{th} grade of school (Fuller et al., 2002). The deficit was most prominent in 11^{th} grade, indicating a gradual decline over time as part of the prodrome (Fuller et al., 2002; Ho et al., 2005). A similar study on adolescents who later developed psychosis displayed some premorbid deficit in comprehension and sentence reading relative to HC (Reichenberg et al., 2002). This study assessed comprehension by measuring the ability to recognise ideas presented in unfamiliar passages of increasing length and to correctly read sentences of increasing difficulty.

Lastly, comprehension was assessed in one study (Gavilán & García-Albea, 2011) by reading non-literal statements like metaphors, ironies and proverbs in the Psycholinguistic Assessments of Language Processing in Aphasia PALPA (Castro et al., 2007) and by the Boston Diagnostic Aphasia Examination (BDAE) (Goodglass & Kaplan, 1972).

Meta-analysis: Across 11 studies (Figure 2.2.2.), SZ showed poorer comprehension than HC with a large overall effect size (*Hedge's* g = -.96, df = 34, p < .00001, CI = [-1.15, -.78]) and medium heterogeneity ($p < .00001$, $I^2 = 69\%$). The test differences were significant ($p < .0001$, $I^2 = 74.5\%$) with NDRT and GORT-4 showing the largest effect sizes for a comprehension deficit in SZ.

Single-Word Reading

Narrative synthesis: Single-word reading in SZ was examined using four different tests. Various editions of the WRAT single-word reading test were used in seven of the 12 studies. In one of these studies (Nelson et al., 2007), SZ scored markedly lower (*M* = 78.00, *SD* = 21.01) than the norm (*M* = 100) on WRAT-III, the rest of the studies were included in the meta-analysis. Two studies (Maj, 1986; Puente et al., 1993) used the Luria-Nebraska Neuropsychological Battery (Golden et al., 1985) reading subtest and in both, SZ showed a deficit compared to HC (data for meta-analysis not provided). Two studies (Dondé et al., 2019; Leonard et al., 2008) used the WJTA-III (Letter Word Identification subtest and Basic Skills), and one study (Arnott et al., 2011) used the WRMT-R Basic Skills.

Meta-analysis: Across 10 studies (Arnott et al., 2011; Dondé et al., 2019; Leonard et al., 2008; Light et al., 2012; Maj, 1986; R. E. Patrick et al., 2015; Potter & Nestor, 2010; Revheim et al., 2006, 2014; Walder et al., 2006), there was a significant medium-size deficit (Figure 2.2.3.) in SZ relative to HC (*Hedge's g* = -.70, df = 9, $p < .00001$, CI = [-.94, -.46]). There was significant heterogeneity within the results ($p = .01$, $I^2 = 58\%$), but no test performed better than others ($p = .20$, $I^2 = 35.6\%$).

Rate, Speed, Accuracy, and Fluency

Narrative synthesis: The GORT-4 was the test most frequently used to assess rate, accuracy and fluency (Martínez et al., 2012; Revheim et al., 2006, 2014). The NARA-III was used for rate and accuracy (Arnott et al., 2011). The NDRT was used to assess the rate in one study (Whitford et al., 2013). The Alouette (Lefavrais, 2006), a French screening test for dyslexia assessing rate, speed, and accuracy, was also used in one study (Curzietti et al., 2018). The WJTA-III was used in two studies (Dondé et al., 2019; Revheim et al., 2014), and BDAE in one study (Halpern et al., 1989), to assess fluency. Reading speed was assessed by the RCBA-2 and Alouette in two studies (Arnott et al., 2011; Curzietti et al., 2018).

Meta-analysis: Across five studies (Arnott et al., 2011; Curzietti et al., 2018; Revheim et al., 2006, 2014; Whitford et al., 2013), there was a significant large effect of SZ diagnosis on reading rate (*Hedge's g* = -1.22, df = 4, $p = .002$, CI = [-1.98, -.46]) (Figure 2.2.4.). The effect of diagnosis (Arnott et al., 2011; Curzietti et al., 2018; Revheim et al., 2006, 2014) in accuracy failed to reach significance

(*Hedge's g* = -.73, df = 3, *p* = .09, CI = [-1.56, .10]) (Figure 2.2.5.). There were, however, significant test differences for both rate ($p = .04$, $I^2 = 64.9\%$) and accuracy ($p = .01$, $I^2 = 77.1\%$), with the GORT-4 revealing large deficits (Revheim et al., 2006, 2014), and the Alouette showing no deficit (Curzietti et al., 2018) (Figures 2.2.4. and 2.2.5.). In fluency (Dondé et al., 2019; Halpern et al., 1989; Martínez et al., 2012; Revheim et al., 2006, 2014), there was a highly significant deficit in SZ (*Hedge's g* = -2.03, df = 4, $p < .00001$, CI = [-2.82, -1.24]), but with large heterogeneity within results (84%) (Figure 2.2.6.). In reading speed (time taken to read certain content) (Arnott et al., 2011; Curzietti et al., 2018), the effect of diagnosis was non-significant (*Hedge's g* = -.50, df = 1, *p* = .11, CI = [-1.11, -.11]) (Figure 2.2.7.). In an additional study (Halpern et al., 1989), 10-11% of SZ demonstrated nonfluencies (e.g., sound repetitions at beginning of word) in sentence and paragraph reading during the BDAE.

Reading-Related Skills

Although this review focuses on core reading skills, these skills are likely to be influenced by some related skills such as vocabulary, spelling, grammar, and orthography. Therefore, we also provide a narrative synthesis of selected studies investigating reading-related skills in psychopathology. Six studies, all in SZ (Fuller et al., 2002; Ho et al., 2005; Revheim et al., 2006, 2014; Walder et al., 2006; J. Wang et al., 2015), included the assessment of reading-related skills.

Vocabulary: Six studies (Fuller et al., 2002; Ho et al., 2005; Revheim et al., 2006, 2014; Walder et al., 2006; J. Wang et al., 2015) assessed reading-related skills in SZ. There was evidence of impaired vocabulary from an early age (Fuller et al., 2002; Ho et al., 2005) and those with prodromal illness scored significantly below grade norms when assessed by the ITBS and ITED as a part of their school performance. Vocabulary, assessed using the NDRT, was also impaired in two studies (Revheim et al., 2006, 2014).

Spelling and Grammar: Spelling in RNST was found to be adversely affected in male patients, while female patients scored similarly to HC (Walder et al., 2006). Another study (Fuller et al., 2002), that longitudinally assessed spelling together with grammar and other language-related skills by ITBS, found a significant decline in abilities at 11^{th} grade in SZ. Similarly, SZ scored significantly lower in the WJTA-III spelling subtest compared to HC (Revheim et al., 2014). Grammar was assessed exclusively in one study (Walder et al., 2006), using Caplan and Hildebrandt's task (Caplan & Hildebrandt, 1992), showing a stronger and significant deficit in male, relative to female, patients (Walder et al., 2006).

Orthography: Orthography processes are not reading abilities. However, in languages such as Chinese, orthography and semantics play an important role in reading, in contrast to alphabetical languages such as English where phonological processing plays a key role (J. Wang et al., 2015). One study (J. Wang et al., 2015) that investigated orthography processes found significant deficits in orthography-phonology, but not in vocabulary when distinguishing real words from nonwords, in SZ compared to HC.

2.4.1.2. Affective Disorders (Depression, Anxiety or Mania)

Two studies (Maj, 1986; Weiss et al., 2006) assessed single-word reading in depression, both using the REALM. Of these, one study (Maj, 1986) showed a non-significant small deficit in people with depression (*Hedge's g* = -.30, df = 0, *p* = .37, CI = [-.96, .36]) and, in the other study (Weiss et al., 2006), all participants performed at 7-8th grade reading level.

2.4.1.3. Bipolar Disorder

The earlier-mentioned study on adolescents (Reichenberg et al., 2002) had also assessed comprehension pre-morbidly in a group who later developed non-psychotic bipolar disorder and found them to have no deficit in comparison to HC.

2.4.1.4. Personality Disorders/Psychopathy

One study (Brites et al., 2015) assessed phonological processing (distinguish between different types of words: verbal, written, pseudowords) and comprehension, using the Portuguese version of the PALPA, and showed medium-size deficits in both phonological processing (*Hedge's g* = -.55, df = 2, *p* = .004, CI = [-.92, -.18]) (Figure 2.3.1.) and comprehension (*Hedge's g* = -.47, df = 0, *p* = .05, CI = [-.87, .39]) (Figure 2.3.2.) in people with diagnosed psychopathy (from community settings), compared with non-psychopathic non-forensic controls.

Figure 2.3. Reading deficits in community/non-forensic samples of people with psychopathy. Within each specific reading skill, the results are presented for each of the test(s)/measures used, followed by the analysis of differences between tests (last row). Negative values represent a poorer performance of people with personality disorders in comparison to HC.

Figure 2.3.1. Phonological processing and decoding.

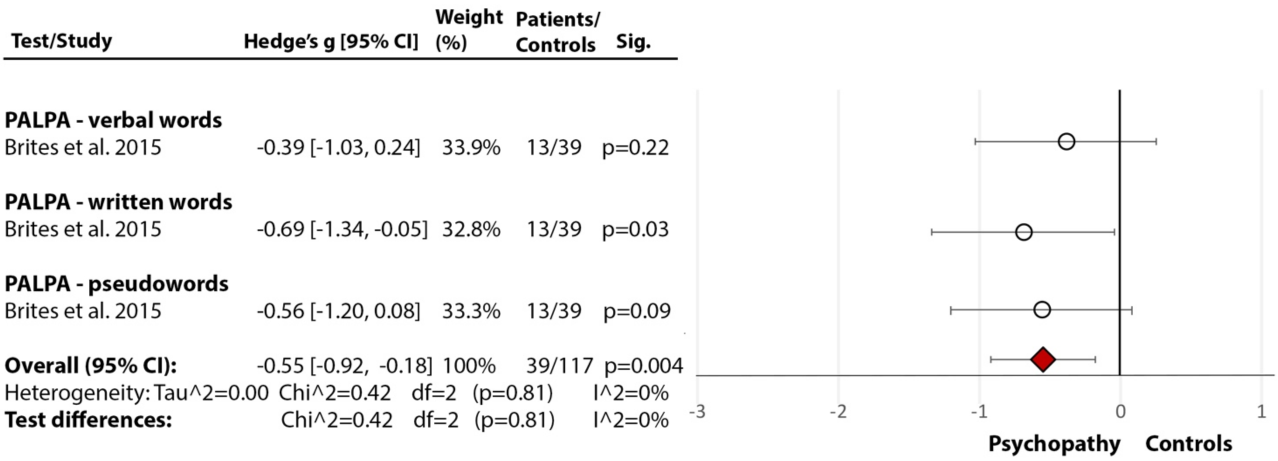
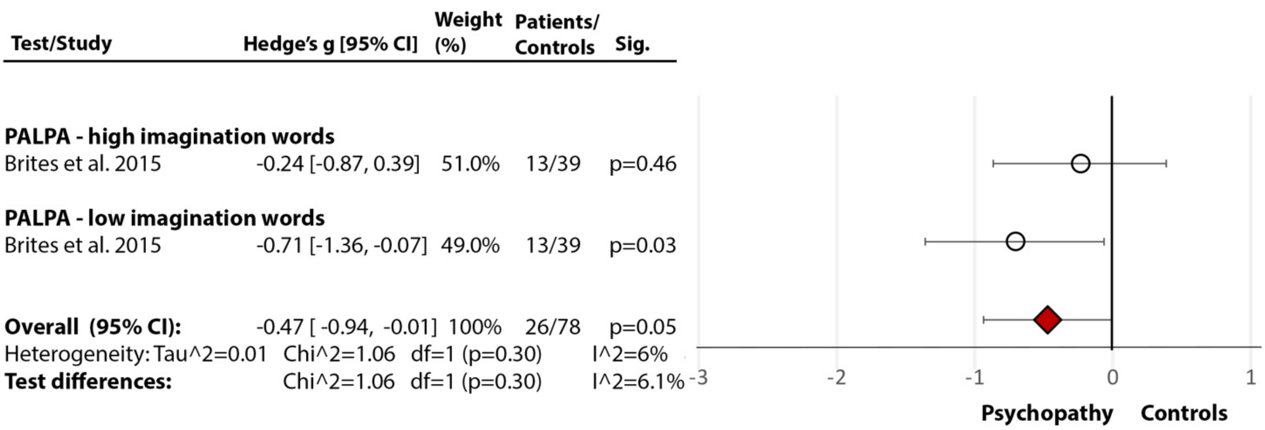


Figure 2.3.2. Comprehension.



Note: PALPA – Psycholinguistic Assessments of Language Processing in Aphasia

White circle (○) – effect size for a particular study determining the difference between patients and controls
Red diamond (◆) – overall effect size for diagnosis for a certain reading skill (e.g. comprehension) including all partial effect sizes

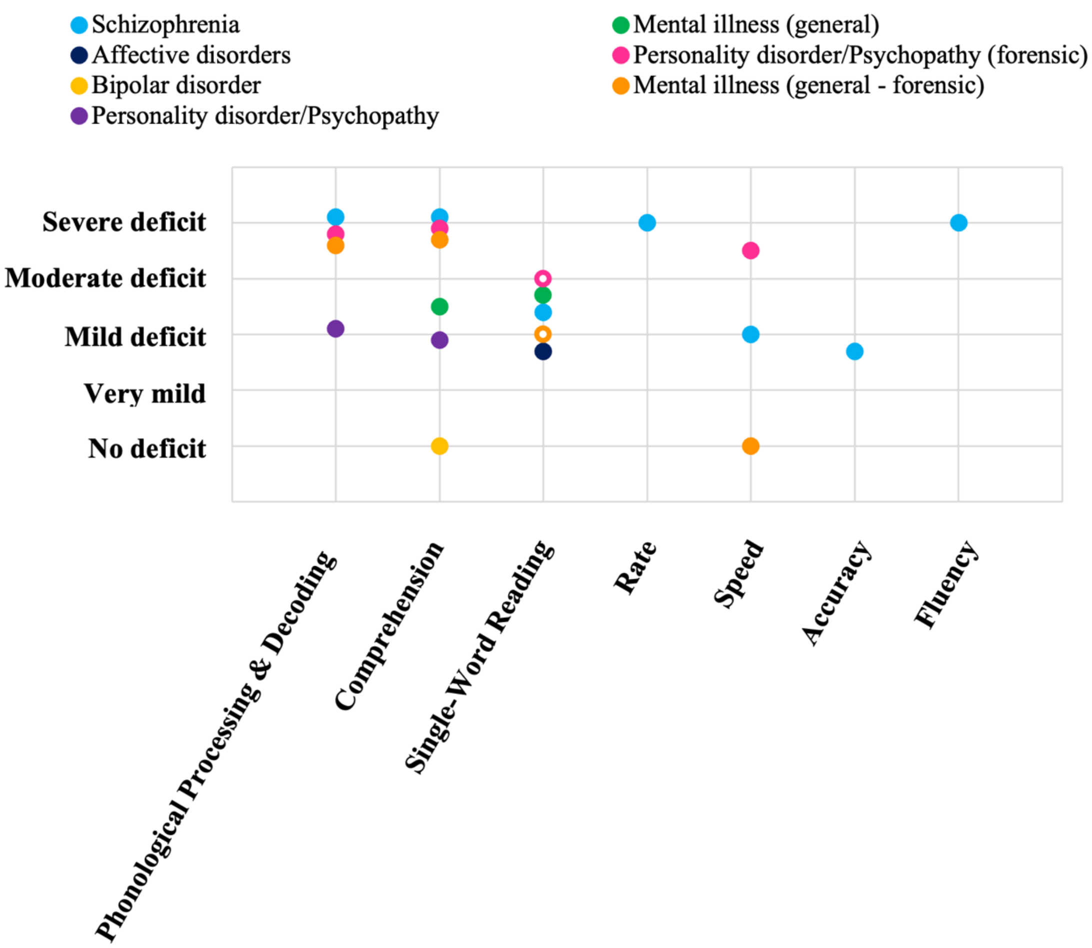
2.4.1.5. General Mental Illnesses (Non-specified/Mixed)

Two studies (Berg & Hammitt, 1980; Ferron et al., 2012) assessed comprehension and single-word reading while the third study (R. C. Christensen & Grace, 1999) assessed single-word reading only. The first study (Ferron et al., 2012) reported 9th-grade level comprehension as well as 9th-grade level single-word reading when assessed by WRAT-IV in people with unspecific MIs. The second study (Berg & Hammitt, 1980), using the Peabody Individual Achievement Test **(**PIAT) -comprehension subtest (Dunn & Markwardt, 1970), reported 7th-grade comprehension, despite 9th – 10th grade for single-word reading, in psychiatric patients (majority with alcoholism or non-organic psychoses). In the third study (R. C. Christensen & Grace, 1999), 75% of the sample with MIs (mainly SZ and affective disorders) read below 7th grade when assessed by REALM.

2.4.2. Summary of Deficits in Non-Forensic Populations

Overall, SZ was associated with pronounced deficits in phonological processing, comprehension, reading rate, and fluency (Figure 2.4.), with deficits also present in reading-related skills. These deficits appear to be present often from an early age, with the reading skills of SZ adults remaining below their achieved education levels. The single-word reading and speed were less impacted. There were few data in affective disorders, and only for single-word reading, showing a mild/non-significant deficit. Individuals with PDs/high psychopathy showed mild deficits in both phonological processing and comprehension (Figure 2.4.). Comprehension and single-word reading skills of people with unspecified MIs from non-forensic settings were at secondary school levels which, although below the norm, were better than those in SZ (Figure 2.4.).

Figure 2.4. Interpretation of observed reading deficits in included diagnoses.



Note: **No deficit** = Non-significant differences between patients and HC; **Very mild deficit** = *Hedge's g* up to -.30 and/or mixed results with the majority of samples scoring within the norm; **Mild deficit** = *Hedge's g* up to -.50 and/or reading skill at 9th – 10th-grade level; **Moderate deficit** = *Hedge's g* up to -.75 and/or reading skill at 7th – 8th-grade level; **Severe deficit** = *Hedge's g* over -.75 and/or reading skill below the 7th-grade level. This interpretation considers whether the results were consistent or mixed. **Empty circle (○) = Mixed evidence**.

2.4.3. Reading Skills in Forensic Populations

Seven studies (Brites et al., 2015; Daderman et al., 2004; Dalby & Williams, 1986; Davidson et al., 2011; Nestor, 1992; Selenius & Strand, 2015; Svensson et al., 2015), all in PDs/psychopathy or general MIs, were found.

2.4.3.1. Personality Disorders/Psychopathy

Phonological Processing and Decoding

In the first study (Brites et al., 2015), the PALPA phonological processing test showed a large deficit in the incarcerated group with diagnosed psychopathy relative to HC (*Hedge's g* = -.85, df = 2, *p* = .0001, CI = [-1.22, -.47]) (Figure 2.5.1.). The second study (Daderman et al., 2004), using the Jacobson's Decoding Test (JDT) (Jacobson, 2001) to examine decoding, showed marked impairment (*Hedge's g* = -.84, df = 0, *p* = .01, CI = [-1.51, -.17]) in people with non-specific PDs (and comorbid MIs), relative to HC.

Comprehension

One study (Brites et al., 2015) used the PALPA and showed a large deficit in comprehension in incarcerated people with diagnosed psychopathy, compared to HC (*Hedge's g* = -.95, df = 0, *p* = .0003, CI = [-1.48, -.43]) (Figure 2.5.2.). The other study (Daderman et al., 2004) used a Swedish prose text (Madison, 1993) and found no deficit in PDs.

Single-Word Reading

The first study (Daderman et al., 2004) used a Swedish single-word reading test (Madison, 2001) and found significant impairment in PD inmates with comorbid MI and dyslexia, as well as in dyslexic inmates, in comparison to inmates without a PD diagnosis. In the second study (Brites et al., 2015), a diagnosis of psychopathy did not influence single-word reading as assessed by PALPA. The third study (Davidson et al., 2011) found literacy scores, as assessed by the Test of Word Reading Efficiency (TOWRE) (Torgesen et al., 1999), to be below the norm in PD. None of these studies (Brites et al., 2015; Daderman et al., 2004; Davidson et al., 2011) provided data for effect size calculation.

Rate, Speed, Accuracy, and Fluency

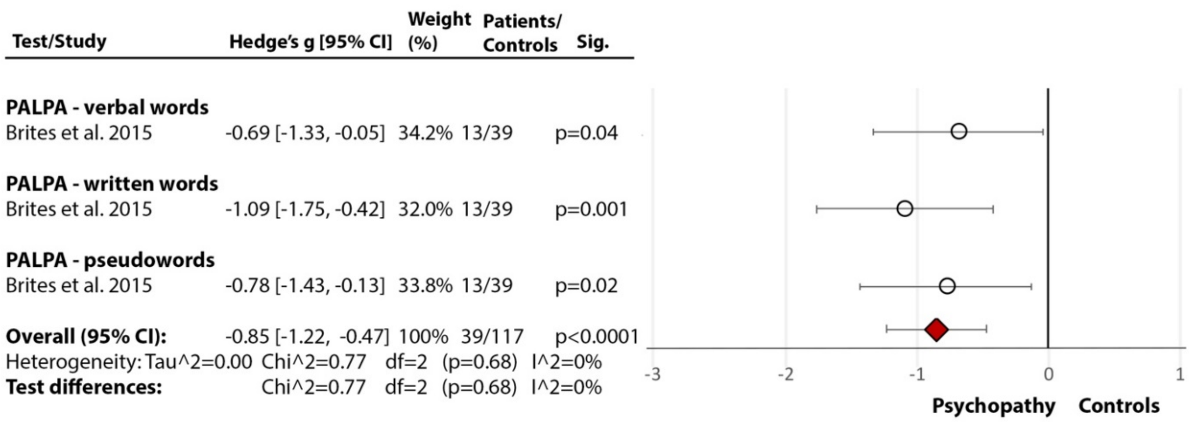
Only one study (Daderman et al., 2004) was found, showing that reading speed was negatively affected in 7 of 10 forensic PD participants, especially in those with comorbid dyslexia.

Reading-Related Skills

One study (Daderman et al., 2004) showed that spelling was poorer in inmates with PD and dyslexia, as opposed to those with no comorbidities.

Figure 2.5. Reading deficits in forensic patients with psychopathy or personality disorders. Within each specific reading skill, the results are presented for each of the test(s)/measures used, followed by the analysis of differences between tests (last row). Negative values represent a poorer performance of people with psychopathy or personality disorder in comparison to HC.

Figure 2.5.1. Phonological processing and decoding.
Psychopathy



Personality disorders – general

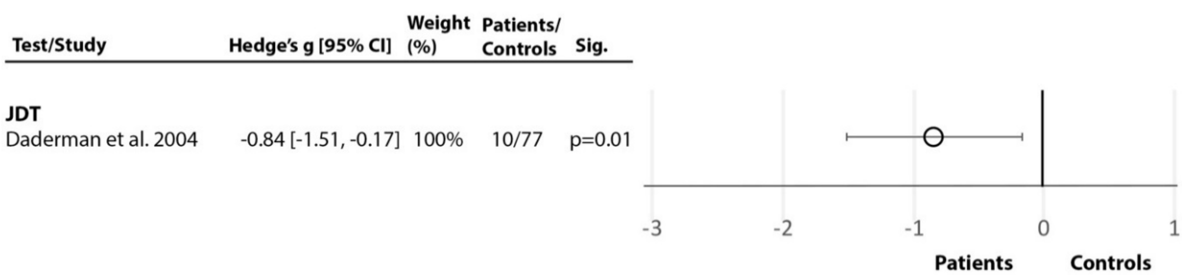
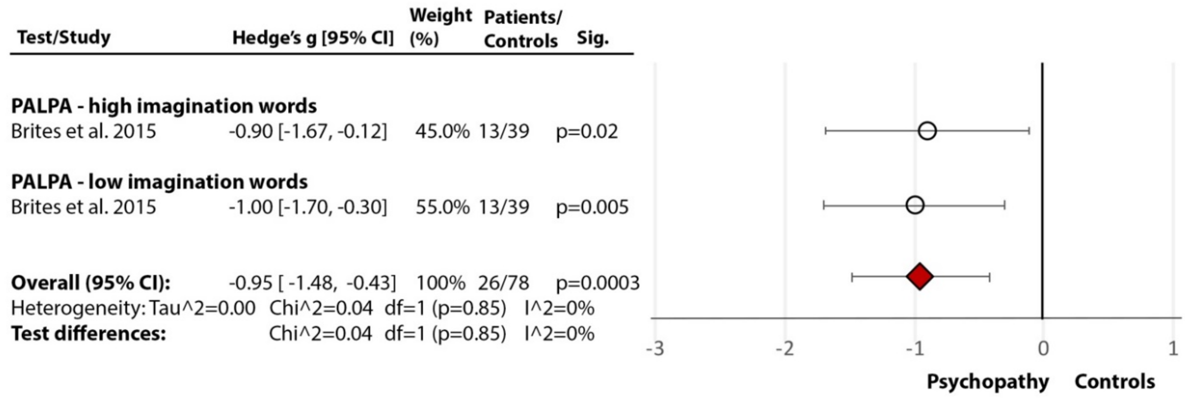


Figure 2.5.2. Comprehension.

Psychopathy



Note: JDT – Jacobson's Decoding Test, PALPA – Psycholinguistic Assessments of Language Processing in Aphasia

White circle (○) – effect size for a particular study determining the difference between patients and controls

Red diamond (◆) – overall effect size for diagnosis for a certain reading skill (e.g., comprehension) including all partial effect sizes

2.4.3.2. General Mental Illnesses (Non-specified/Mixed)

Phonological Processing and Decoding

One study (Svensson et al., 2015) used the JDT–Wordchains, the Word Attack test (Svensson & Jacobson, 2006), and Phonological Choice (Olofsson, 1994), and revealed severely impaired phonological skills (below the 6^{th} grade) in people with various MIs. The second study (Selenius & Strand, 2015) examined correlations between psychopathic traits and phonological and decoding skills in forensic psychiatric patients, assessed with the "Pidgeon" test (Lundberg & Wolff, 2003), the Madison's Word Decoding Test (MWDT) (Madison, 2001), and the JDT, and found positive correlations between the superficial item of the Psychopathy Checklist: Screening Version (PCL:SV) (Hart et al., 1995) and phonological processing and decoding of sentences (but not words). However, as the study did not include HCs or test normative scores, the findings are difficult to understand in terms of quantifying the deficit.

Comprehension

In one study (Svensson et al., 2015) that used the Oral Close subtest of the WRMT-R, comprehension in inmates with MI was below 4th grade in 23% of Swedish natives and over 50% of non-native speakers. In another study (Selenius & Strand, 2015) that used a silent paragraph reading test (Madison, 1985), no significant correlations between psychopathic traits and comprehension scores in people with non-specified MIs were found.

Single-Word Reading

There were two studies (Dalby & Williams, 1986; Nestor, 1992), both using the WRAT. The first study (Dalby & Williams, 1986) assessed people with various diagnoses (psychosis, mania, alcoholism, and ASPD). It found no significant differences between HC and psychosis (*Hedge's g* = 1.42, df = 0, *p* = .68, CI = [-5.40, 8.24]), mania (*Hedge's g* = .53, df = 0, *p* = .13, CI = [-.15, 1.20]), or alcohol abuse (*Hedge's g* = -.49, df = 0, *p* = .10, CI = [-1.06, .09]), but single-word reading was significantly impaired in ASPD (*Hedge's g* = -1.01, df = 0, *p* = .004, CI = [-1.69, -.33]. The second study (Nestor, 1992) found age-moderated differences in people with MIs and a history of violence, with people aged above 45 years scoring significantly better than those below 20 years.

Rate, Speed, Accuracy, and Fluency

One earlier-described study (Selenius & Strand, 2015) found that, within those with MIs, reading speed (Madison, 1985) was positively correlated with affective and interpersonal traits (Factor 1, PCL:SV (Hart et al., 1995)).

Reading-Related Skills

In a study (Selenius & Strand, 2015) involving Swedish inmates with MIs, neither spelling nor vocabulary scores significantly correlated with psychopathic traits.

2.4.4. Summary of Deficits in Forensic Populations

Overall, there was evidence of severe impairment in phonological processing and decoding in forensic populations with PDs/psychopathy (Figures 2.4. and 2.5.), similar to that seen in SZ. There was also evidence of deficits in comprehension, single-word reading, and speed in this population (Figures 2.4.

and 2.5.). Studies on forensic patients with various MIs yielded mixed findings though one study (Svensson et al., 2015) that examined inmates did show phonological processing and comprehension to be well below the norm.

2.4.5. Non-forensic vs Forensic Populations: Direct Comparison

Only one study (Brites et al., 2015) directly compared forensic and non-forensic groups. It used PALPA and revealed a significant medium-size deficit in incarcerated individuals with psychopathy compared to non-incarcerated (community) sample with psychopathy in phonological processing and decoding (*Hedge's g* = -.49, df = 2, *p* = .03, CI = [-.94, -.04] (Figure 2.6.1.), and a large deficit in comprehension (*Hedge's g* = -.85, df = 1, *p* = .003, CI = [-1.43, -.28]) (Figure 2.6.2.). These results support the findings from individual studies indicating severe reading deficits in incarcerated individuals with MI.

2.4.6. Reading Skills Deficits in Mental Illness: Influencing Factors

2.4.6.1. Symptoms and Medication

Of six studies in SZ (Arnott et al., 2011; Curzietti et al., 2018; Nelson et al., 2007; Revheim et al., 2006, 2014; J. Wang et al., 2015) that examined the relationship between psychotic symptoms and reading skills, three (Arnott et al., 2011; Revheim et al., 2006; J. Wang et al., 2015) found a negative influence of positive and negative symptoms on phonological processing, comprehension, and orthography; and hallucinations negatively affected reading efficiency and speed in one study (Curzietti et al., 2018). Five studies (Martínez et al., 2012; Puente et al., 1993; Revheim et al., 2014; Walder et al., 2006; Whitford et al., 2013) examined the effect of antipsychotic dose as chlorpromazine equivalents; four (Puente et al., 1993; Revheim et al., 2014; Walder et al., 2006; Whitford et al., 2013) found no relationship with single-word reading, phonological processing, or comprehension, and one (Martínez et al., 2012) found a negative influence of high dosage on fluency and comprehension. No significant association occurred between depressive symptoms and single-word reading (Weiss et al., 2006).

2.4.6.2. Cognitive Function

Six studies (Dalby & Williams, 1986; Fuller et al., 2002; Hayes & O'Grady, 2003; Martínez et al., 2012; Revheim et al., 2006, 2014) examined the relationship between reading skills and general cognition in SZ. Verbal IQ significantly correlated with comprehension and vocabulary (Fuller et al., 2002). Lower premorbid IQ (single-word reading) predicted reading comprehension (Hayes & O'Grady, 2003; Revheim et al., 2014). However, general IQ did not significantly predict any of the reading skills (Martínez et al., 2012). Similarly, working memory did not correlate with comprehension or reading rate in SZ and HC (Revheim et al., 2006). In forensic populations, full-scale IQ was significantly lower than single-word reading in individuals with SZ and bipolar disorder (Dalby & Williams, 1986). These results suggest that general verbal skills may influence comprehension, but no marked impact of other cognitive abilities was found.

2.4.6.3. Education

In SZ, three studies (Martínez et al., 2012; Revheim et al., 2006, 2014) examined the influence of education and all found reading skills significantly below achieved academic levels. Six studies (Arnott et al., 2011; Curzietti et al., 2018; Dondé et al., 2019; Gavilán & García-Albea, 2011; Maj, 1986; J. Wang et al., 2015) matched their groups on education or entered it as a covariate (Whitford et al., 2013), and all found significant impairments in various reading skills. Non-forensic populations with general MIs had the single-word reading equivalent to their achieved education but their comprehension was lower (Berg & Hammitt, 1980). Forensic PD also had comprehension below their education level (Daderman et al., 2004).

Figure 2.6. Reading deficits in incarcerated vs community samples of people with a diagnosis of psychopathy. Within each specific reading skill, the results are presented for each of the test(s)/measures used, followed by the analysis of differences between tests (last row). Negative values represent a poorer performance of the forensic sample, compared to the non-forensic sample.

Figure 2.6.1. Phonological processing and decoding.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
PALPA - verbal words				
Brites et al., 2015	-0.27 [-1.05, 0.50]	34.3%	13/13	p=0.49
PALPA - written words				
Brites et al., 2015	-0.66 [-1.46, 0.13]	32.5%	13/13	p=0.10
PALPA - pseudowords				
Brites et al., 2015	-0.55 [-1.34, 0.24]	33.2	13/13	p=0.17
Overall (95% CI)	-0.49 [-0.94, -0.04]	100%	39/39	p<0.03

Heterogeneity: Tau^2=0.00 Chi^2=0.51 df=2 (p=0.59) I^2=0%
Test differences: Chi^2=0.51 df=2 (p=0.59) I^2=0%

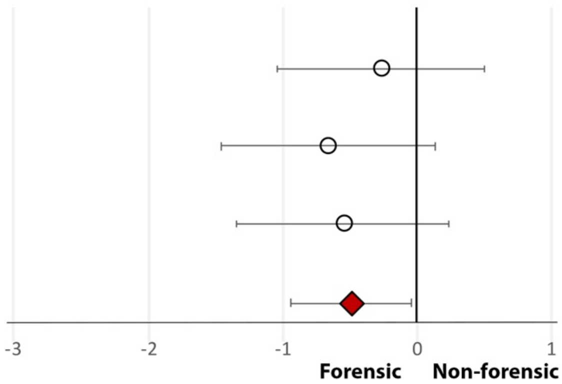
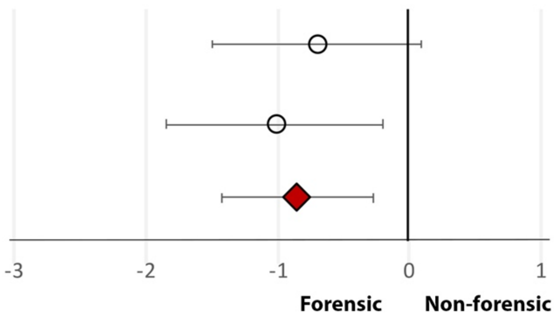


Figure 2.6.2. Comprehension.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
PALPA - high-imagination words				
Brites et al., 2015	-0.70 [-1.50, 0.09]	51.8%	13/13	p=0.08
PALPA - low-imagination words				
Brites et al., 2015	-1.02 [-1.84, -0.19]	48.2%	13/13	p=0.02
Overall (95% CI)	-0.85 [-1.43, -0.28]	100%	26/26	p=0.03

Heterogeneity: Tau^2=0.00 Chi^2=0.29 df=1 (p=0.59) I^2=0%
Test differences: Chi^2=0.29 df=1 (p=0.59) I^2=0%



Note: PALPA - Psycholinguistic Assessments of Language Processing in Aphasia

White circle (○) – effect size for a particular study determining the difference between patients and controls

Red diamond (◆) – overall effect size for diagnosis for a certain reading skill (e.g., comprehension) including all partial effect sizes.

2.5. Discussion

This systematic review and meta-analysis evaluated existing evidence to identify the type and degree of reading impairments in different MIs, the reading assessment tools that might most consistently detect them, and possible differences in the pattern of reading skills deficits in people with different MIs in forensic and non-forensic settings. Most of the reviewed studies (27/34) included people with SZ. The results revealed medium-to-large deficits in phonological processing, comprehension and reading rate, relative to HC. The single-word reading was less affected in SZ. There were only a few studies in other MIs and their findings revealed mostly non-significant deficits, except for PD in forensic settings who did show significant deficits in phonological processing and comprehension compared to HC. There were seven studies of reading skills deficits in people with different MIs (PD or general MI) in forensic settings. Our findings are discussed below.

2.5.1. Effect of Diagnosis in Non-Forensic Samples

We observed significant deficits in multiple reading skills in SZ, resembling the pattern typically seen in dyslexia (Lyon et al., 2003), and consistent with previous evidence for shared genetic and psychophysiological traits in SZ and dyslexia (Whitford et al., 2018). In our meta-analysis, both phonological processing and comprehension were greatly impaired. These impairments may be associated with ineffective use of contextual information (Niznikiewicz et al., 2004) and contribute to poor speech in SZ, especially in close association with thought disorder (Corcoran et al., 2020). The reading rate was low but the deficit in reading accuracy was lower. This indicates relatively preserved single-word reading skills, most likely because they are usually acquired before illness onset and remain intact (Reichenberg et al., 2002). In contrast, there was evidence for impairments in vocabulary and spelling, presumably as a result of disrupted scholastic experience. Disrupted scholastic experience during adolescence can affect complex skills such as comprehension (Fuller et al., 2002; Ho et al., 2005; Reichenberg et al., 2002) which could precipitate difficulties with processing complex written information in SZ.

Poor reading in schizophrenia has been associated with a number of neurophysiological abnormalities which might provide insight into the potential cognitive and sensory mechanisms underlying this problem. Specifically, a delay in the N400 component has been reported during reading, most likely reflecting difficulties in understanding meaning and context (Nestor et al., 1997). While reading sentences, people with schizophrenia also show fewer single fixations, show increased second pass fixations, and demonstrate longer gaze durations (Fernandez et al., 2016). Abnormalities in saccadic eye movement are good indicators of impairment in sensitivity to peripheral visual information, resulting in reduced reading speed (E. O. Roberts et al., 2013). People with schizophrenia also show poorer contrast sensitivity in perception of global shapes, and disruptions in cortical circuitry involved in the processing of such visual information, which can lead to difficulties in passage reading (Martínez et al., 2012). Taken together, these findings indicate that abnormalities within the visual domain, as well poor understanding of the meaning and contextual information, might at least partially explain the poor reading ability of people with schizophrenia.

People with SZ showed reading skills well below their achieved education level (see *Education*). Reading skills deficits in SZ also do not seem to be explained by other aspects of cognition (see *Cognitive Function*) though more comprehensive investigations are needed to substantiate this. Our findings (*Symptoms and Medication*) further indicated that while symptoms and high antipsychotic doses may worsen reading skills, they do not fully explain the profile of reading skills deficits in SZ. Impairment in comprehension and vocabulary was present even before the onset of symptoms (Fuller et al., 2002; Ho et al., 2005) together with deficient phonological processing which has been related to disrupted visual processing in SZ since an early age (Revheim et al., 2006). The symptoms can, however, aggravate deficits in reading skills, such as comprehension which are acquired with experience and also depend on the earlier acquired skills (Cunningham & Stanovich, 1997). Recent data (de Boer, van Hoogdalem, et al., 2020) suggest that some aspects of language production (e.g. slower articulation) that can affect reading skills assessments are particularly sensitive to dopamine-D2 receptor blocking antipsychotics. Furthermore, most studies in SZ included more men than women or men solely and also included people with schizoaffective disorder. Further studies need to comprehensively examine specific reading skills in both men and women with schizophrenia and schizoaffective disorder (separately) while taking medication, symptoms, cognition, education, and socioeconomic status into account.

Unlike in SZ and psychosis (Berg & Hammitt, 1980; R. C. Christensen & Grace, 1999; Ferron et al., 2012), non-psychotic bipolar disorder, and affective disorders seemed to have comprehension and single-word reading skills comparable to HC (Brites et al., 2015; Reichenberg et al., 2002). Although not all studies specified the type of PD, it seems that reading skill deficits may not be as prominent in non-forensic psychopathy as in SZ.

2.5.2. Effect of Diagnosis in Forensic Samples

Our findings suggest only a weak or no deficit in non-forensic psychopathy but indicate a marked phonological processing and comprehension deficit in the incarcerated group. Individuals with PD/psychopathy with good phonological processing and comprehension may be more able to evade incarceration (Brites et al., 2015; Timor & Weiss, 2008). Nonetheless, marked reading deficits in the incarcerated group may have contributed to their poor adjustment within the community (Svensson et al., 2015) which in turn increased the risk of incarceration. Men with MIs within forensic settings had significantly lower general reading abilities and spelling than women with MIs (Svensson et al., 2015), consistent with the pattern seen in healthy samples (Walder et al., 2006).

2.5.3. Clinical Implications

Comprehension has a significant influence on decision-making capacity in SZ (Palmer & Jeste, 2006), and this is likely to be true also for people with other MIs, especially within forensic populations. Dyslexia is often underdiagnosed in people with MIs, and this might explain their inability to complete higher education obtain jobs (Daderman et al., 2004) or the expression of socially unacceptable behaviours (Svensson et al., 2015). Furthermore, progression and engagement in therapeutic activities within mental health services often depend on good reading and language skills. This highlights a need to accurately identify reading deficits and develop specific programmes to improve the reading skills of people in psychiatric services. It may be possible to target reading deficits in SZ and other MIs by building on the less affected aspects, such as lexical knowledge (access to words) (Moro et al., 2015; Tan, Yelland, et al., 2016), and access to familiar information which can compensate for some of the reading deficits (Fernández et al., 2016), while implementing interventions to ameliorate reading skills (Snowling, 2013).

2.5.4. Effect of Assessments

Significant between-test differences were found only in tests detecting deficits in comprehension, accuracy, and rate in SZ. In comprehension and rate, the NDRT and GORT-4, and accuracy, the GORT solely, consistently detected large deficits while the Alouette (French) test detected no deficits (Figure 2.2.). It is conceivable that certain deficits emerge more often/strongly in English compared to some other languages, as is the case in developmental dyslexia (Ziegler et al., 2003). This possibility requires further study.

2.6. Conclusions

Our findings demonstrate pronounced deficits in phonological processing and comprehension in SZ and forensic PD/psychopathy. Reading skills in people with other MIs in non-forensic settings seem relatively unaffected. Among the tests, only the NDRT and GORT detected significantly stronger deficits in SZ than other measures. Considering the importance of good reading skills in everyday life, as well as for the clinical success of mental health services, there is a clear need to identify methods that can improve reading in SZ and forensic PD populations. These interventions could potentially build on relatively spared aspects of reading by implementing approaches already effective in dyslexia.

2.7. Chapter Summary

People with schizophrenia, and possibly forensic populations with PDs, demonstrate a range of reading skills deficits. These deficits seem to be linked to symptoms severity in SZ, but this relationship seems to be understudied in other MIs. Moreover, the links between reading performance and other cognitive abilities have not been clearly investigated, especially in forensic populations. The following chapters will aim to address these gaps through empirical investigations.

Chapter 3: Thesis Aims and Objectives

3.1. Introduction

The systematic literature review and meta-analysis (Vanova et al., 2021) showed clear gaps in the research. Firstly, there is limited research on reading skills in mental illnesses (MIs) other than schizophrenia, and the role of specific symptom dimensions and antipsychotic medication in commonly reported reading skills deficits in people with schizophrenia is not fully clear. Secondly, some findings indicate a high prevalence of dyslexia profiles among people with mental illness and a history of violence (Svensson et al., 2015) but there are very few studies with a comprehensive assessment of reading skills in this population. Thirdly, there appears to be an association between psychopathy and reading skills in clinical samples, but the relationship between specific psychopathy factors or traits and reading skills has been understudied and remains unclear. Lastly, whether and to what extent the relationship between various symptoms of mental illness and reading skills deficits translates dimensionally into the general population (in absence of mediation-related confounds) remains to be comprehensively investigated.

The dimensional approach, currently implemented in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), describes mental illnesses on a continuum considering the severity of the condition without a concrete threshold between normality and a disorder (American Psychiatric Association, 2013). The dimensional model of mental illness (MI) emphasizes the relationship between personality traits and proneness to MI while accounting for the comorbidities of various MI symptoms (Widiger et al., 2019). Symptomatology of MIs can be viewed as a continuum of traits present within individuals' personalities, described in terms of the spectrum of functioning. This view on MIs recognises the existence of individuals with mild or sub-symptomatic psychopathology who, despite showing mild symptoms or traits usually associated with MI, do not meet the criteria for a clinical diagnosis (Cuthbert & Morris, 2021). The dimensional approach aims to connect these traits with behaviour and neural mechanisms while examining the variations in functional impairment (Sanislow, 2020).

This thesis dimensionally examines such connections between relevant psychopathology-related traits and reading skills at the behavioural and brain levels and presents data from a pilot study involving a comprehensive assessment of reading skills of people with MIs and a history of violence.

3.2. Aims and Objectives

The following chapters present data collected from adults in the general populations from Brunel University network, and a forensic psychiatric sample at medium secure units in the West London NHS Trust, St. Bernard's Hospital while aiming to address the following overarching aims:

1. To investigate the association between reading and reading-related skills and various dimensional psychopathology-related traits and their comorbidities in the general population and a forensic sample;
2. To determine the functional neural correlates of reading-related skills and the associated dimensional psychopathology-related traits in the general population;
3. To investigate the role of cognition in reading and reading-related skills in forensic populations.

In order to meet these aims, all participants from clinical and general populations are assessed experimentally for their lexical decision abilities and impulsivity/inhibitory control, and relevant characteristics including demographic information, and dimensional psychopathology-related traits (schizotypy, psychopathy, impulsivity, and affective traits) that were found in the meta-analysis as influential for reading skills deficits. Moreover, the participants from the general population were also examined for neural underpinnings of any association between dimensional psychopathology-related traits and reading skills by using functional magnetic resonance imaging (fMRI). Additionally, the clinical cohort was examined on their reading skills and other cognitive abilities by using a series of standardised measures, in order to understand their current state compared to norms and the potential links between reading skills and cognition.

3.2.1. Plan of Investigation

The thesis contains results from three studies:

i. a behavioural study investigating the relationship between reading-related skills and dimensional psychopathology-related traits (Chapters 4 and 5);
ii. a neuroimaging study investigating the neural correlates of this relationship in the general population (Chapter 6); and
iii. a clinical study investigating the reading skills deficits, their relationship with dimensional psychopathology-related traits, reading-related skills, and reading-influencing factors in a forensic sample (Chapter 7).

Chapter 4: The Relationship between Dimensional Psychopathology-Related Traits and Lexical Decision Performance: An Experimental Study

This chapter is an extended version of an article published as:
Vanova, M., Aldridge-Waddon, L., Jennings, B., Elbers, L., Puzzo, I., & Kumari, V. (2022). Clarifying the roles of schizotypy and psychopathic traits in lexical decision performance. *Schizophrenia Research: Cognition*, *27*, 100224. https://doi.org/10.1016/j.scog.2021.100224

4.1. Chapter Aims and Overview

As highlighted in Chapter 2, some reading skills are found to be impaired in people with severe psychopathology, especially in those with a history of violence. However, the differences between clinical and healthy groups in reading skills have emerged mainly from small sample studies involving heterogeneous patient groups (Vanova et al., 2021; Whitford et al., 2018). The study reported in this chapter focuses on the relationship between psychopathology and reading skills from a dimensional perspective. Specifically, it aims to examine potential links between performance on a lexical decision task (LDT; assessing the ability to recognise words from nonwords) and dimensional measures of psychopathology (schizotypy, psychopathy, impulsivity, and affective traits) in a healthy sample. Additionally, this study explores the effect of language (native versus non-native English speakers) on LDT performance-psychopathology associations.

4.2. Introduction

Reading is a complex process involving multiple skills. Each reading activity begins with the ability to recognise or decode individual words and to compare the written-read entries with the person's vocabulary stored in their memory (Gough & Tunmer, 1986; James & Oberle, 2012). According to the Dual Route Cascaded model of reading, words can be identified by following the sublexical or lexical pathway (Coltheart et al., 2001). The sublexical pathway involves the recognition of words by decoding letters into sounds, putting them together, and comparing the outcome with existing mental vocabulary entries. This pathway jointly engages phonological processing, orthography, and semantic skills, and is often used in the recognition of unfamiliar words (often low-frequency) and nonwords. In contrast, in the lexical pathway, a familiar word (often high-frequency) is recognised as a whole, triggering automatic mental representation (Balota & Yap, 2006; Coltheart et al., 2001). Lexical recognition impacts comprehension and reading fluency (Balota et al., 2006) and, therefore, is a good indicator of overall reading proficiency, especially in bilingual individuals (Harrington, 2006; Park et al., 2012). Lexical recognition is often assessed using a lexical decision task (LDT) where participants are asked to identify a string of letters as either a word or a nonword (Meyer & Schvaneveldt, 1971).

A recent review and meta-analysis (Vanova et al., 2021) revealed significant deficits in reading skills in people with a diagnosis of schizophrenia, personality disorders, and/or psychopathy (often with a history of violence), but not in affective disorders. In the context of LDT, individuals with schizophrenia have been reported to show poorer word-nonword recognition and longer reaction times (RTs) in comparison to healthy controls (Hokama et al., 2003), though not in all studies (Natsubori et al., 2014; Tan, Yelland, et al., 2016). Importantly, none of these studies examined the influence of symptom severity or specific symptom dimensions on LDT performance. The relationship between a high level of schizotypal traits which is considered to reflect a potential vulnerability for schizophrenia in the normative population (Lenzenweger, 2018) and impairments in word recognition is also unclear (Schofield & Mohr, 2014). A study using a categorical approach found similar performance in people with high and low Unusual Experiences scores, indicating no influence of positive schizotypal traits on LDT (Park & Waldie, 2017). Dimensional studies (Carlin & Lindell, 2015; Tan, Wagner, et al., 2016) too revealed no significant relationship between overall schizotypy and LDT performance, though Cognitive Disorganisation was found to predict nonword errors (Tan, Wagner, et al., 2016). Overall, there are few data on dimensional schizotypy and LDT performance, and the categorical approach may be missing the subtle associations, if present.

Psychopathy has been associated with poorer reading skills in forensic populations and, to some extent, in community samples (Vanova et al., 2021). Higher impulsive-antisocial psychopathy scores are found to be associated with poorer overall word-nonword recognition (Heritage & Benning, 2013; Lorenz &

Newman, 2002), and slower RTs, especially in forensic samples (Kiehl et al., 2004; Reidy et al., 2008). More pronounced impulsive-antisocial traits and interpersonal-affective traits are found to correlate with lower word-nonword recognition accuracy and slower RTs (Heritage & Benning, 2013; Reidy et al., 2008). Impulsivity, a core feature of multiple psychopathologies (Whiteside & Lynam, 2001), is also a prominent trait in individuals with higher psychopathic traits - often manifesting as a tendency towards sensation-seeking behaviour and poorer behaviour control (Weidacker, O'Farrell, et al., 2017), and in those with schizotypy (Impulsive Nonconformity) – reflected in impulsive, antisocial tendencies and unstable mood (Mason & Claridge, 2006). In the context of very limited data assessing impulsivity-LDT association, one study (Harmon-Jones et al., 1997) observed higher attentional and non-planning, but not Motor impulsivity to be related to poor reading comprehension and accuracy, while another study (De Pascalis et al., 2009) reported a negative influence of higher overall impulsivity on the RTs and accuracy when processing words incongruent with presented sentences.

There is also little research on reading skills in people with affective disorders, however, existing findings suggest that reading skills are not impaired in these conditions (Vanova et al., 2021). Similarly, the evidence from studies using the LDT suggests that traits of depression and anxiety do not influence word-nonword recognition (Y. R. Li et al., 2014; Notebaert et al., 2019; Stevens et al., 2015; C. N. White et al., 2010). Overall, word-nonword recognition appears to be negatively associated with high schizotypal traits and high psychopathic traits, but not affective traits. However, the differences in reading skills between clinical populations with severe psychopathology and healthy controls have often been reported from small sample studies with a high heterogeneity within clinical samples (A. G. C. Wright & Woods, 2020). It would be valuable to examine whether and how these psychopathology-related differences in schizophrenia and psychopathy relate to relevant psychopathology-related trait dimensions in the general population.

The present study aimed to examine the relationship between schizotypy, psychopathy, impulsivity, and affective traits and LDT performance in an English-speaking sample recruited from the general population. Based on previous findings of significant reading deficits in relation to positive symptoms in people with schizophrenia (Arnott et al., 2011; Curzietti et al., 2018; Revheim et al., 2006; J. Wang et al., 2015), we tentatively hypothesised that higher positive schizotypal traits will be associated with lower LDT performance (i.e. reduced accuracy, and/or longer RTs for words and nonwords) (Hypothesis 1). We further hypothesised, based on our previous review of findings in clinical samples (review, Vanova et al. 2021), that psychopathy, and impulsivity traits, but not affective traits, will be associated with lower LDT performance (Hypothesis 2). Lastly, we explored the role of English language familiarity (native versus non-native speakers) in these hypothesised associations to check that any of the observed effects of psychopathology-related traits in LDT performance were simply not explained by differences in language familiarity between native and non-native speakers.

4.3. Methods

4.3.1. Participants and Design

Seventy-eight healthy adults who had sufficient written and verbal command of the English language, normal or corrected-to-normal vision and hearing, no self-reported history, or current diagnoses of psychiatric or neurological illness and no serious criminal history, took part. All participants were assessed identically on one occasion to examine the hypothesised psychopathology-performance relationships in a correlational design.

The study was approved by the College of Health, Medicine and Life Sciences Research Ethics Committee, Brunel University London (Reference: 16789-MHR-May/2019- 19042-2). All participants provided written informed consent prior to their participation and were compensated for their time.

4.3.2. Materials

4.3.2.1. Self-Report Measures of Psychopathology-Related Traits

The following self-report questionnaires were administered via an online platform using Qualtrics^{XM} 2019 Version (Qualtrics LLC, 2005).

Schizotypy

<u>Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE, 150 items)</u> (Mason & Claridge, 2006)

The O-LIFE is a dimensional measure of psychosis-proneness consisting of four subscales: i) *Unusual Experiences* indexes experiences such as hallucinations, magical thinking, or perceptual aberrations, ii) *Cognitive Disorganisation* reflects problems with attention, decision making and social anxiety, iii) *Introvertive Anhedonia* reflects negative schizotypy characterised by lack of pleasure derived from intimate contact with others or social interactions, and iv) *Impulsive Nonconformity* reflects a lack of self-control, antisocial, eccentric, and/or impulsive behaviour. There are 150 items answered and scored as "Yes" (1 point) or "No" (0 points), with 20 reverse-scored items and higher scores indicate higher schizotypal levels. However, only 104 items are included in the four subscales, as the rest are considered filler questions. The O-LIFE showed good internal consistency of all its subscales (Cronbach's α = .77

to $\alpha = .89$) and a good factorial validity for the majority of the subscales ($p < .001$) when measured on a large sample of the normal population ($N = 508$) (Mason et al., 1995).

Psychopathy

Two scales were used to comprehensively capture this construct. The Self-Report Psychopathy Scale – Short Form (SRP-4-SF) (Paulhus et al., 2016) determines psychopathy as a two-factor model comprising the interpersonal-affective aspect and the antisocial lifestyle aspect. The TriPM (Patrick et al., 2009) is based on a developmental perspective of psychopathy and the phenotypical manifestation of its three aspects – Boldness, Meanness, and Disinhibition (Evans & Tully, 2016).

<u>Self-Report Psychopathy Scale – Short Form (SRP-4-SF, 29 items)</u> (Paulhus et al., 2016)
The items are grouped into four trait subscales. The *Interpersonal* aspect is characterised by pathological lying and manipulativeness. The *Affective* aspect reflects low empathy, lack of guilt or concern about others, the *Lifestyle* scale reflects impulsive and reckless behaviour, and the *Antisocial* scale refers to a violent and criminal type of behaviour (Seara-Cardoso et al., 2019). Each item is scored 1-5 points: Disagree Strongly (1), Disagree (2), Neutral (3), Agree (4) or Agree Strongly (5), e.g., "I rarely follow the rules.", with no reverse-scored items. Higher scores indicate higher levels of psychopathy traits. A large-scale study on a European population sample ($N = 1{,}510$) showed good reliability coefficients of subscales consistency ($r = .15$ to $r = .28$), only satisfactory to good internal consistency (Cronbach's $\alpha = .44$ to $\alpha = .73$), but very good test-retest reliability ($r = .60$ to $r = .86$) (Gordts et al., 2017).

<u>Triarchic Psychopathy Measure (TriPM, 58 items)</u> (C. J. Patrick et al., 2009)
TriPM, a dimensional measure of the triarchic model of psychopathy (C. J. Patrick & Drislane, 2015), has three scales: i) *Boldness* representing traits of high dominance, low anxiousness, and risk-taking, ii) *Meanness* representing callousness, cruelty, and predatory aggression, and iii) *Disinhibition* connected with impulsiveness, irresponsibility, noncompliance, anger and hostility (C. J. Patrick, 2018). Each scale consists of nine different facets which are not individually scored. Items are scored on a 4-point scale: True (3), Mostly True (2), Mostly False (1), and False (0), e.g., "I often act on immediate needs.", with 17 reverse-scored items. Higher scores indicate higher levels of psychopathy traits. This scale showed considerably better psychometric properties than the SRP-4-SF. In a sample of college students ($N = 120$), it showed high internal consistency of each subscale (Cronbach's $\alpha = .80$ to $\alpha = .87$) and high internal correlation coefficients ($r = .64$ to $r = .77$) (Blagov et al., 2016). In a sample of people with a history of violence, all TriPM subscales showed significant moderate to low moderate associations with various facets of the Psychopathy Checklist-Revised (PCL-R) (Hare, 2003) ($r = .18$ to $r = 36$) (Evans & Tully, 2016) which is considered a standard in the assessment of psychopathy traits,

specifically in clinical samples with pronounced psychopathy. These correlations are not available for a non-clinical sample. These results show that the TriPM represents a novel concept of capturing psychopathy and therefore, it was used in combination with a more standard measure of psychopathy, as in this study.

Impulsivity

Impulsivity was assessed with two standardised self-report measures of impulsivity – Barratt Impulsiveness Scale (BIS-11) (Patton et al., 1995) and Impulsive Behavior Scale Short Version (S-UPPS-P) (Whiteside et al., 2005), as well as a behavioural Go/No Go task (see further) to capture the construct of impulsivity in sufficient detail. The BIS-11 is a gold-standard measure of impulsivity traits as a behavioural construct. The S-UPPS-P is less popular but measures impulsivity as an aspect of personality and captures different aspects than BIS-11. It contains two subscales that measure positive and negative urgency, which reflect tendencies to act rashly under positive and/or negative emotions. Higher scores indicate higher levels of impulsivity in both scales.

<u>Barratt Impulsiveness Scale (BIS-11, 30 items)</u> (Patton et al., 1995)
The BIS-11 has six first-order factors: i) Attention, ii) Cognitive Instability, iii) Motor, iv) Perseverance, v) Self-Control, and vi) Cognitive Complexity, which are grouped into three second-order factors: a) *Attentional* factor representing the inability to focus on the present task, b) *Motor* that can be defined as acting without thinking, and c) *Non-planning* is characterised by orientation on the present moment and lack of planning for the future. Items are scored on a 4-point scale: Rarely/Never (1), Occasionally (2), Often (3), Almost Always/Always (4), with 11 items being reverse scored. All measure factors demonstrated significantly high internal correlation coefficients: first-order factors were intercorrelated from $r = .15$ to $r = .42$ ($p < .0001$), and the second-order factors from $r = .46$ to $r = .33$ ($p < .0001$), with a good internal consistency (Cronbach's $\alpha = .82$) measure on undergraduate students ($N = 412$) (Patton et al., 1995).

<u>Impulsive Behavior Scale, Short Version (S-UPPS-P, 20 items)</u> (Whiteside et al., 2005)
This measure consists of five first-order factors: i) *Negative Urgency* (a tendency to act rashly under extreme negative emotions), ii) *Positive Urgency* (a tendency to act rashly under extreme positive emotions), iii) *Lack of Premeditation* (acting without thinking), iv) *Lack of Perseverance* (an inability to remain focused on a task), and v) *Sensation Seeking* (a tendency to seek out novel and thrilling experiences). These factors can be grouped into three second-order factors: a) Emotion-based rash action, b) Sensation Seeking, and c) Deficits in Conscientiousness. Items are scored on a 4-point scale: Agree Strongly (1), Agree Some (2), Disagree Some (3), Disagree Strongly (4), with 12 items being reversed scored. The measure showed significant weak to moderate internal correlations between the

subscales ($r = .13$ to $r = .48$, $p < .001$) (Cyders et al., 2014). There is no other data on the psychometric properties of the short version of the S-UPPS-P, however, the full version demonstrated high levels of internal consistency for each subscale (Cronbach's $\alpha = .82$ to $\alpha = .91$) measure on undergraduate students ($N = 437$) (Whiteside & Lynam, 2001).

Affective Traits

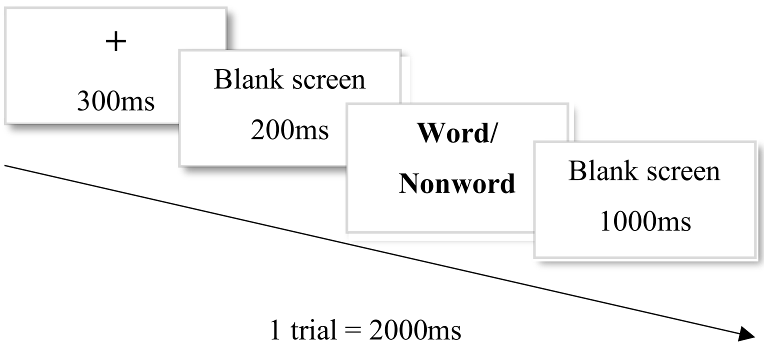
Depression, Anxiety, and Stress Scale (DASS-21, 21 items) (Lovibond & Lovibond, 1995)
This is a non-diagnostic tool to dimensionally assess levels of depression, anxiety, and stress symptoms as emotional states in three corresponding subscales. The *Depression* subscale assesses dysphoria, hopelessness, devaluation of life, self-deprecation, lack of interest, anhedonia, and inertia. The *Anxiety* subscale assesses autonomic arousal, skeletal muscle effects, situational anxiety, and anxious affect. The *Stress* subscale is sensitive to levels of chronic non-specific arousal such as problems with relaxation, emotional overactions and impatience. Participants rate each item on a 4-point scale according to how often in the past week each statement applied to them: "Did not apply to me at all" (0), "Applied to me to some degree, or some of the time" (1), "Applied to me to a considerable degree or a good part of the time" (2), or "Applied to me very much or most of the time" (3), e.g., "I found it hard to wind down". No items are reverse-scored. Higher scores indicate a higher occurrence of each emotional state. An American version of the scale adapted for undergraduate students ($N = 1,413$) demonstrated significantly high internal correlation coefficients ($r = .66$ to $r = .72$), and all subscales showed high reliability (McDonald's $\omega = .87$ to $\omega = .96$) (Kia-Keating et al., 2018).

4.3.2.2. Lexical Decision Task (LDT)

This task is designed to assess the ability to retrieve information from mental vocabulary by judging whether a presented stimulus is a word or nonword (Perea et al., 2002) and was administered using Presentation® Software (version 21.1) (Neurobehavioral Systems Inc., 2018). Participants were presented with 120 stimuli consisting of 60 common English words and 60 nonwords retrieved from the frequency list of the British National Corpus (Leech et al., 2001). The word list consisted of 30 high-frequency word lemmas, 2900-3000 occurrences per million words and 30 low-frequency word lemmas, 10-11 occurrences/million, counterbalanced per word category (adjectives, verbs, and nouns). The nonword list included 30 real nonwords and 30 pseudohomophones that were taken from the ARC Database (Rastle et al., 2002). Real nonwords are letter strings that do not exist in the English language and do not resemble any existing word (e.g., *youns*, *cimes*, *lince*). Pseudohomophones are nonwords that can be pronounced similarly or in the same way as recognisable real words but are spelt incorrectly (e.g., *hense* [hence], *meen* [mean]). The nonword list was counterbalanced in the summed frequency of nonword neighbours, which is an indicator of similarity with other nonwords (high frequency: 300-700 occurrences/million; low frequency: 1-10 occurrences/million). The neighbourhood size of each nonword and pseudohomophone was 1. This refers to the number of words that can be derived by changing one letter while preserving the position of the other letters. The real nonwords and pseudohomophones were orthographically legal – consisting of combinations of letters proper to the English language. All words and nonwords were 5-6 letters long.

Each trial consisted of a 300ms fixation cross (+), followed by a 200ms blank screen, then a 500ms presentation of the main stimulus (word/nonword), and lastly a 1000ms response period during which a blank screen was displayed (Figure 4.1). Participants were asked to respond only when presented with a valid English word and to make no response when a nonword appeared. The instructions were presented before a short practice session of 16 stimuli (50% words) with a maximum word/nonword duration of 2000ms. Feedback on accuracy was provided during the practice only.

Figure 4.1. Lexical Decision Task trial.



Task performance was indexed by the accuracy of responses and speed (RTs) to the four Stimuli-Types: high-frequency words, low-frequency words, pseudohomophones, and real nonwords. Accuracy for words and nonwords were examined as the number of correct button-presses for i) high-frequency, ii) low-frequency words, and correct withdrawals for iii) pseudohomophones, and iv) real nonwords. RTs (in ms) were assessed for correct high and low-frequency words, and incorrect pseudohomophones and real nonwords. Overall LDT performance variable was a sum of the number of correctly identified words and nonwords.

4.3.3. Data Treatment

The data were analysed using IBM SPSS Statistics, Version 26.0 (IBM Corp., 2019). *Alpha* was set at <.05 in all analyses unless stated otherwise.

4.3.3.1. Normality and Outliers

The data for all variables were assessed for the normality of distribution by examining skewness, kurtosis, and homogeneity of variance (Levene's test). The skewness or kurtosis of the variables was judged to be statistically significant if the z-score fell outside ± 1.96 value (Field, 2009). All variables with significant skewness or kurtosis were normalised by replacing outliers [i.e., participants with values above or below the sample mean ± 2 standard deviation (*SD*); each variable assessed individually] with sample mean value ± 2*SD* for each variable (Field, 2009). All outliers for self-report measures had scores above mean+2*SD*, and for LDT performance, they had scores below mean-2*SD*. All LDT variables and eight of the self-report variables were normalised (further details in Tables 4.1. and 4.2.) with no more than six outliers replaced for any individual variable.

4.3.3.2. Statistical Analysis

Sex differences in categorical variables (language, ethnicity, self-reported handedness) were explored using Pearson's Chi-Square, and in continuous variables (self-report measures, task performance) using independent sample t-tests.

Performance accuracy was analysed using a 4 (Stimulus-Type) x 2 (Sex) x 2 (Language) mixed model Analysis of Variance (ANOVA) with Stimulus-Type (high-frequency words, low-frequency words, pseudohomophones, real nonwords) as a within-subject factor, and Sex (males, females) or Language (Native vs Non-native speakers) as the between-subject factors. RTs to correct high and low-frequency words were analysed by a 2 (Stimulus-Type; high and low-frequency words) x 2 (Sex) x 2 (Language) ANOVA with Stimulus-Type as a within-subject factor. Similarly, RTs to incorrect responses (i.e., a failure to withhold responses) to pseudohomophones and real nonwords were analysed with a 2 (Stimulus-Type; pseudohomophones, real nonwords) x 2 (Sex) x 2 (Language) ANOVA with stimulus-type as a within-subject factor. The Greenhouse-Geisser correction was applied to all repeated measures statistics where Mauchly's Test indicated a significant violation of sphericity. Post-hoc mean pairwise comparisons were conducted to probe significant main and interaction effects as required and Bonferroni correction was applied. Effect sizes were calculated as partial eta squared (η^2_p) and interpreted as follows: $\eta^2_p \geq .01$ to $< .06$ (small), $\eta^2_p \geq .06$ to $<.14$ (medium), $\eta^2_p \geq .14$ (large) (J. Cohen, 1992). Cohen's *d* values were interpreted as follows: ≥ .2 to < .5 (small effect), ≥ .5 to < .8 (medium), and ≥ .8 (large) (J. Cohen, 1992).

Due to significant skewness and kurtosis of data, Spearman's rank-order correlation coefficient (rho) – r_s with two-tailed significance was used to examine hypothesised psychopathology-LDT performance associations, and the inter-relationships of various self-report measures (Supplementary Table 1). Correlations were examined separately for the two language groups due to significant group differences in LDT performance (see Results) and the strength of the correlations in the two groups formally compared using Fisher's z transformation. All performance variables associated with more than one trait were analysed further using linear regression analysis (Stepwise method) to determine the amount of shared and unique variance explained by various traits in LDT performance.

4.3.3.3. Sample size calculation

A generic A priori sample size correlation power analysis was executed using G*Power 3.1 (Faul et al., 2007) to determine the sample size which would be required to detect significant correlations. This showed that for a one-tailed test, with an expected power of 80% at $\alpha = .05$, a total of 64 participants would be necessary to detect a moderate effect size of Pearson's $r = .30$. For the same test but to obtain a small-to-moderate effect size of Pearson's $r = .20$, a total of 150 participants would be required.

4.4. Results

4.4.1. Sample Characteristics

The participant age range was 18-55 years ($M = 23.68$; $SD = 7.73$), with the majority achieving education at undergraduate (36%) and postgraduate levels (30%). Males ($n = 25$) and females ($n = 53$) did not differ in age, language, ethnicity, or handedness (all $p > .05$). Full sample characteristics are summarised in Table 4.1.

Table 4.1. Sample characteristics.

Variable/*N*	Males ($n = 25$)	Females ($n = 53$)	Overall sample ($N = 78$)
Age (Mean [±*SD*])	25.96 (9.85)	22.74 (4.48)	23.68 (7.73)
Language (Number [%])			
English	16 (64%)	26 (49.1%)	44 (55.0%)
Other	9 (36%)	27 (50.9%)	36 (45.0%)
Ethnicity (Number [%])			

White	14 (56.0%)	20 (37.7%)	36 (45.0%)
Asian/Pacific Islander	6 (24.0%)	19 (35.8%)	25 (31.3%)
Black/African American	0	5 (9.45)	5 (6.3%)
Hispanic/Latino	0	1 (1.9%)	1 (1.3%)
Other	5 (20.0%)	8 (15.1%)	13 (16.3%)
Handedness (Number [%])			
Right	23 (92.0%)	49 (92.5%)	73 (91.3%)
Left	2 (8.0%)	4 (7.5%)	7 (8.8%)
Education (Number [%])			
Higher Degree	4 (16.0%)	9 (17.0%)	13 (16.3%)
First Degree	10 (40.0%)	14 (26.4%)	24 (30.0%)
Teaching Qualification	1 (4.0%)	0	1 (1.3%)
Other Higher Qualification	0	4 (7.5%)	4 (5.0%)
GCE A Level in 2+	6 (24.0%)	21 (39.6%)	29 (36.3%)
GCE A Level in 1	1 (4.0%)	0	1 (1.3%)
GCSE/O Level in 5	3 (12.0%)	3 (5.7%)	6 (7.5%)
GCSE/O Level in 1-4	0	1 (1.9%)	1 (1.3%)
CSE below 1/GCSE below Grade C	0	1 (1.9%)	1 (1.3%)

In the self-report measures, males showed significantly higher scores than females in psychopathy SRP-4-SF Affective (males: M = 16.1, SD = 4.56; females: M = 13.2, SD = 4.50) and Lifestyle traits (males: M= 18.7, SD = 5.00; females: M = 14.4, SD= 4.41), and TriPM Meanness (males: M = 15.5, SD = 5.32; females: M = 12.1, SD = 6.30) (all p< .05, Cohen's d between .570 and .926). Females showed significantly higher levels of anxiety (males: M = 11.5, SD= 4.16; females: M = 13.8, SD = 4.56) and O-LIFE Cognitive Disorganisation (males: M = 11.5, SD = 6.19; females: M = 14.1, SD = 4.92) than males (all p< .05, Cohen's d = .527 and .492 for anxiety and Cognitive Disorganisation, respectively). Native English-speakers had lower level of self-reported anxiety than non-native speakers (p = .026, Cohen's d = .516). Descriptive statistics for self-report measures are summarised in Table 4.2.

Table 4.2. Descriptive for self-report psychopathology measures in the entire sample (N = 78) and inferential statistics for Sex groups.

	Mean (SD)	Observed Min	Observed Max	Max. possible score	Leven's Test (*p*)	t-test value	df	*p*	Direction of effect	Normative scores
O-LIFE Unusual Experiences	10.38 (6.24)	0	25	30	.927	-.372	76	.711		Median = 9
O-LIFE Cognitive Distortions	13.27 (5.46)	0	24	24	.331	-2.028	76	**.046***	W > M	Median = 12
O-LIFE Introvertive Anhedonia [a]	7.42 (4.63)	0	22	27	.054	-1.129	76	.262		Median = 4-5
O-LIFE Impulsive Nonconformity	8.91 (3.30)	3	17	23	.622	.384	76	.702		Median = 9-10
SRP-4-SF Interpersonal [a]	13.76 (4.93)	7	28	35	.139	1.595	76	.115		10-19
SRP-4-SF Affective	14.15 (4.68)	7	30	35	.212	2.586	76	**.012***	M > W	9-18
SRP-4-SF Lifestyle	15.78 (5.00)	7	29	35	.243	3.816	76	**<.001****	M > W	11-20
SRP-4-SF Antisocial [a]	9.99 (2.24)	8	22	40	.366	.952	76	.344		8-14
TriPM Boldness	27.18 (8.26)	10	46	76	.241	1.68	76	.097		29.8 ± 8.4
TriPM Disinhibition [a]	14.80 (7.70)	1	34	80	.524	.970	76	.335		10.4 ± 7.7
TriPM Meanness	13.2 (6.18)	1	27	76	.115	2.348	76	**.021***	M > W	13.4 ± 7.6
BIS-11 Attention [a]	10.8 (2.78)	6	20	20	.544	-.136	76	.892		5-20
BIS-11 Cognitive Instability	6.31 (2.24)	3	12	12	.091	1.228	76	.223		5-20
BIS-11 Motor	14.36 (3.26)	7	22	28	.59	.745	76	.459		5-20
BIS-11 Perseverance [a]	7.15 (1.83)	3	14	16	**.049***	**-.514***	39.518	.610		5-20
BIS-11 Self Control	13.24 (3.68)	7	21	24	.425	-.597	76	.552		5-20
BIS-11 Cognitive Complexity	11.24 (2.26)	6	16	20	.26	-1.412	76	.162		5-20
S-UPPS-P Negative Urgency	8.77 (2.82)	4	15	16	.198	-.533	76	.596		9.16 ± 2.57
S-UPPS-P lack of Perseverance	7.46 (1.79)	4	11	16	.565	-.207	76	.837		6.97 ± 2.10
S-UPPS-P lack of Premeditation	7.36 (2.27)	4	12	16	.278	-.104	76	.918		7.82 ± 1.93
S-UPPS-P Sensation Seeking	10.65 (2.86)	4	16	16	.284	1.867	76	.066		8.84 ± 2.55
S-UPPS-P Positive Urgency	8.01 (2.71)	4	15	16	.341	.684	76	.496		9.37 ± 2.13
DASS-21 Depression [a]	13.03 (4.71)	7	28	28	.474	-.890	76	.376		0-9
DASS-21 Anxiety [a]	13.07 (4.54)	7	26	28	.318	-2.170	76	**.033***	W > M	0-7
DASS-21 Stress	14.71 (4.14)	7	24	28	.972	-.974	76	.333		0-14

** p < .05; ** p < .01; Significant p values are in **bold**.*

[a] *Normalised by replacing outliers.*

Note. O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; SRP-4-SF = Self-Report Psychopathy Scale – Short Form; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale; S-UPPS-P = Impulsive Behavior Scale, Short Version; DASS-21 = Depression, Anxiety, and Stress Scale. W = Women; M = Men.

4.4.2. LDT Performance: Stimulus-Type, Sex, and Language Effects

Accuracy: There was a significant main effect of Stimulus-Type on accuracy, with a large effect size [$F(2.00,153.96) = 99.445$, $p < .001$, $\eta^2_p = .564$]. Sex did not have a significant main effect [$F(1,76) = .034$, $p = .855$, $\eta^2_p = .004$] and the Sex*Stimulus-Type interaction was also non-significant [$F(2.01,152.47) = .792$, $p = .455$, $\eta^2_p = .015$]. Language had a significant main effect with a large effect size [$F(1,76) = 12.290$, $p = .001$, $\eta^2_p = .139$]. The Language*Stimulus-Type interaction was also significant [$F(2.01,152.66) = 3.226$, $p = .042$, $\eta^2_p = .041$] (Table 4.3). The Sex*Language [$F(1,76) = .773$, $p = .382$, $\eta^2_p = .010$] and the Sex*Language*Stimulus-Type interactions were not significant [$F(2.02,149.29) = .309$, $p = .736$, $\eta^2_p = .004$].

Follow-up analyses of the Stimulus-Type effect using paired-sample t-tests revealed that participants correctly identified significantly more high-frequency words than low-frequency words [$t(77) = 11.148$, $p < .001$, $p_{bonf} = .006$], pseudohomophones [$t(77) = 14.141$, $p < .001$, $p_{bonf} = .006$], and real nonwords [$t(77) = 14.700$, $p < .001$, $p_{bonf} = .006$]. They also correctly identified more low-frequency words than pseudohomophones [$t(77) = 6.234$, $p < .001$, $p_{bonf} = .006$] and real nonwords [$t(77) = 6.449$, $p < .001$, $p_{bonf} = .006$]. The differences between correct pseudohomophones and real nonwords were not significant [$t(77) = .111$, $p = .912$].

Follow-up analysis to probe the Language*Stimulus-Type interaction indicated that the native speakers were significantly better than non-native speakers in distinguishing pseudohomophones [$t(76) = 3.000$, $p = .004$, $p_{bonf} = .016$], and real nonwords [$t(76) = 2.307$, $p = .024$, $p_{bonf} = .096$] but the two groups did not differ in word recognition when identifying high-frequency [$t(49.81)= 1.876$, $p= .067$] and low-frequency [$t(76)= 1.867$, $p= .066$] words (Figure 4.2).

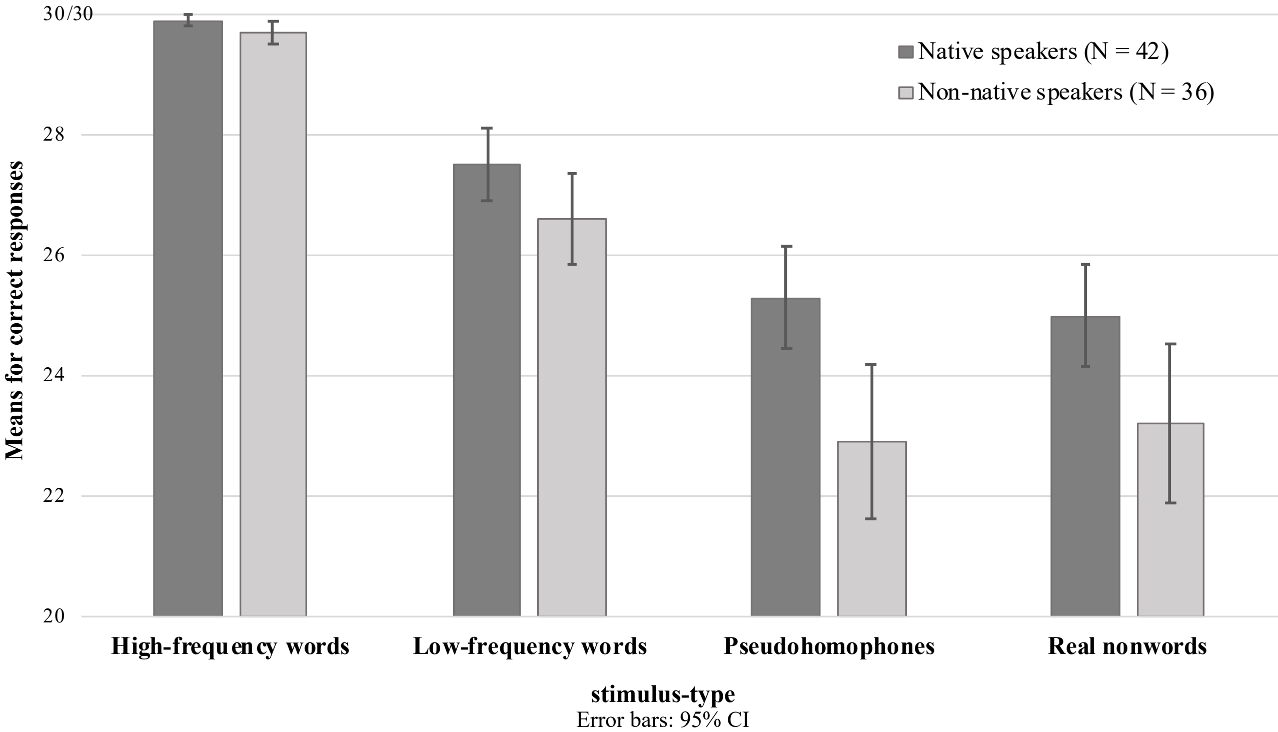
Table 4.3. Descriptive statistics for task performance for the entire sample (*N* = 78) and differences between native and non-native speakers.

	Total		Max. possible score	Native speakers (*N*= 42)		Non-native speakers (*N*= 36)				
	Mean (SD)	Range		Mean (SD)	Range	Mean (SD)	Range	*t* (df=76)	*p*	Cohen's *d*
Overall performance [a]	105.10 (7.35)	77 - 118	120	107.60 (5.70)	93-118	102.20 (8.04)	88.4-116	3.360	**< .001*****	.784
Correct words high-frequency [a]	29.81 (0.47)	25 -30	30	29.90 (0.30)	29-30	29.70 (0.59)	28.3-30	1.876	.053	.446
Correct words low-frequency [a]	27.09 (2.16)	15 - 30	30	27.51 (1.98)	21.3-30	26.61 (2.28)	21.3-30	1.867	.066	.424
Correct pseudohomophones [a]	24.21 (3.55)	13 -29	30	25.29 (2.78)	16.3-29	22.94 (3.95)	16.3-29	3.000	**.004****	.700
Correct real nonwords [a]	24.17 (3.52)	13 -29	30	25.02 (2.75)	18-29	23.18 (4.07)	16.5-29	2.307	**.024***	.539
Correct words high-frequency RT	417.67 (35.02)	327-496	1000	415.87 (35.99)	327-478	419.78 (34.26)	346-496	0.488	.627	.111
Correct words low-frequency RT	478.93 (48.80)	357-621	1000	473.50 (50.96)	357-621	485.26 (46.07)	403-570	1.062	.292	.241
Incorrect pseudohomophones RT	449.08 (82.51)	297-635	1000	453.07 (83.87)	320-635	444.28 (81.84)	297-635	0.459	.648	.104
Incorrect real nonwords RT	429.58 (68.95)	293-579	1000	420.04 (56.33)	299-578	440.70 (80.66)	293-579	1.290	.202	.301

** p < .05; ** p < .01; *** p < .001. Significant p values are in* ***bold****.*

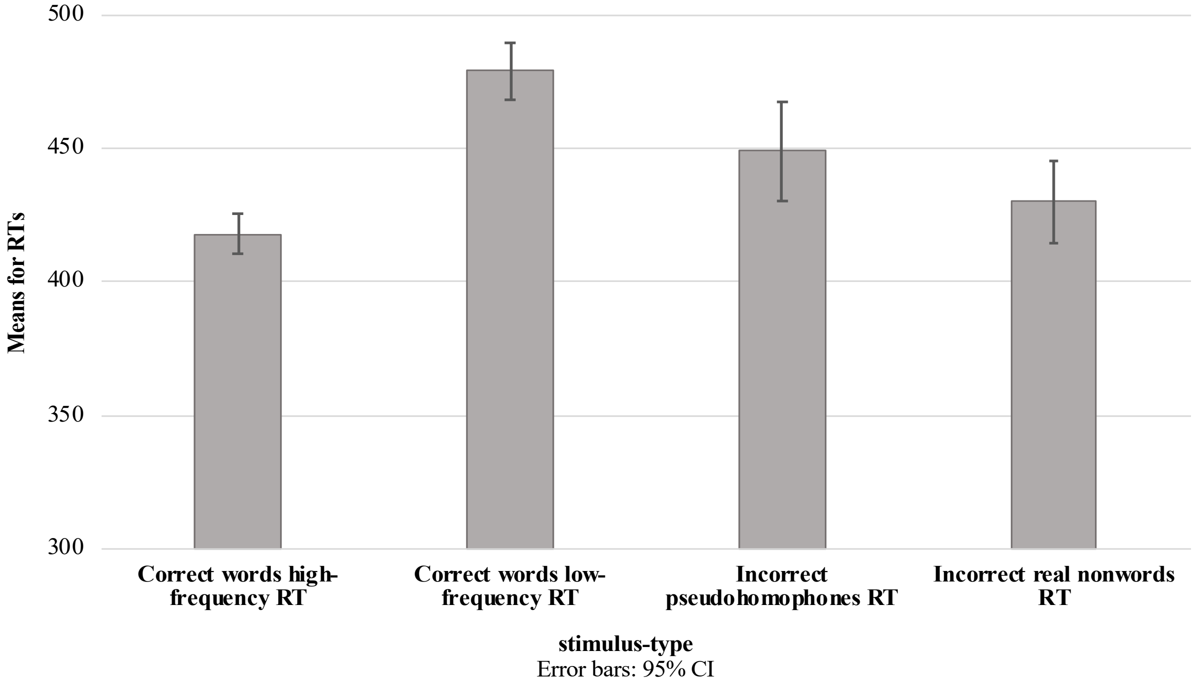
[a] *Normalised by replacing outliers.*

Figure 4.2. Mean accuracy for different stimulus-types by language group.



RTs: There was a significant main effect of stimulus-type on RTs for correctly identified words [$F(1,74) = 240.166$, $p < .001$, $\eta^2_p = .764$] but not for incorrectly identified nonwords [$F(1,74) = 3.594$, $p = .062$, $\eta^2_p = .046$]. Participants were significantly slower when identifying low-frequency than high-frequency words [$t(77) = 17.316$, $p < .001$] and slower when incorrectly identifying pseudohomophones over real nonwords [$t(77) = 2.440$, $p = .017$] (Figure 4.3). No significant interactions involving Sex or Language were found (all $p > .05$).

Figure 4.3. Mean RTs (ms) for correct high and low-frequency words and incorrect pseudohomophones and real nonwords in the entire sample (*N* = 78).



4.4.3. LDT Performance: Speed-Accuracy Trade-off

Longer RTs for incorrect real nonwords correlated with higher real nonword accuracy (r_s = .254, *p* = .025). When examined separately in native and non-native speakers, this was true only for non-native speakers (r_s =.490, *p* = .002; non-significant in native speakers, r_s = .052; *Z* = 2.05, *p* = .020). Furthermore, only in native speakers, longer RTs for high-frequency words correlated with their lower accuracy (r_s = -.395, *p* = .010; non-significant in non-native speakers, r_s = .118; *Z* = 2.27, *p* = .012).

4.4.4. Relationship between LDT Performance and Self-reported Psychopathology-Related Dimensions

4.4.4.1. Schizotypy (Hypothesis 1)

The overall LDT performance significantly negatively correlated with Unusual Experiences (Table 4.4). No other significant relationships between LDT variables and schizotypal traits were identified. There were no significant differences between native and non-native English speakers in correlation coefficients for schizotypy measures.

Table 4.4. Spearman rank-order correlations (r_s) between LDT performance and psychopathology measures in the entire sample (N = 78).

4.4.a. Measure	Overall performance r_s (p)	Correct words high-frequency r_s (p)	Correct words low-frequency r_s (p)	Correct pseudo-homophones r_s (p)	Correct real nonwords r_s (p)
O-LIFE Unusual Experiences	**-.248**[*] (.028)	-.130 (.256)	-.204 (.073)	-.196 (.086)	-.194 (.089)
O-LIFE Cognitive Distortions	.035 (.763)	.022 (.845)	-.025 (.827)	-.007 (.950)	.077 (.501)
O-LIFE Introvertive Anhedonia	-.054 (.639)	.002 (.984)	-.117 (.309)	-.081 (.479)	.022 (.851)
O-LIFE Impulsive Nonconformity	-.125 (.277)	-.081 (.478)	.022 (.846)	-.120 (.295)	-.108 (.347)
SRP-4-SF Interpersonal	-.139 (.223)	-.020 (.859)	.066 (.566)	**-.244**[*] (.032)	-.048 (.677)
SRP-4-SF Affective	**-.247**[*] (.029)	-.011 (.924)	-.046 (.690)	**-.265**[*] (.019)	-.212 (.062)
SRP-4-SF Lifestyle	-.222 (.051)	-.107 (.350)	-.087 (.446)	-.206 (.070)	-.178 (.120)
SRP-4-SF Antisocial	**-.318**[**] (.005)	**-.336**[**] (.003)	**-.244**[*] (.032)	**-.264**[*] (.020)	-.185 (.105)
TriPM Boldness	**-.242**[*] (.033)	-.073 (.526)	-.118 (.302)	-.061 (.594)	**-.320**[**] (.004)
TriPM Disinhibition	-.198 (.082)	-.105 (.359)	-.151 (.187)	-.203 (.074)	-.151 (.188)
TriPM Meanness	**-.318**[**] (.005)	-.121 (.291)	-.115 (.315)	**-.257**[*] (.023)	**-.272**[*] (.016)
BIS-11 Attention	.016 (.890)	-.113 (.324)	.214 (.060)	-.037 (.746)	-.124 (.281)
BIS-11 Cognitive Instability	.024 (.838)	-.006 (.960)	.212 (.063)	-.039 (.734)	-.053 (.645)
BIS-11 Motor	-.214 (.060)	-.211 (.064)	**-.281**[*] (.013)	-.096 (.403)	-.157 (.169)
BIS-11 Perseverance	.018 (.872)	.105 (.360)	.082 (.476)	.058 (.611)	-.085 (.457)
BIS-11 Self-Control	-.134 (.242)	-.045 (.695)	**-.284**[*] (.012)	-.053 (.647)	-.055 (.634)
BIS-11 Cognitive Complexity	.100 (.382)	-.109 (.340)	-.171 (.133)	.141 (.219)	.133 (.247)
S-UPPS-P Negative Urgency	-.121 (.290)	-.034 (.765)	-.077 (.502)	-.098 (.393)	-.103 (.371)
S-UPPS-P lack of Perseverance	.071 (.539)	.164 (.151)	-.084 (.465)	.026 (.819)	.196 (.086)
S-UPPS-P lack of Premeditation	-.047 (.685)	-.104 (.365)	-.122 (.288)	-.054 (.638)	.029 (.798)
S-UPPS-P Sensation Seeking	**-.293**[**] (.009)	-.082 (.477)	-.196 (.086)	-.118 (.305)	**-.324**[**] (.004)
S-UPPS-P Positive Urgency	-.203 (.074)	-.155 (.175)	**-.226**[*] (.047)	-.125 (.277)	-.160 (.162)
DASS-21 Depression	-.061 (.593)	.059 (.607)	.025 (.825)	-.172 (.132)	.004 (.975)
DASS-21 Anxiety	-.219 (.054)	-.113 (.324)	-.165 (.148)	-.185 (.105)	-.161 (.159)
DASS-21 Stress	-.005 (.967)	-.003 (.977)	.017 (.882)	-.074 (.521)	.057 (.618)

4.4.b. Measure	Correct words high-frequency RTs	Correct words low-frequency RTs	Incorrect pseudo-homophones RTs	Incorrect real nonwords RTs
	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*
O-LIFE Unusual Experiences	-.029 (.803)	-.020 (.860)	-.040 (.729)	.019 (.865)
O-LIFE Cognitive Distortions	-.019 (.870)	.072 (.529)	.006 (.956)	.062 (.591)
O-LIFE Introvertive Anhedonia	-.071 (.538)	-.049 (.667)	-.083 (.472)	-.057 (.618)
O-LIFE Impulsive Nonconformity	-.077 (.504)	-.155 (.176)	-.007 (.954)	-.028 (.809)
SRP-4-SF Interpersonal	-.003 (.976)	-.122 (.288)	-.014 (.905)	.026 (.822)
SRP-4-SF Affective	-.074 (.522)	-.186 (.103)	-.133 (.246)	-.089 (.436)
SRP-4-SF Lifestyle	.003 (.983)	-.074 (.518)	-.038 (.740)	-.005 (.968)
SRP-4-SF Antisocial	.041 (.723)	-.049 (.673)	**-.254*** (.025)	-.189 (.097)
TriPM Boldness	-.068 (.554)	-.205 (.072)	-.135 (.237)	**-.294**** (.009)
TriPM Disinhibition	.050 (.663)	-.079 (.492)	-.136 (.235)	-.124 (.278)
TriPM Meanness	.015 (.899)	-.182 (.110)	-.050 (.665)	-.055 (.632)
BIS-11 Attention	-.092 (.424)	-.166 (.146)	.025 (.831)	-.112 (.331)
BIS-11 Cognitive Instability	-.043 (.711)	-.081 (.481)	.055 (.633)	.078 (.495)
BIS-11 Motor	.088 (.444)	-.092 (.423)	-.105 (.360)	-.145 (.204)
BIS-11 Perseverance	.128 (.265)	.124 (.279)	.214 (.060)	**.239*** (.035)
BIS-11 Self-Control	.051 (.655)	.009 (.935)	.001 (.992)	-.032 (.778)
BIS-11 Cognitive Complexity	.060 (.600)	-.049 (.671)	.031 (.785)	-.040 (.729)
S-UPPS-P Negative Urgency	.006 (.957)	.052 (.649)	-.073 (.525)	.041 (.721)
S-UPPS-P lack of Perseverance	.054 (.636)	.117 (.306)	.161 (.160)	.199 (.080)
S-UPPS-P lack of Premeditation	-.050 (.666)	-.092 (.424)	-.043 (.710)	-.068 (.555)
S-UPPS-P Sensation Seeking	-.099 (.386)	-.138 (.227)	-.038 (.744)	-.159 (.165)
S-UPPS-P Positive Urgency	.034 (.767)	-.085 (.458)	-.089 (.437)	-.149 (.193)
DASS-21 Depression	-.042 (.714)	.024 (.832)	-.031 (.789)	.062 (.589)
DASS-21 Anxiety	-.096 (.401)	-.048 (.679)	-.114 (.321)	-.035 (.763)
DASS-21 Stress	.021 (.857)	.039 (.735)	-.016 (.892)	.062 (.588)

** $p < .05$; ** $p < .01$; *** $p < .001$. Significant correlations are in* ***bold****.*

Note. O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; SRP-4-SF = Self-Report Psychopathy Scale – Short Form; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale; S-UPPS-P = Impulsive Behavior Scale, Short Version; DASS-21 = Depression, Anxiety, and Stress Scale.

4.4.4.2. Psychopathy (Hypothesis 2)

Overall LDT performance significantly negatively correlated with four psychopathy subscales, most strongly with the SRP-4-SF Antisocial and TriPM Meanness traits (both $p < .01$) (Table 4.4). High and low-frequency words significantly correlated only with the Antisocial trait. Correct pseudohomophones negatively correlated with four traits – SRP-4-SF Interpersonal, Affective, Antisocial, and TriPM Meanness (all $p < .05$) and correct real nonwords correlated with TriPM Boldness ($p < .05$) and Meanness ($p < .05$). Also, Meanness and Boldness together predicted over 20% of the variance of correct real nonwords identified [$F(2,75) = 9.858$, $p <.0001$; $R^2 =.208$], with Meanness accounting for 12% of the variance [$F(1,76) = 10.370$, $p =.002$; $R^2 = .120$]. Meanness also significantly predicted the number of correctly identified pseudohomophones [$F(1,76) = 7.347$, $p = .008$; $R^2 = .088$]. For RTs, incorrectly identified pseudohomophone RTs negatively correlated with SRP-4-SF Antisocial ($r_s = -.254$, $p = .025$) and incorrect real-nonword RTs negatively correlated with TriPM Boldness ($r_s = -.294$, $p = .009$). There were no significant differences between native and non-native English speakers in correlation coefficients for any psychopathy measures.

4.4.4.3. Impulsivity (Hypothesis 2)

Several significant correlations were found between LDT performance and impulsivity (Table 4.4). Scores on the S-UPPS-P Sensation Seeking subscale significantly negatively correlated with overall performance ($p < .01$), and with correctly identified real nonwords ($p < .01$). The S-UPPS-P Positive Urgency significantly negatively correlated with correctly identified low-frequency words ($p < .05$). The BIS-11 Motor and Self-Control subscales also significantly negatively correlated with the number of low-frequency words correctly identified (both $p < .05$). For RTs, only the incorrect real-nonword RTs significantly positively correlated with BIS-11 lack of Perseverance ($r_s = -.239$, $p = .035$).

Table 4.5. Relationship between LDT performance and self-report impulsivity for the entire sample, and native (n = 42) and non-native (n = 36) speakers separately.

Measure	Overall performance		Correct words high frequency		Correct words low frequency		Correct pseudo-homophones		Correct real nonwords	
	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native
	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*
BIS-11 Attention	-.021 (.896)	.042 (.806)	-.003 (.983)	-.237 (.164)	.206 (.190)	.268 (.114)	-.135 (.395)	.031 (.858)	-.089 (.576)	-.172 (.317)
BIS-11 Cognitive Instability	.038 (.812)	-.015 (.929)	.034 (.831)	-.079 (.648)	**.451**** (.003)	**-.098** ^{b} (.570)	-.182 (.248)	.023 (.894)	-.027 (.868)	-.104 (.547)
BIS-11 Motor	-.192 (.223)	-.243 (.153)	-.212 (.177)	-.224 (.189)	**-.003** ^{b} (.984)	**-.644***** (< .001)	-.220 (.161)	.028 (.871)	-.208 (.185)	-.109 (.528)
BIS-11 Perseverance	-.220 (.162)	.158 (.358)	-.034 (.831)	.184 (.281)	**-.187** ^{b} (.235)	**.381*** (.022)	.004 (.980)	.005 (.977)	-.275 (.078)	.044 (.799)
BIS-11Self-Control	-.171 (.279)	-.121 (.483)	.175 (.268)	-.247 (.146)	-.254 (.105)	-.341* (.042)	-.113 (.477)	-.022 (.898)	-.116 (.464)	.008 (.965)
BIS-11 Cognitive Complexity	.182 (.249)	-.042 (.808)	.102 (.522)	-.304 (.072)	-.226 (.151)	-.149 (.387)	.245 (.117)	-.005 (.975)	.235 (.134)	.015 (.933)
S-UPPS-P Negative Urgency	-.196 (.214)	.053 (.757)	-.040 (.799)	.034 (.845)	.018 (.909)	-.151 (.378)	-.182 (.248)	.075 (.665)	-.264 (.091)	.121 (.482)
S-UPPS-P lack of Perseverance	-.053 (.740)	.062 (.721)	.200 (.204)	.071 (.681)	-.111 (.484)	-.156 (.362)	-.052 (.742)	-.043 (.803)	.059 (.709)	.260 (.126)
S-UPPS-P lack of Premeditation	-.112 (.481)	-.007 (.967)	-.095 (.551)	-.139 (.418)	.007 (.967)	-.303 (.072)	-.256 (.102)	.132 (.444)	-.041 (.798)	.107 (.534)
S-UPPS-P Sensation	-.247 (.115)	-.352* (.035)	.067 (.672)	-.199 (.245)	-.173 (.274)	-.217 (.204)	.025 (.875)	-.266 (.117)	-.327* (.035)	-.310 (.066)
S-UPPS-P Positive Urgency	-.253 (.106)	-.202 (.238)	-.165 (.295)	-.193 (.260)	**-.020** ^{b} (.901)	**-.511***** (.001)	-.249 (.112)	-.028 (.871)	-.297 (.056)	-.061 (.723)

** p < .05; ** p < .01; *** p < .001.*

^{b} *Correlations are significantly different between native and non-native speakers.*

Note. BIS-11 = Barratt Impulsiveness Scale; S-UPPS-P = Impulsive Behavior Scale, Short Version.

Some correlation coefficients were significantly different between native and non-native speakers (Table 4.5). Specifically, higher BIS-11 Cognitive Instability was associated with significantly more correctly identified low-frequency words only in natives with significant between-group correlation coefficients differences (Z = 2.47, p = .013). Higher BIS-11 Perseverance significantly positively correlated with correct low-frequency words, but only in non-native speakers (Z = -2.5, p = .012). On the contrary, higher BIS-11 Motor disinhibition and higher S-UPPS-P Positive Urgency negatively correlated with correct low-frequency words in only non-native speakers, with significant correlation coefficients differences (BIS-11 Motor, $Z = 3.22$, $p = .001$; S-UPPS-P Positive Urgency, $Z = 2.3$, $p = .021$).

In non-native speakers, BIS-11 Motor significantly predicted 30% of the variance in correctly identified low-frequency words [$F(1,34) = 14.714$, $p = .001$, $R^2 = .302$]. In native speakers, only Cognitive Instability significantly predicted 14.7% of low-frequency words [$F(1,40) = 6.878$, $p = .012$, $R^2 = .147$]. Other impulsivity measures were excluded by each model as non-significant.

4.4.4.4. Affective Traits (Hypothesis 2)

No significant correlations were found between any of the LDT performance variables and DASS-21 subscales (Table 4.4).

4.4.5. The Overall Model: LDT and Psychopathology-Related Traits

To determine which dimensional traits and their combinations most significantly influence overall LDT performance, a four-step regression model was created: i) Language group was entered, ii) psychopathic traits TriPM Meanness, SRP-4-SF Antisocial, and TriPM Boldness were inputted Stepwise, iii) schizotypy – Unusual Experiences was entered, iv) BIS-11 Motor impulsivity and Sensation Seeking were inputted Stepwise. The model including the combination of Language group and Meanness and Boldness most significantly predicted task performance and accounted for nearly 32% of all correct word-nonword identifications [$F(3,74) = 11.532$, $p < .001$, $R^2 = .319$] with Language accounting for around 14% [$F(1,76)$ Change = 11.928, $p = .001$, R^2 Change = .136], Meanness over 11% [$F(1,75)$ Change = 11.402, $p = .001$, R^2 Change = .114] and Boldness for nearly 7% of the variance [$F(1,74)$ Change = 7.478, $p = .008$, R^2 Change = .690]. The Unusual Experiences, Antisocial, and impulsivity traits did not significantly change the predictive quality of this overall model (F Change $p > .05$).

The same procedure was applied using the self-report measures only without Language group: Meanness, Antisocial, Boldness, Unusual Experiences, Motor impulsivity, and Sensation Seeking. The model accepted Meanness, Boldness, and Unusual Experiences, which predicted over 21% of the overall lexical decision performance [$F(3,74) = 6.597$, $p = .001$, $R^2 = .211$], with Meanness accounting for nearly 12% [$F(1,76)$ Change = 10.238, $p = .002$, R^2 Change = .119], and Boldness [$F(1,75)$ Change = 4.348, $p = .040$, R^2 Change = .048] and Unusual Experiences [$F(1,74)$ Change = 4.128, $p = .046$, R^2 Change = .044] accounting for over 4% each. The other traits did not significantly change the predictive value of the overall model (*F* Change *p* > .05). For RTs for incorrect real nonwords, the TriPM Boldness and BIS-11 Perseverance were entered stepwise as predictors, but only the TriPM Boldness emerged as significant, accounting for over 12% of the variance [$F(1,76) = 3.243$, $p = .002$, $R^2 = .122$].

4.5. Discussion

We examined the relationship between dimensional psychopathology-related traits and performance on a one-choice LDT. Participants were significantly better at identifying high-frequency than low-frequency words. Native speakers were significantly better at identifying pseudohomophones and real nonwords than non-native speakers, but no differences were found in word recognition or the RTs between the two groups. The two language groups differed from each other in the speed-accuracy trade-off. In non-native speakers, longer RTs for incorrect real nonwords were associated with higher accuracy. Interestingly, native speakers showed an association between shorter RTs and higher accuracy for high-frequency words. No sex differences were found in accuracy or RTs. As hypothesised, the link between poorer LDT performance and psychopathology-related traits was true for psychopathic traits (Meanness and Boldness) and marginally for positive schizotypy (Unusual Experiences), but not for affective traits. Additionally, in non-native speakers, higher Motor Impulsivity was linked to poorer identification of low-frequency words.

4.5.1. Lexical Decision and Dimensional Psychopathology

The LDT included four Stimulus-Types to investigate whether the psychopathology-related traits are differently related to sublexical and lexical mechanisms. The decoding of unfamiliar words (often low-frequency) or nonwords follows the sublexical pathway. The familiar words (often high-frequency) do not require the implementation of phonological processing or orthography skills and can be directly accessed from vocabulary via the lexical route.

In the overall model, Meanness and Boldness were better predictors of the overall LDT performance than Unusual Experiences. The Meanness also significantly predicted a small amount of variance of pseudohomophone and real nonwords accuracy and Boldness predicted the RTs for incorrect real nonwords. The strongest association was observed for the Meanness, which represents callous aggression and lack of empathy, mostly associated with the affective facet of PCL-R, and is a common trait in forensic populations (Hare, 2006; Hare & Neumann, 2009). The Meanness trait is often observed in association with criminal behaviour, whereas Boldness (the fearless dominance trait) is often seen in successful psychopaths (C. J. Patrick et al., 2009). Previously, the impulsive-antisocial aspect of psychopathy (similar to TriPM Boldness) was found most directly associated with lower LDT accuracy in highly psychopathic individuals, purportedly caused by reduced information processing when asked to change response accordingly (Heritage & Benning, 2013). Highly psychopathic individuals demonstrate deficits in processing abstract words in comparison to controls and are also unable to integrate this information and modulate their behaviour accordingly (Kiehl et al., 2004). Processing of nonwords, and especially pseudohomophones, requires significant involvement of phonological processing, decoding, orthography, and vocabulary, as these stimulus-types cannot be identified using the lexical route (Coltheart et al., 2001). Therefore, the negative association between the Meanness and pseudohomophone and real nonwords accuracy could suggest deficits in the sublexical pathway, in addition to potential deficits in the lexical pathway (for words), in people high on this trait. Similarly, the significant association between Boldness and short RTs for incorrect real nonwords could suggest that individuals with higher fearless dominance traits tend to respond instantaneously which can lead to mistakes in real nonword identification. It is possible that highly psychopathic individuals, especially those with traits associated with criminal behaviour, may be unable to accordingly modulate their responses and may be poor at integrating various reading skills at once when dealing with more complex lexical information.

In contrast to psychopathy, schizotypy was not clearly linked to LDT performance and did not resemble the relationship seen in schizophrenia. We observed only a modest association between higher positive schizotypy (Unusual Experiences) and poorer overall word-nonword recognition when not controlling for language familiarity. Processes involved in lexical recognition and reading deficits, including dyslexia can be associated with genetic-neuropsychological aspects of schizophrenia as some deficits are also observed in individuals with a high clinical risk of developing schizophrenia (Revheim et al., 2014; Whitford et al., 2018). However, normal-to-low schizotypal scores without a presence of clinical diagnosis may not necessarily lead to alterations in cognitive activity related to lexical processing. The deficits in higher schizotypy in language-related tasks can be very subtle, dependent on the tested cohort and specific schizotypy dimensions, or not present at all (Schofield & Mohr, 2014). Therefore, future research focusing on associations between dimensional schizotypal traits and the lexical decision should include a broader range of scores together with people from the clinical population, and also clarify the roles of specific symptoms and illness-related factors, for example, antipsychotic medication (de Boer, Voppel, et al., 2020).

Our findings showed no association between LDT performance and affective traits which is consistent with the previous research showing possibly intact word-nonword recognition in people with higher anxiety or depressive symptoms (Y. R. Li et al., 2014; Notebaert et al., 2019; Vanova et al., 2021).

4.5.2. Lexical Decision and Dimensional Psychopathology-Related Traits: The Role of Language Familiarity

The significant speed-accuracy trade-off for real nonword accuracy and RTs for incorrect answers indicates that non-native English speakers took longer to correctly process real nonwords as these follow the sublexical pathway and require the employment of various reading skills. In native speakers, short RTs for high-frequency words were associated with higher accuracy. The native English speakers may have shown a high level of certainty when identifying frequent, familiar words and, therefore, required less time to identify these via the lexical pathway.

Higher self-reported motor impulsivity was associated with lower accuracy of low-frequency words recognition, but not nonword recognition, in non-native speakers. This suggests that more impulsive individuals tend to opt for the first interpretation when facing an unfamiliar word and confound it as a nonword. Thus, they tend to "guess" the answer as a result of an inability to suppress an inadequate vocabulary representation (van der Schoot et al., 2004). Non-native speakers likely may have more difficulty suppressing inadequate lexical information when presented with an unfamiliar word. We can assume that this difficulty suppressing inadequate information is more likely to be influenced by higher impulsivity or lower inhibitory control. Similar research using the LDT suggests that highly impulsive individuals process language information less efficiently than less impulsive individuals and often experience problems in processing complex lexical information (De Pascalis et al., 2009; Ku et al., 2020).

The BIS-11 Cognitive Instability subscale captures impulsive, quickly changing thoughts (Patton et al., 1995). In native speakers, higher Cognitive Instability was associated with better identification of low-frequency words. Cognitive Instability seems to help native speakers shift quickly between different lexical representations and select the correct one, as they already have sufficient command of the language. In combination with the antisocial trait of psychopathy, impulsivity was previously associated with lower accuracy in LDT (Heritage & Benning, 2013), as impulsive individuals are not able to regulate their response. Yet, Cognitive Instability as a part of attentional impulsivity does not necessarily lead to the inability to create a specific and appropriate response but can be beneficial. It may facilitate a faster response when accuracy is dependent on the level of familiarity with a specific lexical stimulus. This assertion is illustrated in the findings of this study, where non-native speakers with more pronounced motor impulsivity traits, who may also lack the efficiency of the native speakers, demonstrated more guessing behaviour – as indicated in poorer accuracy towards low-frequency words.

Overall, the present study suggests that elevated psychopathic traits in combination with non-native language proficiency and higher motor impulsivity are negatively associated with poor lexical recognition skills in the general population. Considering the findings of impaired reading skills in different populations with higher psychopathic traits (and history of violence), our results suggest the existence of a continuum of reading skill deficits related to elevated psychopathic traits.

4.5.3. Research Implications and Limitations

Our results have implications for future research adopting a dimensional approach to psychopathology. Previous research was mostly focused on a discreet categorical approach to psychopathology and its influence on reading skills. We suggest that certain psychopathology-related traits can infer lower lexical skills which are implicated in successful reading. Future research could establish to what extent sub-clinical psychopathological traits influence reading skills in normative populations, to what extent are the underlying mechanisms shared with clinical populations, and what it means in terms of vulnerability to dyslexia. People with high psychopathy in forensic and non-forensic populations show impairments in various reading skills including lexical recognition, with a high prevalence of dyslexia (Brites et al., 2015; Daderman et al., 2004; Selenius et al., 2006). Especially vulnerable are non-native speakers from an immigrant background (Svensson et al., 2015), a factor also associated with a risk for schizophrenia (Selten et al., 2007). Vulnerability to dyslexia can negatively influence their socio-economic status and academic achievements (L. Hemphill & Tivnan, 2008). Our findings on psychopathic traits could help to better understand the cognitive challenges associated with these traits, their possible links with dyslexia, even in educated populations such as the current sample.

As limitations, several correlations were run with no correction for multiple testing which could lead to Type I error. Also, this study with 78 people in total was underpowered to detect any correlations with a small effect size. However, the results are in line with our hypotheses that reduced lexical recognition is specifically associated with higher positive schizotypy and psychopathy scores, but not with affective traits. The sample showed a limited range of scores on some of the schizotypy and psychopathy dimensions (although the sample averages were in line previously reported norms for the general population) which would have resulted in reduced power to detect some associations. Also, the LDT was presented as a one-choice variant (the button was pressed when a word appeared), therefore, we were unable to record and analyse RTs for correct nonwords. Lastly, this is a correlational study, and we cannot infer causation.

4.6. Conclusions

The finding of this study suggested possible associations between positive schizotypal, psychopathic, and impulsivity traits and LDT performance. Among the included psychopathology-related traits, psychopathy manifestations of dominance, risk-taking, callous cruelty, and predatory aggression most significantly related to poorer word-nonword recognition. This study also suggested that self-reported impulsivity may be differently associated with LDT performance depending on familiarity with the English language.

The next chapter further investigates the association between impulsivity (assessed experimentally) and LDT performance while taking language familiarity into account.

Chapter 5: Examining the Influence of Language Familiarity in the Relationship between Lexical Decision Process and Inhibitory Control

5.1. Chapter Aims and Overview

In the previous chapter, higher self-reported trait impulsivity was found to be associated with a lower recognition accuracy of low-frequency English words in non-native English speakers, with no association being found in native English speakers. Impulsivity is closely associated with poor inhibitory control (Leshem & Yefet, 2019; Logan et al., 1997; W. Roberts et al., 2011), and as discussed in Chapter 1, inhibitory control is important for skilled reading. This chapter, therefore, aims to the association between lexical decision performance (including recognition of low-frequency words) and an experimental measure of inhibitory control, namely a Go/No-Go (GNG) task in native and non-native English speakers.

5.2. Introduction

5.2.1. Impulsivity as a Construct

Impulsivity can be defined as a tendency to exhibit rapid and unplanned reactions to internal and external stimuli without considering any potentially negative consequences caused to the individual or others (Moeller et al., 2001). Depue and Collins (1999) characterised it as a deficit in reflecting, planning, and prompt decision making, often failing to inhibit an improper response with potentially negative consequences (Depue & Collins, 1999). Multiple models of impulsivity describe and explain individual facets.

An empirical exploratory study showed the existence of four factors of impulsivity: urgency, lack of premeditation, lack of perseverance, and sensation seeking (Whiteside & Lynam, 2001). In this 4-factor model of impulsivity, urgency is associated with neuroticism, lack of premeditation and lack of perseverance are associated with conscientiousness, and sensation seeking is associated with extraversion. This four-factor model led to a 59-item (UPPS-P) impulsivity scale (Whiteside & Lynam, 2001) which, in later versions (Cyders et al., 2014), also distinguishes between positive and negative urgency. Positive urgency is a tendency to act abruptly when feeling excited whereas negative urgency is the tendency to act abruptly when feeling upset. Negative urgency can manifest itself as higher irritability, dysphoria, or anxiety, lack of perseverance can manifest as low effort in activities, and lack of premeditation can manifest as high uncertainty, with all three factors showing strong links with problematic behaviour (Sperry et al., 2016). Individuals scoring high on sensation-seeking behaviour are reported to show high confidence, stronger reactions to affect, and more engagement and joy from activities (Sperry et al., 2016).

One of the most influential models of impulsivity was proposed by Barratt (1959), the model and assessment tools have since undergone several modifications. In this model, impulsivity consists of three main facets: motor – acting without thinking, non-planning – lack of forethought, and attentional (cognitive) impulsivity – the inability to focus or concentrate (Stanford et al., 2009). This model describes impulsivity from a cognitive-behavioural perspective in comparison to the previously mentioned models focusing mainly on behaviour only.

5.2.1.1. Experimental Measures of Impulsivity

Impulsivity is considered closely associated with inhibitory control - the inability to suppress unwanted actions, thoughts, or feelings, which help the individual to adapt to emerging changes (Anderson & Weaver, 2009; Spechler et al., 2016). It can be behaviourally assessed by experimental tasks requiring suppressing reactions to certain stimuli, e.g., Stop-Signal Task (SST), or a Go/No-Go Task (GNG), with higher impulsivity resulting in a higher number of false alarms (FAs) (Ettinger et al., 2018; Zald, 2015).

In the SST, participants are frequently presented with a stimulus that requires a response (go-signal) but on a small proportion of trials, this stimulus is immediately followed by a visual or auditory stop-signal, which indicates that a response should be withheld. The task, therefore, requires a sudden cancellation (inhibition) of a pre-planned response. The task, first reported by Vince (1948), together with the underlying theory, has undergone several modifications. The main theorem of inhibitory control is called a *race model,* describing the mechanism of inhibition as a constant race between the go and stop responses (Logan & Cowan, 1984). Inhibitory control is a two-part act. The first one is to inhibit a response when a stop signal occurs, whereas the second one is balancing between stopping and going in between the task trials (Logan et al., 2014). The ability to inhibit responses seem to be relatively stable during adulthood with minimal changes in relation to increasing age (Williams et al., 1999).

The GNG task is another broadly used task to assess inhibitory control. The task is similar to the SST. Participants are mostly (60-90%) presented with go-trials that require a response, usually a button press, the rest are no-go trials, where participants are instructed to not respond. When a participant fails to withhold a response, they produce commission errors/false alarms (FA) which indicate poor inhibition, whereas errors by omission (missed trials) are indicators of attention lapses or poor vigilance (L. Wright et al., 2014). Across the literature, the GNG task often includes perceptually simple stimuli such as letters, numbers, or symbols. The version of the GNG task used in this investigation includes non-verbal stimuli which have the form of human avatars, increasing the ecological validity. In the GNG task, the inhibitory mechanism follows an intuitive route from sensory information processing through attention allocation and cognitive control to motor control, whereas in the SST the cognitive control component is active in the pre-stimulus phase allowing quickly switch responses (Raud et al., 2020). Therefore, these two tasks differently engage the components of inhibitory control with GNG focusing primarily on quick sensory information processing which leads to motor control.

Other experimental measures of inhibitory control are the Simon Task (Simon & Wolf, 1963), Flanker Task (Eriksen & Eriksen, 1974), and Stroop Test (Stroop, 1935). These tasks measure response and attentional inhibition, requiring participants to focus attention on, and respond to, target stimuli only while ignoring the distractors (Tiego et al., 2018).

5.2.2. Impulsivity, Poor Inhibitory Control, and their Relationship with Reading

Impulsive individuals tend to have problems in inhibiting undesired responses, as despite having fast pre-potent responses, their inhibitory RTs are slower than those of non-impulsive individuals (Logan et al., 1997). Individuals with high trait impulsivity are also found to show deficits in inhibitory control (resulting in more FAs) for different stimuli in comparison to those with low trait impulsivity (Leshem & Yefet, 2019).

As mentioned in Chapter 1, inhibitory control modulates the selection of appropriate lexical representations from the vocabulary fitting to the context is important for text comprehension (Borella et al., 2010; Chang, 2020). Inhibitory control and attention are responsible for selecting appropriate information for the current context (Dywan & Murphy, 1996). Several representations can be activated at the same time, and inhibitory control ensures the selection of the appropriate one and shifts attention to this source (Kieffer et al., 2013). Inhibitory control is also closely associated with working memory and its role in reading (Borella et al., 2010; Chang, 2020). If the inhibitory control is impaired or insufficient, several irrelevant representations are activated which overloads and reduces the working memory capacity. This causes a slowing down of lexical processing, a phenomenon seen in older people (Lustig et al., 2001), and those with mental illness diagnoses, including schizophrenia (Crawford et al., 2002).

Impaired inhibitory control has been associated with age-related decline in working memory in people with reading disabilities (Chiappe et al., 2000). Better inhibitory control seems to modulate successful phonological word recognition in bilinguals (proficiency/familiarity with two languages) in comparison to monolinguals – those proficient only in one language (Blumenfeld & Marian, 2011). Therefore, bilinguals with good inhibitory control seem to be able to reject irrelevant word representations more efficiently. This effect seems to be also present in people who learned the second language later in life and still present better inhibitory control to language than monolinguals (Linck et al., 2008; Mercier et al., 2014).

This study aims to examine whether there is a relationship between motor impulsivity as assessed by a GNG task (involving non-verbal stimuli) and lexical decision process and also explored whether language familiarity plays a role in this association, if found.

Hypotheses

Based on the previous literature and the findings reported in Chapter 4, the following hypotheses were proposed:

1. A higher number of false alarms (FAs) during the GNG task (indicating higher impulsivity) will be associated with lower overall LDT performance in the entire sample.
2. A higher number of FAs on the GNG task will be associated with lower accuracy for low-frequency words, pseudohomophones, and real nonwords in non-native speakers.

5.3. Methods

5.3.1. Participants and Design

This study included the same participants, procedure as described in the previous chapter (Chapter 4). The self-report measures of impulsivity included in this investigation were: a) O-LIFE (Impulsive Non-conformity), b) TriPM (Disinhibition), S-UPPS-P (all sub-scales), and BIS-11 (all subscales).

A correlational design was used to investigate the relationship between performance on the LDT (as described in Chapter 4) and the GNG task (an experimental measure of impulsivity).

5.3.2. Inhibitory Control – Go/No-Go Task (GNG)

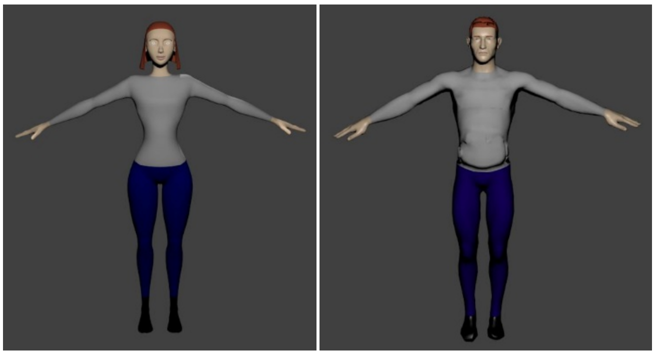
A modified version of the classic Go/No-Go task (Gomez et al., 2007) featuring 3D human avatars was employed. Altogether, there were 150 trials (20% of which were No-Go trials) split between three stimulus durations: 1000ms, 700ms, and 400ms (50 trials each). The stimuli consisted of four different "Go" and two "No-Go" images of male and female avatars in grey clothing. The Go avatars were sideways-facing and the No-Go avatars were forward-facing. Each trial consisted of a 200ms blank screen, the 1000ms, 700ms, or 400ms main stimulus (Figure 5.1. illustrates avatars for both conditions) and another 100ms blank screen. Participants were asked to respond via a button press when a 'Go' stimulus was shown and to withhold their response when a 'No-Go' stimulus appeared. If a response was made before the maximal length of the trial duration was reached the experiment immediately proceeded with the next trial. All three blocks were presented continuously without previous warning to the participant.

The task instructions were presented before a short practice session as follows: *"You will be presented with a series of images. All front-facing characters are Go images. Press the <Go-button> as fast as possible when these appear. All side-facing characters are No-Go images. DO NOT press any button when these appear."* The practice session consisted of 16 practice stimuli (eight Go and eight No-Go) with a maximal main stimulus duration of 2000ms, providing participants with feedback on their accuracy after each stimulus (Figure 5.2.). No feedback was displayed during the main trials. Response accuracy and RTs were recorded throughout. The task duration was approximately five minutes.

The number of FAs and RTs for Go trials were examined. The FAs were calculated as a percentage of incorrectly identified No-Go trials. The overall performance was calculated as a value using the formula: Overall = (correct Go) *minus* (FAs).

Figure 5.1. GNG task “Avatar” stimuli for Go and No-Go trials.

Go trials



No-Go trials

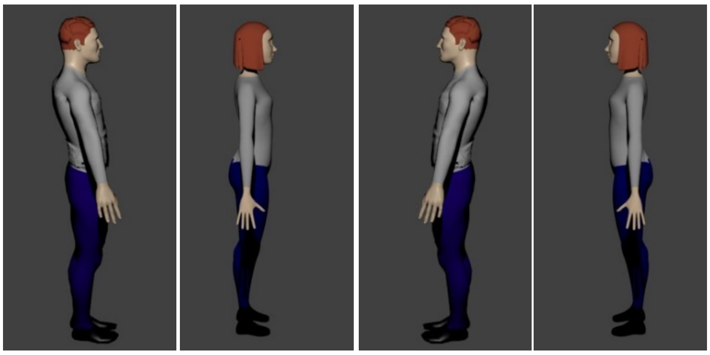
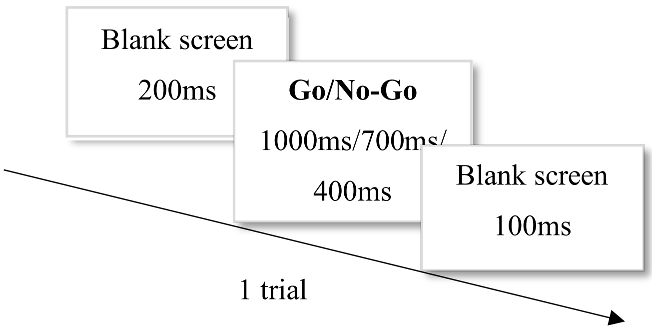


Figure 5.2. Time course of the GNG task trial.



5.3.3. Data Treatment

The data were analysed using IBM SPSS Statistics, Version 26.0 (IBM Corp., 2019), with the level of significance set at .05 unless specified otherwise.

All variables were assessed for normality by examining skewness, kurtosis, and homogeneity of variance (Levene's test). Skewness and kurtosis are reported in Table 5.1. Variables with significant z-scores in skewness or kurtosis were normalised by replacing outliers with the mean value ± double standard deviation (*SD*) (Field, 2009). In the LDT and GNG tasks, all accuracy and RTs variables were normalised. In these affected variables, no more than five outliers were replaced for any individual variable (see Table 5.1). In variables where Levene's test was significant, the *t*-test and significance are reported with adjusted degrees of freedom.

5.3.4. Statistical Analysis

5.3.4.1. GNG Performance: Effect of Stimulus Duration, Sex, and Language

Accuracy and RTs variables (Overall, FAs, RTs for correct go and incorrect no-go trials – FAs) were analysed using 3 (Stimulus Duration) x 2 (Sex) x 2 (Language) mixed model of Analysis of Variance (ANOVA) with Stimulus Duration (1000ms, 700ms, or 400ms) as a within-subject variable, and Sex (men, women) or Language (English-native vs Other-native speakers) as the between-subject factors. The Greenhouse-Geisser correction was applied to all repeated measures statistics where Mauchly's Test indicated a significant violation of sphericity ($p < .05$). Post-hoc mean comparisons with Bonferroni correction (p_{bonf}) were conducted to probe significant main and interaction effects. Effect sizes were calculated as partial eta squared (η^2_p) and interpreted as follows: $\eta^2_p \geq .01$ to < .06 (small), $\eta^2_p \geq .06$ to <.14 (medium), $\eta^2_p \geq .14$ (large) (J. Cohen, 1992; Keppel, 1991).

5.3.4.2. Association between Psychopathology Dimensions and GNG Performance

A non-parametric correlation test (Spearman's rank-order correlation coefficient (*r*ho) – r_s ; two-tailed significance $p < .05$) was used due to significant skewness and kurtosis of data, to test the hypothesised association between the GNG variables (Overall, FAs, RTs) and LDT accuracy for all Stimulus-Types. All LDT performance variables associated with more than one GNG variable were analysed further using linear regression analysis (Stepwise method) to determine the amount of shared and unique variance explained by GNG performance in LDT.

Lastly, correlational analyses were used to confirm (expected) positive associations between GNG variables of inhibitory control and self-report measures of impulsivity across the entire sample, and separately in the two language groups.

5.4. Results

Full sample characteristics are summarised in Chapter 4 (Table 4.1.).

5.4.1. Impulsivity: Stimulus Duration, Sex, and Language Effects

Mauchly's Test for different stimuli durations indicated a violation of sphericity ($p < .05$) for all GNG performance indices. Therefore, Greenhouse-Geisser correction was applied to assess significant effects.

Overall Performance: There was a significant main effect of the Stimulus Duration with a large effect size [$F(1.53,112.94) = 77.965$, $p <.001$, $\eta^2_p = .513$]. The follow-up analysis using post-hoc comparisons showed that participants had significantly lower accuracy for 400ms trials than for 700ms [$t(74) = 7.339$, $p < .001$, $p_{bonf} < .001$], lower accuracy for 700ms than for 1000ms trials [$t(74) = 5.589$, $p < .001$, $p_{bonf} < .001$], and lower accuracy for 400ms than for 1000ms trials [$t(74) = 11.000$, $p < .001$, $p_{bonf} < .001$]. Sex did not have a significant main effect on overall performance [$F(1,74) = .095$, $p = .759$, $\eta^2_p = .001$]. The Sex*Stimulus Duration interaction was also non-significant [$F(1.53,112.94) = .160$, $p = .794$, $\eta^2_p = .002$]. Language did not have a significant main effect [$F(1,74) = .710$, $p = .402$, $\eta^2_p = .010$] and the Language*Stimulus Duration interaction [$F(1.53,112.94) = 0.172$, $p = .783$, $\eta^2_p = .002$] and Sex*Language*Stimulus duration [$F(1.53,112.94) = 1.372$, $p = .255$, $\eta^2_p = .018$] were also non-significant.

FAs: There was a significant main effect of the Stimulus Duration with a large effect size [$F(1.75,129.43) = 43.082$, $p <.001$, $\eta^2_p = .368$]. A follow-up analysis of post-hoc comparisons showed that participants produced significantly more FAs for 400ms No-Go stimuli than for 700ms [$t(74) = 4.688$, $p < .001$, $p_{bonf} < .001$]. They were also significantly more FAs for 700ms No-Go stimuli than for 1000ms stimuli [$t(74) = 5.285$, $p < .001$, $p_{bonf} < .001$]. Similarly, the difference between 400ms FAs and 1000ms FAs was also significant [$t(74) = 8.478$, $p < .001$, $p_{bonf} < .001$] (Figure 5.3.). Sex did not have a significant main effect [$F(1,74) = .021$, $p = .988$, $\eta^2_p = .000$]. Sex*Stimulus Duration interaction was also non-significant [F(1.75,129.43) = .563, p = .548, η^2_p = .008]. Language did not have a significant main effect [F(1,74) = 1.592, p = .211, η^2_p = .021], and Language*Stimulus Duration [F(1.75,129.43) = .240, p = .758, η^2_p = .003] and Language*Sex*Stimulus Duration [F(1.75,129.43) = 1.480, p = .232, η^2_p = .020] interactions were also non-significant.

Go RTs: There was a significant main effect of the Stimulus Duration on RTs with a large effect size [F(1.42,105.00) = 71.821, p <.001, η^2_p = .493]. Participants showed significantly shorter RTs for 400ms Go stimuli than for 700ms (t(74) = 7.234, p < .001, p_{bonf} < .001), for 700ms Go stimuli than for 1000ms stimuli (t(74) = 6.917, p < .001, p_{bonf} < .001), and for 400ms Go stimuli than 1000ms stimuli (t(74) = 9.566, p < .001, p_{bonf} < .001) (Figure 5.4.). Sex did not have a significant main effect [F(1,74) = .201, p = .655, η^2_p = .003]. Sex*Stimulus Duration interaction was also non-significant [F(1.42,105.00) = 1.289, p = .272, η^2_p = .017]. Language did not have a significant main effect [F(1,74) = 2.710, p = .104, η^2_p = .035] and Language*Stimulus Duration [F(1.42,105.00) = .149, p = .787, η^2_p = .002], as well as the Sex*Language*Stimulus Duration interactions [F(1.42,105.00) = .146, p = .790, η^2_p = .002] were non-significant.

FA RTs: There was a significant main effect of the Stimulus Duration on RTs with a large effect size [F(1.74,128.73) = 7.469, p = .001, η^2_p = .092]. Participants showed significantly shorter RTs for 700ms FAs than for 1000ms (t(74) = 2.811, p = .006, p_{bonf} = .019), and for 400ms FAs than for 1000ms stimuli (t(74) = 3.455, p < .001, p_{bonf} = .003). The differences between 400ms and 700ms FA RTs was non-significant (t(74) = .214, p = .831). Sex did not have a significant main effect [F(1,74) = .188, p = .666, η^2_p = .003]. Sex*Stimulus Duration interaction was also non-significant [F(1.74,128.73) = 1.514, p = .225, η^2_p = .020]. Language did not have a significant main effect [F(1,74) = .072, p = .789, η^2_p = .001] and Language*Stimulus Duration [F(1.74,128.73) = 1.033, p = .354, η^2_p = .014], as well as the Sex*Language*Stimulus Duration interactions [F(1.74,128.73) = .251, p = .747, η^2_p = .003] were non-significant.

In summary, there were main effects of Stimulus Duration in Overall performance, FAs, or RTs, but no significant interactions or differences were found involving Sex or Language groups.

Figure 5.3. Mean FAs for each of the three stimulus durations in the entire sample.

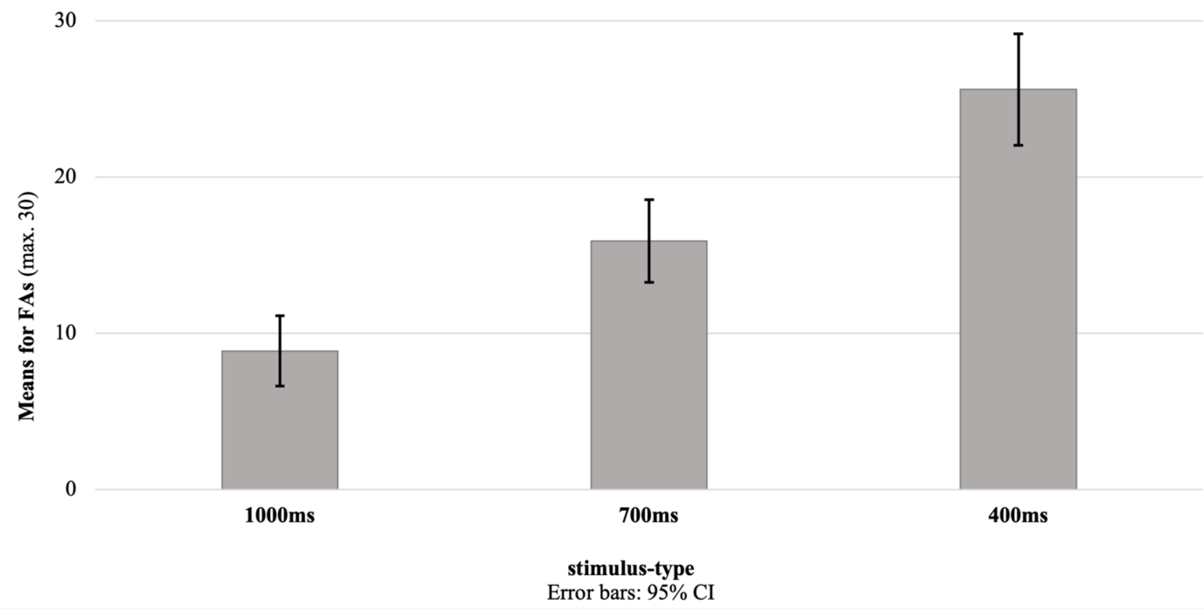


Figure 5.4. Mean RTs (in ms) for each of the three stimulus durations in the entire sample.

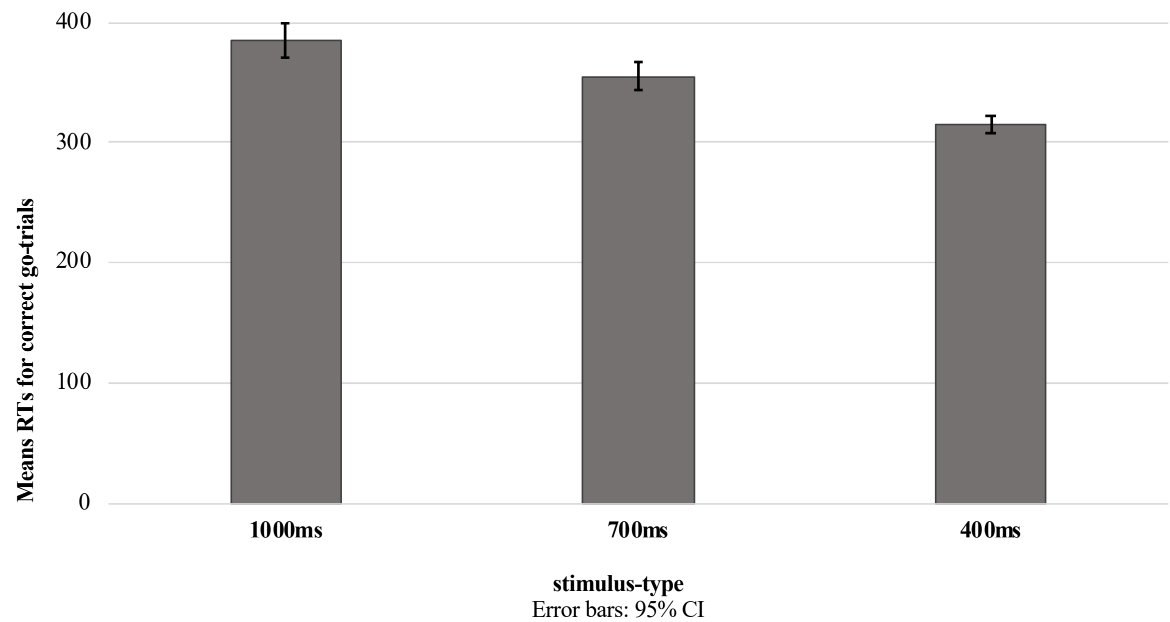


Table 5.1. Descriptive statistics for GNG task performance variables for the entire sample.

	Mean (SD)	Min	Max	Skewness			Kurtosis			No. of outliers changed
				Value	Std. Error	z-score	Value	Std. Error	z-score	
Overall (%)										
1000ms	90.74 (10.07)	69.56	100	-.905	.272	-3.327	-.288	.538	-.535	0
700ms	83.08 (12.37)	55.88	100	-.424	.272	-1.559	-.590	.538	-2.169	0
400ms	63.75 (19.43)	22.73	100	-.319	.272	-1.173	-.646	.538	-2.375	0
FA (%)										
1000ms	8.86 (10.2)	0	30	.912	.272	3.353	-.313	.538	-.582	1
700ms	15.9 (11.9)	0	42	.451	.272	1.658	-.541	.538	-1.006	3
400ms	25.6 (16.1)	0	58	.383	.272	1.408	-.656	.538	-1.219	0
Correct Go Trials RT (ms)										
1000ms	384.94 (67.65)	269.53	582.15	.949	.272	3.489	.825	.538	1.533	5
700ms	354.62 (52.07)	240.66	503.63	.397	.272	1.460	.117	.538	.217	0
400ms	314.57 (31.67)	248.71	387.15	-.033	.272	-.121	-.522	.538	-.970	0
FA RT (ms)										
1000ms	167.81 (172.60)	140.80	580.89	.421	.272	1.548	-1.072	.538	-1.992	2
700ms	229.38 (124.13)	135.14	486.58	-.929	.272	-3.415	-.192	.538	-.357	1
400ms	234.46 (86.60)	59.60	392.40	-1.418	.272	-5.213	2.254	.538	4.189	0

5.4.2. Relationship between Impulsivity and LDT and the Influence of Language (Hypotheses 1 and 2)

Across the entire sample (Table 5.2.), the overall LDT performance significantly positively correlated with GNG Overall at 1000ms (p = .027) and RTs for 400ms FAs (p = .006), and over 14% of variance in LDT was predicted by the RTs for 400ms FAs [F(1,76) = 13.057, p = .001, R^2 = .147].

The number of correct pseudohomophones significantly negatively correlated with the number of FAs at 400ms (p = .010) and RTs for 400ms FAs (p = .007), and positively with RTs for 400ms go-trials (p = .047). The RTs for 400ms FAs significantly predicted nearly 15% of correct pseudohomophones variance [F(1,76) = 13.225, p < .001; R^2 = .148], but the RTs for 400s go-trials or the number of 400ms FAs did not significantly change the model.

The correct real nonwords significantly positively correlated with GNG Overall 1000ms (p = .011) and negatively with 1000ms FAs (p = .049) and RTs for 400ms FAs (p = .047). Over 16% of the correct real nonwords variance [F(2,77) = 7.189, p < .001, R^2 = .161] was significantly predicted by GNG Overall 1000ms [F(1,75) = 6.226, p = .015, R^2 = .070] and RTs for 400ms FAs [F(1,76) = 7.628, p = .007, R^2 = .091].

Table 5.2. Relationship between LDT GNG performance variables for the entire sample.

	LDT Overall performance	LDT Correct high-frequency	LDT Correct low-frequency	LDT Correct pseudo-homophones	LDT Correct real nonwords
	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*
GNG Overall					
1000ms	**.251*** (.027)	.148 (.195)	.092 (.424)	.204 (.073)	**.286*** (.011)
700ms	-.044 (.704)	-.010 (.933)	-.047 (.685)	-.012 (.915)	.023 (.840)
400ms	.172 (.132)	.130 (.256)	-.074 (.522)	.220 (.053)	.179 (.117)
GNG FA					
1000ms	-.176 (.124)	-.130 (.256)	-.044 (.704)	-.178 (.119)	**-.223*** (.049)
700ms	.009 (.940)	.028 (.806)	.022 (.848)	-.025 (.829)	-.046 (.691)
400ms	-.210 (.065)	-.086 (.456)	.108 (.348)	**-.288*** (.010)	-.221 (.052)
GNG Correct Go trials RT					
1000ms-go	.063 (.584)	-.078 (.495)	-.108 (.348)	.216 (.058)	.050 (.661)
700ms-go	.019 (.866)	-.148 (.196)	-.186 (.102)	.149 (.192)	.068 (.554)
400ms-go	.086 (.453)	-.083 (.468)	-.146 (.201)	**.226*** (.047)	.107 (.350)
GNG FA RT					
1000ms	-.102 (.372)	-.214 (.060)	.022 (.851)	-.100 (.384)	-.137 (.233)
700ms	.006 (.961)	-.056 (.627)	.084 (.463)	.006 (.956)	.011 (.922)

400ms	**-.309**** (.006)	-.028 (.805)	-.110 (.339)	**-.305**** (.007)	**-.226*** (.047)

** p < .05; ** p < .01. Significant correlations are in **bold**.*

There were a few significant differences in correlation coefficients observed for the two language groups (Table 5.3.). Correct real nonwords significantly positively correlated with RTs for 400ms trials in non-native speakers, but not in native speakers ($Z = -1.693$, $p = .045$). Correct high-frequency words significantly negatively correlated with RTs for 1000ms FAs in native, but not in non-native speakers ($Z = -2.127$, $p = .017$). In non-native speakers, Overall 1000ms performance significantly predicted over 25% of the accuracy of real nonwords variance [$F(1,34) = 11.576$, $p = .002$, $R^2 = .254$].

In native speakers, RTs for correct 700ms go-trials [$F(1,40) = 7.042$, $p = .011$, $R^2 = .150$] and RTs for 1000ms FAs [$F(1,39) = 4.213$, $p = .047$, $R^2 = .083$] significantly predicted over 23% of the high-frequency word accuracy variance [$F(2,41) = 5.910$, $p = .006$, $R^2 = .233$].

Table 5.3. Relationship between LDT and GNG variable in the native speakers ($n = 42$) and non-native speakers ($n = 36$).

	LDT Overall performance		LDT Correct high-frequency		LDT Correct low-frequency		LDT Correct pseudo-homophones		LDT Correct real nonwords	
	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native
	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*	r_s *(p)*
GNG Overall										
1000ms	.198 (.210)	**.379*** (.022)	.150 (.342)	.155 (.367)	.134 (.397)	.065 (.706)	.219 (.164)	.243 (.153)	.122 (.440)	**.499**** (.002)
700ms	.109 (.493)	-.037 (.830)	-.183 (.247)	.172 (.314)	-.027 (.867)	-.018 (.916)	.126 (.425)	-.035 (.841)	.150 (.343)	.039 (.823)
400ms	.085 (.592)	.294 (.082)	.037 (.817)	.231 (.175)	-.107 (.499)	-.007 (.966)	.185 (.240)	.302 (.074)	.066 (.677)	.296 (.079)
GNG FA										
1000ms	-.146 (.356)	-.285 (.091)	-.167 (.289)	-.103 (.551)	-.085 (.591)	-.035 (.841)	-.217 (.167)	-.186 (.279)	-.076 (.630)	**-.420*** (.011)
700ms	-.123 (.440)	-.006 (.973)	.217 (.167)	-.156 (.363)	.021 (.893)	-.024 (.892)	-.142 (.370)	-.013 (.938)	-.166 (.293)	-.052 (.762)
400ms	-.169 (.283)	**-.348*** (.037)	-.074 (.640)	-.139 (.417)	.098 (.537)	.057 (.739)	-.280 (.072)	**-.399*** (.016)	-.145 (.359)	**-.350*** (.036)
GNG Correct Go trials RT										
1000ms	.099	.080	-.234	.088	-.098	-.123	**.355***	.145	.041	.122

	(.534)	(.642)	(.135)	(.610)	(.537)	(.473)	(.021)	(.398)	(.795)	(.477)
700ms	.033	.020	**-.408**b**	.071	-.085	-.287	.223	.076	-.008	.184
	(.834)	(.906)	**(.007)**	(.681)	(.594)	(.090)	(.155)	(.660)	(.959)	(.282)
400ms	.095	.183	-.187	.048	-.208	-.038	**.377***	.202	-.044	**.342*b**
	(.549)	(.287)	(.235)	(.780)	(.186)	(.824)	(.014)	(.237)	(.781)	(.041)
GNG FA RT										
1000ms	-.072	-.181	**-.428****	-.072	.019	-.001	-.099	-.142	-.054	-.246
	(.650)	(.292)	(.005)	(.677)	(.906)	(.995)	(.532)	(.408)	(.735)	(.148)
700ms	-.049	.003	-.178	.034	.124	.019	.123	-.094	-.219	.174
	(.757)	(.988)	(.261)	(.843)	(.434)	(.914)	(.440)	(.584)	(.164)	(.310)
400ms	-.225	-.291	-.174	.156	-.054	-.108	-.204	-.318	-.257	-.124
	(.152)	(.085)	(.270)	(.364)	(.733)	(.532)	(.194)	(.059)	(.100)	(.473)

** p < .05; ** p < .01. Significant correlations are in **bold**.*

[b] *Correlations are significantly different between native and non-native speakers.*

Table 5.4. Correlations between GNG task variables and self-report measures of impulsivity separately in native and non-native English speakers.

	GNG Overall						GNG FA					
	1000ms		700ms		400ms		1000ms		700ms		400ms	
	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native
	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)
BIS-11 Attention	-.057	-.029	-.193	-.046	-.043	-.263	.062	.038	.192	.010	.060	.206
	(.721)	(.866)	(.221)	(.789)	(.785)	(.121)	(.697)	(.828)	(.223)	(.955)	(.707)	(.227)
BIS-11 Cognitive Instability	.051	-.323	-.008	.065	-.250	-.217	-.008	**.331***	.004	-.065	.177	.235
	(.747)	(.054)	(.961)	(.708)	(.110)	(.203)	(.961)	(.048)	(.982)	(.706)	(.261)	(.167)
BIS-11 Motor	-.141	-.181	-.113	-.139	**-.358***	**-.392***	.073	.133	.155	.147	**.392***	.244
	(.373)	(.290)	(.477)	(.418)	(.020)	(.018)	(.648)	(.441)	(.327)	(.391)	(.010)	(.152)
BIS-11 Perseverance	.075	-.044	-.107	.004	-.015	-.010	-.079	.079	.062	-.010	.090	.099
	(.636)	(.801)	(.498)	(.980)	(.924)	(.955)	(.617)	(.649)	(.695)	(.955)	(.569)	(.564)
BIS-11 Self Control	.067	.055	-.020	.189	-.026	-.228	-.098	-.074	.035	-.193	.081	.126
	(.671)	(.750)	(.898)	(.270)	(.872)	(.181)	(.535)	(.667)	(.828)	(.259)	(.610)	(.464)
BIS-11 Cognitive Complexity	-.008	.217	-.002	.054	.010	-.071	-.006	-.285	.011	-.038	.005	-.011
	(.960)	(.205)	(.990)	(.756)	(.948)	(.681)	(.971)	(.092)	(.945)	(.825)	(.975)	(.950)
S-UPPS-P Negative Urgency	-.195	-.186	-.128	-.014	-.222	-.215	.119	.138	.116	.020	**.332***	.148
	(.215)	(.278)	(.421)	(.937)	(.158)	(.207)	(.451)	(.422)	(.466)	(.909)	(.032)	(.389)
S-UPPS-P Perseverance	.297	.176	.061	-.005	.218	.203	**-.330***	-.185	-.066	-.037	-.175	-.272
	(.056)	(.303)	(.699)	(.978)	(.165)	(.235)	(.033)	(.279)	(.680)	(.830)	(.267)	(.109)
S-UPPS-P Premeditation	-.016	.157	-.070	.176	-.084	-.005	-.010	-.189	.076	-.199	.155	-.020
	(.920)	(.359)	(.660)	(.305)	(.596)	(.976)	(.950)	(.270)	(.630)	(.245)	(.328)	(.908)
S-UPPS-P Sensation	.021	-.179	-.241	.240	-.114	**-.353***	-.021	.133	.252	-.219	.204	**.338***
	(.897)	(.296)	(.125)	(.158)	(.473)	(.035)	(.893)	(.439)	(.107)	(.200)	(.196)	(.044)
S-UPPS-P Positive Urgency	-.131	-.232	-.090	.183	**-.414****	-.274	.066	.206	.098	-.184	**.475****	.188
	(.410)	(.173)	(.570)	(.284)	(.006)	(.106)	(.680)	(.227)	(.536)	(.283)	(.001)	(.271)

** $p < .05$; ** $p < .01$. Significant correlations are in **bold**.*

5.5. Discussion

This study examined the relationship between motor impulsivity as the inability to inhibit responses on the GNG task and the lexical decision process while considering language familiarity. The results did not directly support the first hypothesis as FAs were not found to be associated with the LDT accuracy in the overall sample; however, the RTs for FAs were associated with overall LDT accuracy, correct real nonwords, and correct pseudohomophones. Similarly, no direct support was found for the second hypothesis concerning differential associations between FAs and LDT accuracy. There were differences between native and non-native speakers in the correlations between GNG (overall GNG performance for 1000ms trials and RTs for FAs) and LDT variables that offer indirect support as discussed further.

In the entire sample, RTs for 400ms FAs significantly predicted the variance of overall LDT accuracy, correct real nonwords, and correct pseudohomophones. This suggests that individuals with higher motor impulsivity expressed as shorter RTs when failing to withdraw a response may be more prone to misjudge nonwords for words. As mentioned in Chapter 1, inhibitory control is important for reading to select appropriate lexical information from the mental vocabulary and to determine relevant context (Borella et al., 2010; Chang, 2020). Our findings are in accordance with this model of involvement of inhibitory control in the lexical decision process as nonword recognition requires implementation of the sublexical pathway as mentioned in Chapter 4. This can make impulsive individuals more susceptible to nonword errors as these cannot be identified automatically and require inhibitory control mechanisms to facilitate the correct rejection of irrelevant vocabulary entries.

When investigating the relationships between LDT and GNG measures separately for the two language groups, correct real nonwords were predicted by RTs for 400ms go-trials and Overall 1000ms, in non-native speakers exclusively. This shows that non-native speakers are more accurate at identifying real nonwords when they take longer (slower RTs) for very quick trials (400ms) and are also more accurate when responding to slow (1000ms) trials. Therefore, higher real nonword accuracy can be related to less impulsive, more cautious reactions in non-native speakers that is partially in line with the hypotheses. Similarly, to the findings in Chapter 4, where higher motor impulsivity traits were associated with lower accuracy in low-frequency words that, like real nonwords, follow the sublexical pathway in recognition. This is in line with previous research showing that in non-native speakers good inhibitory control helps them to select between competing lexical options in spoken words and possibly indicating the influence of inhibition on language proficiency (Mercier et al., 2014; Pivneva et al., 2012). Good inhibitory control has also been shown to be involved in non-native speakers developing good phonological processing skills when acquiring the non-native language (Darcy et al., 2016), and phonological skills are important in nonword recognition as these follow the sublexical pathway (Balota

& Yap, 2006; Coltheart et al., 2001). Although no significant differences in experimental indices of motor impulsivity (more FAs or lower Overall accuracy) were found between the language groups, these results suggest that impulsivity/inhibitory control plays a different role in lexical decisions depending on language familiarity. Moreover, the GNG task predictors of the LDT performance in non-native speakers, the 400ms Go RTs, significantly correlated with low perseverance and cognitive instability. Therefore, trait impulsivity could contribute to lower accuracy in recognition of nonwords. In non-native speakers, there is a higher demand on inhibitory control processes in relation to language, specifically in word recognition (Blumenfeld et al., 2016; Blumenfeld & Marian, 2013; Krizman et al., 2014) and when learning new words (Bartolotti et al., 2011). Therefore, longer RTs for very quick stimuli and the ability to carefully modulate their answers can lead to higher accuracy when identifying real nonwords. The idea of impulsivity/inhibitory control differently modifying responses to lexical stimuli in the two language groups could be also supported by the findings in native speakers.

In native speakers, shorter RTs (for correct 700ms trials and 1000ms FAs) significantly predicted higher accuracy in high-frequency words. This could suggest that faster responses lead to higher accuracy for familiar words, as these do not require selecting from various lexical representations and are automatised in native speakers. The automatization being resistant enough to the impulsivity can be supported by the fact that the GNG predictors of LDT performance in native speakers did not significantly correlate with any self-report impulsivity measures. Overall, it can be assumed that impulsivity does not play a significant role in the lexical decision process in native speakers or in people with better familiarity with the language.

In summary, despite the average impulsivity (inhibitory control) being similar in the native and non-native speakers, this process seems to be more involved in nonword recognition in non-native speakers than in native speakers. Non-native speakers appear more prone to making lexical decision mistakes if they had poor inhibitory control.

5.5.1. Limitations

First, a large number of correlations were performed which could lead to a number of false-positive results. Seconds, as indicated in Chapter 4, the experiment was underpowered and data on some of the variables remained non-normally distributed though still analysed using parametric statistical methods. Second, this study experimentally assessed motor impulsivity by a GNG task which to some extent requires the involvement of inhibitory control. However, an SST may be a more suitable measure to assess inhibition as it engages the cognition in the pre-stimulus phase and requires more planning than a GNG task (Raud et al., 2020).

5.6. Conclusions

The findings of the study reported in this chapter suggest that poorer language familiarity, less language proficiency, and less exposure to lexical stimuli may need to be compensated for by good inhibitory control in order to properly access and process unfamiliar lexical information.

5.7. Chapter Summary

The findings from the study reported in this chapter, together with those reported in the previous chapter suggest that trait and motor impulsivity and poor inhibitory control play an important role in word-nonword recognition and as such could negatively affect reading, especially in non-native speakers. Impulsivity is also one of the traits associated with higher psychopathy and tendencies towards violent behaviour (Hart & Dempster, 1997). As demonstrated in Chapter 2, highly psychopathic individuals and those within forensic services (including non-native speakers from immigrant backgrounds) have reading skills severely impaired in comparison to healthy controls. The findings of the study reported in this chapter show that this trend can be observed also in educated young individuals and that psychopathy, motor impulsivity/poor inhibitory control, and language familiarity can negatively influence a range of reading skills.

The next chapter will focus on the neural correlates of the associations between the traits of positive schizotypy (Unusual Experiences), psychopathy (Meanness and Boldness), and motor impulsivity and word-nonword recognition (reported in Chapter 4) in the general population.

Chapter 6: Dimensional Psychopathology and Lexical Decision Task Performance: A Functional Magnetic Resonance Imaging (fMRI) Study

6.1. Aims and Overview

The results from the behavioural studies reported in Chapters 4 and 5 indicated lower word-nonword recognition accuracy in association with higher positive schizotypal, psychopathic, and impulsivity traits. This chapter aims to develop these findings by examining the neural underpinnings of these LDT-psychopathology-related trait associations. To achieve this, it uses functional magnetic resonance imaging (fMRI) in combination with the LDT paradigm and relevant self-report psychopathology measures.

6.2. Introduction

Brain areas associated with phonological processing and comprehension show activation during correct recognition of words (Chapter 1 – *Neural correlates of reading*). Activation of the fusiform gyrus and anterior cingulate, and inferior frontal gyrus (IFG) bilaterally, left middle temporal gyrus and right posterior superior temporal gyrus (STG) occurs during word-nonword recognition as assessed by LDT (Kiehl et al., 2004). Words generate stronger activation than nonwords in the middle, inferior, and lateral occipital areas and alongside the collateral sulcus and fusiform gyrus bilaterally (Fiebach et al., 2002). Left inferior frontal lobe (Broca's areas) activity significantly correlates with task difficulty determined by word frequency (high/low) and stimulus-type (word/nonword) (Carreiras et al., 2006; Fiebach et al., 2002; H.-L. Liu et al., 2004). Broca's areas corresponding to the IFG area is involved in the phonological part of the language; it is strongly activated during nonword recognition which involves orthographic to lexical processing whereas word recognition involves more temporal areas involved in the semantic processing (Paz-Alonso et al., 2018; Wimmer et al., 2010). Low-frequency words also activate the left IFG (pars opercularis; BA 44) – responsible for phonological processing; left inferior parietal lobule – responsible for the orthography-phonology integration; and the left middle temporal gyrus – responsible for the semantic processing (Newman & Joanisse, 2011). Pseudohomophones produce significantly more activation in the areas involved in the phonological processing (left IFG and precentral gyrus, BA 6/9) and semantic processing (pars triangularis IFG, BA 47) than real nonwords (Edwards et al., 2005; Newman & Joanisse, 2011). Real nonwords are reported to produce stronger activation than pseudohomophones, especially in the occipitotemporal regions, IFL, and precentral areas (Wimmer et al., 2010). Low-frequency words show stronger activation than high-frequency words in the anterior cingulate and supplemental motor area (Carreiras et al., 2006) whereas high-frequency words show higher activity in the cingulate and inferior parietal regions (Nakic et al., 2006). In general, lexical stimuli requiring a higher level of phonological processing, such as low-frequency (unfamiliar) words and nonwords, activate the IFG and precentral gyrus, whereas high-frequency words which do not require this level of processing activate the semantic areas in the temporal lobe.

During LDT performance, people with SZ and clinical high-risk individuals compared to healthy controls show reduced activity in the left and right BA 44-46 corresponding to the dorsolateral prefrontal cortex (DLPFC) and Broca's areas, left BAs 20, 37, and 39 corresponding to inferior temporal gyrus, fusiform gyrus, and angular gyrus, and right BA 11 (orbitofrontal gyrus), and BA 40 (supramarginal gyrus) (X. Li et al., 2010). People with SZ also show lower activation in comparison to controls when identifying nouns and verbs in the anterior PFC and the pars opercularis of Broca's area (BA 44), and this deficit may be compensated with higher activation in BA 40 (which was also associated with lower PANSS negative symptoms scores) (Nazli et al., 2020). Lower activation of BA 44-45 has also been observed in SZ and high clinical risk individuals when recognising nonwords over words in comparison to controls (Natsubori et al., 2014).

There are limited neuroimaging data at present examining psychopathy in relation to LDT performance using emotionally-neutral stimuli (Debowska et al., 2014; Kiehl, 2006). Previous research has primarily focused on detecting deficits in recognition of emotional words (Burgess et al., 2014; Ku et al., 2020; Notebaert et al., 2019; Vitale et al., 2011, 2018), and not on the lexical processing accuracy from a reading perspective. High psychopathy individuals are reported to show deficits in the identification of abstract words (often low frequency) accompanied with lower activation in the right anterior temporal gyrus (Kiehl et al., 2004). Typically, higher psychopathy is characterised by reduced activation in the frontal, temporal and limbic regions (e.g. amygdala) (Blair, 2008; Debowska et al., 2014; Kiehl et al., 2006) and this may potentially overlap with neural aberrations during the lexical decision process.

Motor impulsivity/poor inhibitory control can also influence lexical decision processes, especially in non-native speakers, as mentioned in the previous chapter (Chapter 6). There are only a few neuroimaging studies directly examining this topic. EEG indexed event-related potential (EEG-ERP) studies of word recognition have shown lower P300 amplitude in parietal regions in relation to higher attentional and non-planning impulsivity (Harmon-Jones et al., 1997), as well as higher N400 amplitude in frontocentral areas around the midline in association with high sensation-seeking behaviour (De Pascalis et al., 2009). The P300 wave is a large positive amplitude that appears 300ms after the stimulus onset as a response to an infrequent target stimulus and is considered to reflect the cognitive speed and neural efficiency (van Dinteren et al., 2014). The N400 is a negative amplitude peaking 400ms after the onset of a visually or auditorily presented lexical stimulus and is related to language processing and semantic memory (Kutas & Federmeier, 2011). This illustrates that impulsivity/poor inhibitory control can influence lexical processing at the neural level. Inhibitory control levels in non-native speakers are reported to significantly positively correlate with the neural activity for word recognition in IFG, insula, inferior parietal lobule, and middle temporal gyrus (Grant et al., 2015).

Language familiarity also influences brain activation patterns during LDT. Bilinguals show greater bilateral activation (i.e., weaker lateralisation) than monolinguals mainly in the middle occipital gyrus, right IFG, inferior and superior parietal gyri, as well as the fusiform and angular gyri (Park et al., 2012). Reduced lateralisation during the LDT has been also observed in people with SZ compared with controls (Lam et al., 2012; Natsubori et al., 2014).

Given the associations between dimensional psychopathology-related traits of positive schizotypy (Unusual Experiences), psychopathy related callous aggression (Meanness) and fearless dominance (Boldness), Motor impulsivity and poorer lexical decision performance at the behavioural level (Chapters 5-6), this study examined their neural correlates. To our knowledge, this is the first study to examine neural activations for four different Stimuli-Types: high-frequency, low-frequency words, pseudohomophones, and real nonwords in association with various psychopathology-related traits, namely, positive schizotypy, psychopathy, and motor impulsivity which are associated with dyslexia-like profiles in clinical populations (Vanova et al., 2021).

Hypotheses

1. In line with previous literature, the brain areas involved in phonological processing (left IFG, left insula, precentral gyrus bilaterally) will show the strongest activation during real nonwords and lowest activation during the high-frequency words, with pseudohomophones and low-frequency words showing the intermediate level of activity.

2. Higher levels of positive schizotypy (Unusual Experiences), psychopathy (Meanness, Boldness) and motor impulsivity will correlate with lower activations in the areas associated with phonological processing (IFG, insula, precentral gyrus) when identifying: a) low-frequency words, b) pseudohomophones, and c) real nonwords in order of increasing involvement of the phonological processing.

6.3. Methods

6.3.1. Participants and Design

Twenty-two healthy right-handed participants were recruited via the Brunel University London and Royal Holloway University London networks. All participants were over 18 years old, had a sufficient written and verbal command of the English language, and normal or corrected-to-normal vision and hearing. Participants had no history or current diagnosis of any psychiatric or neurological illness and no serious offence history as self-reported. They were pre-screened for any MRI contraindications.

All participants were assessed identically on one occasion in the scanner and on a separate occasion (usually within 1-2 days after the scanning) online by self-report questionnaires.

This research was approved by the College of Health, Medicine and Life Sciences Research Ethics Committee, Brunel University London (Reference: 16789-MHR-May/2019- 19042-2). All participants gave written informed consent after the study procedures had been explained to them. Participants who were currently enrolled in an undergraduate degree at Brunel University London (n = 3) were reimbursed with course credits. Other participants received a £20 voucher as compensation for their time.

6.3.2. Self-Report Questionnaires

The following questionnaires were used: O-LIFE (schizotypy), TriPM (psychopathy), and BIS-11 (impulsivity) (all described in detail in Chapter 4). The questionnaires were administered via an online platform using Qualtrics^{XM} Software, 2019 Version (Qualtrics LLC, 2005).

6.3.3. fMRI: Paradigm and Procedure

The experimental task (LDT) was administered using Presentation® Software (version 21.1) (Neurobehavioral Systems Inc., 2018). Participants were presented with 120 stimuli (60 words and 60 nonwords) in three blocks of 40 stimuli each, counterbalanced for word frequency and stimulus type. The stimuli order was pseudo-randomised. Each trial was 700ms long, consisting of the 500-ms stimulus presentation, and two 100ms ISIs, one at the beginning and one at the end of the trial. Each trial was preceded by a random 1000 to 5000ms jitter (3000ms average for the whole experiment). A

15-second blank screen was presented between the three blocks of stimuli. The overall experiment duration was 474 seconds (approx. 8 minutes). In total, 242 volumes were obtained during the fMRI.

The stimuli were selected by the same process and with the same characteristics as in the behavioural version of the experiment (Chapter 4). The word list consisted of 30 high-frequency word lemmas, 300-306 occurrences per million words and 30 low-frequency word lemmas, 10-11 occurrences/million, counterbalanced per word category (adjectives, verbs, and nouns). The nonword list included 30 real nonwords and 30 pseudohomophones that were taken from the ARC Database (Rastle et al., 2002). The nonword list was counterbalanced in the summed frequency of nonword neighbours, which is an indicator of similarity with other nonwords (high frequency: 300-700 occurrences/million; low frequency: 0-10 occurrences/million) and the type of syllables used (monomorphemic, polymorphemic and morphologically ambiguous). The neighbourhood size of each nonword and pseudohomophone was 1. This refers to the number of words that can be derived by changing one letter while preserving the position of the other letters. The real nonwords and pseudohomophones were orthographically legal – consisting of combinations of letters proper to the English language. All words and nonwords were 5-6 letters long.

A 4-button MRI compatible response box (Lumitouch, Photon Control Inc., Baxter, Canada) was used to record participants' behavioural responses. They were asked to press the button number "3" when they saw a word and to press button "4" when they saw a nonword. The task was explained to participants prior to them going into the scanner and the instructions were presented to them again in the scanner before the scanning started. The researcher spoke to the participant via the intercom to ensure that the instructions were correctly understood. A blank screen was shown, and the experiment started when the first pulse from the scanner was received. After the scanning finished, all participants were debriefed and given instructions on how to fill in the self-report measures.

6.3.4. fMRI: Data Acquisition

The data were acquired on 3Tesla Siemens TIM Trio whole-body MRI scanner (Siemens Medical Solutions, Erlangen, Germany) at the Combined Universities Brain Imaging Centre – CUBIC, Royal Holloway University London, using a 32-channel head coil. Participants were equipped with noise-cancelling earplugs to lower the background scanner noise and were able to communicate with the researchers in between the scans via an intercom. Stimuli were presented back-projected on a screen with a mirror mounted on the head coil. The area between the participant's head and the coil was padded to limit the head movements and participants were asked to remain as still as possible during the scanning.

This study used an event-related design for fMRI data acquisition. The functional images were acquired in one run using the following pulse sequence: TR = 2000ms, TE = 30.6ms, 50 interleaved slices, voxel size = 2x2x3mm, flip angle = 78°, field of view = 192mm, base resolution = 96, 96x96 matrix. Time correction was based on the middle slice and realignment reference volume was the first volume. A total number of 242 volumes was obtained during the experiment. High resolution T1-weighted images were acquired with the following settings: TR = 2300ms, TE = 2.9ms, 192 images of 1x1x1mm voxel size, flip angle = 9°, field of view = 256mm, base resolution = 256, matrix 256x256.

6.3.5. Data analysis

6.3.5.1. Behavioural Data

The data were analysed using IBM SPSS Statistics, Version 26.0 (IBM Corp., 2019), with alpha level for significance testing set at < 0.05, unless stated otherwise. The skewness of all LDT performance and self-report traits variables was checked and found to be within the acceptable range (Field, 2009), except for the correct low-frequency words and correct real nonwords which were mildly skewed (max. z = -2.271). No corrections were applied.

Performance accuracy and RTs were then analysed using a 4 (Stimulus-Type) x 2 (Sex) x 2 (Language) mixed model of Analysis of Variance (ANOVA) with Stimulus-Type (high-frequency words, low-frequency words, pseudohomophones, real nonwords) as a within-subject variable, and Sex (males, females) and Language (Native vs Non-native speakers) as the between-subject factors. The Greenhouse-Geisser correction was applied to all repeated measures statistics where Mauchly's Test indicated a significant violation of sphericity ($p < .05$). Post-hoc mean comparisons were conducted to probe significant main and interaction effects as required. Effect sizes were calculated as partial eta squared (η^2_p) and interpreted as follows: $\eta^2_p \geq .01$ to $< .06$ (small), $\eta^2_p \geq .06$ to $< .14$ (medium), $\eta^2_p \geq .14$ (large) (J. Cohen, 1992). Cohen's d values were interpreted as follows: ≥ .2 to < .5 (small effect), ≥ .5 to < .8 (medium), and ≥ .8 (large) (J. Cohen, 1992).

Pearson' correlations coefficient with two-tailed significance ($p < .05$) was used to examine hypothesised personality-LDT performance associations.

6.3.5.2. fMRI Data

SPM12 toolbox (Friston et al., 2007) for MATLAB R2020a (*MATLAB*, 2020) was used for data pre-processing and analysis. For graphic visualisation of the data, the MRIcroGL (Rorden & Brett, 2000) was used.

6.3.5.3. Pre-Processing

At the beginning of the pre-processing, the anterior commissure was manually set as an origin for the structural and all functional images. All functional images were realigned and co-registered with the corresponding structural images for each participant. The resulting images were normalised to the Montreal Neurological Institute (MNI) space with 2x2x2mm voxel resolution for functional images, and forward deformations field. The transformation parameters were obtained from the segmentation of structural images. The normalised images were then smoothed with full width at a half-maximum (FWHM) Gaussian smoothing kernel of 10mm.

6.3.5.4. Models and Inferences

The smoothed images were then subjected to a two-level analysis. At the first level, we performed a random-effect analysis of participant-specific activations for each of the following contrasts:

1. Correct high-frequency > Correct low-frequency
2. Correct low-frequency > Correct high-frequency
3. Correct pseudo-homophones > Correct real nonwords
4. Correct real nonwords > Correct pseudo-homophones
5. Correct high-frequency words > Correct pseudo-homophones
6. Correct high-frequency words > Correct real nonwords
7. Correct low-frequency words > Correct pseudo-homophones
8. Correct low-frequency words > Correct real nonwords
9. Correct pseudo-homophones > Correct high-frequency words
10. Correct pseudo-homophones > Correct low-frequency words
11. Correct real nonwords > Correct high-frequency words
12. Correct real nonwords > Correct low-frequency words
13. Incorrect pseudohomophones > incorrect real nonwords
14. Incorrect real nonwords > incorrect pseudohomophones
15. Incorrect pseudohomophones > correct pseudohomophones

16. Correct pseudohomophones > incorrect pseudohomophones
17. Incorrect real nonwords > correct real nonwords
18. Correct real nonwords > incorrect real nonwords
19. Correct high-frequency words > rest
20. Correct low-frequency words > rest
21. Correct pseudo-homophones > rest
22. Correct real nonwords > rest
23. Incorrect pseudohomophones > rest
24. Incorrect real nonwords > rest

At the second level, we identified task-related neural activations using one-sample t-tests across the entire sample (height threshold $p < .001$; family-wise error (FWE) corrected for multiple comparisons at the cluster level $p < .05$). The relationships of psychopathology-related traits (O-LIFE Unusual Experiences, TriPM Meanness and Boldness, and BIS-11 Motor impulsivity) that were found to be significant predictors of LDT performance in the behavioural study (reported in Chapter 4) with neural activity across the whole brain were then examined using a regression model within SPM12 with questionnaire scores entered as a covariate for each contrast (height threshold $p <.001$; cluster-corrected $p \leq .05$). Next, the participant-specific activation contrast image values were extracted (from one-sample t-tests including all participants) for the regions (peak voxel) that showed an association with psychopathology-related traits (see Results) in SPM regression analysis and examined for their possible relationships with performance using Pearson correlations (run within the SPSS).

6.4. Results

6.4.1. Sample Characteristics

Participants' age range was 19-42 years (M = 24.14; SD = 5.40), with the majority achieving education at undergraduate (50%) and postgraduate level (50%). Males (n = 7) and females (n = 15) did not differ in age, ethnicity or self-report measures (all p values > .05). There were equal numbers of native and non-native speakers (11 per group). Full sample characteristics are provided in Table 6.1.

Table 6.1. Sample characteristics.

Variable/*N*	Men (*n* = 7)	Women (*n* = 15)	Overall sample (*N* = 22)
Age (Mean [±*SD*])	27.14 (3.17)	22.73 (.69)	24.13 (5.40)
Language (Number [%])			
English	1 (14.3%)	10 (66.7%)	11 (50%)
Other	6 (85.7%)	5 (33.3%)	11 (50%)
Ethnicity (Number [%])			
White	3 (42.9%)	11 (73.3%)	14 (63.6%)
Asian/Pacific Islander	2 (28.6%)	3 (20%)	5 (22.7%)
Black/African American	1 (14.3%)	0	1 (4.5%)
Hispanic/Latino	0	1 (6.7%)	1 (4.5%)
Other	1 (14.3%)	0	1 (4.5%)
Education (Number [%])			
Higher Degree	5 (71.4%)	6 (40.0%)	11 (50%)
First Degree	1 (14.3%)	8 (53.3%)	9 (40.9%)
GCE A Level in 2+	1 (14.3%)	1 (6.7%)	2 (9.1%)

6.4.2. LDT Performance

Accuracy: Mauchly's Test indicated a violation of sphericity (p < .001), therefore, Greenhouse-Geisser correction was applied. There was a significant main effect of the Stimulus-Type with a large effect size [$F(1.62,29.16) = 11.142$, $p = .001$, $\eta^2_p = .382$]. A follow-up analysis showed that participants identified significantly more high than low-frequency words [$t(21) = 4.945.$, $p < .001$, Cohen's $d = 1.414$], more low-frequency words than pseudohomophones [$t(21) = 4.622.$, $p < .001$, Cohen's $d = .766$], and more real nonwords than pseudohomophones [$t(21) = 3.775$, $p = .001$, Cohen's $d = .769$], meaning that the pseudohomophone effect was present in this study (Table 6.2.).

Sex did not have a significant main effect [$F(1,18) = .012$, $p = .913$, $\eta^2_p = .001$]. The Sex*Stimulus Duration interaction was also non-significant [$F(1.62,29.16) = .389$, $p = .638$, $\eta^2_p = .004$]. Language did not have a significant main effect [$F(1,18) = .079$, $p = .781$, $\eta^2_p = .010$] and the Language*Stimulus Duration interaction [$F(1.62,29.16) = .179$, $p = .792$, $\eta^2_p = .010$] and Sex*Language*Stimulus duration [$F(1.62,29.16) = .392$, $p = .636$, $\eta^2_p = .021$] were non-significant.

RTs: There was a significant main effect of the Stimulus-Type with a large effect size [$F(3,54) = 41.849$, $p < .001$, $\eta^2_p = .699$]. A follow-up analysis showed that RTs pattern was identical to that seen in accuracy. Participants were significantly faster when identifying high than low-frequency words [$t(21) = 8.342$, $p < .001$, Cohen's $d = .839$], low-frequency words than pseudohomophones [$t(21) = 6.444$, p

< .001, Cohen's *d* = .728], but the RT differences between pseudohomophones and real nonwords was not significant [$t(21) = 1.897$, $p = .072$, Cohen's *d* = .126] (Table 6.2.).

Sex did not have a significant main effect [$F(1,18) = .008$, $p = .930$, $\eta^2_p = .001$]. The Sex*Stimulus Duration interaction was also non-significant [$F(3,54) = .611$, $p = .611$, $\eta^2_p = .033$]. Language did not have a significant main effect [$F(1,18) = .031$, $p = .862$, $\eta^2_p = .002$] and the Language*Stimulus Duration interaction [$F(3,54) = 2.102$, $p = .111$, $\eta^2_p = .105$] and Sex*Language*Stimulus duration [$F(3,54) = .798$, $p = .500$, $\eta^2_p = .033$] were all non-significant.

6.4.2.1. LDT Performance: Speed-Accuracy Trade-off

In the entire sample, longer RTs correlated positively with recognition accuracy of high-frequency words ($r = .470$, $p = .027$). No further correlations were found in the entire sample, or when examined separately in native and non-native language groups.

Table 6.2. Descriptive statistics for LDT performance and psychopathology-related traits (N = 22).

Measure	Mean (SD)	Min	Max	Max possible
LDT performance				
Correct high-frequency words	29.227 (.92)	27	30	30
Correct low-frequency words	27.500 (1.47)	24	29	30
Correct pseudohomophones	23.682 (3.79)	16	30	30
Correct real nonwords	25.546 (3.31)	17	30	30
Incorrect high-frequency words (n = 18)	.727 (.83)	0	2	30
Incorrect low-frequency words (n = 18)	2.273 (1.35)	1	6	30
Incorrect pseudohomophones (n = 18)	5.954 (3.81)	0	14	30
Incorrect real nonwords (n = 18)	3.954 (3.23)	0	13	30
Missed (n = 10)	1.136 (2.08)	0	9	120
Correct high-frequency words RT (ms)	565.718 (85.84)	420	724	2000
Correct low-frequency words RT (ms)	648.584 (110.24)	460	901	2000
Correct pseudohomophones RT (ms)	740.494 (140.41)	540	989	2000
Correct real nonwords RT (ms)	723.149 (135.90)	539	1059	2000
Psychopathology-related traits* [a]				
O-LIFE Unusual Experiences	8.910 (3.915)	0	17	30
TriPM Boldness	29.770 (7.118)	15	45	76
TriPM Meanness	12.590 (6.493)	3	25	76
BIS-11 Motor	14.500 (3.635)	9	24	28

*Other psychopathology-related traits measures were not associated with LDT performance in the behavioural study (Chapter 4), thus not examined here.

[a] Normative scores for the general population are provided in Table 4.2 (Chapter 4).
Note. O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale.

6.4.2.2. Relationship between LDT Performance and Self-Reported Psychopathology Dimensions

No significant correlation coefficients were found between the psychopathology-related traits and LDT performance as described in Tables 6.3. (accuracy) and 6.4. (RTs) though correlations with positive schizotypy (Unusual Experiences), and Motor impulsivity were generally in the expected direction.

Table 6.3. Correlations between LDT accuracy and psychopathology measures.

Measure	Overall performance *r* (*p*)	Correct words high-frequency *r* (*p*)	Correct words low-frequency *r* (*p*)	Correct pseudo-homophones *r* (*p*)	Correct real nonwords *r* (*p*)
O-LIFE Unusual Experiences	-.224 (.316)	-.126 (.577)	-.331 (.133)	-.063 (.780)	-.272 (.221)
TriPM Boldness	.099 (.662)	.153 (.496)	-.134 (.552)	.178 (.429)	.046 (.839)
TriPM Meanness	.223 (.318)	.350 (.110)	.052 (.817)	.268 (.228)	.097 (.666)
BIS-11 Motor	-.365 (.095)	-.263 (.237)	-.414 (.056)	-.175 (.437)	-.400 (.065)

Note. O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale.

Table 6.4. Correlations between RTs to correctly identified stimuli (LDT) and psychopathology measures.

Measure	RT words high frequency *r* (*p*)	RT words low frequency *r* (*p*)	RT pseudo-homophones *r* (*p*)	RT real nonwords *r* (*p*)
O-LIFE Unusual Experiences	-.178 (.429)	-.146 (.517)	-.065 (.776)	.035 (.878)
TriPM Boldness	.069 (.759)	-.100 (.659)	.148 (.510)	.089 (.693)
TriPM Meanness	.234 (.295)	.301 (.174)	.057 (.803)	.134 (.553)
BIS-11 Motor	-.226 (.313)	-.332 (.131)	-.123 (.584)	-.165 (.464)

Note. O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale.

6.4.2.3. Post-Hoc Power Calculation

For a one-tailed test, with 22 participants and the strongest encountered effect (Pearson's correlation $r = .414$, $\alpha = .056$), we obtained only 68% power. In order to acquire at least 80% power for $r = .414$ at $\alpha = .050$ we would have required 32 participants.

6.4.3. Functional Magnetic Resonance Imaging

6.4.3.1. Task-Related Activations

Brain activation changes associated with all task contrasts are presented in Table 6.5. As can be seen in Figure 6.1, the IFG – pars opercularis (bilaterally), inferior occipital gyrus (bilaterally), fusiform gyrus (bilaterally), postcentral gyrus (left), and insula (left) were activated for all stimulus-types compared to rest (Figure 6.1.). For high-frequency words, the main activated areas were the right inferior occipital gyrus, left postcentral and fusiform gyri. For low-frequency words, large clusters of activation were found in the left hemisphere at Rolandic operculum, postcentral and inferior occipital gyri. For pseudohomophones, left-sided activity, mainly in the postcentral, inferior temporal, and fusiform gyri, and in the Rolandic operculum was found. For the real nonwords, brain activation was present in the left postcentral, inferior temporal, and Rolandic operculum, and the right inferior occipital and fusiform gyri. The main activated region for high-frequency words, in comparison to nonwords, was in the left angular gyrus. The low-frequency words recognition over high-frequency words showed the strongest activations in the IFG – pars triangularis, and in the inferior temporal gyrus.

Table 6.5. Task-related activations (T-contrasts) across the entire sample ($N = 22$) [height threshold family wise error (FWE) corrected $p < .05$; extent threshold = 2 voxels].

Contrast			Cluster level		Peak level		MNI coordinates		
Area name	BA	Side	P_{FWE}	K_E	P_{FWE}	T			x y z (mm)
Correct high-frequency words > correct pseudohomophones									
Precuneus	5	Right	< .001	883	.001	8.68	4	-54	60

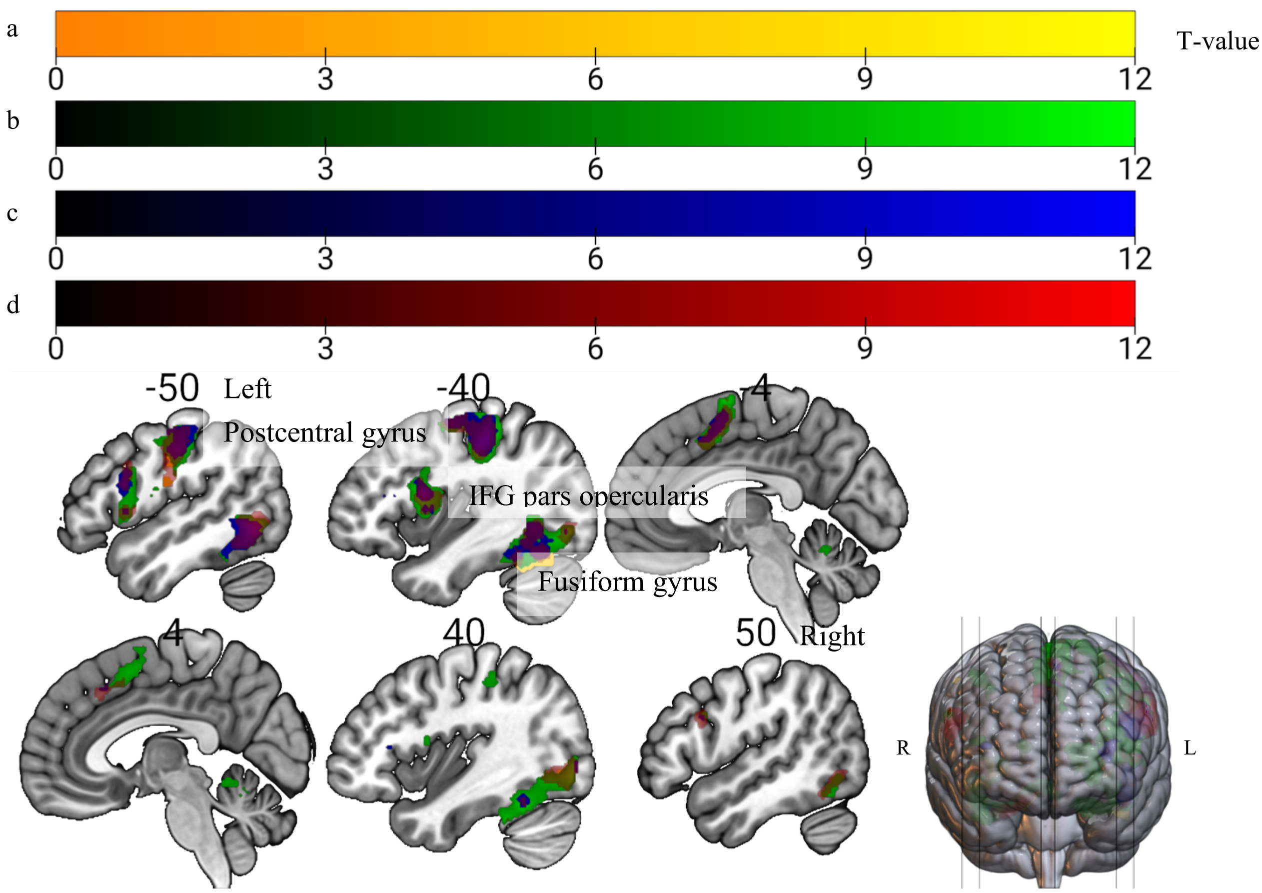
Middle cingulate	23				.002	8.28	6	-22	42
					.003	8.15	2	-48	50
Angular gyrus	39	Left	< .001	228	.002	8.19	-44	-66	32
					.004	7.93	-44	-60	26
Superior temporal gyrus	40	Right	< .001	34	.008	7.49	60	-42	24
Sup. medio-frontal gyrus	10	Right	< .001	103	.009	7.43	10	54	4
Medio-frontal orbital gyrus	11				.015	7.09	14	56	-4
Paracentral lobule		Right	.013	5	.013	7.18	16	-28	60
Angular gyrus	39	Right	< .001	78	.023	6.83	46	-54	34
					.033	6.63	50	-58	26
Correct high-frequency words > correct real nonwords									
Angular gyrus	39	Left	.001	27	.005	7.76	-44	-70	30
Correct low-frequency words > correct high-frequency words									
Inferior frontal triangularis	47	Left	.009	7	.004	7.87	-30	32	-2
Inferior temporal gyrus	20	Left	.008	8	.015	7.12	-46	-44	-14
Correct low-frequency words > correct pseudohomophones									
Precentral gyrus	6	Right	< .001	45	.008	7.45	18	-22	68
Hippocampus	20	Right	.003	16	.008	7.40	36	-22	-12
Correct pseudohomophones > incorrect pseudohomophones (n = 18)									
Precentral gyrus	4	Left	.001	21	.015	8.03	-34	-28	64
	6				.016	7.99	-32	-20	68
Incorrect real nonwords > correct real nonwords (n = 18)									
Insula	47	Left	< .001	30	.005	9.05	-36	22	-2
Middle cingulum	32	Right	.002	8	.025	7.88	6	30	32
Correct high-frequency words > rest									
Inferior occipital gyrus	19	Right	< .001	241	< .001	9.78	40	-82	-4
	18				.004	7.86	30	-88	-4
Postcentral gyrus	3	Left	< .001	983	< .001	9.29	-46	-24	56
					< .001	9.27	-46	-22	42
					.003	8.07	-38	-30	48
Fusiform gyrus	37	Left	< .001	476	.001	8.86	-44	-60	-20
Inferior occipital gyrus					.003	8.02	-46	-64	-10
Middle temporal gyrus					.004	7.89	-46	-60	-2
Inferior occipital gyrus	19	Left	< .001	127	.001	8.84	-36	-80	-8
Cerebellum	37	Right	< .001	360	.003	8.06	30	-42	-26
Culmen	19				.004	7.88	10	-52	-20

Fusiform gyrus	37				.009	7.32	42	-52	-24
Rolandic operculum	48	Left	.002	22	.009	7.35	-46	-26	22
Inferior frontal gyrus	6	Left	.001	28	.014	7.08	-58	10	26
Insula	48	Left	.002	24	.018	6.94	-44	8	8
Insula	48	Left	.011	7	.019	6.89	-34	8	10
Insula	48	Left	.026	2	.022	6.83	-32	24	8
Inferior frontal opercularis	6	Right	.010	8	.023	6.78	58	12	18
Postcentral gyrus	4	Right	.010	8	.027	6.70	56	-14	48
Inferior temporal gyrus	37	Right	.026	2	.034	6.56	42	-62	-6
Correct low-frequency words > rest									
Rolandic operculum	48	Left	< .001	1669	< .001	12.64	-42	6	16
Insula					< .001	9.65	-34	0	14
Putamen					< .001	9.25	-26	6	-8
Postcentral gyrus	3	Left	< .001	2660	< .001	11.80	-38	-32	52
Supplementary motor area	6				< .001	10.71	-8	0	72
Postcentral gyrus					< .001	10.43	-46	-28	58
Inferior occipital gyrus	19	Left	< .001	2837	< .001	10.68	-34	-82	-8
Middle temporal gyrus	37				< .001	10.63	-46	-60	-2
Inferior occipital gyrus					< .001	10.42	-46	-62	-10
Precentral gyrus	6	Right	< .001	70	.001	8.64	58	10	28
Inferior frontal opercularis	44				.028	6.79	48	12	28
Thalamus		Right	< .001	82	.004	7.97	12	-14	12
Ventral anterior nucleus					.007	7.60	14	6	10
					.008	7.50	14	-6	10
Postcentral gyrus	3	Right	< .001	92	.005	7.79	38	-34	50
Supramarginal gyrus	40				.023	6.90	36	-34	42
Postcentral gyrus	48	Left	.012	5	.007	7.64	-48	-8	18
Insula	48	Right	< .001	35	.009	7.45	36	4	10
Postcentral gyrus	3	Right	.008	7	.018	7.06	36	-24	38
Correct pseudohomophones > rest									
Postcentral gyrus	2	Left	< .001	1065	< .001	10.75	-42	-28	46
Precentral gyrus	3				< .001	9.82	-44	-30	54
Inferior parietal gyrus	43				.002	8.24	-58	-10	24
Inferior temporal gyrus	37	Left	< .001	684	< .001	9.98	-48	-58	-4
Middle temporal gyrus					.001	8.69	-48	-56	-12
Fusiform gyrus					.002	8.31	-44	-60	-20
Rolandic operculum	48	Left	< .001	367	< .001	9.67	-40	6	16
Inferior frontal gyrus	44				.001	8.85	-48	12	20
Inferior frontal gyrus					.004	7.77	-54	10	28

Insula	48	Left	< .001	95	.001	8.65	-34	26	8
Inferior frontal gyrus	45				.037	6.50	-42	22	14
Supplementary motor area	6	Left	< .001	110	.007	7.51	-2	6	54
	32				.016	6.98	-6	14	46
Fusiform gyrus	37	Right	< .001	40	.008	7.41	38	-50	-20
Inferior frontal gyrus	48	Right	.003	17	.009	7.32	36	28	10
Inferior frontal opercularis	44	Right	.004	16	.011	7.18	52	14	28
Inferior occipital gyrus	19	Right	.005	14	.012	7.16	40	-82	-2
Fusiform gyrus	37	Right	.001	30	.013	7.09	34	-36	-26
Supplementary motor area	32	Right	.008	10	.019	6.88	4	24	44
Inferior occipital gyrus	19	Left	.010	8	.029	6.64	-38	-76	-8
Superior frontal gyrus	6	Left	.026	2	.033	6.57	-26	-6	68
Correct real nonwords > rest									
Postcentral gyrus	3	Left	< .001	1360	< .001	11.52	-58	-12	40
Precentral gyrus	43				< .001	11.04	-58	-10	22
Inferior parietal gyrus	4				.001	8.91	-48	-20	42
Inferior temporal gyrus	37	Left	< .001	915	< .001	11.03	-52	-64	-6
Inferior occipital gyrus	19				< .001	9.90	-36	-82	-6
Middle temporal gyrus	37				< .001	9.51	-44	-58	-4
Inferior occipital gyrus	19	Right	< .001	495	< .001	10.24	42	-78	-8
					0.001	8.77	36	-86	-6
Inferior temporal gyrus	37				0.012	7.22	42	-64	-8
Rolandic operculum	48	Left	< .001	588	< .001	10.23	-40	6	16
Insula					< .001	9.35	-44	4	8
Precentral gyrus	44				.001	9.06	-56	10	28
Fusiform gyrus	37	Right	< .001	383	.001	8.86	14	-48	-20
					.002	8.28	26	-42	-26
					.003	8.00	28	-34	-26
Inferior frontal opercularis	48	Right	< .001	180	.001	8.76	52	14	28
	44				.031	6.65	56	14	12
Supplementary motor area	6	Left	< .001	381	.002	8.41	-4	4	52
					.002	8.19	-6	0	60
Middle cingulum	32	Right			.004	7.91	6	26	42
Insula	48	Left	.004	15	.019	6.93	-34	24	12
Thalamus (Ventral lateral nucleus)		Left	.004	15	.021	6.88	-18	-14	4
Inferior frontal triangularis	48	Right	.025	2	.029	6.69	38	24	12
Incorrect pseudohomophones > rest (n = 18)									
Supplementary motor area	8	Left	<.001	322	<.001	11.68	-2	22	46
	6				.008	8.38	-6	10	56
Middle cingulum	32	Right			.013	8.03	6	30	34

Postcentral gyrus	2	Left	<.001	65	.001	9.75	-42	-30	44
	40				.012	8.09	-30	-36	46
Inferior frontal triangularis	48	Left	.011	5	.025	7.52	-50	16	18
Inferior frontal opercularis	44	Left	.011	5	.042	7.14	-54	12	22
Incorrect real nonwords > rest (n = 18)									
Supplementary motor area	32	Right	< .001	352	.001	10.19	6	30	34
	6				.003	9.52	2	12	58
					.004	9.26	0	16	50
Insula	47	Left	< .001	139	.002	9.65	-36	26	0
Supplementary motor area	6	Left	.002	9	.017	8.09	-8	0	64
Rest > correct pseudohomophones									
Middle temporal gyrus		Left	< .001	110	< .001	9.94	-54	10	-26
					.002	8.20	-62	-8	-22
					.004	7.81	-58	2	-22
Medial superior frontal gyrus		Right	< .001	412	.001	8.83	4	60	10
					.015	7.03	8	54	-4
		Left			.023	6.77	-2	52	22
Angular gyrus		Left	< .001	149	.001	8.79	-42	-68	34
					.006	7.56	-50	-60	34
Cuneus		Right	.005	13	.004	7.83	12	-90	14
Middle temporal gyrus		Right	.001	28	.009	7.35	64	-12	-16
Posterior cingulate		Left	< .001	113	.018	6.93	-8	-42	36
Anterior cingulate		Right	.001	27	.019	6.89	8	36	-8
Superior frontal gyrus		Left	.022	3	.023	6.78	-14	64	12
Angular gyrus		Right	.008	10	.028	6.65	50	-60	34
Anterior cingulate		Right	.026	2	.041	6.44	4	26	-14
Gyrus rectus		Right	.022	3	.042	6.42	2	28	-24
Rest > correct real nonwords									
Medial superior frontal gyrus		Left	<.001	41		7.49	-2	58	16
Angular gyrus			.020	3		6.55	-40	-62	44
Angular gyrus			.017	4		6.54	-44	-68	32

Figure 6.1. Areas of increased task-related brain activity for: a) high-frequency words, b) low-frequency words, c) pseudohomophones, and d) real nonwords (over rest) (*N* = 22).



Note: L=Left; R = Right.

6.4.3.2. Relationship between Brain Activations and Psychopathology-Related Traits

All brain areas showing a relationship with one or more psychopathology-related traits are described in Table 6.6. As can be seen, Motor impulsivity was most frequently associated with task-related activations. Specifically, lower Motor impulsivity was associated with higher activation in the fusiform gyrus, bilaterally, for correctly identified high and low-frequency words, and real nonwords (all over rest) (Figure 6.2.). Lower Motor impulsivity was also associated with higher activation in the right STG when identifying low-frequency words over pseudohomophones (Figure 6.3.). Higher O-LIFE Unusual Experiences scores were associated with and lower activation in the left cerebellum when identifying low-frequency words over real nonwords. Higher Meanness was associated with higher activity, especially in the left caudate nucleus when identifying high-frequency words over real nonwords. Similarly, higher Boldness was associated with a small cluster of higher activity in the right posterior cingulate when identifying low-frequency words over pseudohomophones.

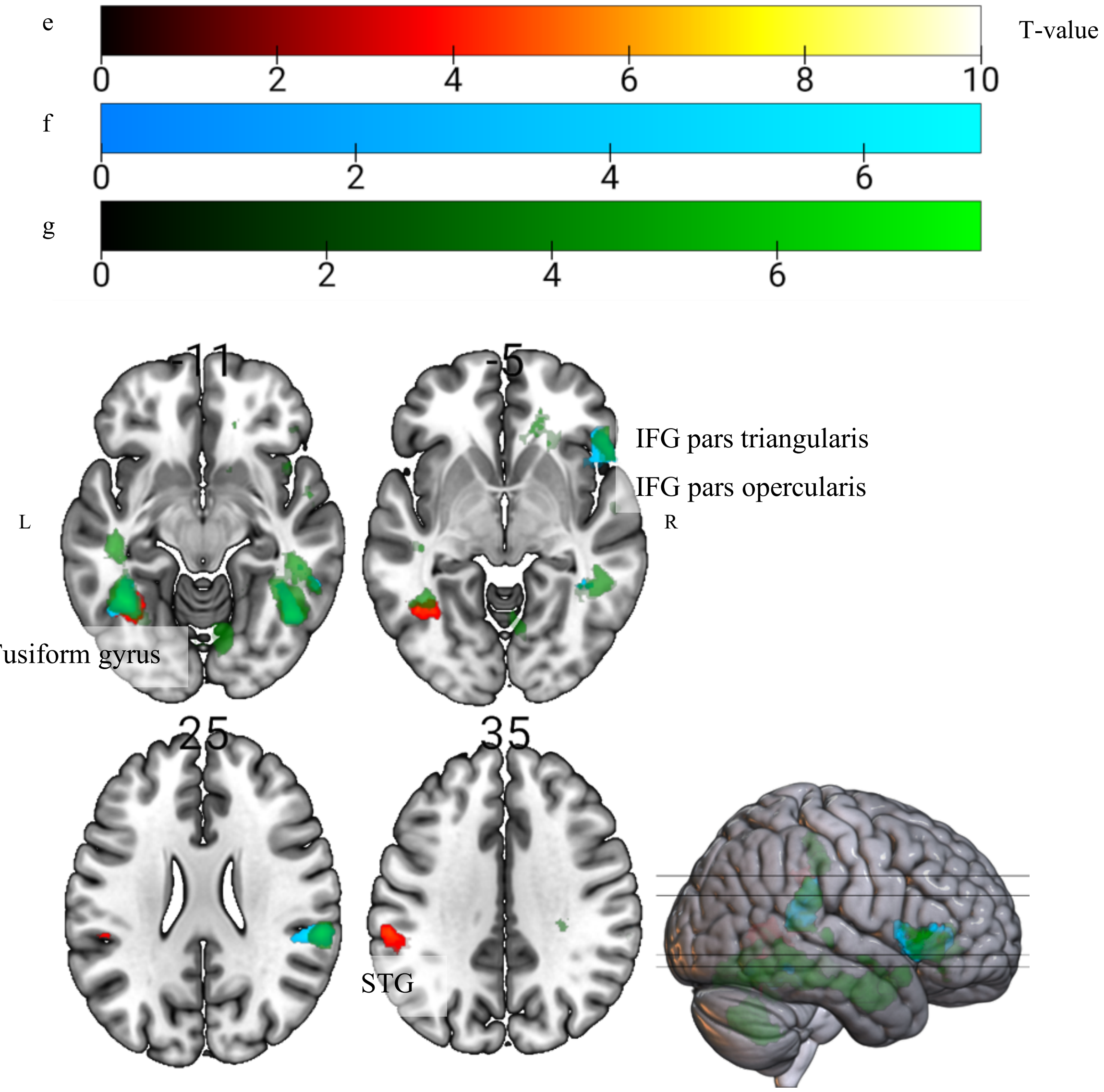
Table 6.6. Relationship between task-related activations and psychopathology-related traits (height threshold $p < .001$ uncorrected).

Contrast / Psychopathology-related trait			Cluster level			Peak level		MNI coordinates		
Area name	BA	Side	P_{FWE}	K_E	$P_{uncor.}$	$P_{uncor.}$	T	x	y	z (mm)
				O-LIFE Unusual Experiences						
Correct low-frequency words > correct real nonwords										
Cerebellum		Left	.004	355	< .001	< .001	6.03	-6	-76	-28
						< .001	5.28	-2	-72	-38
				TriPM Meanness (positive association)						
Correct high-frequency words > real nonwords										
Ventral diencephalon	25	Left	.019	281	.002	< .001	6.66	-6	-4	-12
Caudate nucleus						< .001	5.51	-2	8	-10
		Right				< .001	4.64	4	-2	-12
				TriPM Boldness (positive association)						
Correct low-frequency words > pseudohomophones										
Posterior cingulate		Right	.037	234	.005	< .001	5.97	12	-38	24
						< .001	4.71	22	-40	30
						< .001	4.16	28	-48	24
				BIS-11 Motor						
Correct low-frequency words > correct pseudohomophones										
Superior temporal gyrus	22	Right	.042	225	.005	< .001	5.45	68	-14	0
						< .001	4.67	60	-16	-2
Middle temporal gyrus	20					< .001	4.50	50	-12	-14
Correct real nonwords > correct pseudohomophones										
Cerebellum		Left	.018	335	.003	< .001	4.64	-24	-64	-16
						< .001	4.60	-8	-62	-4
Cerebellar vermis						< .001	4.46	0	-70	-14
Correct high-frequency words > rest										
Fusiform gyrus	37	Left	< .001	866	< .001	< .001	10.10	-44	-54	2
						< .001	5.98	-38	-52	-16
						< .001	5.52	-34	-58	-8
Superior temporal gyrus	22	Left	.002	462	< .001	< .001	6.11	-64	-38	12
	42					< .001	5.87	-48	-40	12
						< .001	4.97	-56	-42	16

Inferior frontal opercularis	47	Right	.016	289	.002	< .001	5.51	48	26	-2
Inferior frontal triangularis	45					< .001	4.34	50	34	8
Insula	48					< .001	4.01	42	16	2
Correct low-frequency words > rest										
Fusiform gyrus	37	Left	.001	477	< .001	< .001	7.07	-40	-52	-16
						< .001	4.15	-32	-32	-20
Fusiform gyrus	42	Right	.001	449	< .001	< .001	6.99	60	-34	24
Superior temporal gyrus						< .001	5.79	58	-42	12
Inferior frontal triangularis	45	Right	< .001	615	< .001	< .001	6.91	48	28	4
						< .001	6.45	50	22	-2
						< .001	6.13	50	36	4
Inferior temporal gyrus	37	Right	.011	274	.001	< .001	5.16	44	-60	-12
						< .001	4.39	42	-48	-12
	20					< .001	4.27	56	-44	-12
Correct real nonwords > rest										
Inferior temporal gyrus	36	Right	< .001	2076	< .001	< .001	8.17	40	-4	-28
	20					< .001	6.58	46	-60	-12
						< .001	6.19	44	-16	-20
Fusiform gyrus	37	Left	< .001	1178	< .001	< .001	7.78	-42	-50	-14
						< .001	7.38	-42	-54	2
						< .001	5.51	-46	-28	-10
Cerebellum		Right	< .001	938	< .001	< .001	6.78	18	-60	-40
						< .001	5.62	10	-64	-36
		Left				< .001	4.84	-12	-64	-42
Inferior frontal triangularis	47	Right	.001	438	< .001	< .001	6.32	50	28	0
Inferior frontal opercularis	48					< .001	5.52	58	16	8
	45					< .001	5.05	58	32	4
Inferior frontal triangularis	47	Right	.001	416	< .001	< .001	6.24	32	36	8
						< .001	6.21	26	26	0
						< .001	4.83	20	34	2
Superior temporal gyrus	48	Right	.001	460	< .001	< .001	6.03	60	-34	24
Middle temporal gyrus	42					< .001	5.18	58	-42	12
	21					< .001	4.30	58	-22	0
Postcentral gyrus	3	Right	.019	241	.002	< .001	5.31	26	-30	42
						< .001	4.79	22	-32	52
						< .001	4.55	34	-28	42
Cerebellum		Right	.029	217	.003	< .001	4.97	14	-70	-12
						< .001	4.09	4	-60	0
Cerebellar vermis						.001	3.93	-2	-76	-14

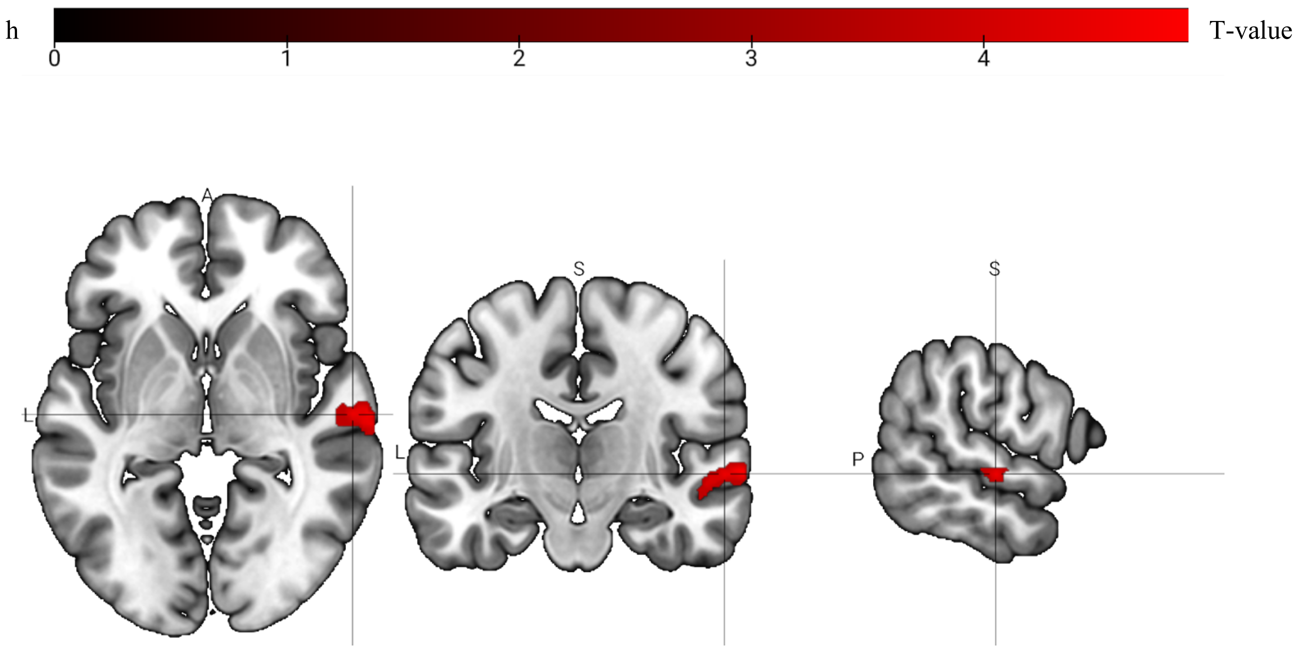
Note. BA = Brodmann area; FWE = Family-wise Error; uncor. = uncorrected; MNI = Montreal Neurological Institute coordinate system; O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale.

Figure 6.2. Areas of brain activity associated negatively with Motor Impulsivity during the correct identification of: e) high-frequency (left fusiform gyrus and left STG), f) low-frequency words (fusiform gyrus bilaterally and IFG pars triangularis), and g) real nonwords (fusiform gyrus bilaterally, IFG pars opercularis).



Note: L=Left; R = Right.

Figure 6.3. Areas of brain activity (right STG; peak MNI coordinates: x = 60, y = -16, z = -2) negatively associated with Motor Impulsivity to the correct identification of: h) low-frequency words over pseudohomophones.



Note: A=Anterior; L=Left; P=Posterior; S=Superior.

6.4.3.3. Relationship between Participant-Specific Brain Activation Values, Psychopathology-Related Traits, and LDT Performance

No significant correlations were found (Table 6.7.). Only the correct real nonwords (over rest) related activation in the inferior temporal gyrus (BA 36) that was found to be associated with lower Motor impulsivity showed a trend-level positive correlation with real nonword accuracy (r = .393, p = .071).

Table 6.7. Correlations between LDT performance and participant-specific activation values extracted from peaks of various clusters found in earlier analyses (SPM regressions) to be associated with psychopathology-related traits.

Contrast Area of activation (BA equiv.)	Correct high-frequency *r* (*p*)	Correct low-frequency *r* (*p*)	Correct pseudo-homophones *r* (*p*)	Correct real nonwords *r* (*p*)	Correct high-frequency RT *r* (*p*)	Correct low-frequency RT *r* (*p*)	Correct pseudo-homophones RT *r* (*p*)	Correct real nonwords RT *r* (*p*)
				Motor impulsivity (negative association)				
Correct high-frequency > rest Left fusiform gyrus (BA 37)	.168 (.456)				.046 (.841)			
Correct high-frequency > rest Left superior temporal gyrus (BA 22)	-.067 (.766)				.104 (.644)			
Correct high-frequency > rest Right inferior frontal triangularis (BA 45)	.075 (.742)				.100 (.657)			
Correct low-frequency > rest Left fusiform gyrus (BA 37)		.265 (.233)				-.035 (.879)		
Correct low-frequency > rest Right fusiform gyrus (BA 42)		.324 (.141)				.103 (.649)		
Correct low-frequency > rest Right inferior frontal triangularis (BA 45)		.156 (.488)				.281 (.206)		
Correct low-frequency > rest Right inferior temporal gyrus (BA 37)		-.101 (.656)				.103 (.648)		
Correct real nonwords > rest Right inferior temporal gyrus (BA 36)				.393 (.071)				.114 (.614)
Correct real nonwords > rest Left fusiform gyrus (BA 37)				.253 (.256)				.032 (.886)
Correct real nonwords > rest Right Cerebellum				.101 (.654)				-.061 (.788)

Contrast Area of activation (BA equiv.)	Correct high-frequency *r* (*p*)	Correct low-frequency *r* (*p*)	Correct pseudo homophones *r* (*p*)	Correct real nonwords *r* (*p*)	Correct high-frequency RT *r* (*p*)	Correct low-frequency RT *r* (*p*)	Correct pseudo-homophones RT *r* (*p*)	Correct real nonwords RT *r* (*p*)
Correct real nonwords > rest Right inferior frontal triangularis (BA 47)				.275 (.215)				.146 (.518)
Correct real nonwords > rest Right superior temporal gyrus (BA 48)				.115 (.610)				.011 (.962)
Correct real nonwords > rest Right postcentral gyrus (BA 3)				.093 (.682)				.167 (.457)
Correct low-frequency > correct pseudo. Right superior temporal gyrus (BA 22)		.145 (.520)	-.100 (.657)			.212 (.344)	.183 (.415)	
Correct real nonwords – correct pseudo Left Cerebellum			-.052 (.817)	.186 (.407)			.077 (734)	.048 (.831)
Unusual Experiences (negative association)								
Correct low-frequency > correct real nonw. Left Cerebellum		.030 (.895)		.244 (.273)		.235 (.293)		.218 (.331)
Boldness (positive association)								
Correct low-frequency > correct pseudo. Right Posterior Cingulate		-.163 (.468)	.289 (.192)				.120 (.595)	.242 (.278)
Meanness (positive association)								
Correct high-frequency > correct real nonw. Left ventral diencephalon (BA 25)	.141 (.530)			-.043 (.849)	.204 (.362)			.133 (.556)

Note: BA – Brodmann are`a

6.5. Discussion

This study utilised fMRI to examine the neural underpinnings of the associations of LDT performance with positive schizotypy (Unusual Experiences), psychopathy traits of callous aggression and fearless dominance (TriPM Meanness and Boldness), and Motor impulsivity. The findings showed that higher Unusual Experiences was associated with lower activity in the left cerebellum when recognising low-frequency words over real nonwords. Higher Boldness was associated with higher activity for low-frequency words over pseudohomophones in the right posterior cingulate. The only association for higher Meanness reflected higher activation in the ventral diencephalon bilaterally. Motor impulsivity was the strongest predictor of lower activity, mainly in the fusiform gyrus bilaterally, right IFG, and temporal gyri bilaterally, across all stimuli-types.

Prior to discussing these associations, it is important to consider whether the neural networks normally activated by other variants of the LDT were found to be activated at the group level (as hypothesised) with the version used in the present study.

6.5.1. Task-Related Activations

As hypothesised, pars opercularis of the IFG bilaterally, left postcentral gyrus, left insula, and additionally, as reported in previous studies (Fiebach et al., 2002; Kiehl et al., 2004), the inferior occipital gyrus, and fusiform gyrus bilaterally were the regions showing strong task-related activations. However, the activation was stronger in some areas when identifying high or low-frequency words over both types of nonwords (real nonwords, pseudo-homophones). Specifically, for high-frequency words, contrasted with pseudohomophones, the left angular gyrus bilaterally and right precuneus were strongly activated and the left angular gyrus solely when compared to real nonwords. The angular gyrus is an area crucial for reading, as it is active in processing whole words and extracting their meanings based on their orthographic properties (Horwitz et al., 1998; Segal & Petrides, 2013), using the direct lexical pathway in word recognition (Chapter 1). The angular gyrus is also functionally connected with Wernicke's area and together play a role in orthographic to phonological processing of words (Pugh et al., 2000) when the word cannot be identified automatically but may require the involvement of the sublexical pathway. The right precuneus plays an important role mainly in self-consciousness, self-awareness, and the theory of mind (Cavanna & Trimble, 2006; Schiffer et al., 2013). However, in relation to reading, together with the angular gyrus, it is involved in context comprehension and coherence (Moss et al., 2011). Thus, the precuneus can act as internal monitoring of the lexical representation meanings previously facilitated by the angular gyrus and have a supporting role in reading.

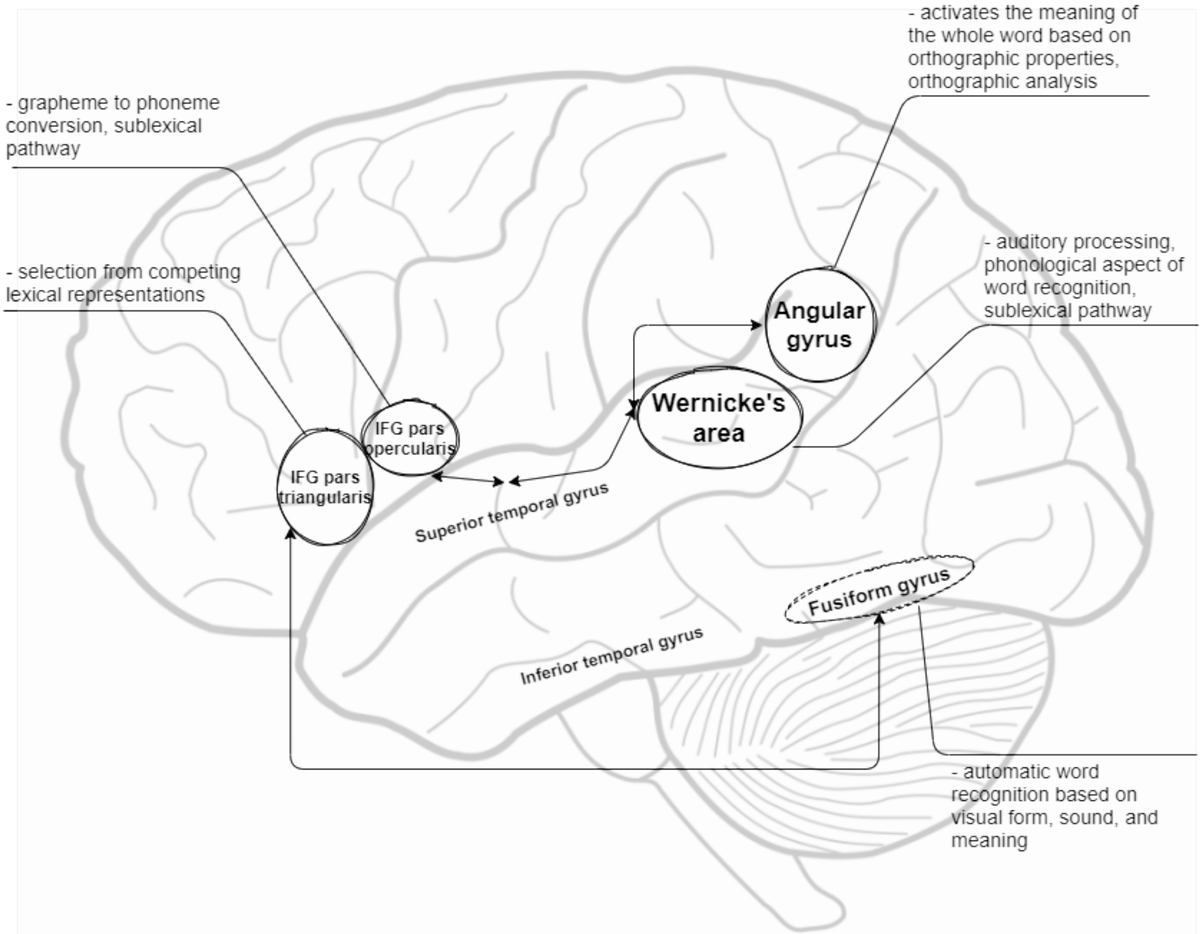
As hypothesised, when identifying low-frequency over high-frequency words, there was greater activity, predominantly in the pars triangularis of the left IFG and in the left inferior temporal gyrus to fusiform gyrus, the areas involved in phonological processing (Binder et al., 2006; Dietz et al., 2005; MacSweeney et al., 2009). The fusiform gyrus is active in quick and easy word recognition in skilled readers who show greater activity in this area in comparison to dyslexics (McCandliss et al., 2003). Therefore, the fusiform gyrus facilitates a quick translation between the visual word and its sound and meaning (Devlin et al., 2006) and it can store and extract visual and sound patterns which serve in quick recognition (Kronbichler et al., 2004). The pars triangularis of the left IFG was previously found to be active in low-frequency word identification, but not in high-frequency or in pseudohomophones, and it is responsible for selection from among competing lexical representations (Fiebach et al., 2002). This area is more active in semantic selection than in phonological processing (Liuzzi et al., 2017; Mechelli et al., 2005). This means that the pars triangularis is active in the later stages of word identification when the individual is deciding whether the word, they see, is identical to any of the words in their mental vocabulary. Therefore, the left fusiform gyrus may help to translate the letters quickly and accurately into sounds that form the final words and then in the left pars triangularis is the final representation compared to the existing knowledge.

Low-frequency words over pseudohomophones contrast yielded a small area of significant activation in the right hippocampus and motor cortex. This could indicate that participants were perhaps trying to guess the right answer when recognising unfamiliar words based on the vocabulary entries in their memory. The hippocampus plays a role in word imageability (Klaver et al., 2005), which could explain that, unlike pseudohomophones, the low-frequency words activate the memory system when trying to compare the word representation to its meaning in the memory. It is possible that low-frequency words and pseudohomophones, as they both require the implementation of the sublexical route, activate the phonological processing areas equally, and therefore, the corresponding areas did not show a differential activation.

Rolandic operculum, IFG, precentral gyrus, supramarginal gyrus, and the insula form part of the dorsal stream is involved in translating sound into articulation (Saur et al., 2008; Tomasino et al., 2020) and lesions in these areas were associated with phonological dyslexia (Tomasino et al., 2020). These areas were active in word and nonword recognition (compared to rest), where they can act as a support to other phonological processing areas that are most visible in pseudohomophone recognition.

Overall, the findings of this study confirmed the role of word frequency in LDT activations, where low-frequency words activate more strongly areas associated with phonological processing and the sublexical pathway, especially the IFG pars triangularis and fusiform gyrus (Figure 6.4.). High-frequency words activate more strongly the angular gyrus that is involved in the orthographic form of words, and these can be easily identified just by their appearance, following the lexical pathway. The pseudohomophones or real nonwords did not show stronger activations than high or low-frequency words but showed several significant clusters of activation compared to rest in the areas of the dorsal stream that act as support for the sublexical pathway areas.

Figure 6.4. Diagram of areas with a significant role in word-nonword recognition, their proposed connections, and functions.



6.5.2. Psychopathology-Related Traits and Brain Activity

This is the first study to examine the association between the neural correlates of the ability to recognise words and nonwords and relevant psychopathology-related traits. Higher Motor impulsivity was the trait related most consistently to lower activation bilaterally in the fusiform gyrus and the STG, right

IFG, and right anterior insula. In people with high impulsivity, the right STG was less active when identifying low-frequency words (over pseudohomophones) and the left STG was less active for real nonwords (over rest). In association with higher Motor impulsivity, the fusiform gyrus bilaterally and right pars triangularis of the IFG were less activated when identifying words and the left fusiform and right inferior temporal gyrus in real nonwords, all over rest. The right anterior insula showed lower activation in real nonwords over rest in impulsive individuals.

The left STG is highly involved in phonological processing and activated during the letter-sound conversion (Simos et al., 2000) so the present results could suggest some disruption of these functions in people with higher attentional and motor impulsivity (Lee et al., 2011). The role of the right STG in phonological processing is not very clear as it is often the left side that is specialised in reading and language processing. However, some evidence suggests that the right STG can be involved in the phonological processing of more difficult stimuli which may require additional resources and the involvement of the STG bilaterally (Graves et al., 2008; Ramos Nuñez et al., 2020). This could be similar to the aphasic patients who activate the right STG and phonological processing areas more than controls as it may serve as a supporting structure in phonological processing (Teki et al., 2013). Also in children with reading difficulties, the right STG is activated more than in controls in tasks requiring letter-sound conversion (Simos et al., 2000). Since the present sample included 50% of non-native English speakers, it is reasonable to assume that non-native speakers with higher impulsivity (based on the results from the behavioural study, Chapter 4) tend to guess the right answer, and thus fail to strongly activate the STG (bilaterally) in more difficult stimuli. The right STG is also involved in successful inhibitory control (Horn et al., 2003) and this area is structurally reduced in forensic psychopathy (Müller et al., 2008). Thus, individuals with higher Motor impulsivity may not be able to activate this area during tasks requiring phonological processing. Motor impulsivity also modulated activity in the fusiform gyrus bilaterally, right IFG, and right insula. As mentioned earlier, these areas are involved and found active in automatic recognition of lexical stimuli, and selection from the competing lexical representations (Figure 6.4.). The anterior insula bilaterally is involved in the auditory temporal processing, supports the phonological representations of verbal stimuli, and is functionally connected with the left IFG (Steinbrink et al., 2009). Higher Motor impulsivity was associated with a decrease in activity in these areas in the right hemisphere. Therefore, this can indicate a reduced bilateral integration of the meaning and sound of mental lexical representations and selecting the appropriate outputs in those with higher impulsivity. However, it is worth noting that the peak activity in none of these areas was strongly or significantly correlated with LDT performance (accuracy, RTs), suggesting that these associations were not fully explained by impulsivity-related differences in performance and possibly included some other trait or impulsivity-related influences. These interpretations, however, have to be viewed with caution considering the high number of correlations and no application of correlation corrections (Vul et al., 2009).

Brain activity related to Unusual Experiences (lower activity in the left cerebellum) and Meanness (higher activation in the ventral diencephalon) was localised in regions that have been previously associated with these traits. Higher schizotypal traits were associated with lower activation of the left cerebellum during anti-saccades (Aichert et al., 2012) which are important for fluent reading, and cerebellar deficits are also present in people with SZ (Kaczorowski et al., 2009). However, the cerebellum also has an important role in language, including word recognition (Mariën et al., 2013) and language proficiency (Baillieux et al., 2008; De Smet et al., 2013). It is functionally connected with frontal and temporal areas and the right cerebellum is also involved in phonological and semantic processing in reading (De Smet et al., 2013). In this sample, lower activity in the left cerebellum was associated with higher Unusual Experiences when identifying low-frequency words over real nonwords.

Higher Meanness was associated with increased activity in the ventral diencephalon and caudate nucleus bilaterally. This is in concordance with previous findings suggesting functional and structural impairments in the ventral striatum (Boccardi et al., 2013; Glenn & Yang, 2012) and caudate nucleus (Viding & McCrory, 2012) in higher psychopathy. Moreover, the ventral diencephalon as part of the striato-thalamo-frontal network was also found to show deficits in association with the antisocial traits in psychopathy (Hoppenbrouwers et al., 2013). Similarly, higher Boldness was associated with higher activity in the right posterior cingulate, an area previously found to be over-activated in people with antisocial personality disorder, high psychopathy, and violent offending (Gregory et al., 2015). However, the psychopathy traits were not directly associated with activations in areas specific to the response to lexical stimuli or reading in this study.

Overall, the findings seem to implicate lower activity in the STG, fusiform gyrus and the IFG in people with high Motor impulsivity and that such individuals may not be able to integrate the information using both hemispheres. Positive schizotypy was associated with lower cerebellum activity while Meanness and Boldness facets of psychopathy were associated with higher striatal and posterior cingulate activity respectively; however, these areas are not directly involved in reading skills. Further studies with larger sample sizes and score ranges are needed to firmly establish whether the influence of different psychopathology-related traits in LDT performance is mediated by different brain areas.

6.5.3. Limitations

First, due to the restriction imposed by the coronavirus pandemic, this study recruited only a limited number of participants, and it prevented a meaningful between-group analysis of native and non-native speakers and allowed only a limited power to examine hypothesised associations. The study also included participants with a relatively low range of scores of schizotypal and psychopathic traits that may have resulted in reduced power to examine the relationship between brain activity and these traits. However, these traits were within the normal limits reported in the general population. A larger sample and functional connectivity analysis would be helpful to clarify the functioning of the sublexical pathway and the connections between the areas crucial for word-nonword recognition and whether any alterations exist in these connections in relationship to dimensional Motor impulsivity and psychopathy traits of Boldness and Meanness.

6.6. Chapter Summary

This chapter examined neural activations during LDT in association with dimensional psychopathology-related traits of positive schizotypy, psychopathy and Motor impulsivity. The findings are in concordance with the behavioural study results (Chapter 4) in showing that higher Motor impulsivity was strongly associated with lower activity in several principal areas involved in word-nonword recognition. Higher positive schizotypal traits were associated with lower neural activity in the left cerebellum. Interestingly, Meanness and Boldness facets of psychopathy were associated with higher striatal and posterior cingulate activity, respectively, but did not significantly associate with activity changes in any areas involved specifically in phonological processing or lexical representations despite previous studies indicating some potential anomalies in these reading skills at the behavioural (Chapter 4) and/or neural levels (Kiehl et al., 2004; Montry et al., 2021).

Chapter 7: Reading Skills Deficits in Relation to Cognitive Characteristics and Psychopathology in Forensic Patients: A Pilot Study

7.1. Chapter Aims and Overview

This chapter aims to explore a) the pattern and extent of reading skills deficits, b) the relationship between reading skills and relevant cognitive abilities, namely: IQ, verbal learning and memory, and executive function, and c) the relationship between reading skills and dimensional measures of psychopathology, especially those linked to schizophrenia, psychopathy and PD, which were found to be linked to poor reading skills and/or LDT performance in previous chapters (Chapters 2 and 4). This is a pilot study involving a small group of men with mental illness and a history of violence.

7.2. Introduction

Certain psychopathology-related traits and certain diagnoses of mental illness have been previously associated with tendencies towards violent behaviour and aggression (Krakowski et al., 1986). Schizophrenia spectrum disorders have been strongly linked with a history of violence and offending (Douglas et al., 2009; Fazel et al., 2009; Wallace et al., 2004). Narcissistic traits are found to be related to higher aggressiveness, while irritability in forensic and clinical samples, borderline personality disorder (BPD), and antisocial personality disorder (ASPD) diagnoses are linked to a higher risk of physical violence (Lowenstein et al., 2016). Diagnosis of BPD has been linked to the inability to control impulses, and this relationship also translates into the general population when dimensional traits of anger and impulsivity aspects of BPD are associated with serious violence (González et al., 2016). In people with PD, the traits of impulsivity, psychopathy, and affective dysregulation are associated with an increased risk of violence (Howard, 2015). Psychopathy syndrome is commonly present among violent individuals with criminal offences (Edens et al., 2001; J. F. Hemphill et al., 1998; Nicholls et al., 2005; Salekin et al., 1996).

These tendencies towards violent behaviour in forensic, but also in the general population, have been linked to poor inhibitory control (Chen et al., 2008; Pawliczek et al., 2013; Zhang et al., 2017) and higher impulsivity traits (Enticott et al., 2006; Stanford et al., 2003). Inhibitory control models of violence (Barratt, 1994; M. I. Krakowski et al., 1997) propose deficits in executive functioning, including inhibitory control, in people with antisocial behaviour, as they are unable to inhibit their violent impulses (Blair, 2001). In support of these models, some studies found that inhibitory control is also altered or deficient in individuals with a history of violent and criminal behaviour (Bergvall et al., 2001; Chen et al., 2005). Poor inhibitory control has been also linked to higher lifestyle psychopathy traits in men with a history of violence (Weidacker, Snowden, et al., 2017). In forensic populations with schizophrenia, the relationship between inhibitory control and self-reported impulsivity remains unclear, due to the multiple aspects and traits of impulsivity (Enticott et al., 2008). These traits reflect on proneness to rapid actions without forethought, higher arousal, inability to delay gratification, or inhibitory dyscontrol (Enticott & Ogloff, 2006).

Cognitive deficits have been repeatedly reported in people with a variety of mental illnesses, especially in those with schizophrenia (Fioravanti et al., 2005; Rund, 1998; Rund & Borg, 1999; Vöhringer et al., 2013), bipolar disorder (Green, 2006; Robinson & Ferrier, 2006; Schouws et al., 2009; Torrent et al., 2006), BPD (P. H. Judd, 2005; Monarch et al., 2004), or depression (Austin et al., 2001; Rock et al., 2014). However, the link between cognitive deficits and violence in mental illness has been mainly reported for people with schizophrenia (Jones & Harvey, 2020). In a meta-analysis, people with schizophrenia and a history of violence and those with ASPD showed significantly lower IQ, memory, and executive functions with medium to large effects of diagnosis (Sedgwick et al., 2017). There is further evidence that deficits in working memory and verbal learning predict impulsive aggression (Ahmed et al., 2018). Proneness to aggression has also been found to be driven by higher impulsivity, psychopathy, and impaired cognition, especially executive functioning and inhibitory control (Krakowski & Czobor, 2017). A study on a forensic psychiatric sample showed that executive functioning influenced aggressive behaviour with positive and negative psychopathology-related traits (The Positive and Negative Syndrome Scale – PANSS) as mediators (Serper et al., 2008).

As noted earlier in Chapter 2, the results from the systematic review and meta-analysis (Vanova et al., 2021) indicated large deficits in a range of reading skills in people with schizophrenia, psychopathy, and PD (including ASPD). This review also suggested possible links between various reading skills and cognitive functions, with IQ (verbal, premorbid, full-scale) being the most prominent predictor of reading performance (Fuller et al., 2002; Hayes & O'Grady, 2003; Revheim et al., 2014). However, the association between reading skills and other cognitive functions remains understudied in people with mental illness (Vanova et al., 2021). Despite this, working memory and executive functioning play a vital role in decoding reading comprehension (Kendeou et al., 2014) (described in detail in Chapter 1). Furthermore, verbal learning and memory have been previously associated with phonological processing and decoding skills (Swanson et al., 2009) and were found to be impaired in people with reading disabilities (Oyler et al., 2012). It has been long hypothesised that reading problems in dyslexia may be associated with impairments in acquiring new phonological information linked to the problems in verbal learning and memory (Elbro & Jensen, 2005). Impaired verbal learning and memory can cause difficulties with accessing semantic and phonological information about letters and words (Shankweiler

& Crain, 1986) leading to the inability to correctly decode, pronounce, and understand lexical information (Stringer & Stanovich, 2000).

This pilot study[1] is part of an ongoing study investigating the influence of cognitive function, including reading skills, on clinical outcomes in forensic mental health services. It aimed to explore the pattern of deficit in reading skills (phonological processing, comprehension, rate, accuracy, fluency) in forensic mental health patients and their link with other cognitive functions, and psychopathology-related traits (schizotypy, borderline, impulsivity, and affective traits) in this population. To achieve this, a group of psychiatric patients with a history of violence were assessed and then compared against the norms in reading skills and IQ. The difference on an LDT (as described in Chapter 4) between forensic patients and healthy controls in performance was also investigated. The relationships between dimensional self-report psychopathology-related traits, cognition, and reading skills were examined subsequently in a series of correlations within the patient group.

Hypotheses

1. The reading skills (comprehension, rate, accuracy, fluency, phonological processing) as measured by established reading tests will be significantly below age norms in forensic patients.
2. Reading skills scores will positively correlate with the scores in other cognitive domains, namely intelligence, verbal learning and memory, and executive functioning.
3. Reading skills scores will negatively correlate with dimensional measures of schizotypy, impulsivity and psychopathy.

7.3. Methods

7.3.1. Participants

Fifteen male participants were recruited from a medium-secure unit at West London Forensic Services, St. Bernard's Hospital in London. All participants had a sufficient written and verbal command of the English language and had normal or corrected-to-normal vision and hearing. All participants gave

[1] Data collection on patients had to be halted and no HC participants could be tested on the cognitive measures due to the restrictions put in place by Brunel University London due to the COVID-19 pandemic.

written informed consent after the study procedures had been explained to them. Participants were reimbursed with £10 per hour of participation (max. £35) as compensation for their time. Fifteen age and language matching healthy controls (HC)[1] were randomly selected from the experimental study sample (Chapter 4) to compare the patients and HC groups on performance in LDT and GNG tasks.

This study procedure had received approval from London - Camberwell St Giles Research Ethics Committee (IRAS Project ID: 260683).

7.3.2. Materials

7.3.2.1. Self-Report Measures

Schizotypal Personality Questionnaire-Brief (SPQ-BR, 32 items) (A. S. Cohen et al., 2010)
Similarly, to the O-LIFE, this is a shorter measure of dimensional schizotypy as a personality trait. It consists of three higher-order factors: a) *Interpersonal*, b) *Disorganised*, c) *Cognitive-Perceptual* and seven subordinate lower-order factors. Each item is answered on a 0-4 points scale: Strongly Disagree (0), Disagree (1), Neutral (2), Agree (3) or Strongly agree (4), e.g. "I rarely laugh and smile", with no reverse-scored items. A higher score indicates more prominent schizotypal traits. Results from a study, including also individuals with a high risk of schizophrenia (N = 405), showed a good internal consistency (mean Cronbach's α = .91) for all subscales (Callaway et al., 2014).

Borderline Personality Disorder Questionnaire (BPQ, 80 items) (Poreh et al., 2006)
The questionnaire is designed to measure an individual's level of borderline personality traits. It consists of 80 items divided into nine subscales: a) Impulsivity, b) Affective Instability, c) Abandonment, d) Relationships, e) Self-Image, f) Suicide/Self-Mutilation, g) Emptiness, h) Intense Anger, and i) Quasi-Psychotic Symptoms. *Impulsivity* is characterised by reckless lifestyle choices (e.g., drugs, speed driving, or unprotected sex). *Affective instability* reflects on experiences of intense emotions or irritability, *Abandonment* on experiences of loneliness and fear of being left alone, and *Relationships* on disappointment with close relationships with family and friends. *Self-Image* score represents dissatisfaction with self and feelings of inferiority, and *Suicide/Self-Mutilation* represents current or past intentions and/or experiences with self-harm. The *Emptiness* scale reflects on feelings of loneliness, boredom, and having no purpose or direction in life. *Intense Anger* higher scores are characterised by difficulties in temper control and high irritability, and the *Quasi-Psychotic Symptoms* reflects unusual experiences like mind-reading, hallucinations and detachment from reality. The items are answered as either True or False (e.g., "People often leave me"). One mark is scored for each "True" answer and zero for each "False", except for 12 reverse-scored items. A higher score indicates a higher level of

borderline personality traits. Discriminant validity was examined in the general population (*N* = 181) and the BPQ significantly correlated with Minnesota Multiphasic Personality Inventory – Schizotypal Disorder Scale (MMPI-2 STY) (r = .48) and SPQ-BR (r = .45), and for convergent validity, BPQ correlated with MMPI-2 Borderline Personality Disorder Scale at r = .85 (Poreh et al., 2006). Psychometric properties for the scale in clinical and/or forensic populations are not available.

Barratt Impulsiveness Scale (BIS-11, 30 items) (Patton et al., 1995)

The measure is described in Chapter 4.

Generalised Anxiety Disorder Assessment (GAD, 7 items) (Spitzer et al., 2006)

This scale measures anxiety symptoms on a four-point scale: Not at all (0), Several days (1), Over half the days (2), and Nearly every day (3). Item 8 assesses the impact of the symptoms on activities of daily living and is scored on a 4-point scale: a) Not difficult at all, b) Somewhat difficult, c) Very difficult, and d) Extremely difficult. The cut-off point for a diagnosis is a score ≥ 10. The scale showed a good internal consistency (α = 0.89) with intercorrelations between items ranging from r = 0.45 to r = 0.65 in a sample including primary care patients with an anxiety disorder (*N* = 73) (Spitzer et al., 2006).

Patient Health Questionnaire for Depression (PHQ, 9 items) (Kroenke et al., 2001)

The questionnaire participants to rate how often recently they have been affected by certain difficulties whilst measuring the severity of depression symptoms. The questionnaire rates the frequency of symptoms in the past two weeks on a 4-point scale: Not at all (0), Several days (1), More than half the days (2), and Nearly every day (3). Item 10 asks about the impact of the symptoms on activities of daily living and is scored on a 4-point scale: a) Not difficult at all, b) Somewhat difficult, c) Very difficult, and d) Extremely difficult. Overall scores of 5-9 points indicate minimal symptoms, 10-14 minor depression, 15-19 moderately severe major depression, and 20+ points indicate severe major depression. Overall scores above 10 points indicated sensitivity and specificity of 88% each for major depression in primary care patients (*N* = 3000) (Kroenke et al., 2001).

Psychopathy Checklist-Revised (PCL-R, 20 items) (Hare, 2003)

The PCL-R is used as a diagnostic tool to measure psychopathy scores in patients and individuals in the criminal justice system. It includes four main facets, each consisting of the following items: a) *Interpersonal* facet: superficial charm, grandiosity, pathological lying, and manipulativeness, b) *Affective*: lack of remorse, shallow affect, lack of empathy, and failure to accept responsibility, c) *Lifestyle*: stimulation seeking, impulsivity, lack of goals, irresponsibility, and parasitic lifestyle, d) *Antisocial*: early behaviour problems, poor behaviour control, juvenile delinquency, violations of conditional release, and criminal versatility. The facets can be further combined into two factors: e) Factor 1 – Interpersonal-Affective, and f) Factor 2 – Antisocial-Lifestyle. There are two more independently scored items contributing to the *Total* score: promiscuous sexual behaviour, and many short-term marital relationships. The PCL-R items are often evaluated in an interview; however, the items can also be scored "off-record" by reviewing the information from the patient's clinical files.

7.3.2.2. Neuropsychological Measures of Reading Skills, IQ and other Cognitive Functions

Reading Skills

The tests below were chosen because they most consistently detected reading deficits in SZ and/or forensic populations (Vanova et al., 2021).

Gray Oral Reading Test – Fifth Edition (GORT-5) (Bryant & Wiederholt, 2012)
This is a test of reading *comprehension* (number of correctly answered questions about the story read), *rate* (time taken to read a story aloud), *accuracy* (number of correctly pronounced words), *fluency* (combination of reading rate and accuracy), and *Oral Reading Index* (ORI – a combination of comprehension and fluency scores). Each story is followed by five comprehension questions. The test takes approximately 15-45 minutes to complete depending on reading proficiency. The testing starts at the most appropriate story considering participants' education and reading abilities. The baseline is established when a participant scores 9-10 on two consecutive stories. This reflects the lowest level of reading difficulty which the participant is able to execute. The testing ends when the fluency score is two or less on two consecutive stories. The Form B (with extended norms for adults) of the GORT which consists of 16 stories of increasing length and complexity, and is suitable for administration to adults, was used in this study.

Comprehensive Test of Phonological Processing – Second Edition (CTOPP-2) (Wagner et al., 2013)
This is a test of phonological processing, assessing the ability to pronounce nonwords, distinguish and pronounce the individual sounds, and then associate the sounds with individual letters. For this study, two subscores were obtained. The *Alternate Phonological Awareness* (APA) consists of two subtests: a) Segmenting Nonwords, and b) Blending Nonwords and measures the capacity to distinguish, pronounce, and manipulate the sounds that form a nonword. The *Rapid Symbolic Naming* (RSN) also consists of two subtests: c) Rapid Digit Naming, and d) Rapid Letter Naming, and requires a quick retrieval of phonological information – letters and numbers. The administration of all four subtests takes approximately 15 minutes.

Intelligence

Test of Premorbid Functioning - UK Version (TOPF-UK) (Wechsler, 2011a)

TOPF-UK is a single-word reading test used to assess premorbid intelligence. The test requires the participant to read a list of 60 words. The number of correct pronunciations and time taken to complete the test are assessed. It takes approximately five minutes to administer. The test is discontinued after five consecutive scores of 0 – incorrectly pronounced words.

Wechsler Abbreviated Scale of Intelligence–Second Edition (WASI-II) (Wechsler, 2011b)

To obtain an estimate of current intellectual functioning, two subtests of the WASI-II were administered: Vocabulary and Matrix Reasoning. The *Vocabulary* measures the understanding of words. Each item is scored as: (0) no adequate definition of the words was given, (1) the definition is incomplete, lacks details, or (2) full, a comprehensive definition was obtained. For the population age range included in this study, the administration starts on Item 9. If the participants score 2 points on this item, the administration continues with item 10 and finishes after 5 consecutive scores of 0. If the participant obtains a score of 0 or 1 point on Item 9, Items 5-8 are administered in reversed order until the participant obtains a score of 2 points on two consecutive items. If the participant scores 0 or 1 point on Items 5-6, the administration continues with Items 1 to 4 in that order.

The *Matrix Reasoning* subtest measures abstract reasoning skills. The participant is presented with pictures of matrices where one item is missing. The participant's task is to choose the missing piece from the options at the bottom of the page. Starting matrix (Item) depends on the participant's age. For participants in this study, these are either Item 5 (for ages 45-79) or 7 (for ages 12-44). The administration stops after four consecutive scores of 0 or after the maximum number of correct items per participant age group has been reached. If the participant fails on the first presented item, the previously not administered items (1-7 or 1-5) are administered in reverse order.

Verbal Learning and Memory: Immediate Recall and Recognition

Hopkins Verbal Learning Test-Revised (HVLT-R) (Brandt, 1991)

This test consists of a list of 12 words from three semantic categories (animals, precious stones, and human dwellings). The researcher reads the list out loud and asks the participant to repeat the word in no particular order. This process is repeated three times. Each correctly remembered item is scored by 1 point. After three repetitions, a list of 24 words containing related and unrelated distractors is read to the participant who is asked to recognise if the words in the list were previously read or not. False-positive identifications of related and unrelated items are scored by 1point. The discrimination index is calculated by subtracting the false positives from correctly remembered items. A maximum score is 12 with a higher score indicating a better ability.

Executive Functioning (Including Working Memory)

Letter Number Span Task (LNST) (Gold et al., 1997; Wechsler, 1997)

This task assesses verbal working memory by requiring a participant to remember a random sequence of letters and numbers and to re-order the numbers from lowest to highest and letters alphabetically. The has 6 levels of difficulty, starting with a span of two (one letter, one number) and finishing with a span of seven. Each difficulty level has four different spans. The task is discontinued when the participant cannot re-order all four spans on one difficulty level. Each correctly re-ordered span is scored 1 and an incorrect with 0 points. The task maximum score is 24.

Digit Symbol Substitution Test (DSST) (Wechsler, 1944)

The DSST was first introduced as an experimental measure of associative learning and processing speed and was later incorporated into the Wechsler-Bellevue Battery (Jaeger, 2018). The test presents numbers 1-9 with their corresponding symbols. Participants are asked to transcribe as many numbers as possible into the symbols in 90 seconds. There are 100 numbers in pseudo-random order, out of which 10 serve as a practice.

Trial Making Test (TMT) (Reitan, 1958; Reitan & Wolfson, 1995)

The test assesses processing speed (TMT-A) and mental flexibility (TMT-B). It consists of two parts, each of 25 circles of numbers and/or letters randomly printed on a sheet. In Part A, participants are asked to connect all numbers 1-25 from lowest to highest. In Part B, participants are asked to connect all numbers 1-13 from lowest to highest and the letters A-L alphabetically, interchangeably, alternating between the lowest number and the first letter in the alphabet. Participant time is recorded. The Part A average based on age and education is between 25-35 seconds, Part B approx. between 50-79 seconds (Tombaugh, 2004).

Behavioural Assessment of the Dysexecutive Syndrome (BADS) (Wilson et al., 1996)

This is a test battery that evaluates executive functioning in six subtests. In this study, only the Key Search and ZOO Map subtests were used. The Key Search assesses planning ability and strategy formation. Participants are presented with a sheet of paper with an empty square symbolising a field. They are asked to draw a line to show how they would search the field to find a set of keys lost anywhere within the field. Participants are scored based on consistency (continuous horizontal or parallel line) and precision (within 10mm of the corner) of their search and on time necessary to plan and execute the strategy. The ZOO Map has two versions. In the first one, participants are presented with a map with several locations they are asked to visit in no particular order while following a set of rules. In the second version, participants are presented with the same map and rules and are asked to visit the locations in a particular order. This test assesses planning a strategy, determining priorities, and problem-solving. The sequence, time, and errors of each strategy are scored. Each subtest raw score is converted into the profile score of 0-4 points with a higher score indicating better performance.

7.3.2.3. Experimental measures of reading-related skills and inhibitory control

Reading-Related Skills

Lexical Decision Task (LDT)
The task is described in detail in Chapter 4.

Inhibitory Control

Go/No-Go Task
The task is described in detail in Chapter 5.

Executive Functioning

Stroop Task
The task consisted of three individual blocks (neutral, congruent and incongruent conditions) of 48 trials each. During the block of neutral condition, participants were presented with four words (W) ("red", "green", "blue", "yellow") in black colour. The aim was to press as fast as possible one of the four buttons each corresponding to one of the words. In the congruent condition, participants were presented with strings of letter "X" (3-5 characters long) printed in four different colours (C) with the aim to identify the colour of each string by pressing a corresponding button. In neutral and congruent blocks, each stimulus (the four colour words either in the black or congruent colour) was presented 12 times. In the incongruent condition (WC), participants were presented with the same four words as previously although each in three of the incongruent colours. Each incongruent colour-word combination (12 in total) was presented four times. The aim was to identify the colour of the word as fast as possible and ignore the word written.

Each trial consisted of a black fixation mark "+" presented for 300ms, a blank screen for 200ms and a stimulus presentation for 2000ms followed by another 200ms of a blank screen presentation. All stimuli were presented over a white background.

At the beginning of each block, participants were presented with a short practice session consisting of 12 trials providing feedback on accuracy after each trial. The duration of each feedback was 1 second. A screen with brief instructions reads as follows: *"Press the button that matches the WORD (or COLOUR of the word) you see. Red = R*; *green = G*; *blue = B*; *yellow = Y. Now, let's practice! Press <ENTER> to begin."* These were modified for congruent and incongruent blocks.

After the practice session, the main block started with repeating the instructions. Subsequently, participants started the main block of 48 trials. During each trial, if a response was made before the 2000ms presentation interval terminated, another trial was presented immediately. Feedback was not presented during the main block. When the block terminated, participants continued with another condition block. The maximal length of the experiment was approximately 8 minutes. Reaction time and response accuracy were recorded in a log file for each participant. Interference score was calculated based on the formula: $WC – [(W \times C)/(W + C)]$, where WC was correct responses from the incongruent condition, W was from the word condition, and C was from the colour condition (Scarpina & Tagini, 2017). The maximum possible score in each condition was 48 correct responses.

7.3.3. General Procedure

Participants were recruited from different hospital wards. Firstly, the clinical staff lead of each ward was approached by the researchers and their on-site supervisor with a list of patients eligible to take part in the research. Researchers were introduced to patients at the weekly ward meetings where they explained the purpose of the study. Patients were free to approach the researchers or the clinical staff if interested in taking part. Before taking part, participants received the Information Sheet, were able to ask questions about the research, and were required to provide written informed consent. Participants attended one to three research sessions in a quiet room within their ward. At the beginning of the research session, they were informed about the structure and duration of sessions, the possibility to take breaks, withdrawals procedure, and then to provide written informed consent. After allocating them a unique anonymisation code, demographic information was collected, followed by the administration of self-report measures and experimental tasks. Towards the end of the session, participants were given the Debrief Sheet and were reimbursed for their time via the inpatient bank system.

7.3.4. Data Treatment

The data were analysed using IBM SPSS Statistics, Version 26.0 (IBM Corp., 2019). The alpha level was .05 unless otherwise specified.

7.3.4.1. Normality and Outliers

Cognitive and reading assessments variables were assessed for normality by examining skewness and kurtosis. Skewness was calculated to determine the symmetry of data distribution, whether the scores are skewed towards the lower or higher end of each scale. Kurtosis determined the data peaks for each variable, with low kurtosis scores (<1) indicating higher peaks and low presence of outliers. The skewness or kurtosis of the variables was judged to be statistically significant ($p < .05$) if the z-score overpassed the ±1.96 value (Field, 2009). Due to the limited number of participants and no significant skewness and kurtosis, no variables were adjusted. All variables were assessed for homogeneity of variance by Levene's test. In variables where Levene's test revealed a significant violation of homogeneity of variance ($p < .05$), the *t*-test results are reported with adjusted degrees of freedom.

7.3.5. Statistical Analysis

7.3.5.1. Sample Characteristics

To explore possible differences between patients and matched HC in categorical demographic variables (language, ethnicity, self-reported handedness) a Pearson's Chi-Square test was used. Series of *t*-tests were used to examine possible group differences in self-report measures of psychopathology (total score in each subscale). Due to the limited sample size, this needs to be considered as a pilot study with further data collection needed[2].

7.3.5.2. Group Differences in LDT and GNG Performance

For LDT and GNG, performance accuracy was analysed using a 4 (LDT) or 3 (GNG) (Stimulus-Type) x 2 (Group) mixed model of analysis of variance (ANOVA) with stimulus-type (LDT: high-frequency words, low-frequency words, pseudohomophones, real nonwords; GNG: 1000ms, 700ms, 400ms) as a within-subject variable, and Group (Patients, HC) as the between-subject factors. For LDT, RTs to

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[2] Data collection was disrupted by the COVID-19 pandemic.

correct high and low-frequency words were analysed by a 2 (Stimulus-Type; high and low-frequency words) x 2 (Group) ANOVA with Stimulus-Type as a within-subject variable. Similarly, RTs to incorrect responses (i.e., a failure to withhold responses) to pseudohomophones and real nonwords were analysed with a 2 (Stimulus-Type; pseudohomophones, real nonwords) x 2 (Group) ANOVA with Stimulus-Type as a within-subject variable. For GNG Task, RTs to correct go and incorrect no-go (FAs) trials were analysed (separately) by a 2 (Stimulus-Type; 1000ms, 700ms, 400ms) x 2 (Group) ANOVA with Stimulus-Type as a within-subject variable.

The Greenhouse-Geisser correction was applied to all repeated measures statistics where Mauchly's Test indicated a significant violation of sphericity ($p < .05$). Effect sizes were calculated as partial eta squared (η^2_p) and interpreted as follows: $\eta^2_p \geq .01$ to < .06 (small), $\eta^2_p \geq .06$ to <.14 (medium), $\eta^2_p \geq .14$ (large) (J. Cohen, 1992). Post-hoc mean comparisons with Bonferroni correction (p_{bonf}) were conducted to probe significant main and interaction effects as required. Cohen's *d* values were interpreted as follows: ≥ .2 to < .5 (small effect), ≥ .5 to < .8 (medium), and ≥ .8 (large) (J. Cohen, 1992).

7.3.5.3. Association between Reading Skills, Neuropsychological Measures, and Psychopathology Dimensions

Due to significant skewness and kurtosis of LDT data, a Spearman's rank-order correlation coefficient (rho) – r_s with two-tailed significance ($p < .05$) was used to examine hypothesised reading skills and psychopathology-related traits-LDT performance associations. All performance variables associated with more than one trait were analysed further using linear regression analysis (Stepwise method) to determine the amount of shared and unique variance explained by various reading skills and psychopathology-related traits in LDT performance.

Results from Stroop experimental task include descriptive and correlational analysis only, due to no existing control group or norms.

7.4. Results

7.4.1. Sample Characteristics

The patients and HC group were matched on age ($p = .114$), language (native vs non-native English speakers) ($p = .638$), and handedness ($p = .559$). Significant differences were found in education ($p =$

.010) and ethnicity ($p < .001$) with HC as prevalently Caucasian individuals in comparison to patients with people of prevalently Black and Asian origins. Full demographic characteristics are summarised in Table 7.1. Following the ICD-10 classification, 13 patients were diagnosed with some form of psychotic disorder: nine with paranoid schizophrenia (F200), three with schizoaffective disorder (F250), and one patient with hebephrenic schizophrenia (F201). Two patients were diagnosed with bipolar disorder (F31), one with hypomanic and one with manic without psychosis.

Table 7.1. Demographic characteristics of the patient and health control (HC) groups.

Variable / *N*	Patients (n = 15)	HC (n = 15)
Age (Mean [±*SD*])	36.80 (12.59)	29.67 (11.32)
Language (Number [%])		
English	13 (87%)	12 (80%)
Other	2 (13%)	3 (20%)
Ethnicity (Number [%])		
White	2 (13%)	10 (67%)
Asian/Pacific Islander	4 (27%)	1 (7%)
Black/African American	7 (47%)	0
Hispanic/Latino	0	0
Other	2 (13%)	4 (24%)
Handedness (Number [%])		
Right	14 (93%)	13 (87%)
Left	1 (7%)	2 (13%)
Education (Number [%])		
Higher Degree	0	3 (20%)
First Degree	2 (13%)	5 (33%)
Teaching Qualification	0	1 (7%)
Other Higher Qualification	5 (33%)	0
GCE A Level in 2+	1 (7%)	3 (20%)
GCE A Level in 1	0	1 (7%)
GCSE/O Level in 5	0	2 (13%)
GCSE/O Level in 1-4	1 (7%)	0
CSE below 1 or GSCE below Grade C	0	0
Other Basic Qualification	4 (27%)	0
Never Attended School	2 (13%)	0

In self-report measures, patients showed significantly higher scores than HC in SPQ-BR Interpersonal ($p = .008$, Cohen's $d = 1.081$), BPQ Suicide tendencies ($p < .001$, Cohen's $d = 1.490$), BPQ Intense Anger ($p = .021$, Cohen's $d = .897$), and BPQ Quasi-psychotic States ($p = .020$, Cohen's $d = .904$). No other significant differences in psychopathology-related traits were found (Table 7.2.). Patients PCL-R scores ranged between 4-25.6 points, indicating low to moderate levels of psychopathy (Hare, 2003).

7.4.2. Neuropsychological performance in patients

Reading and other cognitive skills (premorbid IQ, current IQ, memory, and executive functioning) in patients were compared against the norms.

7.4.2.1. Reading Skills

In the GORT-5, the grade equivalents of reading rate (M = 4.28, SD = 2.08), accuracy (M = 4.29, SD = 3.68), fluency (M = 4.39, SD = 2.83), and comprehension (M = 4.26, SD = 2.79) were between 4th and 5th grade (equivalent to 9-10.5 years of age), which is below their corresponding age norm (>18). The ORI was very poor, below all age-related norms (M = 65.30, SD = 11.10) (Table 7.3.). In the CTOPP, the grade equivalents of Rapid Digit Naming (M = 6.23, SD = 2.95) and Rapid Letter Naming (M = 6.46, SD = 3.02), were between 6-7 years of education, and Blending Nonword (M = 1.18, SD = 1.86) and Segmenting Nonwords (M = .42, SD = .45) were between 1st and 2nd grade (equivalent to 5-6 years of age), scoring significantly below their age norm (>18). The APA and RSN composite scores were very poor, below all norms (Table 7.3.). The differences between these two composite scores were also significant [$t(12) = 3.205$, $p = .008$] indicating a significantly better ability to retrieve phonological information from long term memory than phonological awareness skills.

7.4.2.2. Intelligence

The TOPF-UK (M = 37.90, SD = 12.90) was below the low-average level indicating a mildly lower premorbid functioning. The WASI-II (M = 88.40, SD = 11.10) current functioning was also low average.

7.4.2.3. Memory

The HVLT-R Discrimination Index (M = 7.44, SD = 2.79) indicated reduced learning ability and immediate recall capacity of around 8 out of 12 items remembered after three repetitions.

7.4.2.4. Executive Functioning

The LNST score (*M* = 9.45, *SD* = 4.25) indicated a working memory capacity of 3-4 items. The DSST (*M* = 30.13, *SD* = 16.10) showed slower processing and psychomotor speed. There was a significant difference with a large effect size ($t(8) = -7.445$, $p < .001$, Cohen's $d = 2.482$) between the speed of executing the TMT – A (*M* = 44.87, *SD* = 15.55) and TMT – B (*M* = 117.67, *SD* = 42.41) assessments, indicating difficulties in set shifting and mental flexibility. The BADS Key Search (*M* = 2.00, *SD* = 1.73) and BADS ZOO Map (*M* = 1.29, *SD* = 1.60) scores indicated impaired executive functioning[3].

[3] BADS overall scores classification distinguishes between very superior to impaired executive functioning. A profile score between 1-2 points per subtest is impaired. In this study, only two subtests were used out of six. The maximum average possible was 8 points out of the two subtests (4 points max. each). Participants scored on average 3.29 out of 8 (2 points for Key Search + 1.29 for ZOO Map), equal to 41.1% out of max. possible. This is .411 x 24 (the maximum profile score if all tests were administered) = 9.87. Scores between 0-11 are interpreted as an impairment in executive functioning when all tests are administered.

Table 7.2. Descriptive statistics, homogeneity of variance, and inferential statistics of self-report measures data for patients and HC.

	Patients			HC			Max. possible score	Leven's Test for Equality of Variance (*p*)	t-test Statistics	df	*p*	Direction of effect
	N	Mean (*SD*)	Range	*N*	Mean (*SD*)	Range						
SPQ-BR Cognitive Perceptual	13	24.40 (13.40)	2-43	15	22.67 (5.58)	6-40	56	.110	-.409	26	.686	
SPQ-BR Interpersonal	13	19.40 (8.03)	0-32	15	11.73 (6.02)	4-28	40	.497	-2.878	26	**.008***	Patients > HC
SPQ-BR Disorganised	13	14.00 (7.07)	0-25	15	10.67 (6.10)	2-27	32	.629	-1.341	26	.192	
BIS-11 Attention	15	8.53 (4.29)	0-14	15	10.87 (2.97)	7-18	20	.216	1.731	28	.094	
BIS-11 Cognitive Instability	15	4.87 (3.34)	0-11	15	7.00 (2.88)	3-12	12	.626	1.875	28	.071	
BIS-11 Motor	15	13.40 (6.24)	0-22	15	14.20 (3.45)	10-19	28	.288	.434	28	.667	
BIS-11 lack of Perseverance	15	8.00 (2.73)	4-12	15	8.27 (2.58)	5-14	16	.684	.275	28	.785	
BIS-11 lack of Self-Control	15	11.70 (5.52)	0-18	15	13.33 (4.24)	7-21	24	.595	.927	28	.362	
BIS-11 Cognitive Complexity	15	12.10 (3.39)	5-17	15	10.93 (2.12)	6-14	20	.182	-1.098	28	.282	
BPQ Impulsivity	15	2.87 (1.19)	1-6	15	3.00 (2.75)	0-8	9	**<.001*****	.172 [a]	19.04	.865	
BPQ Affective Instability	15	4.87 (3.04)	0-9	15	3.07 (3.15)	0-9	10	.934	-1.591	28	.123	
BPQ Abandonment	15	3.00 (2.67)	0-9	15	1.60 (2.32)	0-9	10	.274	-1.531	28	.137	
BPQ Relationships	15	3.00 (2.14)	0-6	15	1.67 (1.91)	0-6	8	.536	-1.799	28	.083	
BPQ Self-Image	15	2.20 (2.04)	0-7	15	2.00 (2.56)	0-9	9	.507	-.236	28	.815	
BPQ Suicide	15	2.93 (1.79)	0-5	15	0.60 (1.30)	0-5	7	.096	-4.084	28	**<.001 *****	Patients > HC
BPQ Emptiness	15	2.73 (2.22)	0-7	15	2.67 (2.64)	0-10	10	.756	-.075	28	.941	
BPQ Intense Anger	15	3.73 (2.40)	0-7	15	1.60 (2.35)	0-7	10	.327	-2.455	28	**.021***	Patients > HC
BPQ Quasi-Psychotic States	15	2.07 (1.75)	0-6	15	.80 (.94)	0-2	7	.167	-2.468	28	**.020***	Patients > HC
PHQ	11	4.45 (5.47)	0-20	-	-	-	30	-	-	-	-	

	Patients			HC			Max. possible score	Leven's Test for Equality of Variance (p)	t-test Statistics	df	p	Direction of effect
	N	Mean (*SD*)	Range	*N*	Mean (*SD*)	Range						
GAD-7	9	6.33 (6.93)	0-21	-	-	-	21	-	-	-	-	
PCL-R Interpersonal	14	1.79 (1.97)	0-7	-	-	-	8	-	-	-	-	
PCL-R Affective	14	3.93 (1.82)	1-7	-	-	-	8	-	-	-	-	
PCL-R Lifestyle	14	4.21 (2.75)	0-8	-	-	-	10	-	-	-	-	
PCL-R Antisocial	14	3.86 (2.63)	0-8	-	-	-	10	-	-	-	-	
PCL-R Total Prorated	14	14.72 (7.56)	4-25.6	-	-	-	40	-	-	-	-	

* $p < .05$; ** $p < .01$; *** $p < .001$; ^{a} = *t-test for "equal variances not assumed"*

Note: SPQ-BR – Schizotypal Personality Questionnaire - Brief; BIS-11 – Barratt Impulsiveness Scale; BPQ – Borderline Personality Questionnaire; PHQ - Patient Health Questionnaire for Depression; GAD-7 – Generalised Anxiety Disorder Assessment; PCL-R – Psychopathy Checklist-Revised.

Table 7.3. Descriptive statistics, skewness, and kurtosis of cognitive measures data for patients.

	N	Mean (SD)	Observed Min	Observed Max	Max possible	Skewness			Kurtosis		
						Value	**SE**	**z-score**	**Value**	**SE**	**z-score**
GORT-5 Rate (age)	15	10.30 (2.24)	7	15.50	> 18	.720	.58	1.241	.803	1.12	.717
GORT-5 Accuracy (age)	15	9.80 (3.94)	6.25	18.50	> 18	1.350	.58	2.328	.550	1.12	.491
GORT-5 Fluency (age)	15	9.92 (2.94)	6.75	17.30	> 18	1.390	.58	2.397	1.560	1.12	1.393
GORT-5 Comprehension (age)	15	9.88 (2.90)	6	16	> 18	.527	.58	.909	-.385	1.12	-.344
GORT-5 Oral Reading Index	15	65.30 (11.10)	52	86	<70 Very poor; >130 Very superior	.527	.58	.909	-.803	1.12	-.717
CTOPP Rapid Digit Naming (age)	12	11.30 (2.94)	5	15	> 15	-.643	.64	-1.009	.500	1.23	.407
CTOPP Rapid Letter Naming (age)	13	11.50 (3.01)	6	15	> 15	-.481	.62	-.781	-.939	1.19	-.789
CTOPP Blending nonwords (age)	13	6.10 (2.11)	3.5	10.50	> 15	.870	.62	1.412	.365	1.19	.307
CTOPP Segmenting nonwords (age)	13	5.21 (.96)	3.5	6.25	> 15	-.619	.62	-1.005	-1.140	1.19	-.958
CTOPP Alternate Phonological Awareness	13	63.90 (14.10)	45	85	<70 Very poor; >130 Very superior	.374	.62	.607	-1.360	1.19	-1.143
CTOPP Rapid Symbolic Naming	13	81.80 (18.40)	45	104	<70 Very poor; >130 Very superior	-.676	.62	-1.097	-.436	1.19	-.366
TOPF-UK	9	37.90 (12.90)	25	56	70; 40-44 low average; 35-39 mild functional decline	.608	.72	.848	-1.720	1.40	-1.229
WASI-II Vocabulary	11	48.40 (11.50)	35	68	80	.355	.66	.537	-1.270	1.28	-.992
WASI-II Matrices	11	19.00 (5.83)	10	27	35	-.126	.66	-.191	-1.170	1.28	-.914
WASI-II IQ	11	88.40 (11.10)	76	108	80-89 low average	.928	.66	1.404	-.301	1.28	-.235
LNST	11	9.45 (4.25)	3	15	24	-.257	.64	-.403	-1.250	1.23	-1.016
HVLT-R (Discrimination Index)	9	7.44 (2.79)	5	12	12	.787	.72	1.093	-1.255	1.40	-.896
HVLT-R (Free recall)	9	8.56 (2.35)	5	12	12	-.053	.72	-.074	-1.120	1.40	-.800
DSST	8	30.13 (16.10)	15	60	90	1.059	.75	1.412	.190	1.48	.128

	N	Mean (SD)	Observed Min	Observed Max	Max possible	Skewness			Kurtosis		
						Value	SE	z-score	Value	SE	z-score
TMT – A (sec.)	9	44.78 (15.55)	27	68	-	.534	.72	.742	-1.653	1.40	-1.181
TMT – B (sec.)	9	117.67 (42.41)	70	199	-	.790	.72	1.097	-.067	1.40	-.048
BADS – Key Search (Profile score)	9	2.00 (1.73)	0	4	4	.000	.72	.000	-1.714	1.40	-1.224
BADS – ZOO Map (Profile score)	7	1.29 (1.60)	0	3	4	.374	.79	.473	-2.800	1.59	-1.761
Stroop (Interference score)	8	17.65 (6.66)	7	25.05	> 24 no interference < 24 interference	-.552	.75	-.736	-1.326	1.48	-.896

Note: GORT-5 – Gray Oral Reading Test; ORI – Oral Reading Index; CTOPP – Comprehensive Test of Phonological Processing; TOPF-UK – Test of Premorbid Functioning; WASI-II – Wechsler Abbreviated Scale of Intelligence; LNST – Letter Number Span Task; HVLT-R – Hopkin's Verbal Learning Test-Revised; DSST – Digit Symbol Substitution Test; TMT – Trail Making Test; BADS - Behavioural Assessment of the Dysexecutive Syndrome.

7.4.3. Association between Reading Skills and Other Neuropsychological Measures

The correlations between reading skills and cognitive abilities assessments scores are summarised in Table 7.4. For GORT-5, the TOPF-UK scores significantly predicted 72% of the reading rate variance [$F(1,7) = 17.81$, $p = .004$, $R^2 = .720$]. For CTOPP, the WASI-II Matrices and BADS Zoo Map significantly negatively correlated with RDN – the ability to quickly read numbers (all $p < .05$), but only the ZOO Map significantly predicted over 70% of the variance [$F(1,5) = 13.761$, $p = .014$, $R^2 = .733$]. The WASI-II current IQ, Matrices, and BADS ZOO Map significantly negatively correlated with RLN and RSN (all $p < .05$), but only current IQ scores significantly predicted nearly 70% of RLN variance [$F(1,5) = 11.443$, $p = .020$, $R^2 = .696$] and ZOO Map predicted nearly 70% of the RSN variance [$F(1,5) = 11.551$, $p = .019$, $R^2 = .698$]. The TMT – B significantly negatively correlated with Segmenting nonwords ($p < .05$).

7.4.5. Association between Reading Skills and Self-Reported Psychopathology Scores

The correlations between reading skills and psychopathology scores are summarised in Table 7.5. The Cognitive Perceptual subscale of SPQ-BR significantly predicted variance of GORT-5 Accuracy [$F(1,11) = 7.107$, $p = .022$, $R^2 = .392$], Comprehension [$F(1,11) = 9.868$, $p = .009$, $R^2 = .473$], and the ORI [$F(1,11) = 7.859$, $p = .017$, $R^2 = .417$]. The BPQ Abandonment significantly predicted the variance of GORT-5 Rate [$F(1,12) = 15.447$, $p = .002$, $R^2 = .563$] and Fluency [$F(1,11) = 6.610$, $p = .026$, $R^2 = .375$]. All other significant correlations were excluded by the regression model as non-significant. For the CTOPP, BPQ Impulsivity and PCL-R Lifestyle facet significantly predicted variance of RDN [$F(1,11) = 24.012$, $p < .001$, $R^2 = .842$] with BPQ Impulsivity accounting for 58% of the variance [F *Change* $(1,10) = 13.953$, $p = .004$, R^2 *Change* $= .583$] and PCL-R Lifestyle accounting for 26% [F *Change* $(1,9) = 14.807$, $p = .004$, R^2 *Change* $= .260$]. The Lifestyle facet also predicted the variance of RLN [$F(1,10) = 14.435$, $p = .003$, $R^2 = .591$]. The RSN composite score was significantly predicted by PCL-R Lifestyle [F *Change* $(1,10) = 12.437$, $p = .005$, R^2 *Change* $= .554$] and BPQ Impulsivity [F *Change* $(1,9) = 6.648$, $p = .030$, R^2 *Change* $= .189$], together accounting for 74% of the variance [F $(1,11) = 13.054$, $p = .002$, $R^2 = .744$]. The GAD-7 significantly predicted the Blending nonword scores [$F(1,7) = 13.533$, $p = .008$, $R^2 = .659$].

7.4.6. Experimental Task Performance in Patients and its Relationship with Reading Skills

7.4.6.1. Group Differences

LDT

Accuracy: There was a significant main effect of Stimulus-Type in accuracy, with a large effect size [$F(1.33,37.23) = 17.324$, $p < .001$, $\eta^2_p = .382$]. The main effect of Group [$F(1,28) = 4.057$, $p = .054$, $\eta^2_p = .127$] and the Group*Stimulus-Type interaction just missed significance [$F(1.33,37.23) = 3.678$, $p = .052$, $\eta^2_p = .116$].

Follow-up analyses of the Stimulus-Type effect using post-hoc comparisons revealed that participants correctly identified significantly more high-frequency words than low-frequency words [$t(28) = 6.073$, $p < .001$, $p_{bonf} < .001$], pseudohomophones [$t(28) = 6.729$, $p < .001$, $p_{bonf} < .001$], and real nonwords [$t(28) = 6.922$, $p < .001$, $p_{bonf} < .001$]. The differences were not significant between correct low-frequency words and pseudohomophones [$t(28) = 1.452$, $p = .157$, $p_{bonf} = .254$], low-frequency words and real nonwords [$t(28) = 1.373$, $p = .181$, $p_{bonf} = .495$], and between correct pseudohomophones and real nonwords [$t(28) = .745$, $p = .463$, $p_{bonf} = 1.000$].

Post Hoc analysis to probe the Group*Stimulus-Type interaction indicated that HC were significantly better than patients in distinguishing low-frequency words [$t(103.43) = 3.797$, $p < .001$, $p_{bonf} = .007$] (Figure 7.1.). The two groups had comparable performance when identifying high-frequency words [$t(103.43) = .916$, $p = .362$, $p_{bonf} = 1.000$], pseudohomophones [$t(103.43) = .087$, $p = .931$, $p_{bonf} = 1.000$], and real nonwords [$t(103.43) = .131$, $p = .896$, $p_{bonf} = 1.000$].

Table 7.4. Spearman correlation coefficients between reading skills and cognitive measures in patients.

	GORT-5 Rate scaled	GORT-5 Accuracy scaled	GORT-5 Fluency scaled	GORT-5 Compreh. scaled	GORT-5 ORI	CTOPP RDN scaled	CTOPP RLN scaled	CTOPP Blending nonwords scaled	CTOPP Segmenting nonwords scaled	CTOPP APA composite	CTOPP RSN composite
	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)
TOPF-UK	**.820****	.600	.640	.660	.660	-.310	-.520	-.300	-.180	-.240	-.490
(n = 9)	(.007)	(.088)	(.064)	(.055)	(.055)	(.412)	(.148)	(.440)	(.637)	(.527)	(.177)
WASI-II IQ	.110	.190	.150	.190	.190	-.540	**-.790****	-.490	-.470	-.470	**-.680***
(n = 11)	(.758)	(.572)	(.658)	(.581)	(.568)	(.084)	(.004)	(.126)	(.142)	(.149)	(.022)
WASI-II Vocabulary	.140	.390	.220	.270	.260	-.050	-.350	-.260	-.400	-.340	-.190
(n = 11)	(.676)	(.237)	(.521)	(.425)	(.438)	(.887)	(.288)	(.431)	(.222)	(.304)	(.582)
WASI-II Matrices	-.160	-.160	-.110	-.140	-.130	**-.660***	**-.710***	-.470	-.310	-.360	**-.710***
(n = 11)	(.631)	(.642)	(.751)	(.689)	(.710)	(.028)	(.015)	(.142)	(.358)	(.273)	(.014)
LNST	.325	.264	.263	.250	.258	-.299	-.341	.225	-.116	.030	-.395
(n = 11)	(.330)	(.434)	(.434)	(.436)	(.445)	(.371)	(.305)	(.507)	(.735)	(.930)	(.229)
HVLT-R	.208	.078	.112	.144	.174	-.076	-.073	.096	.242	.155	-.111
(n = 9)	(.592)	(.843)	(.775)	(.711)	(.655)	(.847)	(.852)	(.806)	(.530)	(.690)	(.776)
DSST	.512	.588	.519	.640	.594	-.209	-.114	-.335	.143	-.048	-.187
(n = 8)	(.195)	(.125)	(.188)	(.087)	(.121)	(.620)	(.787)	(.417)	(.736)	(.909)	(.658)
TMT – A	.306	.182	.272	.146	.180	-.223	-.262	.039	-.459	-.229	-.277
(n = 9)	(.423)	(.639)	(.479)	(.708)	(.644)	(.564)	(.497)	(.921)	(.214)	(.554)	(.470)
TMT – B	.288	.084	.192	.085	.094	-.522	-.647	-.351	**-.703***	-.582	-.628
(n = 9)	(.452)	(.829)	(.620)	(.827)	(.811)	(.149)	(.060)	(.355)	(.035)	(.100)	(.070)
BADS – Key Search	-.275	-.160	-.277	-.162	-.162	-.083	.133	.108	.361	.292	0
(n = 9)	(.473)	(.681)	(.471)	(.678)	(.678)	(.833)	(.732)	(.783)	(.340)	(.445)	(1.000)

	GORT-5 Rate scaled	GORT-5 Accuracy scaled	GORT-5 Fluency scaled	GORT-5 Compreh. scaled	GORT-5 ORI	CTOPP RDN scaled	CTOPP RLN scaled	CTOPP Blending nonwords scaled	CTOPP Segmenting nonwords scaled	CTOPP APA composite	CTOPP RSN composite
	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)	r_s (*p*)
BADS – ZOO Map	.080	.220	.080	.150	.150	**-.874***	**-.808***	-.073	-.239	0	**-.866***
(*n* = 7)	(.865)	(.635)	(.865)	(.749)	(.749)	(.010)	(.028)	(.876)	(.606)	(1.000)	(.012)
Stroop	.012	.172	.115	.270	.220	.024	.060	-.133	.440	.109	.048
(*n* = 8)	(.977)	(.684)	(.786)	(.518)	(.601)	(.954)	(.887)	(.753)	(.275)	(.797)	(.910)

* $p < .05$; ** $p < .01$

Note: GORT-5 – Gray Oral Reading Test; ORI – Oral Reading Index; CTOPP – Comprehensive Test Of Phonological Processing; RDN – Rapid Digit Naming; RLN – Rapid Letter Naming; APA – Alternative Phonological Awareness; RSN – Rapid Symbolic Naming; WASI-II – Wechsler Abbreviated Scale of Intelligence; LNST – Letter Number Span Task; TOPF-UK – Test Of Premorbid Functioning; HVLT-R – Hopkin's Verbal Learning Test-Revised; DSST – Digit Symbol Substitution Test; TMT – Trail Making Test; BADS - Behavioural Assessment of the Dysexecutive Syndrome.

Table 7.5. Spearman correlation coefficients between reading skills and psychopathology self-report measures in patients.

	GORT-5 rate scaled r_s (p)	GORT-5 accuracy scaled r_s (p)	GORT-5 fluency scaled r_s (p)	GORT-5 compr. scaled r_s (p)	GORT-5 ORI r_s (p)	CTOPP RDN scaled r_s (p)	CTOPP RLN scaled r_s (p)	CTOPP Blending scaled r_s (p)	CTOPP Segmenting scaled r_s (p)	CTOPP APA scaled r_s (p)	CTOPP RSN scaled r_s (p)
SPQ-BR Cognitive Perceptual (n = 13)	**-.591*** (.033)	**-.624*** (.023)	**-.586*** (.036)	**-.621*** (.023)	**-.615*** (.025)	-.332 (.292)	-.373 (.233)	.064 (.842)	-.083 (.798)	.021 (.948)	-.298 (.346)
SPQ-BR Interpersonal (n = 13)	**-.603*** (.029)	-.397 (.179)	-.469 (.106)	-.427 (.146)	-.470 (.105)	-.285 (.369)	-.207 (.518)	.129 (.690)	-.068 (.834)	.088 (.785)	-.207 (.519)
SPQ-BR Disorganised (n = 13)	-.337 (.260)	-.251 (.409)	-.285 (.346)	-.224 (.462)	-.270 (.372)	-.080 (.804)	-.243 (.447)	.111 (.731)	.023 (.944)	.092 (.776)	-.104 (.748)
BIS-11 Attention (n = 15)	-.157 (.577)	-.011 (.968)	-.084 (.765)	-.116 (.681)	-.137 (.627)	-.100 (.745)	.036 (.907)	.156 (.610)	-.173 (.571)	-.021 (.946)	.001 (.996)
BIS-11 Cognitive Instability (n = 15)	-.147 (.602)	-.258 (.353)	-.212 (.447)	-.188 (.502)	-.205 (.463)	-.174 (.571)	-.227 (.456)	.098 (.751)	.099 (.748)	.142 (.643)	-.160 (.602)
BIS-11 Motor (n = 15)	.106 (.707)	.248 (.373)	.185 (.509)	.262 (.346)	.239 (.390)	.155 (.614)	.158 (.605)	-.183 (.549)	-.041 (.893)	-.065 (.834)	.202 (.509)
BIS-11 Perseverance (n = 15)	-.406 (.133)	-.198 (.480)	-.356 (.193)	-.249 (.370)	-.302 (.274)	-.017 (.956)	-.011 (.971)	-.243 (.423)	-.292 (.332)	-.254 (.403)	.006 (.986)
BIS-11 Self Control (n = 15)	.149 (.597)	-.038 (.894)	.077 (.785)	.118 (.675)	.068 (.810)	.071 (.818)	-.201 (.510)	.378 (.202)	.111 (.717)	.190 (.534)	-.056 (.857)
BIS-11 Cognitive Complexity (n = 15)	.050 (.860)	.261 (.347)	.163 (.561)	.204 (.466)	.144 (.608)	.056 (.857)	.102 (.741)	.388 (.191)	.057 (.854)	.246 (.418)	.056 (.855)
BPQ Impulsivity (n = 15)	.198 (.479)	.048 (.866)	.161 (.566)	.129 (.648)	.141 (.616)	**.752**** (.003)	.444 (.128)	.243 (.423)	.315 (.294)	.213 (.486)	**.588*** (.035)

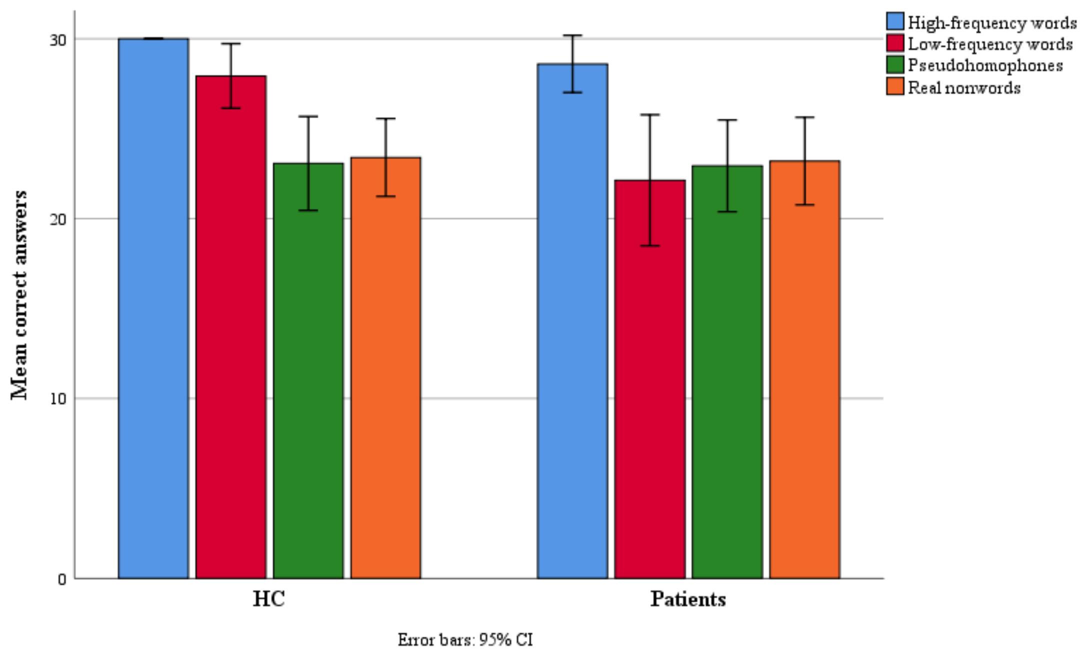
	GORT-5 rate scaled r_s (*p*)	GORT-5 accuracy scaled r_s (*p*)	GORT-5 fluency scaled r_s (*p*)	GORT-5 compr. scaled r_s (*p*)	GORT-5 ORI r_s (*p*)	CTOPP RDN scaled r_s (*p*)	CTOPP RLN scaled r_s (*p*)	CTOPP Blending scaled r_s (*p*)	CTOPP Segmenting scaled r_s (*p*)	CTOPP APA scaled r_s (*p*)	CTOPP RSN scaled r_s (*p*)
BPQ Affective Instability (*n* = 15)	-.286 (.301)	-.070 (.804)	-.109 (.698)	.002 (.995)	-.054 (.850)	-.244 (.422)	-.533 (.060)	.354 (.235)	.193 (.528)	.323 (.282)	-.387 (.192)
BPQ Abandonment (*n* = 15)	**-.800**** (.000)	**-.545*** (.035)	**-.591*** (.020)	**-.542*** (.037)	**-.586*** (.022)	-.196 (.521)	-.277 (.359)	.166 (.587)	.009 (.977)	.108 (.727)	-.236 (.437)
BPQ Relationships (*n* = 15)	**-.578*** (.024)	**-.538*** (.039)	**-.530*** (.042)	-.433 (.107)	-.468 (.078)	.000 (1.000)	-.283 (.349)	.184 (.546)	.188 (.539)	.222 (.466)	-.088 (.775)
BPQ Self-Image (*n* = 15)	-.288 (.298)	-.296 (.284)	-.233 (.404)	-.178 (.525)	-.217 (.437)	.064 (.837)	.237 (.436)	.240 (.429)	.301 (.318)	.294 (.329)	.167 (.587)
BPQ Suicide (*n* = 15)	-.141 (.617)	-.161 (.567)	-.130 (.645)	-.103 (.716)	-.111 (.692)	.215 (.481)	-.028 (.928)	.388 (.190)	.489 (.090)	.487 (.092)	.150 (.624)
BPQ Emptiness (*n* = 15)	-.455 (.088)	-.288 (.298)	-.280 (.312)	-.236 (.398)	-.276 (.319)	-.336 (.262)	-.443 (.129)	.340 (.256)	-.037 (.905)	.160 (.602)	-.397 (.180)
BPQ Intense Anger (*n* = 15)	-.246 (.376)	-.140 (.619)	-.093 (.742)	-.210 (.453)	-.165 (.558)	-.097 (.753)	-.262 (.388)	.449 (.124)	-.003 (.992)	.230 (.450)	-.150 (.624)
BPQ Quasi-Psychotic States (*n* = 15)	**-.734**** (.002)	**-.671**** (.006)	**-.704**** (.003)	**-.645**** (.009)	**-.671**** (.006)	-.194 (.525)	-.442 (.131)	.074 (.810)	.064 (.835)	.103 (.737)	-.282 (.351)
PHQ-9 (*n* = 11)	-.422 (.196)	-.279 (.406)	-.346 (.297)	-.353 (.287)	-.336 (.313)	-.247 (.464)	-.120 (.725)	.036 (.917)	.172 (.614)	.196 (.564)	-.169 (.620)
GAD-7 (*n* = 9)	-.138 (.724)	-.157 (.688)	-.138 (.724)	-.278 (.468)	-.234 (.545)	.018 (.964)	-.034 (.930)	**.804**** (.009)	.367 (.331)	.597 (.090)	.017 (.965)
PCL-R Interpersonal (*n* = 14)	-.200 (.492)	-.407 (.149)	-.406 (.149)	-.510 (.063)	-.448 (.108)	**.759**** (.004)	**.655*** (.021)	.450 (.142)	.178 (.579)	.257 (.421)	**.775**** (.003)
PCL-R Affective (*n* = 14)	**-.568*** (.034)	-.344 (.229)	-.450 (.106)	-.475 (.086)	-.502 (.067)	.152 (.638)	.048 (.882)	.453 (.139)	.032 (.920)	.263 (.410)	.128 (.692)
PCL-R Lifestyle (*n* = 14)	-.339 (.236)	-.239 (.411)	-.266 (.359)	-.389 (.169)	-.349 (.222)	**.652*** (.022)	**.794**** (.002)	-.016 (.960)	-.168 (.602)	-.150 (.642)	**.764**** (.004)

	GORT-5 rate scaled r_s (*p*)	GORT-5 accuracy scaled r_s (*p*)	GORT-5 fluency scaled r_s (*p*)	GORT-5 compr. scaled r_s (*p*)	GORT-5 ORI r_s (*p*)	CTOPP RDN scaled r_s (*p*)	CTOPP RLN scaled r_s (*p*)	CTOPP Blending scaled r_s (*p*)	CTOPP Segmenting scaled r_s (*p*)	CTOPP APA scaled r_s (*p*)	CTOPP RSN scaled r_s (*p*)
PCL-R Antisocial	-.421	-.435	-.382	-.515	-.457	**.585***	**.607***	.223	.050	.095	**.645***
(*n* = 14)	(.134)	(.120)	(.178)	(.060)	(.100)	(.046)	(.036)	(.486)	(.878)	(.770)	(.024)
PCL-R Total	-.528	-.482	-.519	**-.615***	**-.596***	.549	.569	.236	.026	.092	**.611***
(*n* = 14)	(.052)	(.081)	(.057)	(.019)	(.024)	(.064)	(.053)	(.460)	(.935)	(.777)	(.035)

* $p < .05$; ** $p < .01$

Note: GORT-5 – Gray Oral Reading Test; ORI – Oral Reading Index; CTOPP – Comprehensive Test Of Phonological Processing; RDN – Rapid Digit Naming; RLN – Rapid Letter Naming; APA – Alternative Phonological Awareness; RSN – Rapid Symbolic Naming; SPQ-BR – Schizotypal Personality Questionnaire - Brief; BIS-11 – Barratt Impulsiveness Scale; BPQ – Borderline Personality Questionnaire; PHQ - Patient Health Questionnaire for Depression; GAD – Generalised Anxiety Disorder Assessment; PCL-R – Psychopathy Checklist-Revised.

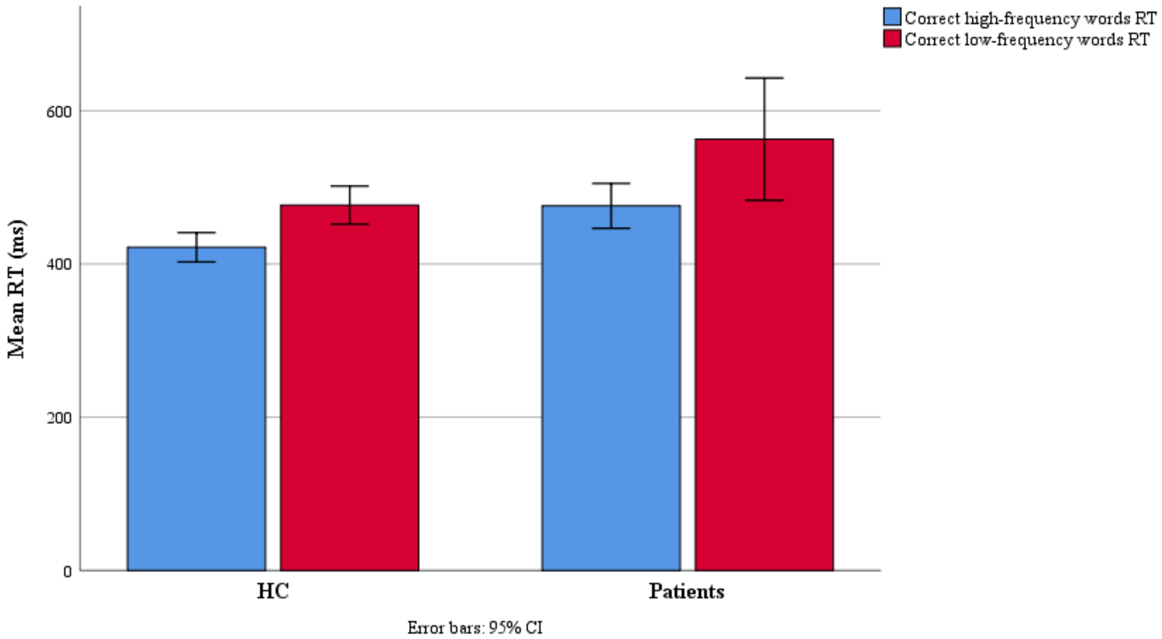
Figure 7.1. Mean correct responses for each Stimulus-Type (max. 30) in LDT for patients.



RTs: There was a significant main effect of stimulus-type on RTs for correctly identified words [F (1,28) = 21.998, $p < .001$, $\eta^2_p = .440$]. Group had a significant main effect [$F(1,28) = 7.408$, $p = .011$, $\eta^2_p = .209$] with HC having significantly shorter RTs than patients [$t(28) = -2.722$, $p = .011$, $p_{bonf} = .011$]. All participants were significantly slower when identifying low-frequency than high-frequency words [$t(28) = 4.690$, $p < .001$, $p_{bonf} < .001$]. The Group*Stimulus-Type interaction was non-significant [F (1,28) = 1.120, $p = .299$, $\eta^2_p = .038$], but the follow-up analysis to probe the Group*Stimulus-Type interaction indicated that HC had significantly shorter RTs for low-frequency words than patients [$t(28) = 3.316$, $p = .003$, $p_{bonf} = .015$], but the difference for high-frequency words did not survive Bonferroni correction [$t(28) = 2.209$, $p = .036$, $p_{bonf} = .213$] (Figure 7.2.).

The effect of stimulus type on RTs for incorrectly identified nonwords was non-significant [$F(1,28) = 3.054$, $p = .092$, $p_{bonf} = .092$, $\eta^2_p = .098$]. Group did not have a significant main effect [$F(1,28) = 2.403$, $p = .132$, $\eta^2_p = .079$]. No significant interactions involving Group were found (all $p > .05$).

Figure 7.2. Mean RTs (ms) for correctly identified words in patients.



GNG

Overall Accuracy: Mauchly's test of sphericity was significant (p < .001), Greenhouse-Geisser correction was applied. The main effect of Stimulus-Duration was significant [$F(1.40, 36.40) = .019$, $p < .001$, $\eta^2_p = .680$]. Group did not have a significant main effect [$F(1,26) = 1.074$, $p = .310$, $\eta^2_p = .040$] and the Group*Stimulus-Duration interaction was also non-significant [$F(2,52) = 1.256$, $p = .285$, $\eta^2_p = .046$]. Follow-up analyses of the stimulus-type effect using post-hoc comparisons revealed that participants had significantly lower Overall accuracy for 400ms than for 700ms trials [$t(26) = 6.425$, $p < .001$, $p_{bonf} < .001$], lower Overall accuracy for 700ms than 1000ms [$t(26) = 3.870$, $p < .001$, $p_{bonf} = .002$], and lower Overall accuracy for 400ms than 1000ms trials [$t(26) = 7.428$, $p < .001$, $p_{bonf} < .001$].

FAs: There was a significant main effect of Stimulus-Duration, with a large effect size [$F(2,52) = 24.015$, $p < .001$, $\eta^2_p = .480$]. Group did not have a significant main effect [$F(1,26) = .056$, $p = .815$, $\eta^2_p = .002$] and the Group*Stimulus-Duration interaction was also non-significant [$F(2,52) = .021$, $p = .980$, $\eta^2_p = .001$]. Follow-up analyses of the stimulus-type effect using post-hoc comparisons revealed that participants had significantly more FAs for 400ms than for 700ms trials [$t(26) = 3.808$, $p < .001$, $p_{bonf} < .001$], more 700ms than 1000ms FAs [$t(26) = 3.721$, $p < .001$, $p_{bonf} =.003$], and more 400ms than 1000ms FAs [$t(26) = 6.098$, $p < .001$, $p_{bonf} < .001$].

RTs: There was a significant main effect of Stimulus-Duration on Go-trials RTs, with a large effect size [$F(2,52) = 48.366$, $p < .001$, $\eta^2_p = .650$]. Group had a significant main effect [$F(1,26) = 10.106$, $p = .004$, $\eta^2_p = .280$] with HC showing significantly shorter RTs than patients [$t(26) = 3.179$, $p = .004$], but the Group*Stimulus-dDuration interaction in Go RTs was non-significant [$F(2,52) = .150$, $p = .861$, $\eta^2_p = .006$]. Follow-up analyses of the stimulus-type effect using post-hoc comparisons revealed that participants had significantly shorter RTs for 400ms than for 700ms Go-trials [$t(26) = 5.770$, $p < .001$, $p_{bonf} < .001$], for 700ms than 1000ms Go-trials [$t(26) = 4.979$, $p < .001$, $p_{bonf} < .001$], and for 400ms than 1000ms Go-trials [$t(26) = 8.403$, $p < .001$, $p_{bonf} < .001$].

There was a trend for the main effect of Stimulus-Duration on RTs for FAs, with a large effect size [$F(1.65,42.84) = 3.245$, $p = .058$, $\eta^2_p = .111$]. Group did not have a significant main effect [$F(1,26) = 1.302$, $p = .264$, $\eta^2_p = .048$], and the Group*Stimulus-Duration interaction in FA RTs was also non-significant [$F(1.65,42.84) = .012$, $p = .977$, $\eta^2_p = .000$]. Follow-up analyses of the stimulus-type effect using post-hoc comparisons revealed that participants had significantly shorter RTs for 700ms than for 1000ms FAs but the comparison did not survive Bonferroni correction [$t(26) = 2.201$, $p = .037$, $p_{bonf} < .110$], but the other comparisons were non-significant [$p > .05$].

7.4.7. Relationship between LDT Performance and Neuropsychological Measures

Correlations between the LDT variables and neuropsychological measures are presented in Table 7.6.a. The HVLT-R discrimination index scores significantly predicted 57% of the overall LDT performance variance in patients [$F(1,6) = 8.062$, $p = .030$, $R^2 = .573$]. The LNST significantly predicted 55% of the variance of high-frequency words accuracy [$F(1,6) = 7.496$, $p = .034$, $R^2 = .555$]. No other significant associations were found.

7.4.8. Relationship between LDT Performance and Psychopathology Scores

Table 7.7. shows all correlations between LDT performance and psychopathology scores. In patients, the Relationships subscale of BPQ significantly predicted over 47% of the overall LDT performance variance [$F(1,11) = 9.853$, $p = .009$, $R^2 = .473$] and over 49% of the variance of correct pseudohomophones [$F(1,13) = 12.748$, $p = .003$, $R^2 = .495$]. The Relationships subscale of BPQ and BIS-11 Motor impulsivity significantly predicted over 63% of the real nonwords variance [$F(1,12) = 10.336$, $p = .002$, $R^2 = .633$] with the Relationships subscale of BPQ accounting for nearly 46% [*F Change* $(1,13) = 10.973$, $p = .006$, R^2 *Change* $= .458$]. The PCL-R Lifestyle and SPQ Interpersonal together predicted over 61% of the variance of low-frequency words [$F(1,12) = 7.980$, $p = .008$, $R^2 =$

.615], with psychopathic Lifestyle accounting for 34% [*F Change* (1,11) = 5.748, p = .035, R^2 *Change* = .343] and SPQ Interpersonal accounting for 27% [*F Change* (1,10) = 7.051, p = .024, R^2 *Change* = .272] of the overall variance. All other measures which significantly correlated with the LDT variables (Table 7.7.) were excluded as non-significant by the regression models.

Table 7.6. Spearman correlation coefficients between LDT performance variables and reading skills and other neuropsychological measures for patients.

7.6.a. Self-report measures	LDT Correct All r_s (p)	LDT Correct high-frequency r_s (p)	LDT Correct low-frequency r_s (p)	LDT Correct pseudo-homophones r_s (p)	LDT Correct real nonwords r_s (p)
TOPF-UK (n = 9)	.533 (.139)	.550 (.125)	**.778*** (.014)	-.034 (.932)	.102 (.794)
WASI-II IQ (n = 11)	.114 (.739)	-.068 (.844)	.373 (.258)	-.147 (.666)	.073 (.831)
WASI-II Vocabulary (n = 11)	-.182 (.592)	-.164 (.630)	.433 (.183)	-.487 (.128)	-.366 (.268)
WASI-II Matrices (n = 11)	.014 (.968)	-.261 (.439)	-.249 (.461)	.248 (.462)	.398 (.225)
LNST (n = 11)	**.680*** (.021)	**.604*** (.049)	.531 (.092)	.348 (.294)	.396 (.228)
HVLT-R (n = 9)	**.817**** (.007)	**.811**** (.008)	.322 (.398)	.217 (.574)	.391 (.298)
DSST (n = 8)	.491 (.217)	.520 (.186)	.599 (.117)	.074 (.862)	.073 (.864)
TMT A (n = 9)	.092 (.814)	-.418 (.262)	.372 (.324)	.171 (.660)	.094 (.810)
TMT B (n = 9)	.067 (.865)	-.151 (.699)	.375 (.321)	.051 (.896)	-.009 (.983)
BADS Key Search (n = 9)	.211 (.586)	**.757*** (.018)	-.081 (.836)	.000 (1.000)	.000 (1.000)
BADS Zoo Map (n = 7)	.722 (.067)	.529 (.222)	.661 (.106)	.000 (1.000)	.000 (1.000)
Stroop (n = 8)	-.262 (.531)	.164 (.699)	-.048 (.910)	-.275 (.509)	.049 (.908)

$^{*} p < .05$; $^{**} p < .01$

Note: TOPF-UK – Test of Premorbid Functioning; WASI-II – Wechsler Abbreviated Scale of Intelligence; LNST – Letter Number Span Task; HVLT-R – Hopkin's Verbal Learning Test-Revised; DSST – Digit Symbol Substitution Test; TMT – Trail Making Test; BADS - Behavioural Assessment of the Dysexecutive Syndrome.

7.6.b. Reading skills	LDT Correct All r_s (*p*)	LDT Correct high-frequency r_s (*p*)	LDT Correct low-frequency r_s (*p*)	LDT Correct pseudo-homophones r_s (*p*)	LDT Correct real nonwords r_s (*p*)
GORT-5 rate scaled (*n* = 15)	.448 (.094)	-.031 (.911)	**.633*** (.011)	.162 (.565)	.151 (.591)
GORT-5 accuracy scaled (*n* = 15)	.321 (.244)	-.296 (.284)	**.566*** (.028)	.106 (.706)	.101 (.721)
GORT-5 fluency scaled (*n* = 15)	.397 (.143)	-.227 (.415)	**.651**** (.009)	.147 (.602)	.174 (.535)
GORT-5 comprehension scaled (*n* = 15)	.321 (.244)	-.151 (.592)	**.669**** (.006)	.058 (.836)	.042 (.882)
GORT-5 ORI (*n* = 15)	.389 (.152)	-.153 (.587)	**.699**** (.004)	.091 (.748)	.107 (.705)
CTOPP RDN scaled (*n* = 13)	-.227 (.457)	-.003 (.992)	-.080 (.794)	-.196 (.522)	-.328 (.274)
CTOPP RLN scaled (*n* = 13)	.097 (.753)	.006 (.985)	-.180 (.557)	.206 (.500)	.035 (.910)
CTOPP Blending nonwords scaled (*n* = 13)	.072 (.814)	.308 (.306)	.198 (.517)	-.100 (.745)	-.166 (.588)
CTOPP Segmenting nonwords scaled (*n* = 13)	.198 (.516)	.543 (.055)	.313 (.298)	-.135 (.660)	-.176 (.565)
CTOPP APA composite (*n* = 13)	.177 (.562)	.455 (.118)	.306 (.309)	-.139 (.650)	-.185 (.545)
CTOPP RSN composite (*n* = 13)	-.079 (.798)	.007 (.981)	-.132 (.667)	-.033 (.914)	-.191 (.531)

* $p < .05$; ** $p < .01$

Note: GORT-5 – Gray Oral Reading Test; ORI – Oral Reading Index; CTOPP – Comprehensive Test Of Phonological Processing; RDN – Rapid Digit Naming; RLN – Rapid Letter Naming; APA – Alternative Phonological Awareness; RSN – Rapid Symbolic Naming;

Table 7.7. Spearman correlations between LDT performance variables self-report psychopathology measures (n = 15) and PCL-R scores (n = 14) in patients.

	LDT Correct All	LDT Correct high-frequency	LDT Correct low-frequency	LDT Correct pseudo-homophones	LDT Correct real nonwords
	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)
SPQ-BR Cognitive Perceptual	-.242 (.426)	.088 (.775)	-.424 (.148)	-.116 (.705)	.044 (.886)
SPQ-BR Interpersonal	-.551 (.051)	-.265 (.382)	**-.596*** (.032)	-.179 (.559)	-.197 (.520)
SPQ-BR Disorganised	**-.780**** (.002)	-.205 (.503)	-.343 (.251)	-.549 (.052)	-.526 (.065)
BIS-11 Attention	-.327 (.234)	-.471 (.076)	-.385 (.157)	.008 (.977)	-.060 (.832)
BIS-11 Cognitive Instability	-.164 (.560)	.130 (.644)	.060 (.832)	-.416 (.123)	-.337 (.220)
BIS-11 Motor	-.317 (.250)	-.224 (.423)	.294 (.288)	**-.593*** (.020)	**-.677**** (.006)
BIS-11 Perseverance	**-.522*** (.046)	-.116 (.682)	-.103 (.714)	**-.609*** (.016)	**-.714**** (.003)
BIS-11 Self-Control	-.294 (.287)	-.021 (.941)	.040 (.886)	-.249 (.372)	-.316 (.251)
BIS-11 Cognitive Complexity	-.243 (.384)	-.257 (.354)	-.016 (.956)	-.179 (.523)	-.298 (.281)
BPQ Impulsivity	.027 (.923)	.161 (.567)	.230 (.409)	-.098 (.729)	-.114 (.686)
BPQ Affective Instability	**-.528*** (.043)	-.093 (.742)	.135 (.631)	**-.732**** (.002)	**-.579*** (.024)
BPQ Abandonment	**-.592*** (.020)	-.263 (.344)	**-.572*** (.026)	-.237 (.394)	-.158 (.574)
BPQ Relationships	**-.682**** (.005)	-.025 (.930)	-.176 (.531)	**-.742**** (.002)	**-.667**** (.007)
BPQ Self-Image	-.217 (.438)	-.021 (.940)	-.441 (.100)	.091 (.748)	.017 (.953)
BPQ Suicide	-.199 (.476)	-.047 (.868)	.172 (.539)	-.379 (.163)	-.352 (.198)
BPQ Emptiness	-.432 (.108)	-.179 (.523)	-.282 (.308)	-.262 (.345)	-.139 (.621)
BPQ Intense Anger	-.205 (.464)	-.324 (.238)	.030 (.915)	-.143 (.611)	-.057 (.840)
BPQ Quasi-Psychotic States	-.402 (.137)	.079 (.780)	-.215 (.443)	-.513 (.051)	-.341 (.213)
PCL-R Interpersonal	-.097 (.741)	.250 (.388)	-.240 (.409)	-.039 (.896)	-.136 (.642)
PCL-R Affective	**-.584*** (.028)	-.135 (.646)	-.446 (.110)	-.289 (.317)	-.339 (.236)
PCL-R Lifestyle	-.389 (.169)	-.418 (.137)	**-.596*** (.025)	.078 (.790)	-.054 (.855)
PCL-R Antisocial	-.281 (.331)	-.206 (.480)	**-.558*** (.038)	.134 (.649)	.119 (.685)
PCL-R Total	-.521 (.056)	-.227 (.435)	**-.747**** (.002)	.032 (.913)	-.138 (.639)

** p < .05; ** p < .01. Significant correlations are in* ***bold****.*

Note: SPQ-BR – Schizotypal Personality Questionnaire - Brief; BIS-11 – Barratt Impulsiveness Scale; BPQ – Borderline Personality Questionnaire; PCL-R – Psychopathy Checklist-Revised; LDT – Lexical Decision Task.

7.5. Discussion

This study examined reading skills in forensic mental health services (medium secure units) and their relationship with other cognitive abilities (premorbid IQ, current IQ, working memory, verbal learning and memory, and executive functioning) and a range of self-reported psychopathology-related traits, out of which some were found associated with the reading skills, namely: positive schizotypy (Cognitive Perceptual), Lifestyle psychopathy, and borderline traits of Abandonment and Impulsivity.

As hypothesised, patients scored significantly below their age group norms in all reading skills, with very poor performance in phonological processing and comprehension reflected in the respective composite scores. In GORT-5, comprehension, rate, accuracy, and fluency scores were between 9-11 years of age, equivalent to 5-6 years of schooling, which suggests significant deficits. The phonological processing scores in manipulating with and separating individual sounds were between 5-6 years of age, an equivalent to 1-2 years of schooling. The Rapid Symbolic Naming (RSN) score reflecting the phonological ability to quickly recognise and read letters and numbers was poor but significantly higher than Alternate Phonological Awareness (APA), the ability to manipulate with and separate sounds. Patients in this sample scored below the overall education levels and their age norms, with the sample including only two patients without a formal education. These results are in concordance with the finding from previous studies on people with schizophrenia using the same instruments (Martínez et al., 2012; Revheim et al., 2006, 2014), although patients scored even lower than found in these previous studies. Patients in this study were prevalently diagnosed with paranoid schizophrenia or another form of psychotic disorder and had a serious offence history. Therefore, these findings are in line with earlier discussed differences between non-forensic and forensic psychiatric samples with comorbid diagnoses in a variety of reading skills (Chapter 2 - Vanova et al., (2021)).

When investigating the relationship between readings skills and cognitive abilities, few significant results were found. The premorbid IQ which uses a single-word reading method significantly predicted reading rate scores. This result could be expected because of the similarity between the two assessment methods. In phonological processing, only the ZOO map (executive functioning) and current IQ scores were significant predictors of abilities to rapidly recognise and vocalise letters and numbers. Executive functioning is considered to facilitate phonological processing in decoding letters into sounds and merging them together (Cartwright, 2012). However, the lack of a strong predictive relationship between reading skills measures and cognitive abilities is a pattern seen in people with SZ (Chapter 2, Vanova et al., (2021)). Previous studies did not find direct links between executive functioning or working memory and reading in SZ (Martínez et al., 2012). Proposedly, phonological processing can be viewed as a function independent from other cognitive abilities (Siegel, 1993) which could explain the pattern observed in this and other studies. Moreover, no cognitive abilities were able to predict comprehension scores as reported previously in SZ suggesting that some reading deficits can be unrelated to cognition (Revheim et al., 2006). Given the links between SZ and dyslexia (Whitford et al., 2018), the reading deficits in SZ follow the same pattern as in dyslexia that cannot be explained by other cognitive deficits (Lyon et al., 2003).

In psychopathology measures, as hypothesised, a strong negative relationship was detected between the Cognitive Perceptual subscale of schizotypy and accuracy, comprehension, and general reading ability scores. The Cognitive Perceptual subscale reflects on the positive schizotypy symptoms. Positive symptoms, including hallucinations, have been also previously associated with deficits in phonological processing (Arnott et al., 2011; Revheim et al., 2006; J. Wang et al., 2015), reading efficiency (Curzietti et al., 2018), and comprehension (Revheim et al., 2006). A similar pattern can be seen in the results from Chapter 4, where positive schizotypy (Unusual Experiences) scores partially predicted the lexical decision performance in HC. The association between positive schizotypy and reading-related skills deficits can be related to the results from the LDT in patients as they were significantly lower in accuracy with longer RTs than HC in identifying low-frequency words. However, the two groups in this study did not differ in positive schizotypy and differed only in the Interpersonal traits which are related to the negative symptomatology in schizophrenia. This may be due to the limited power but also to the use of antipsychotic medication which is known to be most effective in reducing the positive symptoms of psychosis (Gharabawi et al., 2006; Lally & MacCabe, 2015; Tapp et al., 2003).

Patients in this sample had low to medium scores on psychopathy. The PCL-R Lifestyle was a significant predictor of the ability to quickly and accurately pronounce letters and numbers (RSN). Higher Lifestyle psychopathy had a facilitating effect on rapid letter (RLN) and number (RDN) naming abilities, leading to a shorter time necessary to complete the task without excessive errors. The RSN skills are an important part of phonological processing and require quick access to the information in long-term memory and directly influence word recognition and pronunciation (Wagner et al., 2013).

Interestingly, a previous study reported the positive relationship between RSN and the Superficial item of the short form of PCL (Selenius & Strand, 2015). The authors argued that psychopaths with high Superficial charm scores possess a good ability to quickly express themselves to avoid unfavourable situations, or that individuals with good rapid naming skills tend to score higher on the Superficial item. However, patients in this sample scored overall very poorly in RSN, below their age norms. This can indicate that RSN is the least impaired component of phonological processing and that the other components (e.g., APA) are severely impaired which leads to reading deficits. The Lifestyle facet was also a significant predictor of the ability to recognise low-frequency words when higher psychopathy Lifestyle led to lower low-frequency words scores in the LDT. This finding supports the theory of impaired phonological processing components, especially the APA. As discussed in previous chapters

(Chapters 1 and 4), low-frequency words recognition follows the sublexical pathway and therefore good phonological processing is a key to successful word recognition and low-frequency word recognition was significantly impaired in patients compared to HC.

The feelings of abandonment and loneliness dimensionally related to BPD traits showed a significant negative relationship with reading rate and fluency. Neurocognition can be severely impaired in BPD diagnosis (Fertuck et al., 2006; Ruocco, 2005), including deficits in single-word reading tests (Black et al., 2009; Swirsky-Sacchetti et al., 1993). These deficits in single-word recognition can result in slower and less accurate text reading. A positive relationship was found between increased impulsivity in BPQ and the ability to quickly recognise and pronounce letters and numbers. This may suggest that certain aspects of impulsivity can have a positive relationship with reading skills (Ku et al., 2020), which require quick reactions or recognition.

7.5.1. Limitations

The present study is presented as a pilot as it included only a small number of patients, without control data on reading skills and other cognitive measures. Due to the linear regression models ran on a small number of data points, we were unable to determine the combinations of psychopathology-related traits that are linked to reading skills deficits. Also, the large number of correlations examined, increase the probability of false-positive results. No information about patients' medication was retrieved. These findings present limited support to the hypotheses and any interpretations need to be considered within the study context of people with MI and a history of violence as a non-forensic group with MI was not included.

7.6. Chapter Summary

People with psychotic disorders (13/15 with SZ) and a history of violence demonstrated severe reading deficits in phonological processing and comprehension. The deficits in phonological processing seem to be related to executive functioning, premorbid and current IQ whereas the comprehension deficits are independent of cognitive performance. This patient cohort, in comparison to HC, also showed a pattern of decreased ability to accurately recognise low-frequency words that require good phonological processing as it follows the sublexical route in word recognition. Additionally, the deficits in phonological processing and low-frequency word recognition were predicted by the Lifestyle psychopathy trait (Factor 2) and poor reading accuracy, comprehension, and low-frequency word recognition were predicted by the positive schizotypal traits (Cognitive Perceptual). The findings from this chapter are in line with the behavioural study (Chapter 4) where psychopathy traits of callous aggression – Meanness (the equivalent of PCL-R Factors 2 and 1) was the most significant predictor of word-nonword recognition, with a contribution of Motor impulsivity, fearless dominance (Boldness – Factor 1), and positive schizotypal traits (Unusual Experiences).

Chapter 8: General Discussion

8.1. Chapter Aims and Overview

This chapter provides a summary and synthesis of the findings reported in this thesis. First, the research questions are presented alongside the hypotheses probed in each of the empirical investigations, followed by the evidence offering (or a lack of) support for them. Then, the implications of the findings for the clinical practice and future research are discussed.

8.2. Overview of Thesis Findings

The data presented in Chapters 4-7 contribute to the overreaching aims to: a) characterise the relationships between reading skills and psychopathology-related traits, and b) examine the role of factors, such as functioning in other cognitive domains, sex, and language familiarity in reading skills. The research questions, hypotheses, and findings are summarised in Table 8.1.

As noted in Table 8.1, psychopathy traits were found to be the most prominent predictors of reading skills both in the general population (Chapter 4) and the forensic sample (Chapter 7). Higher Motor impulsivity also emerged as an important trait in the context of reading skills. Specifically, higher Motor impulsivity was associated with lower accuracy in word-nonword recognition in non-native speakers (Chapters 4 and 5). Motor impulsivity was also associated with lower neural activity in areas commonly associated with phonological processing (Chapter 6). The traits of impulsivity are typically elevated in people with psychopathy and a history of violence (Hart & Dempster, 1997; Ray et al., 2009; Snowden & Gray, 2011) who also have poor reading skills (Chapter 2; Vanova et al., 2021). Consistent with this, patients with higher Lifestyle psychopathy (Factor 2) that manifests as impulsivity in everyday life and choices, were found to have lower accuracy in unfamiliar (low-frequency) word recognition related (Chapter 7). Therefore, higher impulsivity/low inhibitory control appears to be driving the relationship between psychopathic traits and poor reading skills. Moreover, positive schizotypal traits were suggested to be associated to some extent with poor word-nonword recognition in the general and clinical populations and to poor reading accuracy and comprehension (Chapters 4 and 7). Positive schizotypy was related to lower activity in the cerebellum, but not in any core reading-related areas (Chapter 6).

Out of the possible reading influencing factors that were examined, sex did not play a role, but language familiarity did (Chapters 4 and 5). Language familiarity also played a role in the relationship between reading-related skills and impulsivity, where non-native speakers tended to guess the right lexical response (Chapter 5). Among specific cognitive abilities, executive functioning was negatively associated with the ability to quickly pronounce letters and numbers (Rapid Symbolic Naming – RSN), and immediate verbal learning was associated with LDT performance in the forensic sample (Chapter 7). This indicates a dyslexia-like profile in people with mental illness and a history of violence, although some of the reading skills deficits may be explained by impairments in executive functioning and verbal learning.

Table 8.1. Research questions, hypotheses, and main findings from investigations reported in Chapters 4-7.

Chapter	Research question	Hypothesis	Findings
4 – LDT and psychopathology	How are the psychopathology-related traits of schizotypy, psychopathy, impulsivity, and affective dysregulation associated with various aspects of lexical decision task (LDT) performance?	Higher schizotypal, psychopathic, and impulsivity traits will be associated with lower accuracy for words and nonwords and longer RTs (especially for schizotypy) for correct recognition of words.	Psychopathic traits of Meanness and Boldness were the strongest predictors of LDT accuracy with a smaller contribution of positive schizotypy (Unusual Experiences). Motor impulsivity and Positive Urgency were associated with lower low-frequency words accuracy in non-native English speakers only.
		Affective traits will have no association with task performance.	No significant associations were found between LDT performance and affective traits.

Chapter	Research question	Hypothesis	Findings
5 – LDT, impulsivity, and language	How is motor impulsivity/poor inhibitory control associated with lexical decision performance?	A higher number of false alarms (FAs) on the Go/No-Go (GNG) task (indicating higher impulsivity) will be associated with lower overall LDT performance in the entire sample.	The FAs were not associated with LDT performance, but the RTs for FAs were. Shorter RTs for FAs accompanied lower nonword accuracy.
	Is the motor impulsivity/poor inhibitory control associated	A higher number of FAs on the GNG task will be associated with lower	No association was found between FAs and LDT performance. In non-native speakers,

	differently with lexical decision performance in native and non-native English speakers?	accuracy for low-frequency words, pseudohomophones, and real nonwords in non-native speakers.	lower impulsivity (longer RTs for 400ms FAs and higher accuracy for 1000ms) was associated with higher real nonwords accuracy.

Chapter	Research question	Hypothesis	Findings
6 – fMRI of LDT and psychopathology	What are the common and distinct neural correlates of recognition of high and low-frequency words, pseudohomophones and real nonwords in the general population?	In line with previous literature, the brain areas involved in phonological processing (left inferior frontal gyrus – IFG, left insula, precentral gyrus bilaterally) will show the strongest activation during real nonwords and lowest activation during the high-frequency words, with pseudohomophones and low-frequency words showing the intermediate level of activity.	The areas of phonological processing were strongly activated in low-frequency words, but the contrasts examining higher activity for nonwords than words did not show significant activity in phonological processing-related areas. High-frequency words showed stronger activity in orthography-related regions of the angular gyrus compared to pseudohomophones or real nonwords.
	What are the neural underpinnings of the association between relevant psychopathology-related traits and LDT performance?	Higher levels of positive schizotypy (Unusual Experiences), psychopathy (Meanness, Boldness) and Motor impulsivity will correlate with lower activations in the areas responsible for phonological processing (IFG, insula, precentral gyrus) when identifying a) low-frequency words, b) pseudohomophones, and c) real	Higher Motor impulsivity was associated with lower activation of the fusiform gyrus bilaterally when identifying high and low-frequency words and real nonwords compared to the baseline. It was also associated with lower activation in the right superior temporal gyrus (STG) when identifying high or low-frequency words over pseudohomophones.

		nonwords in order of increasing involvement of the phonological processing.	Higher Boldness was associated with higher activity for low-frequency words over pseudohomophones in the right posterior cingulate. Meanness was associated with higher activity in the ventral diencephalon and caudate nucleus during high-frequency words over real nonwords. Unusual Experiences was associated with lower activation of the left cerebellum in low-frequency words over real nonwords. Only higher Motor impulsivity was related to lower activity in phonological processing areas.

Chapter	**Research question**	**Hypothesis**	**Findings**
7 – Reading deficits in the clinical (forensic) sample	How do individuals with mental illness and a history of violence perform in reading skills in relation to the population norms; and how are their reading skills related to specific cognitive abilities?	The reading skills (comprehension, rate, accuracy, fluency, phonological processing) as measured by established reading tests in patients will be significantly below their age norms. Reading skills scores will positively correlate with the scores in other cognitive domains, namely verbal	All examined reading skills were significantly below the age norms with participants scoring at the primary school levels. Only the executive functioning was negatively associated with phonological processing skills (Rapid Symbolic Naming and Segmenting

	learning and memory, and executive functioning.	Nonwords subscales). The overall LDT performance was positively associated with immediate verbal learning.
How are the traits of schizotypy, borderline personality, and impulsivity related to reading skills in people with mental illness and a history of violence?	Reading skills scores will negatively correlate with dimensional schizotypal and psychopathy scores.	The Cognitive Perceptual domain of schizotypy was significantly negatively associated with accuracy and comprehension, and low-frequency word recognition accuracy. Lifestyle psychopathy was positively associated with the ability to quickly pronounce letters and numbers, but negatively with low-frequency words recognition accuracy. Overall psychopathy scores (PCL-R Total) were negatively associated with reading comprehension and overall reading ability. The BPQ Abandonment was negatively associated with rate and fluency. The Impulsivity in BPQ was positively associated with the ability to quickly pronounce numbers. BPQ Relationships were negatively associated with overall word-nonword recognition, especially with the pseudohomophones.

Note: BPQ – Borderline Personality Questionnaire; GNG – Go/No-Go (task); IFG – Inferior frontal gyrus; LDT – Lexical decision task; RT – Reaction time; STG – Superior temporal gyrus.

8.3. Reading Skills and Psychopathology: Dimensions and Categories

The investigation presented in this thesis examined the links between reading skills deficits and dimensional psychopathology-related traits and their corresponding functional neural correlates. The systematic review and meta-analysis revealed severe deficits in reading skills in people diagnosed with MI, specifically in people with SZ and those with psychopathy and a history of violence (categorical approach). However, some of the symptoms can be on a continuum and present as personality traits dimensions in non-clinical populations. Moreover, some enhanced psychopathology-related traits are often present in combinations (comorbidities) and are found to be etiologically connected in behavioural or psychobiological aspects (Insel & Cuthbert, 2009). That was also modestly present in the findings reported in this thesis (Chapter 4, Supplementary Table 1). The investigations reported in this thesis examined their unique and shared contribution to reading skills deficits in clinical and non-clinical samples. It is essential to understand how the trait interactions and each trait individually can contribute to difficulties in reading, how these are reflected in neural functioning, and what is the overlap between dimensional and categorical approaches.

The categorical approach in describing MIs has been long embedded in clinical practice. It is considered as a standard due to the relative ease of use, reliability, or the similarities with the diagnostic process of somatic illnesses (Simonsen, 2010). However, the categorical approach poses several limitations, especially, when discussing comorbidities and atypical cases within one category. Therefore, the latest versions of the Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition (DSM-5) (American Psychiatric Association, 2013) and the International Classification of Diseases – 11th Edition (ICD-11) (World Health Organization, 2020) have been extended for the dimensional assessment of symptoms severity and subclinical symptomatology (Gaebel et al., 2020; Narrow & Kuhl, 2011).

In recent years, a research framework focusing on the dimensional investigation of mental illnesses emerged – the Research Domain Criteria Initiative (RDoC), emphasizing the need to explore the dimensions of cognitive domains functioning (among other domains) ranging from normal to abnormal. Although not meeting all RDoC framework criteria for dimensional research (Cuthbert & Insel, 2010), the research presented in this thesis focused on dimensional traits in both clinical and non-clinical samples, integrated data from multiple modalities, and assumed interactions between the dimensional traits. The dimensional approach focuses on transdiagnostic criteria of mental illnesses rather than specific symptoms categories and their underlying mechanisms within multidisciplinary research (Insel et al., 2010). Future research should focus on the transdiagnostic cognitive deficits in a relation to psychopathology, as cognitive deficits often overlap between clinical diagnoses (Abramovitch et al., 2021).

The scarcity of the dimensional approach in investigations of reading skills meant that it was difficult at times to fully place the findings into context. The dimensional approach in comparison to the categorical approach can better describe and examine the subtle changes in relationships between psychopathology-related traits and cognition. Another advantage and a reason to research psychopathology-related traits as a dimensional construct is the presence of comorbidities among mental illnesses which can be better described as a continuum with the various interactions than as mutually exclusive categories (Krueger & Piasecki, 2002). The categorical diagnoses are well-described constructs with a strong background of evidence, therefore, incorporating the examination of the dimensional psychopathology in discreet diagnoses would help to build on the already obtained knowledge and improve the predictive validity of the diagnostic tools (Helzer et al., 2006). Despite the small sample size (due to the COVID-19 pandemic) presented in the clinical study (Chapter 7), this thesis attempted to integrate these two approaches, and further research should focus on describing the reading skills deficits on a continuum in various MIs and with regard to the related traits.

8.3.1. Schizophrenia Spectrum Conditions

People with SZ spectrum conditions show mild to severe deficits in all reading skills – phonological processing, comprehension, single-word reading, rate, speed, accuracy, and fluency (Chapter 2). These deficits are even more pronounced in forensic populations, often diagnosed with a comorbid MI, psychopathy, and/or PD (Chapter 2 – Sections 2.4.4 and 2.4.5). Schizophrenia and dyslexia share common neurodevelopmental precursors (Whitford et al., 2013) and oculomotor movement deficits (Richardson & Gruzelier, 1994; Whitford et al., 2018) which can contribute to reading deficits. This could indicate that elevated schizotypal traits, SZ, and dyslexia can share common deficits in bottom-up processing of visual information which can lead to reading skills deficits. The deficits were also present in the clinical study (Chapter 7) where forensic participants with MI (13/15 with psychosis) and low-to-medium levels of psychopathy scored on an equivalent to primary school levels in comprehension, rate, accuracy, fluency, and in all phonological processing skills, below their age norms or achieved education levels. These deficits were not fully explained by their performance of measures of verbal learning and memory, and executive functioning only partially explained their poor phonological processing skills (the rapid symbolic naming). These results support the presence of a dyslexia-like reading profile among psychosis patients with a history of violence.

Higher schizotypy has been previously observed in people with dyslexia (Richardson, 1994; Richardson & Gruzelier, 1994). A strong predictive relationship between positive schizotypal traits (O-LIFE – Cognitive Perceptual) and poor reading comprehension and accuracy and low-frequency word recognition was observed in the clinical sample (Chapter 7). The lack of an association between schizotypal traits and any of the phonological processing measures was most likely explained by the very poor performance shown by the entire sample.

These findings are in line with the suggestions (Richardson, 1994; Richardson & Gruzelier, 1994) that certain aspects of schizotypy can potentially contribute to, or aggravate, poor reading skills. However, schizotypal traits (O-LIFE Unusual Experiences) alone seem not to be the only or strong-enoughpredictor of reading skills in the general population as these only partially explained the word-nonword recognition accuracy (Chapter 4). Similarly, in the fMRI study (Chapter 6), positive schizotypal traits were only associated with changes in the activity in the left cerebellum when identifying low-frequency words over real nonwords. Although the cerebellum is not a core reading brain area, it is has been implicated in reading (Elnakib et al., 2014) as well as in task management and multitasking components of executive function (Bellebaum & Daum, 2007). It is also an area strongly implicated in the cognitive dysmetria model of SZ (Andreasen et al., 1998), and is known to show structural and functional aberrations in people with schizotypal traits (Andreasen et al., 1996, 1998; Y. Wang et al., 2019). In this context, it is also relevant to mention that executive function was found to be positively associated with reading skills in the clinical sample (Chapter 7), supporting further the findings of some (though not all) earlier studies showing a positive association between cerebellar volumes and cognitive functions, including verbal IQ, as reviewed and discussed previously by (Antonova et al., 2004).

8.3.2. Psychopathy

Elevated psychopathy traits and the clinical diagnosis of psychopathy/PD consistently emerged as significant predictors of poor reading skills (Chapters 2, 4, 7). As discussed in Chapter 2, community and forensic psychiatry samples with high psychopathy traits show medium to high deficits in phonological processing and comprehension in comparison to controls, with the forensic samples showing significantly greater deficits than the community sample (Chapter 2). The forensic sample in the clinical study (Chapter 7) scored low to medium in psychopathy measures with comorbid MI (mainly psychosis) and a history of violence. In this study, the total psychopathy levels negatively correlated with reading comprehension, and elevated psychopathy Lifestyle trait was a significant predictor of poorer ability to recognise low-frequency (mostly unfamiliar) words from nonwords which could indicate deficits in the integration of reading skills of the sublexical pathway (orthography to phonology integration and phonological awareness). Elevated psychopathy Lifestyle trait, however, was positively associated with the rapid symbolic naming requiring quick (and low level) processing of information. It, therefore, appears that elevated psychopathy related deficit probably lies in more complex reading skills (e.g., comprehension) and their integration reflected by low word-nonword recognition accuracy (Chapters 2 and 7) but not apparent otherwise. This was also partially reflected in the behavioural study where callous aggression (Meanness) and fearless dominance (Boldness) were associated with poorer nonword recognition (Chapter 4). In the fMRI study (Chapter 6), higher Meanness was related to neural activations for high-frequency words (over real nonwords) in the ventral diencephalon and caudate nucleus (can also be expressed as lower activation during real non-words over high-frequency words). These areas have been associated with psychopathy in previous studies (Boccardi et al., 2013; Glenn & Yang, 2012) and also found to be overactive in patients with antisocial PD and a history of violence (Kumari et al., 2009). However, they are not considered core reading-related areas, suggesting that the impact of psychopathy in reading skills is likely to be mediated by some other functions linked to these regions, such as atypical sensory processing or poor impulse control (Brimo et al., 2021; Reinig et al., 2017).

8.3.3. Impulsivity/Inhibitory Control and Language Familiarity

Self-reported Motor impulsivity was associated with poorer low-frequency word accuracy in non-native speakers (Chapter 4). This suggests individuals who are less familiar with a language (non-native speakers), due to higher impulsivity/poorer inhibitory control, may not be able to adequately reject incorrect or inappropriate lexical representations in their memory similar to the presented stimulus and therefore, guess the right answer (leading to mistakes). Moreover, behavioural motor impulsivity/poor inhibitory control seems to be associated with poorer nonword recognition in non-native speakers (Chapter 5). This also suggests inappropriate lexical rejections due to poor inhibitory control. Low-frequency words and nonwords follow the same sublexical pathway in recognition and cannot be identified automatically as the stimulus does not compare to those lexical entries available in the mental vocabulary. At the neural level, higher Motor impulsivity was associated with activity changes for high and low-frequency words and real nonwords (Chapter 6), mainly in the areas responsible for phonological processing (right STG) and selection of the competing lexical representations (right IFG). These results also suggest that individuals with higher Motor impulsivity have a lower ability to integrate lexical information bilaterally.

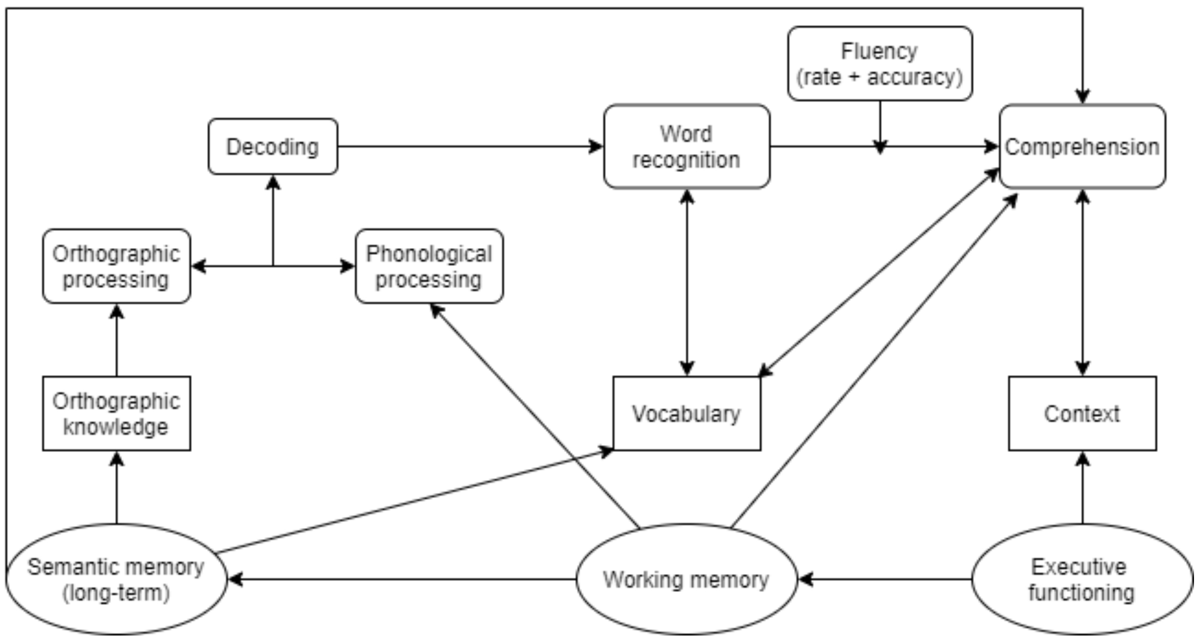
Impulsivity can also have a facilitatory effect in native speakers with a proficient command of the language. Behavioural impulsivity in the GNG task led to quicker responses to familiar stimuli (high-frequency words) in native speakers (Chapter 5), suggesting a high level of certainty with these stimuli. The Cognitive Instability trait was associated with better accuracy in identifying low-frequency words (Chapter 4). Thus, to a certain extent, attentional impulsivity can help to shift between competing lexical representations. It is reasonable to conclude that higher impulsivity/poor inhibitory control plays a significant role and depending on the command of the language it can have a beneficial effect in individuals with a sufficient command of the language but lead to more errors in non-native speakers or individuals with a poorer command of the language. In multilingual individuals, inhibitory control is responsible for switching from non-native to native language and selecting from competing representations (Linck et al., 2008, 2012).

Impulsivity is implicated in multiple psychopathologies (Nigg, 2000), including SZ spectrum conditions (Ettinger et al., 2018) and psychopathy (Moeller et al., 2001). In the latter, and a subgroup of SZ patients who tend to repetitively engage in violence (Kumari et al., 2009), it can lead to aggression and impulsive violence (Edens et al., 2001). In forensic populations (Chapter 7), Motor impulsivity was related to lower real nonword accuracy, but secondary impulsive traits in psychopathy (Lifestyle) appear to play a bigger role in reading than primary motor impulsivity.

8.3.4. Cognitive Functioning and Reading Skills

In the clinical study (Chapter 7), only a few associations were found between reading skills and cognitive functioning. Rapid symbolic naming of letters and numbers, which are part of the low-level phonological processing, was associated with executive functioning, and the overall LDT performance was associated with verbal learning. Findings from the clinical study support the previous research suggesting a dyslexia-like profile in forensic clinical populations, especially in SZ (Whitford et al., 2018) but also suggest that reading deficits in these groups may be partly explained by specific cognitive deficits as theorised in Figure 8.1. Several possible deficits may be related to dyslexia: low-level visual deficits originating in the magnocellular pathway (and potentially responsible for saccadic eye movements), deficits in low-level auditory processing responsible for the detection of certain sounds and tones, and semantic and syntactic deficits that can, however, be an effect of poor reading skills themselves (Vellutino & Fletcher, 2005). In general, dyslexia is characterised by deficits in orthographic knowledge and phonological processing and leads to the inability to create orthographic representations of whole words. Thus, an individual with dyslexia may rather use the sublexical pathway (Zoccolotti et al., 2016) that can lead to a slower reading rate and accuracy. This was also partially reflected in the behavioural study (Chapter 4) where the positive schizotypal traits modestly predicted a small amount of the LDT accuracy. Future research should focus on clarifying the role of SZ symptomatology in the risk of developing dyslexia to predict instances of it with increased accuracy.

Figure 8.1. Hypothesised contributions of specific cognitive domains to reading skills.



8.4. Clinical Implications and Considerations

8.4.1. Impact on Everyday Life

The findings reported in this thesis add to the current literature on poor reading skills in people with MIs. Poor reading can negatively affect behaviour and can lead to problems in the ability to live fulfilling and independent lives, create social bonds, and be productive in a working environment. Social functioning, personal autonomy, organisation ability, physical activity, and the ability to function in structured environments are significantly negatively affected in people with psychosis who also demonstrate significant impairment in reading comprehension (Reichenberg et al., 2002). Impairments in comprehension and single-word reading are also associated with lower socioeconomic status and can negatively affect the independent living ability in SZ (Revheim et al., 2014). Moreover, in the systematic review (Chapter 2), apart from deficits in reading comprehension, people with SZ demonstrate pronounced impairments in lower-level reading abilities (phonological processing and decoding) that are known to be essential for good reading comprehension. Some research findings also indicate that deficits in phonological processing and reading fluency have a strong negative impact on social functioning (Dondé et al., 2019). Comprehension deficits are known to have a significant negative influence on decision-making capacity in SZ (Palmer & Jeste, 2006), which should be considered when seeking written informed consent (often requiring a long information sheet) to include cohort in research studies. For example, it would be advisable to dedicate more time to explain the research aims, procedures and ethical considerations to the patient (Hayes & O'Grady, 2003), and not rely on their understanding of the written materials alone. Furthermore, everyday functioning is also likely to be strongly affected by the combination of reading problems with lower intelligence, working memory, and executive functioning abilities (Bagner et al., 2003; Dondé et al., 2019; Palmer & Jeste, 2006; Revheim et al., 2014). Reading in combination with other cognitive abilities can serve as strong predictors for socioeconomic achievement, functioning and rehabilitation efforts in the SZ spectrum and psychosis.

In addition to SZ, reading deficits and symptoms of dyslexia are often underdiagnosed in people with MI, which can explain their inability to complete higher education and obtain jobs (Daderman et al., 2004). Similarly, in forensic settings, marked reading deficits in people with MI and a history of violence may have contributed to their poor adjustment within the community (Svensson et al., 2015) which in turn increased the risk of incarceration. Hospitalisation often puts high demands on a reading of people with MIs. A study analysing hospital documents usually presented to patients (e.g. treatment plans, evaluation forms, help booklets, etc.) found that these required comprehension levels between 11 and 13 years of education, while most of the psychiatry patients evaluated (psychosis, alcoholism, PD) had comprehension equivalent to 9.5 years of education (Berg & Hammitt, 1980). This indicates a gap that exists between reading levels required in everyday life compared to the actual reading abilities of people with MI. Furthermore, progression and engagement in therapeutic activities within mental health services often depend on good reading and language skills (e.g., understanding care plans) which highlights the need to accurately identify reading skills deficits in people with mental illness. Similarly, to people with SZ, reading deficits in other MIs and PD especially in forensic settings also pose specific demands on conducting research. Low literacy reflected as the deficit in single-word reading skills was found to have an impact on research participation of people with ASPD which resulted in problems to comprehend research terms and instructions (Davidson et al., 2011).

Reading skills, therefore, should be considered as important predictors of socioeconomic achievement, functioning and rehabilitation efforts for people with MIs, especially those with psychosis and/or in forensic populations.

8.4.2. Possible Interventions to Improve Reading Skills in Relevant Clinical Populations

Poor reading skills pose a serious challenge for mental health interventions and their accessibility (Sentell & Shumway, 2003) for a variety of reasons, including understanding information related to medical and clinical appointments, prescription labels, consent forms, therapy, and related assignments.

Reading deficits also predict poor psychosocial outcomes in people with MI (Dondé et al., 2019; Revheim et al., 2014). Given these negative outcomes, there is a need to consider reading skills deficits as a therapeutic target and address them, for example, with interventions used for treating or managing dyslexia (Law et al., 2015; Whitford et al., 2018). These interventions include attempts to improve phonological awareness and connecting letters with sounds (orthography-to-phonology conversion) (Snowling, 2013). Previous research has found personalised reading skills interventions targeting phonological processing, orthographic conversion, and comprehension to be effective in adults with reading deficits and learning disabilities (Vanderberg et al., 2011). Also, adults diagnosed with dyslexia are reported to benefit from multifactorial interventions including error corrections, repeated reading sessions, or fluency exercises (Halldórsdóttir et al., 2017).

It may be possible to improve reading skills in people with SZ and/or psychopathy by building on the aspects of reading skills that are intact or relatively less affected. For example, previous research has shown impaired syntactic information processing (e.g. creating a word salad, when the meaning is not understandable) but intact lexical knowledge (access to words – vocabulary) in SZ (Moro et al., 2015; Tan, Yelland, et al., 2016). Higher context predictability facilitated reading in SZ as accessing familiar information can compensate for some of the reading deficits (Fernández et al., 2016). Similarly, in our findings, word recognition was not associated with positive schizotypal traits in the general population (Chapter 4). In the clinical sample (Chapter 7), the vocabulary (WASI-II), single-word reading (TOPF-UK), and word-nonword recognition were relatively spared in comparison to the deficits observed in comprehension and phonological processing. Future interventions for improving reading could build on the results of the systematic review (Chapter 2), behavioural study (Chapter 4), and the clinical study (Chapter 7), and use the skills that were found to be relatively intact.

Long-term systematic interventions focused on reading, writing, and cognitive skills (i.e., memory, attention, executive functioning) can improve self-perceived reading performance in adults with dyslexia and objectively improve their reading memory, processing speed, and attention (Nukari et al., 2020). Therefore, dyslexia-targeted interventions for adults with MI could also benefit from an approach including sessions focused on cognitive abilities, such as executive function (Chapter 7) that appeared to be related to reading. To some extent, the occupational therapy approach implementing visual aids (e.g. electronic magnification, viewing training) too can improve reading in adults, especially those with vision problems (Smallfield & Kaldenberg, 2019).

Considering the importance of good reading skills in everyday life, as well as for the clinical success of mental health services, there is a clear need to identify methods that can improve reading in SZ and forensic PD populations. Further research is needed to develop targeted reading skills interventions for people with SZ, impulsivity, or psychopathy and reading skills deficits.

8.4.3. Methodological Considerations and Future Research Directions

The investigations reported in this thesis integrated aspects of dimensional and categorical research and included participants from the clinical as well as general populations and had certain methodological strengths and weaknesses. Firstly, the use of a novel version of a well-established GNG paradigm featuring human avatars (Chapter 5) could be considered a strength. This feature was created to use a more ecologically valid task. In recent years, experimental psychological research started including more dynamic stimuli that resemble the real-world experience as an opposition to the often used static, symbolic stimuli (Parsons, 2015). Although the avatars used in the GNG task were static, the images used were extracted from 3D models of full-body human figures. Presumably, cognitive neuroscience research will more frequently use virtual reality in order to simulate real-life, ecologically valid scenarios in research (Kothgassner & Felnhofer, 2020). Secondly, a comprehensive battery of standardised reading assessments was used to capture the extent of deficits in various individual reading skills domains in the clinical populations (Chapter 7). The battery was selected based on previous studies in SZ (Martínez et al., 2012; Revheim et al., 2006, 2014) to capture deficits in the domains crucial in diagnosing dyslexia (Lindstrom, 2019).

As for the limitations, it is important to acknowledge the very limited sample size in the clinical study and a missing control group. This investigation was conducted during the COVID-19 pandemic which caused severe delays in the data collection and limited access to patients. The clinical study aimed to combine the categorical and dimensional approaches in a much larger sample (target $N = 100$), thus, the current data were presented only as a pilot study. This topic requires further research as reading skills assessments are not routinely carried out as part of the evaluation of cognitive abilities in forensic psychiatric services and, therefore, these are not usually part of the cognitive training or other clinical interventions.

In relation to the studies conducted in the general population (Chapter 4-6), the participants were recruited primarily from the university network which poses some limitations. Firstly, the mean age was relatively low (approx. 24 years) with the majority of participants being undergraduate and postgraduate students. Conceivably, this resulted in a limited range of psychopathology-related traits scores. Also, studies presented in this thesis did not control for all demographic characteristics – e.g., sex, ethnicity, handedness, years of education, or language proficiency, although apart from the language other demographic factors were not related to reading skills. To be able to predict the reading skills more reliably in the general population by psychopathology-related traits, future research will need to include a larger sample and account for a broader demographic range regarding age, and objectively quantify the language proficiency of participants. Secondly, most participants had a higher degree education that implies their higher exposure to a broader and more specialised vocabulary. Thus, the LDT may not have been a very demanding task for some participants. On the other hand, recruiting the participants via the university network could be perceived as a strength as these participants provided a considerably homogeneous sample. The future study should incorporate a standardised measure of mental vocabulary as this ability is directly linked with lexical recognition.

The investigation of the associations between the neural correlates of the dimensional psychopathology-related traits and reading-related skills indicated meaningful associations, especially between Motor impulsivity and activation of some areas crucial for reading (Chapter 6), despite a modest sample size. However, due to the limited sample, it was not possible to investigate the impact of the English language familiarity, and this also meant limited power in terms of investigation of the individual differences. The next step would be to investigate the functional connectivity between these areas and their modulation by psychopathology-related traits. It is well known that the magnocellular pathway that plays a role in reading shows some functional and structural alteration in SZ spectrum conditions (Ettinger et al., 2015; Martínez et al., 2012; Revheim et al., 2006). However, little is known as to whether these alterations are present trans-diagnostically in relation to psychopathy and impulsivity and their comorbidities. Additionally, Motor impulsivity as a significant factor modulating the neural activity for lexical recognition was examined via a self-report measure. It would be beneficial to behaviourally examine the effect of poor inhibitory control (high impulsivity) on changes in activations during reading-related skills and to examine the potential overlap between the changes in inhibitory control activations and reading-related skills network.

There is a limited number of studies examining reading skills in psychopathy, using more of a categorical approach, and indicating abnormalities in lexical processing in clinical psychopathy (Kiehl et al., 2000, 2004; Ku et al., 2020; Montry et al., 2021). Further research is needed to determine to what extent different dimensional psychopathy traits relate to deficits in different reading skills and which parts of the DRC model are affected by abnormal lexical processing in psychopathy.

8.5. Conclusion

Based on the findings presented in this thesis, this chapter considered reading skills in association with dimensional psychopathology-related traits, their potential links with dyslexia, as well as the implications of poor reading skills for everyday life, and potential intervention approaches to ameliorate them. It also considered potential methodological limitations of the investigation presented in this thesis and provided future research directions focused on the dimensional approach to psychopathologies and reading skills deficits.

The studies reported in this thesis aimed to examine the associations between reading skills, psychopathology-related traits and their comorbidities (Chapter 4 and 5), and cognition (Chapter 7) in the general and clinical populations, respectively. It also sought to investigate how psychopathology-related traits modulate neural responses to lexical stimuli (Chapter 6). Overall, the findings showed that the psychopathology-related traits and their comorbidities as a dimensional continuum are associated with poor reading skills in a similar way in the general and forensic populations. Despite relatively small sample sizes included in some of the studies reported in this thesis, the results offer support for the following:

- The combinations (comorbidities) of psychopathology-related traits of positive schizotypy, psychopathy, and Motor impulsivity can predict reading-related skills in clinical and partially in general populations.
- Motor impulsivity is a more prominent factor in reading-related skills in non-native speakers than in native speakers.
- Motor impulsivity also significantly modulates brain activity in some of the core areas associated with reading in the general population, regardless of language familiarity.
- Forensic patients diagnosed with psychotic disorders show significant reading skills deficits in phonological processing and comprehension that were only partly explained by deficits in executive functioning and verbal learning.
- The Lifestyle psychopathy traits are related to lower reading-related skills in the forensic clinical sample.

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Supplementary Material

Chapter 4 Supplementary Table 1.

Spearman inter-correlations between psychopathology-related traits in the entire sample ($N = 78$).

	Schizotypy				Psychopathy – SRP-4-SF				Psychopathy - TriPM			Impulsivity – BIS-11					
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1. O-LIFE Unusual Experiences		.560**	.206	.497**	.359**	.275*	.163	.188	-.126	.359**	.258*	.185	.491**	.284*	.076	.239*	.078
	.	.000	.070	.000	.001	.015	.155	.099	.271	.001	.022	.105	.000	.012	.506	.035	.499
2. O-LIFE Cognitive Distortions	.560**		.361**	.387**	.195	.087	.002	.061	-.613**	.400**	.072	.450**	.510**	.126	.366**	.405**	.220
	.000	.	.001	.000	.088	.448	.988	.593	.000	.000	.533	.000	.000	.270	.001	.000	.053
3. O-LIFE Introvertive Anhedonia	.206	.361**		.007	.085	.272*	-.040	.099	-.411**	.136	.213	.101	.082	-.236*	.019	-.033	.084
	.070	.001	.	.955	.460	.016	.731	.388	.000	.235	.061	.379	.476	.037	.869	.775	.466
4. O-LIFE Impulsive Nonconformity	.497**	.387**	.007		.514**	.185	.436**	.337**	-.023	.592**	.481**	.358**	.437**	.549**	.268*	.489**	.205
	.000	.000	.955	.	.000	.104	.000	.003	.838	.000	.000	.001	.000	.000	.018	.000	.072
5. SRP-4-SF Interpersonal	.359**	.195	.085	.514**		.663**	.583**	.263*	.008	.450**	.590**	.273*	.370**	.457**	.020	.136	.015
	.001	.088	.460	.000	.	.000	.000	.020	.947	.000	.000	.016	.001	.000	.863	.236	.894
6. SRP-4-SF Affective	.275*	.087	.272*	.185	.663**		.551**	.215	.098	.379**	.574**	.202	.245*	.294**	-.046	.013	-.097
	.015	.448	.016	.104	.000	.	.000	.059	.391	.001	.000	.077	.030	.009	.692	.907	.398
7. SRP-4-SF Lifestyle	.163	.002	-.040	.436**	.583**	.551**		.357**	.163	.553**	.676**	.308**	.335**	.467**	.120	.337**	.066
	.155	.988	.731	.000	.000	.000	.	.001	.154	.000	.000	.006	.003	.000	.295	.003	.567
8. SRP-4-SF Antisocial	.188	.061	.099	.337**	.263*	.215	.357**		-.006	.329**	.360**	.086	.106	.316**	.139	.139	.017
	.099	.593	.388	.003	.020	.059	.001	.	.956	.003	.001	.453	.356	.005	.224	.225	.882
9. TriPM Boldness	-.126	-.613**	-.411**	-.023	.008	.098	.163	-.006		-.109	.084	-.210	-.182	.267*	-.254*	-.148	-.262*
	.271	.000	.000	.838	.947	.391	.154	.956	.	.344	.467	.065	.111	.018	.025	.196	.021
10. TriPM Disinhibition	.359**	.400**	.136	.592**	.450**	.379**	.553**	.329**	-.109		.518**	.373**	.351**	.526**	.230*	.503**	.363**
	.001	.000	.235	.000	.000	.001	.000	.003	.344	.	.000	.001	.002	.000	.043	.000	.001

	Schizotypy				Psychopathy – SRP-4-SF				Psychopathy - TriPM			Impulsivity – BIS-11					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
11. TriPM Meanness	.258*	.072	.213	.481**	.590**	.574**	.676**	.360**	.084	.518**		.329**	.294**	.380**	.051	.320**	.059
	.022	.533	.061	.000	.000	.000	.000	.001	.467	.000	.	.003	.009	.001	.660	.004	.606
12. BIS-11 Attention	.185	.450**	.101	.358**	.273*	.202	.308**	.086	-.210	.373**	.329**		.424**	.300**	.283*	.474**	.233*
	.105	.000	.379	.001	.016	.077	.006	.453	.065	.001	.003	.	.000	.008	.012	.000	.040
13. BIS-11 Cognitive Instability	.491**	.510**	.082	.437**	.370**	.245*	.335**	.106	-.182	.351**	.294**	.424**		.226*	.237*	.234*	-.101
	.000	.000	.476	.000	.001	.030	.003	.356	.111	.002	.009	.000	.	.047	.037	.039	.379
14. BIS-11 Motor	.284*	.126	-.236*	.549**	.457**	.294**	.467**	.316**	.267*	.526**	.380**	.300**	.226*		.055	.515**	.223*
	.012	.270	.037	.000	.000	.009	.000	.005	.018	.000	.001	.008	.047	.	.633	.000	.049
15. BIS-11 Perseverance	.076	.366**	.019	.268*	.020	-.046	.120	.139	-.254*	.230*	.051	.283*	.237*	.055		.459**	.293**
	.506	.001	.869	.018	.863	.692	.295	.224	.025	.043	.660	.012	.037	.633	.	.000	.009
16. BIS-11 Self Control	.239*	.405**	-.033	.489**	.136	.013	.337**	.139	-.148	.503**	.320**	.474**	.234*	.515**	.459**		.518**
	.035	.000	.775	.000	.236	.907	.003	.225	.196	.000	.004	.000	.039	.000	.000	.	.000
17. BIS-11 Cognitive Complexity	.078	.220	.084	.205	.015	-.097	.066	.017	-.262*	.363**	.059	.233*	-.101	.223*	.293**	.518**	
	.499	.053	.466	.072	.894	.398	.567	.882	.021	.001	.606	.040	.379	.049	.009	.000	.
18. S-UPPS-P Negative Urgency	.295**	.391**	.085	.499**	.249*	.110	.258*	.334**	-.232*	.535**	.203	.113	.262*	.348**	.390**	.331**	.126
	.009	.000	.458	.000	.028	.336	.023	.003	.041	.000	.074	.324	.020	.002	.000	.003	.272
19. S-UPPS-P Perseverance	-.145	.091	-.186	.030	.045	-.054	.114	-.145	-.127	.000	.048	.253*	.028	.128	.227*	.455**	.235*
	.205	.429	.103	.792	.699	.641	.321	.206	.270	.997	.674	.025	.809	.263	.045	.000	.038
20. S-UPPS-P Premeditation	.028	.287*	-.093	.415**	.227*	.122	.439**	.147	-.100	.419**	.246*	.448**	.190	.482**	.227*	.717**	.320**
	.807	.011	.416	.000	.045	.287	.000	.199	.382	.000	.030	.000	.095	.000	.046	.000	.004
21. S-UPPS-P Sensation	.116	-.240*	-.323**	.225*	.189	.161	.400**	.080	.484**	.148	.226*	-.013	.053	.330**	.019	.217	-.030
	.313	.035	.004	.048	.098	.160	.000	.488	.000	.197	.046	.912	.644	.003	.867	.056	.793
22. S-UPPS-P Positive Urgency	.478**	.318**	-.078	.520**	.389**	.295**	.465**	.330**	.103	.606**	.369**	.161	.346**	.610**	.211	.444**	.209
	.000	.005	.498	.000	.000	.009	.000	.003	.368	.000	.001	.160	.002	.000	.063	.000	.066
23. DASS-21 Depression	.256*	.553**	.399**	.296**	.268*	.323**	.152	.189	-.444**	.449**	.227*	.342**	.218	.082	.375**	.293**	.174
	.024	.000	.000	.009	.018	.004	.183	.098	.000	.000	.046	.002	.055	.478	.001	.009	.129

	Schizotypy				Psychopathy – SRP-4-SF				Psychopathy - TriPM			Impulsivity – BIS-11					
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
24. DASS-21 Anxiety	.585**	.615**	.301**	.262*	.242*	.270*	.087	.240*	-.359**	.383**	.230*	.274*	.334**	.137	.153	.199	.154
	.000	.000	.007	.021	.033	.017	.448	.034	.001	.001	.042	.015	.003	.233	.181	.081	.179
25. DASS-21 Stress	.353**	.614**	.327**	.361**	.290*	.197	.160	.244*	-.464**	.423**	.232*	.168	.333**	.084	.407**	.260*	.279*
	.002	.000	.004	.001	.010	.084	.162	.031	.000	.000	.041	.142	.003	.467	.000	.022	.013

(continued)

	Impulsivity – S-UPPS-P					Affective – DASS-21		
	18	**19**	**20**	**21**	**22**	**23**	**24**	**25**
1. O-LIFE Unusual Experiences	.295**	-.145	.028	.116	.478**	.256*	.585**	.353**
	.009	.205	.807	.313	.000	.024	.000	.002
2. O-LIFE Cognitive Distortions	.391**	.091	.287*	-.240*	.318**	.553**	.615**	.614**
	.000	.429	.011	.035	.005	.000	.000	.000
3. O-LIFE Introvertive Anhedonia	.085	-.186	-.093	-.323**	-.078	.399**	.301**	.327**
	.458	.103	.416	.004	.498	.000	.007	.004
4. O-LIFE Impulsive Nonconformity	.499**	.030	.415**	.225*	.520**	.296**	.262*	.361**
	.000	.792	.000	.048	.000	.009	.021	.001
5. SRP-4-SF Interpersonal	.249*	.045	.227*	.189	.389**	.268*	.242*	.290*
	.028	.699	.045	.098	.000	.018	.033	.010
6. SRP-4-SF Affective	.110	-.054	.122	.161	.295**	.323**	.270*	.197
	.336	.641	.287	.160	.009	.004	.017	.084
7. SRP-4-SF Lifestyle	.258*	.114	.439**	.400**	.465**	.152	.087	.160
	.023	.321	.000	.000	.000	.183	.448	.162
8. SRP-4-SF Antisocial	.334**	-.145	.147	.080	.330**	.189	.240*	.244*
	.003	.206	.199	.488	.003	.098	.034	.031

	Impulsivity – S-UPPS-P					Affective – DASS-21		
	18	**19**	**20**	**21**	**22**	**23**	**24**	**25**
9. TriPM Boldness	-.232*	-.127	-.100	.484**	.103	-.444**	-.359**	-.464**
	.041	.270	.382	.000	.368	.000	.001	.000
10. TriPM Disinhibition	.535**	.000	.419**	.148	.606**	.449**	.383**	.423**
	.000	.997	.000	.197	.000	.000	.001	.000
11. TriPM Meanness	.203	.048	.246*	.226*	.369**	.227*	.230*	.232*
	.074	.674	.030	.046	.001	.046	.042	.041
12. BIS-11 Attention	.113	.253*	.448**	-.013	.161	.342**	.274*	.168
	.324	.025	.000	.912	.160	.002	.015	.142
13. BIS-11 Cognitive Instability	.262*	.028	.190	.053	.346**	.218	.334**	.333**
	.020	.809	.095	.644	.002	.055	.003	.003
14. BIS-11 Motor	.348**	.128	.482**	.330**	.610**	.082	.137	.084
	.002	.263	.000	.003	.000	.478	.233	.467
15. BIS-11 Perseverance	.390**	.227*	.227*	.019	.211	.375**	.153	.407**
	.000	.045	.046	.867	.063	.001	.181	.000
16. BIS-11 Self Control	.331**	.455**	.717**	.217	.444**	.293**	.199	.260*
	.003	.000	.000	.056	.000	.009	.081	.022
17. BIS-11 Cognitive Complexity	.126	.235*	.320**	-.030	.209	.174	.154	.279*
	.272	.038	.004	.793	.066	.129	.179	.013
18. S-UPPS-P Negative Urgency		.018	.259*	.063	.582**	.415**	.310**	.413**
	.	.875	.022	.584	.000	.000	.006	.000
19. S-UPPS-P Perseverance	.018		.365**	.060	.011	.085	-.116	-.031
	.875	.	.001	.603	.921	.460	.313	.785
20. S-UPPS-P Premeditation	.259*	.365**		.131	.354**	.302**	.120	.148
	.022	.001	.	.255	.001	.007	.294	.195
21. S-UPPS-P Sensation	.063	.060	.131		.342**	-.156	-.101	-.039
	.584	.603	.255	.	.002	.173	.378	.732

	Impulsivity – S-UPPS-P					Affective – DASS-21		
	18	19	20	21	22	23	24	25
22. S-UPPS-P Positive Urgency	.582**	.011	.354**	.342**		.230*	.300**	.270*
	.000	.921	.001	.002	.	.043	.008	.017
23. DASS-21 Depression	.415**	.085	.302**	-.156	.230*		.577**	.660**
	.000	.460	.007	.173	.043	.	.000	.000
24. DASS-21 Anxiety	.310**	-.116	.120	-.101	.300**	.577**		.591**
	.006	.313	.294	.378	.008	.000	.	.000
25. DASS-21 Stress	.413**	-.031	.148	-.039	.270*	.660**	.591**	
	.000	.785	.195	.732	.017	.000	.000	.

$* p < .05$; $** p < .01$

Note. O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; SRP-4-SF = Self-Report Psychopathy Scale – Short Form; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale; S-UPPS-P = Impulsive Behavior Scale, Short Version; DASS-21 = Depression, Anxiety, and Stress Scale.

Appendices

Appendix A: Reading skills deficits in people with mental illness: A systematic review and meta-analysis

Appendix B: Clarifying the Roles of Positive Schizotypal and Psychopathic Traits in Lexical Decision Performance.

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Review/Meta-analysis

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Reading skills deficits in people with mental illness: A systematic review and meta-analysis

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Abstract

Background: Good reading skills are important for appropriate functioning in everyday life, scholastic performance, and acquiring a higher socioeconomic status. We conducted the first systematic review and meta-analysis to quantify possible deficits in specific reading skills in people with a variety of mental illnesses, including personality disorders (PDs).
Methods: We performed a systematic search of multiple databases from inception until February 2020 and conducted random-effects meta-analyses.
Results: The search yielded 34 studies with standardized assessments of reading skills in people with one or more mental illnesses. Of these, 19 studies provided data for the meta-analysis. Most studies ($k = 27$; meta-analysis, $k = 17$) were in people with schizophrenia and revealed large deficits in phonological processing (Hedge's $g = -0.88$, $p < 0.00001$), comprehension (Hedge's $g = -0.96$, $p < 0.00001$) and reading rate (Hedge's $g = -1.22$, $p = 0.002$), relative to healthy controls; the single-word reading was less affected (Hedge's $g = -0.70$, $p < 0.00001$). A few studies in affective disorders and nonforensic PDs suggested weaker deficits (for all, Hedge's $g < -0.60$). In forensic populations with PDs, there was evidence of marked phonological processing (Hedge's $g = -0.85$, $p < 0.0001$) and comprehension deficits (Hedge's $g = -0.95$, $p = 0.0003$).
Conclusions: People with schizophrenia, and possibly forensic PD populations, demonstrate a range of reading skills deficits. Future studies are needed to establish how these deficits directly compare to those seen in developmental or acquired dyslexia and to explore the potential of dyslexia interventions to improve reading skills in these populations.

Introduction

Reading is a complex process that requires the implementation of various skills simultaneously. To begin with, it requires recognition of the visual information necessary to extract the information from text [1]. The core reading skill is phonological processing, which involves recognition of the sound structure of the language, the decoding of written symbols into sounds (phonological awareness), and then their maintenance in working memory (phonological memory) [2]. Phonological processing facilitates the decoding of written information, which leads to word identification and subsequent extraction of meaning [3]. A failure to read each word correctly leads to problems with comprehension [4] as comprehension involves the processing of individual letters and words, and then putting them together to form meaning [5]. When one or more of these reading skills are impaired, and this impairment cannot be explained by general cognitive dysfunction or intelligence, this is referred to as dyslexia [6]. Overlaps between dyslexia and schizophrenia (SZ) have been suggested, based on previous findings of disruption in the processes that support skilled reading (e.g., deficits in language, auditory and visual perception, oculomotor control) in both disorders [7] but the nature and severity of reading skills deficits in SZ and other severe mental illnesses (MIs) remain unclear at present.

Reading skills are of enormous significance for a range of socioeconomic outcomes in modern societies, including academic performance, occupational achievement, and family and social relationships [8,9]. Furthermore, poor reading skills in children have been associated with increased antisocial behavior [10,11]. Likewise, in forensic populations, poor reading skills and dyslexia traits have been associated with increased anxiety and poor socialization, which, in turn, might explain their antisocial behavior [12,13]. In people with various MIs, undiagnosed reading problems, and dyslexia result in scholastic failure, in turn raising the risk for mood problems [14] and future criminal behavior [15]. Poor reading skills also pose a challenge for accessibility of mental health interventions [16] and predict poor psychosocial outcomes [17,18]. There is thus a need to consider reading deficits as a therapeutic target and address them, for example, with interventions used for dyslexia [7,19]. A thorough understanding of the pattern and magnitude of reading deficits in people with specific MIs is an important first step toward this goal.

The main aim of this systematic and meta-analytic review was to conduct a comprehensive analysis to delineate the nature and magnitude of reading impairments based on data from studies that employed standardized tools to assess reading skills in people with SZ, bipolar disorder, affective disorders (major depression, anxiety, mania), personality disorders (PDs; borderline personality disorder [BPD], antisocial personality disorder [ASPD], psychopathy), and general MIs (across diagnoses/not-specified). Our secondary aims were to examine whether (a) particular reading skill deficits were more strongly present when assessed with some tests compared to others, given that reading skills in different studies have been quantified using a variety of tests and batteries, and (b) groups with MIs and a forensic history show more pronounced deficits relative to those from nonforensic settings.

Methods

This systematic literature review and meta-analysis followed PRISMA guidelines [20]. Search terms and key articles were identified based on an exploratory search of databases and an internet search engine (Google Scholar). We then searched Academic Search Complete, CINAHL Plus, PsycINFO, PsycARTICLES, SocINDEX, MEDLINE via EBSCO Host and PubMed (up to Feb 2020) for all studies including reading assessment(s) in MIs (see Table 1 for the full search strategy and eligibility criteria). Manual searches were conducted using the relevant literature [7,17,21].

Two independent reviewers selected the studies (MV, BJ), and extracted and reviewed data for inconsistencies to reach a consensus (MV, LAW). Extracted data included tests and measures (Table 2), as well as participant characteristics, main findings, the language of assessment, and country (Table 3).

Studies that reported means and standard deviations (s.d.) for patient and healthy control (HC) groups to permit the calculation of effect sizes were included in the meta-analysis (effect sizes also presented where only one study available). The remaining studies contributed only to the narrative synthesis (see Table 3 for details). Studies assessing individuals with conditions primarily classified as neurodevelopmental (ADHD, autism, learning difficulties, and intellectual disabilities) [82] were excluded.

Statistical analysis

The meta-analysis was conducted using Review Manager 5.3 Software—RevMan [83]. For eligible studies, effect sizes were calculated as Hedge's g (standardized mean difference). A random-effects model was used as a more conservative approach. Heterogeneity was calculated as the I^2 measure of consistency for each meta-analytic calculation. Planned analyses included comparing each diagnosis (SZ, bipolar disorder, depression, anxiety, PDs, psychopathy), and unspecified general MI with healthy groups on specific reading skills (phonological processing and decoding; comprehension; single-word reading; rate, speed, accuracy, and fluency). For each reading skill, differences between tests to assess deficits in the patient group were calculated by investigating overlaps of confidence intervals of the summary effect sizes for each test. Risk of publication bias (none identified) was formally assessed via Egger's and Begg's tests and with funnel plots.

Results

Of 34 studies in total (Tables 2–3), 19 studies provided data for meta-analysis (Figure 1. *PRISMA flowchart*); five of these studies also presented composite scores (combining two or more measures) that are covered in the narrative synthesis. The remaining 15 studies contributed to the narrative synthesis only. The findings from the nonforensic and forensic samples are presented separately, followed by a direct comparison of forensic and nonforensic groups.

Reading Skills in Nonforensic Populations

Schizophrenia

Phonological Processing and Decoding: Across seven studies (Figure 2(2.1)), SZ showed significantly poorer phonological processing compared to HC with a large effect size (Hedge's $g = -0.88$, $df = 24$, $p < 0.00001$, $CI = [-1.07, -0.70]$). There was medium heterogeneity within the data ($p = 0.001$, $I^2 = 53\%$), with nonsignificant differences between the tests ($p = 0.15$, $I^2 = 32.3\%$).

Comprehension: Across 11 studies (Figure 2(2.2)), SZ showed poorer comprehension than HC with a large overall effect size (Hedge's $g = -0.96$, $df = 34$, $p < 0.00001$, $CI = [-1.15, -0.78]$) and medium heterogeneity ($p < 0.00001$, $I^2 = 69\%$). The test differences were significant ($p < 0.0001$, $I^2 = 74.5\%$) with NDRT [49] and GORT-4 [40] showing the largest effect sizes for a comprehension deficit in SZ. In addition, three studies [17,21,41] reported lower Oral Reading Quotient from GORT-4 [40]. In other studies, retrospective assessment revealed that those with a current diagnosis were below the norm during 4th to 11th grade of school [44], with the most prominent deficit in the 11th grade, indicating a gradual decline [44,45]. A similar study on adolescents, who later developed psychosis, displayed a premorbid deficit in comprehension and sentence reading relative to HC [47].

Single-Word Reading: Across 10 studies [17,18,21,22,24,36,59,62,73,74], there was a significant medium-size deficit (Figure 2(2.3)) in SZ relative to HC (Hedge's $g = -0.70$, $df = 9$, $p < 0.00001$, $CI = [-0.94, -0.46]$). There was significant heterogeneity within the results ($p = 0.01$, $I^2 = 58\%$) but no test performed better than others ($p = 0.20$, $I^2 = 35.6\%$). Moreover, in two studies [62,63], both using LNNB—Reading subtest (see Table 2 for test descriptions) [61]—SZ showed a deficit compared to HC (data for meta-analysis not provided). In a third study [72], SZ scored markedly lower ($M = 78.00$, $SD = 21.01$) than the norm ($M = 100$) on WRAT-III [84].

Rate, Speed, Accuracy, and Fluency: Across five studies [17,21,24,76,85], there was a significant large effect of SZ diagnosis on reading rate (Hedge's $g = -1.22$, $df = 4$, $p = 0.002$, $CI = [-1.98, -0.46]$) (Figure 2(2.4)). The effect of diagnosis [17,21,24,76] in accuracy failed to reach significance (Hedge's $g = -0.73$, $df = 3$, $p = 0.09$, $CI = [-1.56, 0.10]$) (Figure 2(2.5)). There were, however, significant test differences for both rate ($p = 0.04$, $I^2 = 64.9\%$) and accuracy ($p = 0.01$, $I^2 = 77.1\%$), with the GORT-4 revealing large deficits [17,21], and the Alouette [75] showing no deficit [76] (Figures 2(2.4–2.5)). In fluency [17,18,21,41,77], there was a highly significant deficit in SZ (Hedge's $g = -2.03$, $df = 4$, $p < 0.00001$, $CI = [-2.82, -1.24]$), but with large heterogeneity within results (84%) (Figure 2(2.6)). In reading speed (time taken to read certain content) [24,76], the effect of diagnosis was nonsignificant (Hedge's $g = -0.50$, $df = 1$, $p = 0.11$, $CI = [-1.11, -0.11]$) (Figure 2(2.7)). In an additional study [77], 10–11% of SZ demonstrated

Table 1. Full search strategy per database and eligibility criteria.

EBSCO search: *Academic Search Complete, CINAHL Plus, PsycINFO, PsycARTICLES, SocINDEX, MEDLINE*	PubMed
(Reading* OR literacy OR scholastic) AND (schizophren* OR "schizoaffective disorder" OR psychosis OR psychotic OR bipolar OR psychopathy OR "personality disorder" OR "antisocial personality disorder" OR "mental disorder" OR "mental ill*" OR "mood disorder" OR "anxiety" OR depress*) AND adult* (Dyslexia OR "learning disability" OR "reading disorder" OR "reading dysfunction" OR "reading deficit") AND (schizophren* OR "schizoaffective disorder" OR psychosis OR psychotic OR bipolar OR psychopathy OR "personality disorder" OR "antisocial personality disorder" OR "mental disorder" OR "mental ill*" OR "mood disorder" OR "anxiety" OR depress*) AND adult* **Related words and related subjects, only peer-reviewed.*	((((((("Mental Disorders"[Mesh]) OR ("Schizophrenia"[Mesh] OR "Schizophrenia Spectrum and Other Psychotic Disorders"[Mesh] OR "Schizophrenia, Paranoid"[Mesh] OR "Schizophrenia, Disorganized"[Mesh] OR "Schizophrenia, Catatonic"[Mesh] OR "Schizotypal Personality Disorder"[Mesh])) OR "Psychotic Disorders"[Mesh]) OR ("Bipolar Disorder"[Mesh] OR "Depressive Disorder, Major"[Mesh] OR "Major Affective Disorder 1" [Supplementary Concept] OR "Major Affective Disorder 2" [Supplementary Concept])) OR "Antisocial Personality Disorder"[Mesh]) OR ("Personality Disorders"[Mesh] OR "Schizoid Personality Disorder"[Mesh] OR "Passive-Aggressive Personality Disorder"[Mesh] OR "Paranoid Personality Disorder"[Mesh] OR "Multiple Personality Disorder"[Mesh] OR "Histrionic Personality Disorder"[Mesh] OR "Dependent Personality Disorder"[Mesh] OR "Compulsive Personality Disorder"[Mesh] OR "Borderline Personality Disorder"[Mesh])) AND ("Reading"[Mesh] OR "Dyslexia"[Mesh] OR "Dyslexia, Acquired"[Mesh])) AND ("Adult"[Mesh] OR "Young Adult"[Mesh]) ((("mood disorders"[MeSH Terms] OR ("mood"[All Fields] AND "disorders"[All Fields]) OR "mood disorders"[All Fields] OR ("mood"[All Fields] AND "disorder"[All Fields]) OR "mood disorder"[All Fields]) OR ("anxiety"[MeSH Terms] OR "anxiety"[All Fields])) AND ("Reading"[Mesh] OR "Dyslexia"[Mesh] OR "Dyslexia, Acquired"[Mesh])) AND ("Adult"[Mesh] OR "Young Adult"[Mesh])
Inclusion criteria	
- Case–control, cohort, and cross-sectional studies reporting measures assessing reading abilities in adults with psychosis, depression, anxiety, personality disorders, antisocial personality disorder, psychopathy, and/or general mental illness. - Studies using standardized tests and/or translated versions of these into their national language. - Quantitative studies published in peer-reviewed journals in English, without publication date restrictions. - Abstract and full-text available.	
Exclusion criteria	
- Nonpeer reviewed articles, case studies, theses, books, editorial letters, descriptive articles, conference papers, personal opinions, and protocols were excluded. - Studies using experimental methods to assess reading in people with MI without reporting scores from standardized tests or - Single-word reading tests only to assess premorbid IQ were excluded.	

Abbreviations: MI, Mental Illness; Intelligence Quotient, IQ

nonfluencies (e.g., sound repetitions at beginning of word) in sentence and paragraph reading during the BDAE [38].

Composite Scores: Two studies [17,21] that examined Basic Reading Skills (phonological processing and single-word reading) and Phoneme-Grapheme Knowledge (phonological processing and orthography) composite scores from WJTA-III [35] showed different results, with only one of these showing a significant deficit in SZ [17]. Both studies [17,21] found significantly lower WJTA-III Broad Reading (phonological processing, comprehension, speed) scores in SZ, relative to HC. The study [22] that created a phonology composite score by combining the RNRT [33], RNST [33], WRAT-R [86], and the Controlled Oral Word Association Test (COWAT) [87] also reported a significant deficit in SZ relative to HC.

Reading-related skills

Vocabulary: Six studies [17,21,22,44,45,81] assessed reading-related skills in SZ. There was evidence of impaired vocabulary from an early age [44,45] and those with prodromal illness scored significantly below grade-norms when assessed by the ITBS [42] and ITED [43] as a part of their school performance. Vocabulary, assessed using the NDRT [49], was also impaired in two studies [17,21].

Spelling and Grammar: Spelling in RNST [33] was found to be adversely affected in male patients, while female patients scored similarly to HC [22]. Another study [44], which longitudinally assessed spelling together with grammar and other language-related skills by ITBS [42], found a significant decline in abilities at 11th grade in SZ. Similarly, SZ scored significantly lower in the WJTA-III [35] spelling subtest compared to HC [17]. Grammar was assessed exclusively in one study [22], using Caplan and Hildebrandt's task [79], showing a stronger and significant deficit in male, relative to female, patients [22].

Orthography: Orthography processes are not reading abilities. However, in languages such as Chinese, orthography and semantics play an important role in reading, in contrast to alphabetical languages such as English where phonological processing plays a key role [81]. One study [81] that investigated orthography processes found significant deficits in orthography-phonology, but not in vocabulary when distinguishing real words from nonwords, in SZ compared to HC.

Affective disorders (depression, anxiety or mania)

Two studies [62,66] assessed single-word reading in depression, both using the REALM [64]. Of these, one study [62] showed a nonsignificant small deficit in people with depression (Hedge's $g = -0.30$, $df = 0$, $p = 0.37$, $CI = [-0.96, 0.36]$) and, in the other study [66], all participants performed at 7–8th grade reading level.

Bipolar disorder

The earlier-mentioned study on adolescents [47] had also assessed comprehension premorbidly in a group who later developed non-psychotic bipolar disorder and found them to have no deficit in comparison to HC.

Table 2. Tests and measures used in the selected studies ($k = 34$) and diagnoses assessed. Studies involving forensic populations are in *italics.*

Measures (test - subtest name)	Measure description	Used by	Diagnoses assessed
	Phonological processing and decoding		
Auditory blending test [22]	*Pronounce sounds separately and put them together to form a word.*	Walder et al. [22]	SZ
CTOPP-PA [23]	*Manipulate with sounds, distinguish, pronounce, and synthesize sounds to create words.*	Arnott et al. [24]; Revheim et al. [21]; Revheim et al. [17]; Whitford et al. [7]; Dondé et al. [18]	SZ, SZAD
CTOPP-PM [23]	*Remember and reproduce digits and pronounce nonwords.*	Arnott et al. [24]; Revheim et al. [21]; Revheim et al. [17]; Whitford et al. [7]; Dondé et al. [18]	SZ, SZAD
CTOPP-RN [23]	*Name objects and colours as quickly as possible.*	Arnott et al. [24]; Revheim et al. [21]; Revheim et al. [17]; Whitford et al. [7]	SZ, SZAD
CTOPP-APA [23]	*Manipulate with sounds, distinguish, pronounce, and synthesize sounds to create nonwords.*	Arnott et al. [24]; Revheim et al. [21]; Revheim et al. [17]; Dondé et al. [18]	SZ, SZAD
CTOPP-ARN [23]	*Name letters and numbers as quickly as possible.*	Revheim et al. [21]; Revheim et al. [17]	SZ, SZAD
JDT [25] (Wordchains)	*Decode words from a group of letters and mark a space between them (e.g., girl/chair/meet).*	*Daderman et al.* [15]; *Selenius et al.* [26]; *Svensson et al.* [27]	PD, MI
MWDT [28]	*Read specific words.*	*Selenius et al.* [26]	MI
PALPA [29]	*Nonword judgments or segment words/ nonwords.*	*Brites et al.* [30]; *Selenius et al.* [26]	Psychopathy, MI
Phonological choice [31]	*Decide which nonword in a pair sounds like a real word.*	*Svensson et al.* [27]	MI
RAN [32]	*Name the letters, numbers, colours, or pictures presented on cards.*	Walder et al. [22]	SZ
RNRT, RNST [33]	*Read or spell a list of nonwords and identify words read to the subject each syllable separately.*	Walder et al. [22]	SZ
The Pidgeon [34]	*Five tasks: self-reported dyslexic problems, working memory, vocabulary, reversed spoonerism, phonological choice, and orthographic choice.*	*Selenius et al.* [26]	MI
WJTA-III [35]	*Read or spell a list of nonwords.*	Leonard et al. [36]; Revheim et al. [21]; Revheim et al. [17]	SZ, SZAD
WRMT-R [37] (Word attack)	*Read as many nonwords as possible in 1 min.*	*Svensson et al.* [27]	MI
	Comprehension		
BDAE [38]	*Answer questions (multiple-choice) about a text.*	Gavilán and García-Albea [39]	SZ
GORT-4 [40]	*Respond to questions about the block of text read.*	Martinez et al. [41]; Revheim et al. [21]; Revheim et al. [17]	SZ, SZAD
ITBS [42], ITED [43]	*Comprehension of fiction and nonfiction text.*	Fuller et al. [44]; Ho et al. [45]	SZ
Israeli language skills test [46]	*Comprehension of ideas presented in a block of text of increasing difficulty.*	Reichenberg et al. [47]	SZ, SZAD, BD
NARA-III [48]	*Respond to open questions about the block of text read.*	Arnott et al. [24]	SZ
NDRT [49]	*Respond to questions about the block of text read.*	Revheim et al. [21]; Revheim et al. [17]; Whitford et al. [7]	SZ, SZAD
PIAT [50]	*Use pictures to describe the meaning of a sentence.*	Berg and Hammitt [51]	MI
PALPA	*Choose a picture which fits the meaning of a sentence or a word.*	*Brites et al.* [30]; Gavilán and García-Albea [39]	Psychopathy, SZ
RAN	*Reproduce letters and digits.*	*Svensson et al.* [27]	MI
RCBA [52], RCBA-2 [53]	*10 subscales (I-X). Answer questions (multiple-choice, silent reading) about single words, sentences, paragraphs, functional information, synonyms.*	Arnott et al. [24]; Hayes and O'Grady [54]	SZ
"Summer with Monika" [55]	*"Fill in the blank" response about a text.*	*Daderman et al.* [15]	PD
"The Hedgehog" [56]	*Underline a salient word in a text.*	*Selenius et al.* [26]	MI

Continued

Table 2. *Continued*

Measures (test - subtest name)	Measure description	Used by	Diagnoses assessed
WJTA-III	*"Fill in the blank" response about a text.*	Leonard et al. [36]; Revheim et al. [21]; Revheim et al. [17]; Dondé et al. [18]	SZ, SZAD
WRAT-IV [57]	*Complete a sentence with an appropriate word.*	Ferron et al. [58]; Patrick et al. [59]	MI, SZ
WRMT-R	*Text passages followed by a blank line to orally fill in a word that fits the passage.*	Arnott et al. [24]; *Svensson et al.* [27]	SZ, MI
Paragraph reading [60]	*Answer questions (Yes/No, and multiple choice) about a block of text.*	Disimoni et al. [60]	SZ
	Single-word reading		
LNNB [61]	*A comprehensive battery assesses various neuropsychological functions, including reading.*	Maj [62]; Puente et al. [63]	SZ, SZAD, DD
MWDT	*Read specific words out loud.*	*Daderman et al.* [15]	PD
PALPA	*Read letters, syllables, words, and sentences out loud.*	*Brites et al.* [30]	Psychopathy
PIAT	*Read individual words out loud.*	Berg and Hammitt [51]	MI
REALM [64]	*Pronounce words commonly used in medicine. A scale from 3rd grade and up to high school reading performance.*	Christensen and Grace [65]; Weiss et al. [66]	MI, DD
TOWRE [67]	*Read individual words out loud.*	*Davidson et al.* [68]	ASPD
WJTA-III	*Read individual words out loud.*	Leonard et al. [36]; Dondé et al. [18]	SZ, SZAD
WRAT [69]	*Read individual words out loud.*	*Dalby and Williams* [70]*; Nestor* [71]; Revheim et al. [21]; Walder et al. [22]; Nelson et al. [72]; Potter and Nestor [73]; Ferron et al. [58]; Light et al. [74]; Martínez et al. [41]; Revheim et al. [17]	SZ, SZAD, MI
WRMT-R	*Read individual words/nonwords out loud.*	Arnott et al. [24]	SZ
	Rate		
Alouette [75]	*Total number of words correctly read.*	Curzietti et al. [76]	SZ
GORT-4	*Time taken to read a block of text.*	Revheim et al. [21]; Revheim et al. [17]	SZ, SZAD
NARA-III	*Number of words read per minute.*	Arnott et al. [24]	SZ
NDRT	*Number of words read in the first min.*	Whitford et al. [7]	SZ
	Speed		
Alouette	*Overall reading time (max. 180 s.).*	Curzietti et al. [76]	SZ
"Summer with Monika"	*Overall reading time of the text.*	*Daderman et al.* [15]	PD
"The Hedgehog"	*Overall reading time of the text.*	*Selenius et al.* [26]	MI
RCBA-2	*Overall completion time of 10 tasks.*	Arnott et al. [24]	SZ
	Accuracy		
Alouette	*Number of words correctly read in 180 s. limit.*	Curzietti et al. [76]	SZ
GORT-4	*Number of correctly/incorrectly read words.*	Revheim et al. [21]; Revheim et al. [17]	SZ, SZAD
NARA-III	*Number of errors made when reading a block of text.*	Arnott et al. [24]	SZ
	Fluency		
GORT-4	*Sum of rate and accuracy scores.*	Revheim et al. [21]; Martinez et al. [41]; Revheim et al. [17]	SZ, SZAD
"Arthur the Young Rat" [77]	*Number of nonfluencies in text reading (i.e., repetitions of a sound, syllable, word, or phrase).*	Halpern et al. [77]	SZ
"Grandfather" [77]		Halpern et al. [77]	SZ
BDAE		Halpern et al. [77]	SZ
Fisher-Logemann [78]		Halpern et al. [77]	SZ
WJTA-III	*Time taken to read a block of text followed by questions.*	Revheim et al. [17]; Dondé et al. [18]	SZ, SZAD

Continued

Table 2. *Continued*

Measures (test - subtest name)	Measure description	Used by	Diagnoses assessed
		Vocabulary	
ITBS, ITED	*Select a word or phrase synonymous to the target word.*	Fuller et al. [44]; Ho et al. [45]	SZ
NDRT	*Answer multiple-choice questions about words.*	Revheim et al. [21]; Revheim et al. [17]	SZ, SZAD
MSVT [56]	*Find word's synonym among five options.*	*Selenius et al.* [26]	MI
		Spelling	
ITBS, ITED	*Spelling of real word by writing.*	Fuller et al. [44]	SZ
MST [56]	*Spelling of real word by writing.*	*Daderman et al.* [15]; *Selenius et al.* [26]	PD, MI
Orthographic choice [31]	*Decide which of the two words presented is correctly spelt.*	*Svensson et al.* [27]	MI
WJTA-III	*Spelling of real words out loud or by writing.*	Revheim et al. [17]	SZ, SZAD
		Grammar	
Caplan and Hildebrandt task [79]	*Identify the subject and object of the actions of phrases.*	Walder et al. [22]	SZ
		Orthography	
Pseudo-homophone discrimination [80], Animal word cross-out test [80], onset judgment test [80]	*Mark particular words/nonwords within a time limit.*	Wang et al. [81]	SZ

Abbreviations: BD, Bipolar Disorder; BDAE, Boston Diagnostic Aphasia Examination; CTOPP, Comprehensive Test of Phonological Processing (PA, Phonological Awareness; PM, Phonological Memory; RN, Rapid Naming; APA, Alternative Phonological Awareness; ARN, Alternative Rapid Naming); DD, Depressive Disorder; GORT, Gray Oral Reading Test; HC, Healthy Controls; ITBS, Iowa Test of Basic Skills; ITED, Iowa Test of Educational Development; JDT, Jacobson's Decoding Test; LNNB, Luria-Nebraska Neuropsychological Battery; MI, Mental Illness; MST, Madison's Spelling Test; MSVT, Madison's Standardized Vocabulary Test; MWDT, Madison's Word Decoding Test; NARA, Neale Analysis of Reading Ability; NDRT, Nelson–Denny Reading Test; PALPA, Psycholinguistic Assessments of Language Processing in Aphasia; PD, Personality Disorder; PIAT, Peabody Individual Achievement Test; RAN, Rapid Automatised Naming; RCBA, Reading Comprehension Battery for Aphasia; REALM, Rapid Estimate of Adult Literacy in Medicine; RNRT, Roentgen's Nonwords Reading Test; RNST, Roeltgen's Nonwords Spelling Test; SZ, Schizophrenia; SZAD, Schizoaffective Disorder; TOWRE, Test of Word Reading Efficiency; WJTA-III, Woodcock–Johnson III Tests of Achievement (BR, Broad Reading; BRS, Basic Reading Skills; RC, Reading Comprehension; PKG, Phoneme-Grapheme Knowledge); WRAT, Wide Range Achievement Test; WRMT-R, Woodcock Reading Mastery Test—Revised (BS, Basic Skills; PC, Passage Comprehension; PKG, Phoneme-Grapheme Knowledge).

Personality disorders/psychopathy

One study [30] assessed phonological processing and comprehension, using the Portuguese version of the PALPA [29], and showed medium-size deficits in both phonological processing (Hedge's $g = -0.55$, $df = 2$, $p = 0.004$, CI = [−0.92, −0.18]) (Figure 3(3.1)) and comprehension (Hedge's $g = -0.47$, $df = 0$, $p = 0.05$, CI = [−0.87, 0.39]) (Figure 3(3.2)) in people with diagnosed psychopathy (from community settings), compared with nonpsychopathic nonforensic controls.

General mental illnesses (nonspecified/mixed)

Two studies [51,58] assessed comprehension and single-word reading while the third study [65] assessed single-word reading only. The first study [58] reported 9th-grade level comprehension as well as 9th-grade level single-word reading when assessed by WRAT-IV [88] in people with unspecific MIs. The second study [51], using the PIAT-comprehension subtest [50], reported 7th-grade comprehension, despite 9–10th grade for single-word reading, in psychiatric patients (majority with alcoholism or nonorganic psychoses). In the third study [65], 75% of the sample with MIs (mainly SZ and affective disorders) read below 7th grade when assessed by REALM [64].

Summary of Deficits in Nonforensic Populations

Overall, SZ was associated with pronounced deficits in phonological processing, comprehension, reading rate, and fluency (Figure 4), with deficits also present in reading-related skills. These deficits appear to be present often from an early age, with reading skills of SZ adults remaining below their achieved education levels. The single-word reading and speed were less impacted. There were few data in affective disorders, and only for single-word reading, showing a mild/nonsignificant deficit. Individuals with PDs/high psychopathy showed mild deficits in both phonological processing and comprehension (Figure 4). Comprehension and single-word reading skills of people with unspecified MIs from nonforensic settings were at secondary school levels, which, although below the norm, were better than those in SZ (Figure 4).

Reading Skills in Forensic Populations

Seven studies [15,26,27,30,68,70,71], all in PDs/psychopathy or general MIs, were found.

Personality disorders/psychopathy

Phonological Processing and Decoding: In the first study [30], the PALPA [29] phonological processing test showed a large deficit in the incarcerated group with diagnosed psychopathy relative to HC (Hedge's $g = -0.85$, $df = 2$, $p = 0.0001$, CI = [−1.22, −0.47]) (Figure 5 (5.1)). The second study [15], using the JDT [25] to examine decoding, showed marked impairment (Hedge's $g = -0.84$, $df = 0$, $p = 0.01$, CI = [−1.51, −0.17]) in people with nonspecific PDs (and comorbid MIs), relative to HC.

Comprehension: One study [30] used the PALPA [29] and showed a large deficit in comprehension in incarcerated people with diagnosed psychopathy, compared to HC (Hedge's $g = -0.95$, $df = 0$, $p = 0.0003$, CI = [−1.48, −0.43]) (Figure 5(5.2)). The other study [15] used a Swedish prose text [55] and found no deficit in PDs.

Single-word Reading: The first study [15] used a Swedish single-word reading test [28] and found significant impairment in PD inmates with comorbid MI and dyslexia, as well as in dyslexic inmates, in comparison to inmates without a PD diagnosis. In the second study [30], a diagnosis of psychopathy did not influence single-word reading as assessed by PALPA [29]. The third study [68] found literacy scores, as assessed by the TOWRE [67], to be below the norm in PD. None of these studies [15,30,68] provided data for effect size calculation.

Rate, Speed, Accuracy, and Fluency: Only one study [15] was found, showing that reading speed was negatively affected in 7 of 10 forensic PD participants, especially in those with comorbid dyslexia.

Reading-related skills

One study [15] showed that spelling was poorer in inmates with PD and dyslexia, as opposed to those with no comorbidities.

General mental illnesses (nonspecified/mixed)

Phonological Processing and Decoding: One study [27] used the JDT–Wordchains [25], the Word Attack test [89], and Phonological Choice [31], and revealed severely impaired phonological skills (below the 6th grade) in people with various MIs. The second study [26] examined correlations between psychopathic traits and phonological and decoding skills in forensic psychiatric patients, assessed with the "Pidgeon" test [34], the MWDT [28], and the JDT [25], and found positive correlations between the superficial item of the Psychopathy Checklist: Screening Version (PCL:SV) [90] and phonological processing and decoding of sentences (but not words). However, as the study did not include HCs or test normative scores, the findings are difficult to understand in terms of quantifying the deficit.

Comprehension: In one study [27] that used the Oral Close subtest of the WRMT-R [37], comprehension in inmates with MI was below 4th grade in 23% of Swedish native and in over 50% of non-native speakers. In another study [26] that used a silent paragraph reading test [56], no significant correlations between psychopathic traits and comprehension scores in people with non-specified MIs were found.

Single-word Reading: There were two studies [70,71], both using the WRAT [69]. The first study [70] assessed people with various diagnoses (psychosis, mania, alcoholism, and ASPD). It found no significant differences between HC and psychosis (Hedge's $g = 1.42$, $df = 0$, $p = 0.68$, CI = [−5.40, 8.24]), mania (Hedge's $g = 0.53$, $df = 0$, $p = 0.13$, CI = [−0.15, 1.20]), or alcohol abuse (Hedge's $g = -0.49$, $df = 0$, $p = 0.10$, CI = [−1.06, 0.09]) but single-word reading was significantly impaired in ASPD (Hedge's $g = -1.01$, $df = 0$, $p = 0.004$, CI = [−1.69, −0.33]. The second study [71] found age-moderated differences in people with MIs and a history of violence, with people aged above 45 years scoring significantly better than those below 20 years.

Rate, Speed, Accuracy, and Fluency: One earlier-described study [26] found that, within those with MIs, reading speed [56] was positively correlated with affective and interpersonal traits (Factor 1, PCL:SV [90]).

Reading-related skills

In a study [26] involving Swedish inmates with MIs, neither spelling nor vocabulary scores significantly correlated with psychopathic traits.

Summary of Deficits in Forensic Populations

Overall, there was evidence of severe impairment in phonological processing and decoding in forensic populations with PDs/psychopathy (Figures 4 and 5), similar to that seen in SZ. There was also evidence of deficits in comprehension, single-word reading, and speed in this population (Figures 4 and 5). Studies on forensic patients with various MIs yielded mixed findings although one study [27] that examined inmates did show phonological processing and comprehension to be well below the norm.

Nonforensic versus Forensic Populations: Direct Comparison

Only one study [30] directly compared forensic and nonforensic groups. It used PALPA [29] and revealed a significant medium-size deficit in incarcerated individuals with psychopathy compared to nonincarcerated (community) sample with psychopathy in phonological processing and decoding (Hedge's $g = -0.49$, $df = 2$, $p = 0.03$, CI = [−0.94, −0.04] (Figure 6(6.1)), and a large deficit in comprehension (Hedge's $g = -0.85$, $df = 1$, $p = 0.003$, CI = [−1.43, −0.28]) (Figure 6(6.2)). These results support the findings from individual studies indicating severe reading deficits in incarcerated individuals with MI.

Reading Skills Deficits in Mental Illness: Influencing Factors

Symptoms and medication

Of six studies in SZ [17,21,24,72,76,81] that examined the relationship between psychotic symptoms and reading skills, three [21,24,81] found a negative influence of positive and negative symptoms on phonological processing, comprehension, and orthography; and hallucinations negatively affected reading efficiency and speed in one study [76]. Five studies [17,22,41,63,85] examined the effect of antipsychotic dose as chlorpromazine equivalents; four [17,22,63,85] found no relationship with single-word reading, phonological processing, or comprehension, and one [41] found a negative influence of high dosage on fluency and comprehension. No significant association occurred between depressive symptoms and single-word reading [66].

Cognitive function

Six studies [17,21,41,44,54,70] examined the relationship between reading skills and general cognition in SZ. Verbal IQ significantly correlated with comprehension and vocabulary [44]. Lower premorbid IQ (single-word reading) predicted reading comprehension [17,54]. However, general IQ did not significantly predict any of the reading skills [41]. Similarly, working memory did not correlate with comprehension or reading rate in SZ and HC [21]. In forensic populations, full-scale IQ was significantly lower than single-word reading in individuals with SZ and bipolar disorder [70]. These results suggest that general verbal skills may influence comprehension but no marked impact of other cognitive abilities was found.

Table 3 Summary of key data extracted from selected studies (*k* = 34).

Study	Dg.	Sample (N) (M/F)	Age (Mean, SD)	Medication (mg/day, CPZE)	Education years (Mean, SD)	Tests (subtests)
1. Psychosis						
Disimoni et al. [60]	**SZ**	SZ = 27 (9/18)	SZ = 36.3 (13.2)	NR	SZ = 11.3 (2.6)	Language battery: comprehension (3 subtests), naming, writing, arithmetic
Maj [62] *Meta-analysis*	**SZ, SZAD, DD**	SZAD = 16 (7/9); SZ = 20 (8/12); DD = 16 (7/9); ex SZAD = 15 (7/8); **HC = 20** (8/12)	SZAD = 33.6 (6.1), DD = 36.5 (6.9), SZ = 31.7 (8.9), HC = 33.5 (5.8), exSzAD = 36.5 (5.6), HC = 37.7 (5.9)	Lithium <1200, antidepressants <75, and/or haloperidol <5 or chlorpromazine <100	NR	LNNB (reading: 13 items)
Halpern et al. [77]	**SZ**	SZ = 7 (7/0); Atypical Organic Brain Syndrome =1 (1/0)	SZ = 51.5	NR	NR	BDAE (subtest L), Fisher-Logemann sentences, “Grandfather” passage, “Arthur the Young Rat” passage
Puente et al. [63]	**SZ**	SZ total = 60; SZ-brain damage = 20 (15/5); nonbrain damage = 20 (15/5); acute = 20 (11/9); **HC = 20** (6/14)	SZ-brain damage = 51.7 (17.8) nonbrain damage = 36.1 (11.1) acute = 34.5 (14.2) **HC = 19.5** (2.1)	SZ-brain damage = 405.0; CPZE nonbrain damage = 234.8; CPZE acute = 492.2; CPZE	SZ-brain damaged = 9.8 (2.6); Nonbrain damaged = 10.7 (2.4); acute = 11.4 (3.1); HC = 12.6 (1.1)	LNNB
Fuller et al. [44]	**SZ**	SZ = 70 (57/13)	SZ = 28.0 (6.9)	NR	NR	ITBS, ITED
Reichenberg et al. [47]	**SZ, SZAD, BD**	SZ = 536 (390/146); SZAD = 31 (23/8); BD = 68 (38/30); **HC = 635** (451/184)	SZ = 20.7 (2.0); SZAD = 20.0 (1.5); BD = 21.5 (2.8)	NR	NR	Israeli language skills assessment (2 subtests)
Hayes and O’Grady [54] *Meta-analysis*	**SZ**	SZ = 30 (26/4); **HC = 30** (26/4)	SZ = 37.3 (11.20); HC = 37.2 (11.85)	NR	NR	RCBA (10 subtests)
Ho et al. [45] *Meta-analysis*	**SZ**	SZ = 70 (57/13); comparison subjects =147 (**HC = 36:** Alc = 66.7% drug = 34.7% DD = 29.9%) (63/84)	NR	NR	NR	ITBS, ITED
Revheim et al. [21]	**SZ, SZAD**	SZ/SZAD = 19 (18/1); **HC = 10** (6/4)	SZ = 38.3 (9.6); HC = 28.7 (9.0)	1077.7 ± 574 CPZE	SZ = 12.4 (2.3); HC = 15.2 (0.85)	GORT-4, CTOPP (12 subtests), WJTA-

Variables examined	Reading performance	Symptoms, medication and reading	Cognition, education and reading	Language
comprehension	SZ was impaired in comprehension but less than aphasics. Poorer speaking and listening scores were linked with better reading. This indicated independence of communication skills from reading.	NE	NE	English
single-word reading	SZ scored significantly worse than HC in reading. SZ also demonstrated (nonsignificantly) worse reading skills than the SZAD and the DD.	NE	Means for cognitive domains were reported but the relationship with reading NE. Groups did not differ in years of education.	Italian
reading fluency of words, sentences, and paragraphs	No significant amount of nonfluencies in reading were found based on location in a sentence, location in the utterance (sound, syllable, word, phrase, and sentence) or symptoms (repetitions, prolongations, hesitations). Significantly more nonfluencies occurred in sentence reading and paragraph reading and in the middle and beginning of sentences.	NE	NE	English
single-word reading	No significant differences between SZ and HC.	No significant correlation between medication dosage and LNNB battery. Other relationships NE.	NE	English
comprehension, spelling, language, vocabulary	SZ scores were significantly lower than average general rank between 11th grade and the 4th and 8th grade respectively in reading, vocabulary, language, and other scholastic skills. Reading performance significantly dropped between grades 8 and 11. ITED scores did not predict the age of onset of SZ.	NE	WAIS-R verbal IQ significantly positively correlated with reading, vocabulary and language skills measured by ITED in 11th grade in SZ.	English
comprehension, reading sentences	SZ but not BD had significantly worse scores in reading and reading comprehension in comparison with HC.	NE	NE	Israeli
single-word comprehension, functional reading, comprehension of synonyms, sentence comprehension, paragraph comprehension, factual comprehension, inferential reading, comprehension with structure variation, reading speed	SZ scored lower in comprehension (9/10 RCBA subtests were significantly lower in SZ) than HC but retained word-recognition skills (NART). Reading time is longer in SZ. Functional reading necessary for real-life functioning was significantly impaired in SZ.	NE	Lower premorbid IQ (NART) correlated with low RCBA scores. Education levels for each group were similar.	English
comprehension, vocabulary	SZ patients scored lower in all subtests than comparisons. However, tests had poor screening efficiency for SZ due to low positive predictive values. Reading in SZ was lower than in comparison group in all grades (4th, 8th, and 11th), lowest in 11th grade. Effect sizes were reduced when gender and parental social-economic status were accounted for.	NE	NE	English
GORT: comprehension, rate, accuracy, fluency, ORQ; CTOPP: PA, PM, RN,	SZ show significantly impaired reading abilities than HC. Patients' reading	PANSS-Cog negatively correlated with GORT-	WAIS-III working memory or processing speed could not	English

Continued

Table 3 *Continued*

1. Psychosis						
Study	Dg.	Sample (N) (M/F)	Age (Mean, SD)	Medication (mg/ day, CPZE)	Education years (Mean, SD)	Tests (subtests)
Meta-analysis						III (7 subtests), NDRT (3 subtests), WRAT-III
Walder et al. [22] *Meta-analysis*	**SZ**	SZ = 31 (17/14); **HC = 27** (13/14)	SZ = 39.1 (7.0)	520 ± 428 CPZE	NR	RNRT, RNST, Auditory blending test, RAN, Caplan and Hildebrandt's task, WRAT-R
Nelson et al. [72]	**SZ**	SZ = 100 (72/28)	SZ = 38.28 (9.37)	795.80 ± 566.16 CPZE	SZ = 12.31 (9.10)	WRAT-III
Leonard et al. [36] *Meta-analysis*	**SZ**	SZ = 45 (36/9); **HC = 39** (36/3)	SZ = 41.1 (10); HC = 42.0 (10)	NR	NR	WJTA-III (3 subtests)
Potter and Nestor [73] *Meta-analysis*	**SZ**	SZ-Preserved =21 (19/2); SZ-Deteriorated = 21 (16/5); SZ-Compromised = 31 (23/8); **HC = 74** (47/27)	SZ-P = 36.31 (11.06); SZ-D = 41.40 (10.42); SZ-C = 38.71 (10.93); HC = 40.59 (8.89)	410.70 ± 298.76 CPZE	SZ-P = 13.7 (1.809); SZ-D = 13.214 (1.29); SZ-C = 12.18 (1.98); HC = 15.27 (2.029)	WRAT-III
Arnott et al. [24] *Meta-analysis*	**SZ**	SZ = 16 (10/6); **HC = 12** (6/6)	SZ = 41.19 (13.43); HC = 42.17 (15.56)	417.86 ± 375.22 CPZE	SZ = 11.88 (1.78); HC = 11.75 (2.18)	NARA-III; WRMT-R (3 subtests), RCBA-2 (10 subtests), CTOPP (8 subtests)
Gavilán and Garcia-Albea [39] *Meta-analysis*	**SZ**	SZ = 22 (18/4); **HC = 22** (18/4)	SZ = 42.82 (10.84); HC = 41.95 (10.78)	833.46 CPZE	SZ = 10.18 (2.38); HC = 10.05 (2.44)	PALPA-computerized (compre hension of words and sentences), BDAE (paragraph comprehension), experimental test of figurative language comprehension.
Light et al. [74] *Meta-analysis*	**SZ**	SZ = 341; **HC = 205** (all: 247/94)	SZ = 45.49 (9.37)	NR	SZ = 11.98 (1.99)	WRAT-III

Variables examined	Reading performance	Symptoms, medication and reading	Cognition, education and reading	Language
APA, ARN WJTA-III: (BR) - reading decoding, speed, comprehension/ (BRS) - vocabulary, phonics, structure/(RC) - comprehension, vocabulary, reasoning/(PGK) - phonic and orthographic processes; NDRT: vocabulary, comprehension and total score; WRAT-III: single-word reading	levels were 3.4 years below their education level. Significant differences between SZ and HC were in all subtests except in CTOPP-RN and NDRT-PKG. No differences between SZ and HC in WRAT scores.	4 comprehension. Relationship between medication and reading NE.	predict GORT-4 scores. Groups differed significantly in education. Sz had reading 3.4 years below achieved education years.	
RNRT, RNST, auditory blending test & RAN: all phonological processing; WRAT-R: single-word reading; Caplan and Hildebrandt's task: grammar	Women with SZ had relatively preserved phonology and grammar function when compared with HC women. SZ men generally impaired in language skills in comparison with HC men, especially in phonology and grammar. Men and women with SZ differed most in grammar. Sex and group had a significant effect on phonology and grammar.	No significant differences in chlorpromazine levels. Relationship between symptoms and reading NE.	Attention scores entered as a covariate in the analysis. Relationship between education and reading NE.	English
single-word reading	SZ scored *M* = 78.00 (21.01) in WRAT. Relationship between premorbid functioning (WRAT) and social cognition is unclear.	No significant correlation between BPRS scores and WRAT. Relationship between medication and reading NE.	NE	English
Word attack: phonological decoding; Letter-Word Identification: single-word reading (word recognition); Passage comprehension: comprehension	SZ scored significantly lower than HC in phonological decoding, comprehension, and single-word reading. Anatomical risk index predicted 38% of the variance in verbal ability and 44% of the variance in comprehension.	NE	Broad cognitive ability was significantly lower in SZ, but no correlations with reading skills were reported. Relationship between education and reading NE.	English
single-word reading	SZ-compromised scored significantly lower than all other groups. No significant differences between other SZ groups and HC.	NE	Significant differences were found between the SZ IQ subgroups in memory and executive functioning. No correlation with reading was reported. Relationship between education and reading NE.	English
NARA-III: comprehension, rate, accuracy; WRMT-R: comprehension, word recognition (Basic Skills subscore); RCBA-2: comprehension, total time; CTOPP: PA, APA, PM, RN	SZ had impaired comprehension and rate in NARA. Phonological processes were related to symptomatology but only CTOPP-RN was significantly lower in SZ than HC. Reading comprehension measured by RCBA was mostly spared in SZ. Reading words and nonwords was comparable in SZ and HC.	PANSS-N and PANSS-G negatively correlated with CTOPP RN. PANSS-P negatively correlated with CTOPP-PA. Relationship between medication and reading NE.	No significant differences between groups in education. Relationship between cognition and reading NE.	English
PALPA, BDAE: reading comprehension (words, sentences, paragraphs); experimental: comprehension of metaphors, ironies, proverbs	SZ patients had difficulties in understanding the theory of Mind, which was closely related to the understanding of figurative language. SZ understood proverbs (in isolation) less than ironies and less than metaphors (in context). All figurative language significantly impaired in SZ when compared to HC.	NE	Groups significantly differed in IQ but not premorbid IQ. IQ was a covariate in the analysis. Relationship between education and reading NE.	Spanish
single-word reading	SZ scored significantly lower in WRAT reading than HC at baseline and after 1 year.	NE	NE	English

Continued

Table 3 *Continued*

1. Psychosis						
Study	Dg.	Sample (N) (M/F)	Age (Mean, SD)	Medication (mg/day, CPZE)	Education years (Mean, SD)	Tests (subtests)
Martinez et al. [41] *Meta-analysis*	**SZ, SZAD**	SZ = 21; SZAD = 5 (20/5); **HC = 17** (15/2)	SZ/SZAD = 39.4 (10.8); HC = 32.7 (11.0)	1314.1 ± 973.5 CPZE	SZ = 12.4 (2.3); HC = 16.1 (2.4)	GORT-4, WRAT-III
Whitford et al. [7] *Meta-analysis*	**SZ**	SZ = 20 (16/4); **HC = 16** (13/3)	SZ = 31.05 (9.08); HC = 31.56 (10.08)	443.57 ± 277.55 CPZE	SZ = 11.85 (1.99); HC = 13.66 (1.87)	CTOPP (6 subtests), NDRT (2 subtests)
Revheim et al. [17] *Meta-analysis*	**SZ, SZAD**	SZ = 37; SZAD = 8 (40/5); **HC = 24** (17/7)	SZ/SZAD = 37.6 (11.6); HC = 39.6 (11.3)	944.3 ± 702.7 CPZE	SZ/SZAD = 12.7 (2.2); HC = 14.6 (1.8)	GORT-4, CTOPP (12 subtests), WJTA-III (7 subtests), NDRT (2 subtests) WRAT
Patrick et al. [59] *Meta-analysis*	**SZ**	SZ = 29 (26/3); **HC = 29** (15/14)	SZ = 44.77 (8.24); HC = 40.93 (9.02)	NR	SZ = 13.33 (1.75); HC = 15.34 (2.32)	WRAT-IV
Wang et al. [81]	**SZ**	SZ = 22 (12/10); **HC = 22** (13/9)	SZ = 24.36 (4.03); HC = 23.14 (1.94)	582.16 CPZE	SZ = 14.77 (1.06); HC = 15.00 (0.01)	Nonword cross-out test, onset judgment test, animal word cross-out test, pseudo-homophone discrimination test
Curzietti et al. [76] *Meta-analysis*	**SZ**	SZ = 22 (13/9); **HC = 22** (13/9)	SZ = 41.0 (8.84); HC = 40.03 (8.4)	261 ± 144 CPZE	SZ = 12.3 (2.8); HC = 12.5 (2.7)	Alouette
Dondé et al. [18] *Meta-analysis*	**SZ**	SZ = 30 (21/11); **HC = 28 (24/6)**	SZ = 39.4 (11.2); HC = 37.2 (10.2)	NR	SZ = 14.1 (2.5); HC = 14.9 (2.0)	CTOPP (3 subscales), WJTA-III (3 subscales)

Variables examined	Reading performance	Symptoms, medication and reading	Cognition, education and reading	Language
GORT-4: comprehension, fluency (rate + accuracy), ORQ; WRAT-III: single-word reading	SZ scored significantly lower than HC in all passage reading measures. These impairments correlated with reduced fMRI activation in low spatial frequency (LSF) regions (dorsal stream visual system). Deficits in comprehension were greater than in single-word reading.	Reading negatively correlated with antipsychotic dosage. Relationship between symptoms and reading NE.	General intelligence did not predict reading scores. Group differences in reading ability remained when cognitive deficits (processing speed and working memory) were accounted for analyses. Reading was at the 6th-grade level despite achieved 12.4 years of education.	English
CTOPP: PA, PM, RN; NDRT: comprehension, rate	SZ scored significantly lower than HC in all reading measures.	No influence of medication on reading. Relationship between symptoms and reading NE.	Education in years entered as a covariate.	English
GORT: rate, accuracy, fluency, comprehension; CTOPP: PA, APA, RN, ARN; WJTA-III: fluency, spelling, (BR) - reading decoding, speed, comprehension/(BRS) - vocabulary, phonics, structure/(RC) - comprehension, vocabulary, reasoning/(PGK) - phonic and orthographic processes; NDRT: comprehension, vocabulary, total score; WRAT: single-word reading	Reading skills (GORT-4, CTOPP - APA, RN, ARN, and WJTA-III) were significantly reduced in all SZ in comparison with HC, and significantly below than would be expected based on their general cognition. 73% of SZ met the criteria for dyslexia. WRAT scores were relatively intact in SZ.	No correlation between PANSS scores and reading. Reading deficits positively correlated with the gap between their and parental socioeconomic status. No correlation between medication and reading.	Passage reading was significantly reduced relative to premorbid IQ measured by WRAT. Reading was significantly below achieved education level.	English
comprehension	SZ patients scored significantly lower in comprehension than HC.	NE	NE	English
Nonword cross-out test: orthography onset judgment test: orthography-phonology animal word cross-out test: orthography-semantics (comprehension) pseudo-homophone discrimination test: vocabulary	SZ had impaired all orthographic skills in Chinese while their access to mental lexicon was intact. Reading in Chinese requires also deep orthographic processing which results in impaired reading in Chinese in SZ and this correlated with the severity of psychosis symptoms.	BPRS scores negatively correlated with orthography and orthography-semantics. Relationship between medication and reading NE.	Groups did not differ in achieved education levels. Relationship between cognition and reading NE.	Chinese
rate, accuracy, speed	No significant differences were found between SZ and HC in neither of the three variables examined.	PANSS overall scores did not correlate with any reading subscores. The hallucination scores correlated significantly with reading efficiency and speed. Relationship between medication and reading NE.	Groups did not differ in achieved education levels. Groups were significantly different in WAIS scores. Relationship between cognition and reading NE.	French
CTOPP PA, PM, APA: phonological processing; WJTA-III: comprehension, fluency, (BRS) – single-word reading	SZ had impaired phonological awareness for words and nonwords whereas phonological memory was intact. Reading comprehension and fluency were also significantly impaired. Single-word reading was intact in comparison to HC.	NE	MCCB correlations with reading skills were not reported. Groups did not differ in achieved education levels.	English

Continued

Table 3 *Continued*

1. Psychosis						
Study	Dg.	Sample (N) (M/F)	Age (Mean, SD)	Medication (mg/day, CPZE)	Education years (Mean, SD)	Tests (subtests)
2. Affective disorders						
Weiss et al. [66]	**DD**	DD-intervention =38 (22/16); DD-control = 32 (17/15)	DD intervention = 41.4 (14.3); DD control = 43.7 (15.3)	NR	NR	REALM
3. Personality disorders/psychopathy						
Daderman et al. [15] ***Forensic*** *Meta-analysis*	**PD**	PD = 10 (7 dyslexia) (10/0); FC dyslexia = 26 (26/0); FC = 31 (31/0); **HC = 77** (77/0)	PD = 38.7 (5.89); FC = 35.1 (10.5) ; HC = 31.2 (10.8)	NR	PD = 9.8 (2.5); FC dyslexia = 9.1 (1.5); FC = 10.4 (2.1); HC = 11.1 (1.6)	"Summer with Monika", MST, MWDT, JDT (Word chains)
Brites et al. [30] ***Forensic*** *Meta-analysis*	**Psychopathy**	Psychopathy = 13; Psychopathy-Forensic =13; FC = 25 (51/0); **HC = 39**	38.19 (7.67)	NR	*M* = 9.3 (1.88)	PALPA
Davidson et al. [68] ***Forensic***	**ASPD**	ASPD: Research Naive = 18 (18/0); Research Experienced = 7 (7/0)	Research naive = 38.67 (9.7); Research experienced = 38.86 (8.0)	NR	NR	TOWRE
4. General mental illness						
Berg and Hammitt [51]	**MI**	Alc = 53; PD = 6; Psychosis =30; Mental Retardation = 5; Organic Brain Syndrome = 6 (all: 74/26)	39	NR	MI = 9.0	PIAT (2 subtests)
Dalby and Williams [70] ***Forensic***	**MI**	SZ = 30 (29/1); BD Manic = 15 (9/6); Alc = 28 (26/2); ASPD =	SZ = 29.37 (5.94); BP = 31.69 (9.37); Alc = 39.00 (11.54); ASPD	NR	SZ = 10.73 (2.60); BP = 11.07 (2.44); Alc = 9.54 (1.53); ASPD = 8.41	WRAT

Variables examined	Reading performance	Symptoms, medication and reading	Cognition, education and reading	Language
single-word reading (literacy)	Only patients with limited literacy (scoring <60) were included. Literacy skills improved in DD intervention group after literacy training, and the depression severity lessened.	No correlation between depression symptoms (PHQ-9) and REALM at baseline. Relationship between medication and reading NE.	NE	English
"Summer with Monika": reading speed, comprehension; MST: spelling; MWDT: reading pronunciation; JDT: word decoding	Dyslexia remains underdiagnosed in forensic psychiatric patients. 7/10 of forensic participants had dyslexia. Reading speed was slower in PD with dyslexia. Verbal comprehension was normal. PD with dyslexia scored significantly lower than FC without dyslexia and HC on measures of decoding and spelling and significantly poorer than HC in reading out loud. Reading was characterized by distortion and misreading.	NE	Patients had reading skills below their education levels. Relationship between cognition and reading NE.	Swedish
phonological processing, reading pronunciation and writing, comprehension of words and images, comprehension of sentences	Phonological processing and single-word reading were similar between psychopaths (forensic + nonforensic) and nonpsychopaths (forensic + nonforensic). Phonological processing was lower in imprisoned participants. Comprehension was also intact in psychopaths.	NE	Groups did not differ in achieved education levels. Relationship between cognition and reading NE.	Portuguese
single-word reading (literacy)	Research experienced participants had higher literacy scores than research naïve ones. Participants with lower literacy prefer shorter wording and answered fewer questions correctly. Understanding of research terms may infer a higher ability to integrate research information.	NE	NE	English
comprehension, single-word reading (word recognition)	Over 50% of the patients scored below 7th grade in comprehension, resulting in being functionally illiterate. Patients scored significantly worse in comprehension than in single-word reading. Therefore, they could have read the text but did not understand it. Formal education was an indicator of word pronunciation but not comprehension. PD and Psychosis groups scored similarly in single-word reading and comprehension. Mental retardation and organic brain syndrome performed significantly lower than PD and Psychosis groups.	NE	Formal education was a good predictor of single-word reading but not for comprehension. Relationship between cognition and reading NE.	English
single-word reading (word recognition), spelling, arithmetic	Significant differences in reading, spelling, and arithmetic between all groups. Reading scores: Mania > SZ > HC > Alc > ASPD>	NE	In HC, IQ correlated with reading and spelling. Reading was significantly better than full-scale IQ in	English

Continued

Table 3 *Continued*

1. Psychosis						
Study	Dg.	Sample (N) (M/F)	Age (Mean, SD)	Medication (mg/ day, CPZE)	Education years (Mean, SD)	Tests (subtests)
Meta-analysis		17 (17/0); **HC = 21** (21/0)	= 25.53 (5.59); HC = 30.33 (10.31)		(2.12); HC = 10.43 (1.16)	
Nestor et al. [71] ***Forensic***	**MI**	MI = 40: Young = 22 (22/0); Old = 18 (18/0)	MI Young = 19.3; MI Old = 41.4	NR	NR	WRAT-R
Christensen and Grace [65]	**MI**	SZ = 7; AfD = 27; AdjD = 2; Other = 9 (all: 32/13)	32	NR	NR	REALM
Ferron et al. [58]	**MI**	SZ/SZAD = 95; Mood disorder = 34; Other MI = 6 (all: 97/38)	35 (10.0)	NR	NR	WRAT-IV
Selenius et al. [26] ***Forensic***	**MI with Psychopathy**	MI = 40: violence =29; sexual = 8; other = 3 (all: 32/8)	36 (10.0)	NR	MI = 10.04 (1.79)	MWDT, MST, The Hedgehog, MSVT (all tests by Madison), "The Pidgeon", JDT
Svensson et al. [27] ***Forensic***	**MI**	MI = 185: Neurodevelopmental disorder = 58; DD = 40; Psychosis = 57; Anxiety = 13; PD = 12 (all: 133/52)	33 (9.9)	NR	NR	JDT (wordchains), word attack, phonological choice, orthographic choice, WRMT (oral close), RAN

Abbreviations: AdjD, Adjustment Disorder; AfD, Affective Disorder; Alc, Alcoholism; BD, Bipolar Disorder; BDAE, Boston Diagnostic Aphasia Examination; BPRS, Brief Psychiatric Rating Scale; CPZE, Awareness, ARN, Alternative Rapid Naming); DD, Depressive Disorder; FC, Forensic Controls (history of violence without MI); GORT, Gray Oral Reading Test; HC, Healthy Controls; ITBS, Iowa Test Assessment Tool for Clinical Research; MCCB, MATRICS Consensus Cognitive Battery; MI, Mental Illness; MST, Madison's Spelling Test; MSVT, Madison's Standardized Vocabulary Test; MWDT, Language Processing in Aphasia; PANNS, Positive and Negative Syndrome Scale; PD, Personality Disorder; PIAT, Peabody Individual Achievement Test; RAN, Rapid Automatised Naming; RCBA, Schizophrenia; SZAD, Schizo-Affective Disorder; TOWRE, Test of Word Reading Efficiency; WJCog, Woodcock–Johnson Test of Cognitive Ability; WJTA-III, Woodcock–Johnson III Tests of Woodcock Reading Mastery Test—Revised (BS, Basic Skills, PC, Passage Comprehension, PKG, Phoneme-Grapheme Knowledge).
Studies including forensic populations are marked ***Forensic***.
Studies included in the meta-analysis are marked "*Meta-analysis*".
Bold entries indicates Visual aid to distinguish studies using a control group as a reference

Variables examined	Reading performance	Symptoms, medication and reading	Cognition, education and reading	Language
			SZ and BD. Reading and spelling were preserved in psychotics despite lowered general IQ. Relationship between education and reading NE.	
single-word reading, spelling, arithmetic	Violent patients: MI-Old scored significantly higher in WRAT-R reading subtest than MI-Young, suggesting developmental learning disability. Scores in Spelling and Arithmetic were not significantly different. Murder: MI-Old scored significantly higher in reading and spelling than MI-Young. Scores in arithmetic were not significant. Learning disability and conduct disorder may increase the probability of violence in MI-Young.	NE	NE	English
single-word reading (word recognition and pronunciation)	Over 75% of MI have reading skills on the level of 7th or 8th grade. People with MI are usually unaware of their reading problems. Reading screening recommended in routine evaluations.	NE	NE	English
comprehension	WRAT reading and comprehension on the level of 9th grade of education.	NE	NE	English
The Pidgeon: phonological processing; MWDT and JDT: word decoding; MST: spelling; The Hedgehog: reading speed, and comprehension; MSVT: vocabulary	Antisocial traits are not associated with reading. However, affective and interpersonal (Factor 1) traits were significantly related to decoding, reading speed and phonological processing. Phonology, semantics and syntactic skills significantly positively correlated with Superficial traits in psychopaths with MI.	Antisocial lifestyle did not correlate with reading skills. Affective and personality traits significantly positively correlated with sentence decoding and reading speed. Relationship between medication and reading NE.	NE	Swedish
JDT: decoding; word attack, phonolo gical choice: phonolo gical decoding; orthog raphic choice: spelling; oral close, RAN: reading compre hension	Low reading abilities interfere with psychiatric treatment in forensic mental health facilities. 16% of patients had a dyslexic profile. Psychosis and anxiety have the lowest general reading skills (phonolo gical processing + comprehension). DD had a significantly better word, nonword reading, and comprehension than psychosis. General reading skills could not predict diagnoses.	NE	NE	

Chlorpromazine equivalents; CTOPP, Comprehensive Test of Phonological Processing (PA, Phonological Awareness, PM, Phonological Memory, RN, Rapid Naming, APA, Alternative Phonological of Basic Skills; ITED, Iowa Test of Educational Development; JDT, Jacobson's Decoding Test; LNNB, Luria-Nebraska Neuropsychological Battery; Mac-CAT-CR, MacArthur Treatment Competence Madison's Word Decoding Test; NARA, Neale Analysis of Reading Ability; NDRT, Nelson–Denny Reading Test; NE, Not Examined; NR, Not Reported; PALPA, Psycholinguistic Assessments of Reading Comprehension Battery for Aphasia; REALM, Rapid Estimate of Adult Literacy in Medicine; RNRT, Roentgen's Nonwords Reading Test; RNST, Roeltgen's Nonwords Spelling Test; SZ, Achievement (BR, Broad Reading, BRS, Basic Reading Skills, RC, Reading Comprehension, PKG, Phoneme-Grapheme Knowledge); WRAT, Wide Range Achievement Test; WRMT-R,

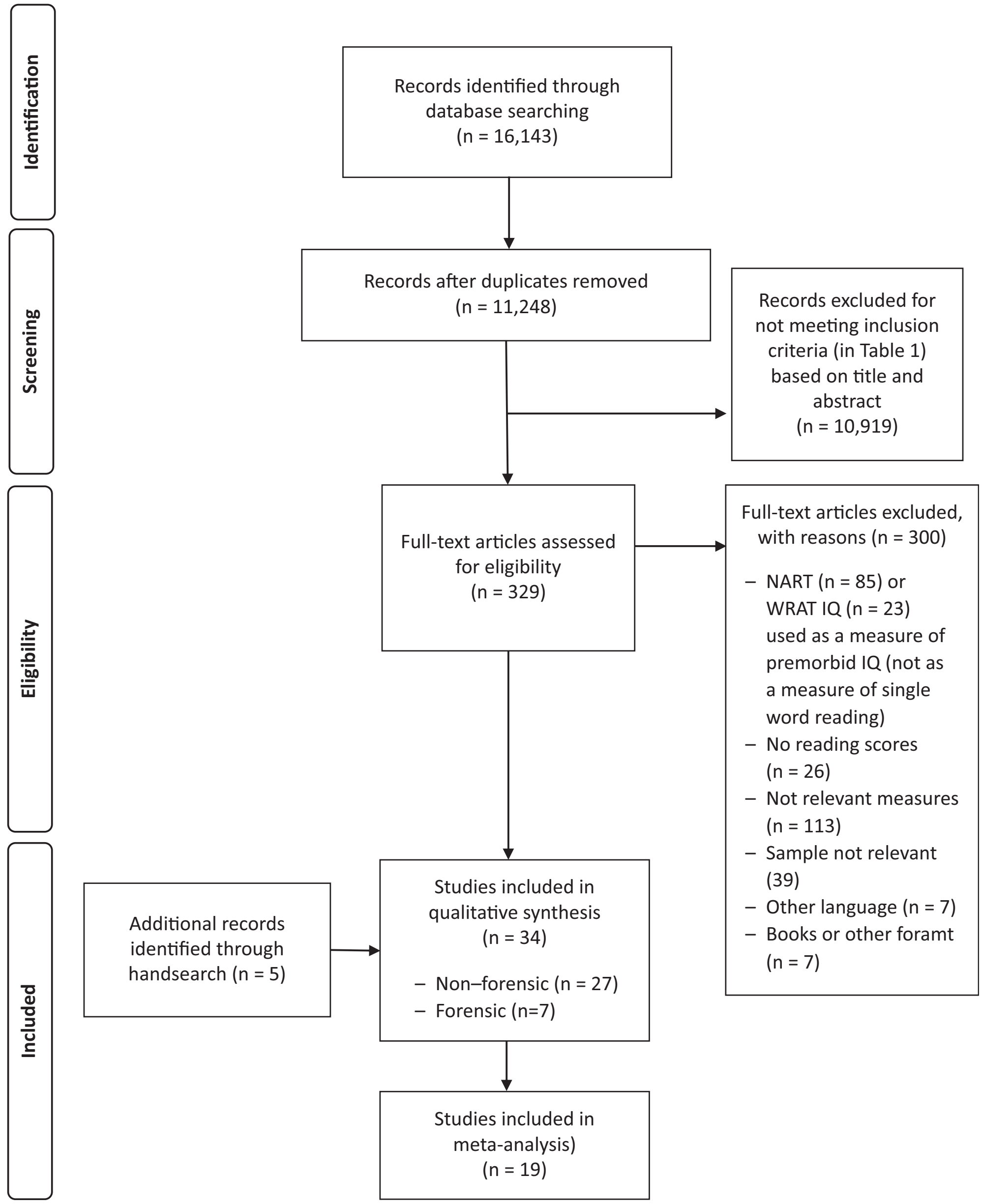


Figure 1. PRISMA flowchart.

Education

In SZ, three studies [17,21,41] examined the influence of education and all found reading skills significantly below achieved academic levels. Six studies [18,24,39,62,76,81] matched their groups on education or entered it as a covariate [85], and all found significant impairments in various reading skills. Nonforensic populations with general MIs had single-word reading equivalent to their achieved education but their comprehension was lower [51]. Forensic PD also had comprehension below their education level [15].

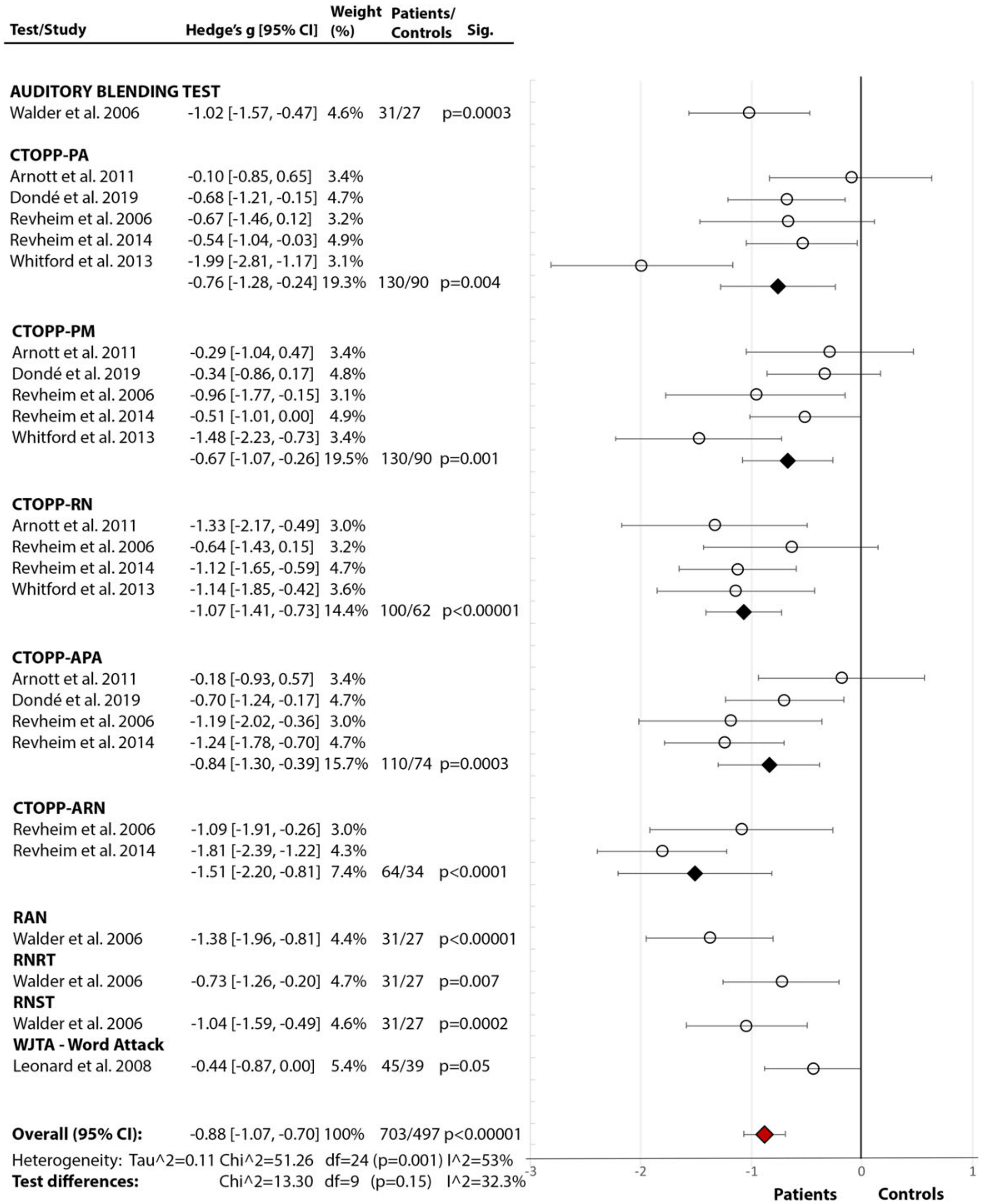
Discussion

This systematic review and meta-analysis evaluated existing evidence to identify the type and degree of reading impairments in different MIs, the reading assessment tools that might most consistently detect them, and possible differences in the pattern of reading skills deficits in people with different MIs in forensic and nonforensic settings. Most of the reviewed studies (27/34) included people with SZ. There were seven studies of reading skills deficits in people with different MIs (PD or general MI) in forensic settings. Our findings are discussed below.

Effect of diagnosis in nonforensic samples

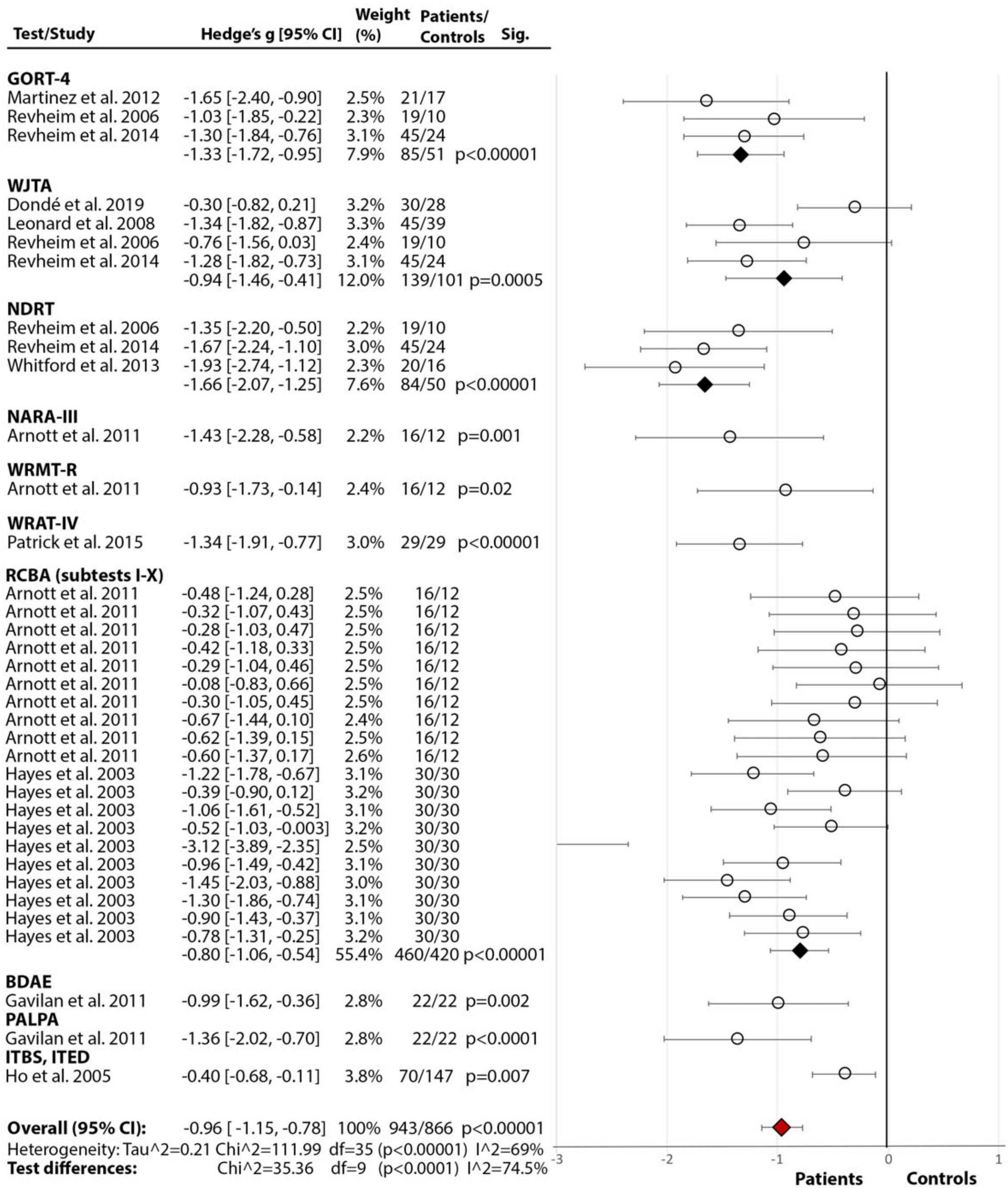
We observed significant deficits in multiple reading skills in SZ, resembling the pattern typically seen in dyslexia [6], and consistent with previous evidence for shared genetic and psychophysiological traits in SZ and dyslexia [7]. In our meta-analysis, both phonological processing and comprehension were greatly impaired. These impairments may be associated with ineffective use of contextual information [91] and contribute to poor speech in SZ, especially in close association with thought disorder [92]. Reading rate was low but the deficit in reading accuracy was lower. This indicates

2.1. Phonological processing and decoding



relatively preserved single-word reading skills, most likely because they are usually acquired before illness onset and remain intact [47]. In contrast, there was evidence for impairments in vocabulary and spelling, presumably as a result of disrupted scholastic experience. Disrupted scholastic experience during adolescence can affect complex skills such as comprehension [44,45,47], which could precipitate difficulties with processing complex written information in SZ. People with SZ showed reading skills well below their achieved education level (see *Education*). Reading skills deficits in SZ also do not seem to be explained by other aspects of cognition (see *Cognitive Function*) although more comprehensive investigations are needed to substantiate this. Our findings (*Symptoms and Medication*) further indicated that while symptoms and high antipsychotic doses may worsen reading skills, they do not fully explain the profile of reading skills deficits in SZ. Impairment in comprehension and vocabulary was present even before the onset of symptoms [44,45] together with deficient phonological processing, which has been related to disrupted visual processing in SZ since early age [21]. The symptoms can, however, aggravate deficits in reading skills, such as comprehension, which are acquired with

2.2. Comprehension



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experience, and also depend on the earlier acquired skills [93]. Recent data [94] suggest that some aspects of language production (e.g., slower articulation) that can affect reading skills assessments are particularly sensitive to dopamine-D2 receptor blocking antipsychotics. Furthermore, most studies in SZ included more men than women or men solely and also included people with schizoaffective disorder. Further studies need to comprehensively examine specific reading skills in both men and women with schizophrenia and schizoaffective disorder (separately) while taking medication, symptoms, cognition, education, and socioeconomic status into account.

Unlike in SZ and psychosis [51,58,65], nonpsychotic bipolar disorder, and affective disorders, seemed to have comprehension and single-word reading skills comparable to HC [30,47]. Although not all studies specified the type of PD, it seems that reading skill deficits may not be as prominent in nonforensic psychopathy as in SZ.

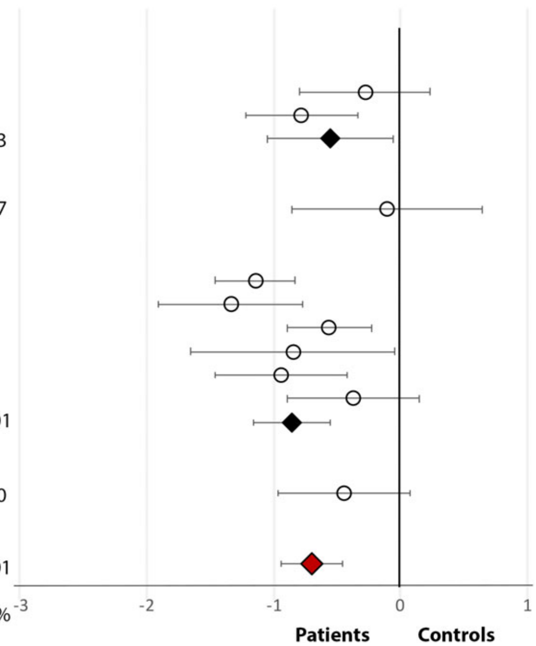
Effect of diagnosis in forensic samples

Our findings suggest only a weak or no deficit in nonforensic psychopathy but indicate a marked phonological processing and comprehension deficit in the incarcerated group. It is possible that

2.3 Single-word reading

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
WJTA				
Dondé et al. 2019	-0.28 [-0.79, 0.24]	9.9%	30/28	
Leonard et al. 2008	-0.78 [-1.23, -0.34]	11.3%	45/39	
	-0.55 [-1.04, -0.05]	21.2%	75/67	p=0.03
WRMT-R				
Arnott et al. 2011	-0.11 [-0.86, 0.64]	6.6%	16/12	p=0.77
WRAT-IV				
Light et al. 2012	-1.15 [-1.46, -0.83]	13.9%	163/58	
Patrick et al. 2015	-1.34 [-1.91, -0.77]	9.0%	29/29	
Potter et al. 2010	-0.56 [-0.89, -0.23]	13.7%	73/74	
Revheim et al. 2006	-0.85 [-1.65, -0.05]	6.1%	19/10	
Revheim et al. 2014	-0.94 [-1.47, -0.42]	9.9%	45/24	
Walder et al. 2006	-0.37 [-0.89, 0.15]	9.9%	31/27	
	-0.86 [-1.17, -0.56]	62.3%	360/222	p<0.00001
LNNB				
Maj 1986	-0.44 [-0.96, 0.08]	9.9%	52/20	p=0.10
Overall (95% CI):	-0.70 [-0.94, -0.46]	100%	503/321	p<0.00001

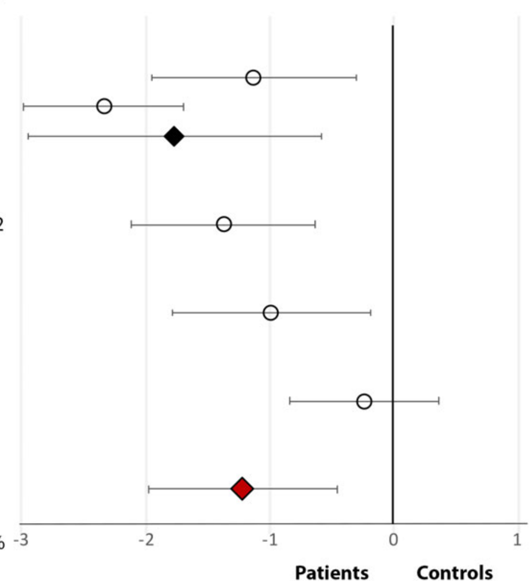
Heterogeneity: Tau^2=0.08 Chi^2=21.34 df=9 (p=0.01) I^2=58%
Test differences: Chi^2=4.66 df=3 (p=0.20) I^2=35.6%



2.4. Rate

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
GORT-4				
Revheim et al. 2006	-1.13 [-1.96, -0.31]	18.9%	19/10	
Revheim et al. 2014	-2.34 [-2.98, -1.70]	20.8%	45/24	
	-1.77 [-2.95, -0.59]	39.7%	64/34	p=0.003
NDRT				
Whitford et al. 2013	-1.38 [-2.12, -0.64]	19.8%	20/16	p=0.0002
NARA-III				
Arnott t al. 2011	-0.99 [-1.79, -0.19]	19.2%	16/12	p=0.02
Alouette				
Curzietti et al. 2018	-0.24 [-0.83, 0.36]	21.2%	22/22	p=0.44
Overall (95% CI):	-1.22 [-1.98, -0.46]	100%	122/84	p=0.002

Heterogeneity: Tau^2=0.62 Chi^2=22.96 df=4 (p=0.0001) I^2=83%
Test differences: Chi^2=8.54 df=3 (p=0.04) I^2=64.9%

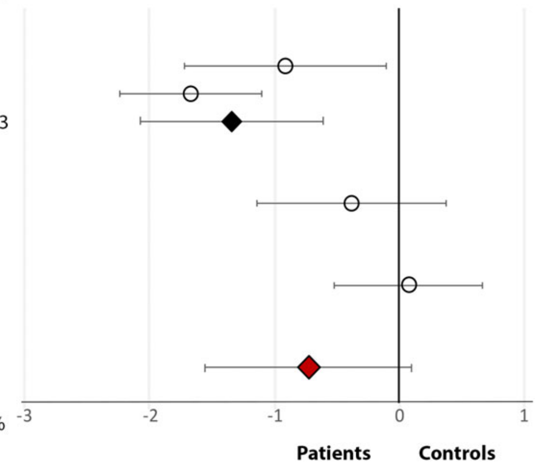


PD/psychopathic individuals with good phonological processing and comprehension are more able to evade incarceration [30,95]. Nonetheless, marked reading deficits in the incarcerated group may have contributed to their poor adjustment within the community [27], which, in turn, increased the risk of incarceration. Men with MIs within forensic settings had significantly lower general reading abilities and spelling than women with MIs [27], consistent with the pattern seen in healthy samples [22].

2.5 Accuracy

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
GORT-4				
Revheim et al. 2006	-0.91 [-1.72, -0.10]	23.4%	19/10	
Revheim et al. 2014	-1.67 [-2.24, -1.10]	26.3%	45/24	
	-1.34 [-2.08, -0.61]	49.8%	64/34	p=0.0003
NARA-III				
Arnott et al. 2011	-0.38 [-1.14, 0.37]	24.1%	16/12	p=0.32
Alouette				
Curzietti et al. 2018	0.07 [-0.52, 0.66]	26.1%	22/22	p=0.82
Overall (95% CI):	-0.73 [-1.56, 0.10]	100%	102/68	p=0.09

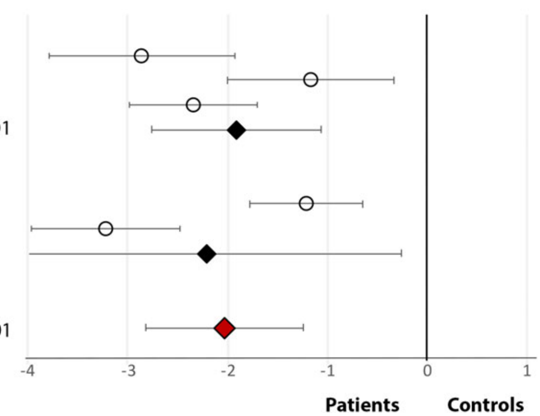
Heterogeneity: Tau^2=0.59 Chi^2=18.32 df=3 (p=0.0004) I^2=83%
Test differences: Chi^2=8.72 df=2 (p=0.01) I^2=77.1%



2.6 Fluency

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
GORT-4				
Martinez et al. 2012	-2.86 [-3.79, -1.93]	18.1%	21/17	
Revheim et al. 2006	-1.17 [-2.00, -0.34]	19.1%	19/10	
Revheim et al. 2014	-2.34 [-2.98, -1.70]	21.4%	45/24	
	-1.91 [-2.76, -1.07]	58.5%	85/51	p<0.00001
WJTA				
Dondé et al. 2019	-1.22 [-1.79, -0.66]	21.5%	30/28	
Revheim et al. 2014	-3.22 [-3.96, -2.48]	19.9%	45/24	
	-2.21 [-4.16, -0.25]	41.5%	75/52	p=0.03
Overall (95% CI):	-2.03[-2.82, -1.24]	100%	160/103	p<0.00001

Heterogeneity: Tau^2=0.67 Chi^2=24.83 df=4 (p<0.0001) I^2=84%
Test differences: Chi^2=0.07 df=1 (p=0.79) I^2=0%



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Clinical implications

Comprehension has a significant influence on decision-making capacity in SZ [96], and this is likely to be true also for people with other MIs, especially within forensic populations. Dyslexia is often underdiagnosed in people with MIs, and this might explain their inability to complete higher education and obtain jobs [15], or the expression of socially unacceptable behaviors [27]. Furthermore, progression and engagement in therapeutic activities within mental health services often depend on good reading and language skills. This highlights a need to accurately identify reading deficits and develop specific programs to improve reading skills of people in psychiatric services. It may be possible to target reading deficits in SZ and other MIs by building on the less affected aspects, such as lexical knowledge (access to words) [97,98], and access to familiar information that can compensate for some of the reading deficits [99], while implementing interventions to ameliorate reading skills [100].

Effect of assessments

Significant between-test differences were found only in tests detecting deficits in comprehension, accuracy, and rate in SZ. In comprehension and rate, the NDRT and GORT-4, and in accuracy, the GORT solely, consistently detected large deficits while the Alouette (French) test detected no deficits (Figure 2). It is conceivable that certain deficits emerge more often/strongly in English compared to some other languages, as is the case in developmental dyslexia [101]. This possibility requires further study.

2.7 Speed

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
RCBA-2				
Arnott et al. 2011	-0.87 [-1.66, -0.08]	41.3%	16/12	p=0.03
Alouette				
Curzietti et al. 2018	-0.24 [-0.84, 0.36]	58.7%	22/22	p=0.44
Overall (95% CI):	-0.55 [-1.11, 0.11]	100%	38/34	p=0.11
Heterogeneity: Tau^2=0.07	Chi^2=1.58 df=1 (p=0.21)			I^2=37%
Test differences:	Chi^2=1.58 df=1 (p=0.21)			I^2=36.7%

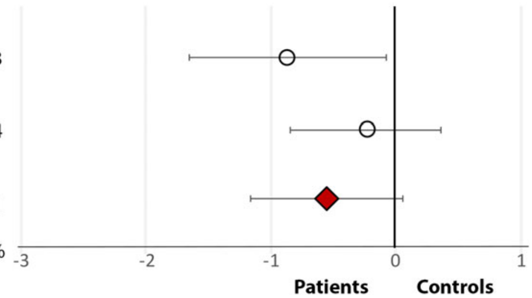
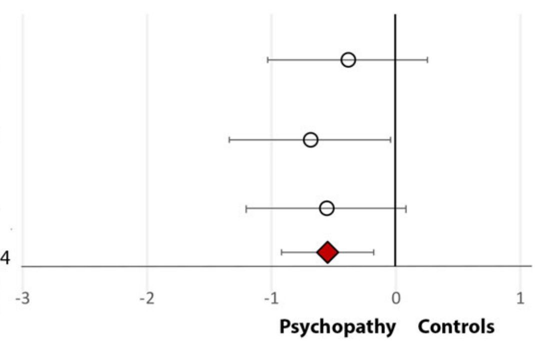


Figure 2. Reading deficits in schizophrenia (non-forensic population). Within each specific reading skill, the results are presented for each of the test(s)/measures used, followed by the analysis of differences between tests (last row). Negative values represent a poorer performance of people with schizophrenia in comparison to HC.
References: Arnott et al. [24]; Curzietti et al. [76]; Dondé et al. [18]; Gavilán and García-Albea [39]; Hayes and O'Grady [54]; Ho et al. [45]; Leonard et al. [36]; Light et al. [74]; Maj [62]; Martinez et al. [41]; Patrick et al. [59]; Potter and Nestor [73]; Revheim et al. [21]; Revheim et al. [17]; Walder et al. [22]; Whitford et al. [7]. Abbreviations: BDAE, Boston Diagnostic Aphasia Examination; CTOPP, Comprehensive Test of Phonological Processing (PA, Phonological Awareness, PM, Phonological Memory, RN, Rapid Naming, APA, Alternative Phonological Awareness, ARN, Alternative Rapid Naming); GORT, Gray Oral Reading Test; ITBS, Iowa Test of Basic Skills; ITED, Iowa Test of Educational Development; LNNB, Luria-Nebraska Neuropsychological Battery; NARA, Neale Analysis of Reading Ability; NDRT, Nelson–Denny Reading Test; PALPA, Psycholinguistic Assessments of Language Processing in Aphasia; RAN, Rapid Automatised Naming; RCBA, Reading Comprehension Battery for Aphasia; RNRT, Roentgen's Nonwords Reading Test; RNST, Roeltgen's Nonwords Spelling Test; WJTA-III, Woodcock-Johnson III Tests of Achievement Knowledge); WRAT, Wide Range Achievement Test; WRMT-R, Woodcock Reading Mastery Test-Revised. White circle (○)—effect size for a particular study determining the difference between patients and controls. Black diamond (◆)—pooled effect size for particular test/subtest. Red diamond (◆)—overall effect size for diagnosis for a certain reading skill (e.g., comprehension) including all partial effect sizes.

3.1 Phonological processing and decoding.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
PALPA - verbal words				
Brites et al. 2015	-0.39 [-1.03, 0.24]	33.9%	13/39	p=0.22
PALPA - written words				
Brites et al. 2015	-0.69 [-1.34, -0.05]	32.8%	13/39	p=0.03
PALPA - pseudowords				
Brites et al. 2015	-0.56 [-1.20, 0.08]	33.3%	13/39	p=0.09
Overall (95% CI):	-0.55 [-0.92, -0.18]	100%	39/117	p=0.004
Heterogeneity: Tau^2=0.00	Chi^2=0.42 df=2 (p=0.81)			I^2=0%
Test differences:	Chi^2=0.42 df=2 (p=0.81)			I^2=0%



3.2 Comprehension.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
PALPA - high imagination words				
Brites et al. 2015	-0.24 [-0.87, 0.39]	51.0%	13/39	p=0.46
PALPA - low imagination words				
Brites et al. 2015	-0.71 [-1.36, -0.07]	49.0%	13/39	p=0.03
Overall (95% CI):	-0.47 [-0.94, -0.01]	100%	26/78	p=0.05
Heterogeneity: Tau^2=0.01	Chi^2=1.06 df=1 (p=0.30)			I^2=6%
Test differences:	Chi^2=1.06 df=1 (p=0.30)			I^2=6.1%

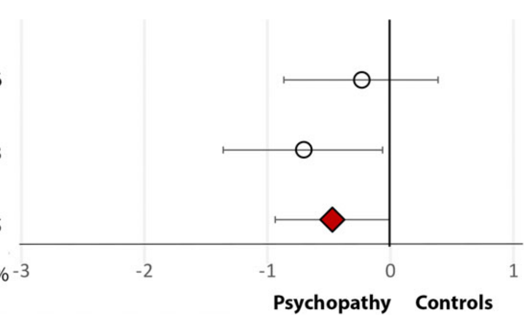


Figure 3. Reading deficits in community/nonforensic samples of people with psychopathy. Within each specific reading skill, the results are presented for each of the test(s)/measures used, followed by the analysis of differences between tests (last row). Negative values represent a poorer performance of people with personality disorder in comparison to healthy control.
Brites et al. [30]. Abbreviations: PALPA, Psycholinguistic Assessments of Language Processing in Aphasia. White circle (○)—effect size for a particular study determining the difference between patients and controls. Red diamond (◆)—overall effect size for diagnosis for a certain reading skill (e.g., comprehension) including all partial effect sizes.

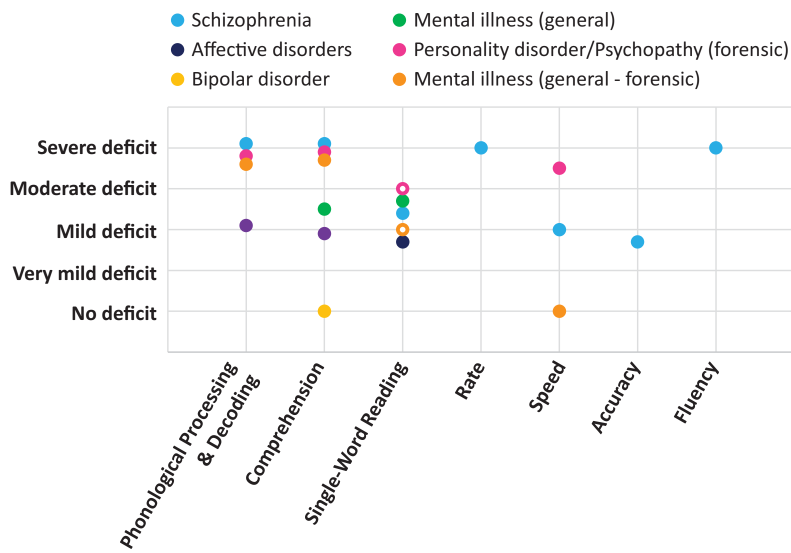


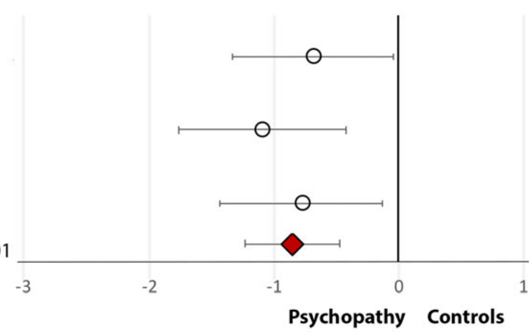
Figure 4. Interpretation of observed reading deficits in included diagnoses.
No deficit = nonsignificant differences between patients and healthy control (HC); Very mild deficit = Hedge's g up to −0.30 and/or mixed results with the majority of samples scoring within the norm; Mild deficit = Hedge's g up to −0.50 and/or reading skill at 9–10th-grade level; Moderate deficit = Hedge's g up to −0.75 and/or reading skill at 7–8th grade level; Severe deficit = Hedge's g over −0.75 and/or reading skill below 7th grade level. This interpretation considers whether the results were consistent or mixed. Empty circle (○) = Mixed evidence.

5.1. Phonological processing and decoding

Psychopathy

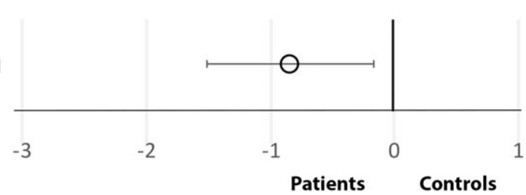
Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
PALPA - verbal words				
Brites et al. 2015	-0.69 [-1.33, -0.05]	34.2%	13/39	p=0.04
PALPA - written words				
Brites et al. 2015	-1.09 [-1.75, -0.42]	32.0%	13/39	p=0.001
PALPA - pseudowords				
Brites et al. 2015	-0.78 [-1.43, -0.13]	33.8%	13/39	p=0.02
Overall (95% CI):	-0.85 [-1.22, -0.47]	100%	39/117	p<0.0001

Heterogeneity: Tau^2=0.00 Chi^2=0.77 df=2 (p=0.68) I^2=0%
Test differences: Chi^2=0.77 df=2 (p=0.68) I^2=0%



Personality disorders - general

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
JDT				
Daderman et al. 2004	-0.84 [-1.51, -0.17]	100%	10/77	p=0.01



5.2. Comprehension. Psychopathy.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
PALPA - high imagination words				
Brites et al. 2015	-0.90 [-1.67, -0.12]	45.0%	13/39	p=0.02
PALPA - low imagination words				
Brites et al. 2015	-1.00 [-1.70, -0.30]	55.0%	13/39	p=0.005
Overall (95% CI):	-0.95 [-1.48, -0.43]	100%	26/78	p=0.0003

Heterogeneity: Tau^2=0.00 Chi^2=0.04 df=1 (p=0.85) I^2=0%
Test differences: Chi^2=0.04 df=1 (p=0.85) I^2=0%

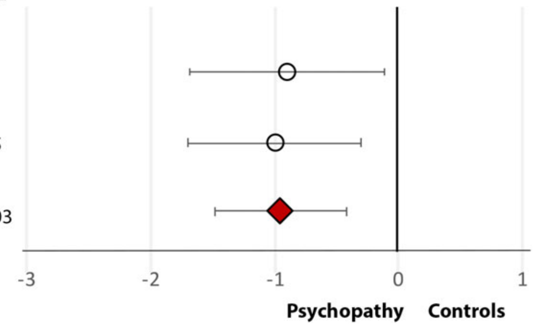
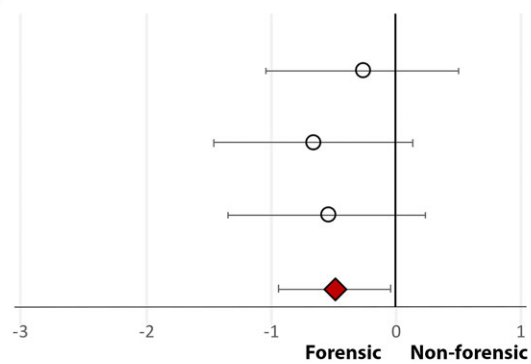


Figure 5. Reading deficits in forensic patients with psychopathy or personality disorders. Within each specific reading skill, the results are presented for each of the test(s)/measures used, followed by the analysis of differences between tests (last row). Negative values represent a poorer performance of people with psychopathy or personality disorder in comparison to healthy control.
Brites et al. [30]; Daderman et al. [15]. Abbreviations: JDT, Jacobson's Decoding Test; PALPA, Psycholinguistic Assessments of Language Processing in Aphasia. White circle (○)—effect size for a particular study determining the difference between patients and controls. Red diamond (◆)—overall effect size for diagnosis for a certain reading skill (e.g., comprehension) including all partial effect sizes.

6.1 Phonological processing and decoding.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
PALPA - verbal words				
Brites et al., 2015	-0.27 [-1.05, 0.50]	34.3%	13/13	p=0.49
PALPA - written words				
Brites et al., 2015	-0.66 [-1.46, 0.13]	32.5%	13/13	p=0.10
PALPA - pseudowords				
Brites et al., 2015	-0.55 [-1.34, 0.24]	33.2	13/13	p=0.17
Overall (95% CI)	-0.49 [-0.94, -0.04]	100%	39/39	p<0.03

Heterogeneity: Tau^2=0.00 Chi^2=0.51 df=2 (p=0.59) I^2=0%
Test differences: Chi^2=0.51 df=2 (p=0.59) I^2=0%



6.2 Comprehension.

Test/Study	Hedge's g [95% CI]	Weight (%)	Patients/ Controls	Sig.
PALPA - high-imagination words				
Brites et al., 2015	-0.70 [-1.50, 0.09]	51.8%	13/13	p=0.08
PALPA - low-imagination words				
Brites et al., 2015	-1.02 [-1.84, -0.19]	48.2%	13/13	p=0.02
Overall (95% CI)	-0.85 [-1.43, -0.28]	100%	26/26	p=0.03

Heterogeneity: Tau^2=0.00 Chi^2=0.29 df=1 (p=0.59) I^2=0%
Test differences: Chi^2=0.29 df=1 (p=0.59) I^2=0%

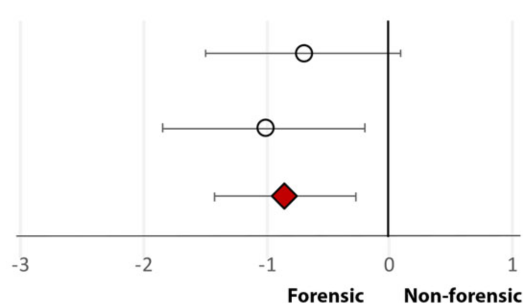


Figure 6. Reading deficits in incarcerated vs community samples of people with a diagnosis of psychopathy. Within each specific reading skill, the results are presented for each of the test(s)/measures used, followed by the analysis of differences between tests (last row). Negative values represent a poorer performance of the forensic sample, compared to the nonforensic sample.
Brites et al. [30]. Abbreviations: PALPA, Psycholinguistic Assessments of Language Processing in Aphasia. White circle (○)—effect size for a particular study determining the difference between patients and controls. Red diamond (◆)—overall effect size for diagnosis for a certain reading skill (e.g., comprehension) including all partial effect sizes.

Conclusions

Our findings demonstrate pronounced deficits in phonological processing and comprehension in SZ and forensic PD/psychopathy. Reading skills in people with other MIs in nonforensic settings seem relatively unaffected. Among the tests, only the NDRT and GORT detected significantly stronger deficits in SZ than other measures. Considering the importance of good reading skills in everyday life, as well as for the clinical success of mental health services, there is a clear need to identify methods that can improve reading in SZ and forensic PD populations. These interventions could potentially build on relatively spared aspects of reading by implementing approaches already effective in dyslexia.

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Conflict of Interest. The authors report no conflicts of interest.

Data Availability Statement. All data supporting the meta-analysis reported in this article are available from Brunel University London research repository at 10.17633/rd.brunel.13123334.

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Clarifying the roles of schizotypy and psychopathic traits in lexical decision performance

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ABSTRACT

Introduction: Some studies suggest that lexical recognition is impaired in people with schizophrenia, psychopathy and/or antisocial personality disorders, but not affective disorders. We examined the extent to which various traits dimensionally linked to one or more of these disorders are associated with lexical recognition performance in the general population.
Methods: Seventy-eight healthy English-speaking participants completed self-report measures of schizotypy, psychopathy, impulsivity, depression, anxiety and stress. All participants were assessed on a one-choice variant of a lexical decision task (LDT).
Results: Meanness and Boldness traits of psychopathy (Triarchic Psychopathy Measure), and positive schizotypy (Unusual Experiences, Oxford-Liverpool Inventory of Feelings and Experiences) were associated with poor word-nonword accuracy, and predicted a significant amount of unique variance (Meanness, 12%; Boldness, 4.8%; Positive Schizotypy, 4.4%; total 21%) in performance. Higher motor impulsivity predicted 30% of the variance in low-frequency words recognition accuracy, but only in non-native English speakers. Affective traits were not associated with LDT performance.
Conclusion: Psychopathic traits show stronger negative associations with lexical recognition performance than schizotypal traits, and impulsivity may differently influence lexical decision performance in native and non-native speakers. Further studies are needed to replicate these findings, especially the influence of language familiarity in the impulsivity-performance relationship, and to clarify the influence of corresponding symptom dimensions in lexical recognition abilities, taking language familiarity, migration status, and comorbidity into account, in people with schizophrenia, psychopathy, and/or antisocial personality disorders.

1. Introduction

Reading begins with the recognition or decoding of words and comparison of the written-read entries with the person's vocabulary in memory (Gough and Tunmer, 1986; James and Oberle, 2012). According to the Dual Route Cascaded model, words can be identified by following the sublexical or lexical pathway (Coltheart et al., 2001). The sublexical pathway recognises words by decoding letters into sounds, putting them together, and comparing the outcome with existing mental vocabulary entries. This pathway engages phonological processing, orthography, and semantic skills, and is used in the recognition of unfamiliar words (often low-frequency) and nonwords. In the lexical pathway, a familiar word (often high-frequency) is recognised as a whole, triggering automatic mental representation (Balota and Yap, 2006; Coltheart et al., 2001). Lexical recognition is a good indicator of overall reading proficiency, especially in bilingual individuals (Harrington, 2006; Park et al., 2012), and typically assessed using variants of the lexical decision task (LDT) requiring participants to identify a string of letters as a word or nonword (Meyer and Schvaneveldt, 1971).

A recent meta-analysis (Vanova et al., 2021) revealed significant deficits in reading skills in schizophrenia, personality disorders and/or psychopathy, but not in affective disorders. In the context of LDT, individuals with schizophrenia showed poorer word-nonword recognition and longer reaction times (RTs) than controls in some (Hokama et al., 2003), but not all studies (Natsubori et al., 2014; Tan et al., 2016b). The relationship between schizotypy, a potential vulnerability factor for

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schizophrenia (Lenzenweger, 2018), and LDT performance is unclear (Schofield and Mohr, 2014), with reports of similar performance in groups with high and low schizotypy (Park and Waldie, 2017), and no significant dimensional relationships between schizotypy and LDT performance (Carlin and Lindell, 2015; Tan et al., 2016a) though Cognitive Disorganisation aspect of schizotypy did predict nonword errors in one study (Tan et al., 2016a).

Psychopathy has been associated with poorer reading skills in forensic and community samples (Vanova et al., 2021). Higher impulsive-antisocial psychopathy scores correlate with poorer overall word-nonword recognition (Heritage and Benning, 2013; Lorenz and Newman, 2002), and slower RTs, especially in forensic samples (Kiehl et al., 2004; Reidy et al., 2008). Impulsivity, a core feature of multiple psychopathologies (Whiteside and Lynam, 2001), is commonly present in individuals with psychopathic traits (Weidacker et al., 2017) or schizotypy (Mason and Claridge, 2006). One study (Harmon-Jones et al., 1997) observed higher attentional and non-planning, but not motor, impulsivity to be related to poor reading comprehension and accuracy, while another study (De Pascalis et al., 2009) reported a negative influence of higher overall impulsivity on the RTs and accuracy when processing words incongruent with presented sentences. Previous research suggests intact reading skills in people with affective disorders (Vanova et al., 2021), and no effect of subclinical depression and anxiety in word-nonword recognition (Li et al., 2014; Notebaert et al., 2019; Stevens et al., 2015; White et al., 2010). However, much of the evidence for reading skills deficits in clinical populations comes from small sample studies with high heterogeneity, and rarely accounts for confounders such as medication (Wright and Woods, 2020).

The present study, therefore, examined the relationship between schizotypy, psychopathy, impulsivity, affective traits, and LDT performance, in a general population sample. Based on previous findings (Vanova et al., 2021), we hypothesised that higher schizotypy, psychopathy, and impulsivity will be associated with lower LDT performance. Furthermore, we examined the common and unique contribution of schizotypy, psychopathy and/or impulsivity to LDT performance and explored the role of language familiarity (native versus non-native speakers) in these associations.

2. Methods

2.1. Participants

Seventy-eight healthy adults with sufficient written and verbal command of the English language, normal/corrected-to-normal vision and hearing, no self-reported incidence of psychiatric/neurological illness, and no serious criminal history participated. The study was approved by the university research ethics committee. Participants provided written informed consent and were compensated for their time.

2.2. Materials

2.2.1. Self-report measures of psychopathology-related traits

Schizotypy was assessed using the Oxford-Liverpool Inventory of Feelings and Experiences (O-LIFE; 150 items; subscales: Unusual Experiences, Cognitive Disorganisation, Introvertive Anhedonia, Impulsive Nonconformity) (Mason and Claridge, 2006). Psychopathy was assessed using the Self-Report Psychopathy Scale–Short Form (SRP-4-SFl; 29 items; subscales: Interpersonal, Affective, Lifestyle, Antisocial) (Paulhus et al., 2016) and Triarchic Psychopathy Measure (TriPM; 58 items; subscales: Boldness, Meanness, Disinhibition) (Patrick et al., 2009). Impulsivity was assessed using the Barratt Impulsiveness Scale (BIS-11; 30 items; subscales: Attention, Cognitive Instability, Motor, Perseverance, Self-Control, Cognitive Complexity) (Patton et al., 1995) and Impulsive Behavior Scale-Short (S-UPPS-P; 20 items; Negative Urgency, Positive Urgency, Lack of Premeditation, Lack of Perseverance, Sensation Seeking) (Whiteside et al., 2005). Affective traits were assessed using the Depression, Anxiety, and Stress Scale (DASS-21, 21 items) (Lovibond and Lovibond, 1995). All measures were administered using Qualtrics^{XM} (Qualtrics LLC, 2005).

2.2.2. Lexical decision task (LDT)

The task was administered using Presentation® Software (version 21.1) (Neurobehavioral Systems Inc., 2018). Participants were presented with 120 stimuli (5–6 letters long) consisting of 60 English words from the frequency list of the British National Corpus (Leech et al., 2001) and 60 nonwords from the ARC Database (Rastle et al., 2002). The word list consisted of 30 high-frequency (2900–3000 occurrences per million words) and 30 low-frequency word lemmas (10–11 /million), counterbalanced per word category (adjectives, verbs, nouns). The nonword list included 30 real nonwords (letter strings not existing in the English language and not resembling any existing word, e.g., *youns*, *cimes*) and 30 pseudohomophones (nonwords pronounced as recognisable words but spelt incorrectly, e.g., *hense* [hence]). The nonword list was counterbalanced in the summed frequency of nonword neighbours, which is an indicator of similarity with other nonwords (high-frequency: 300–700/million; low-frequency: 1–10/million). The neighbourhood size for all nonwords was 1, representing the number of words that can be derived by changing one letter. Each trial consisted of a 300 ms fixation cross, a 200 ms blank screen, a 500 ms main stimulus (word/nonword), and a 1000 ms (blank screen) response period (Fig. 1).

Participants were asked to respond with a button press when presented with a valid English word and make no response to nonwords. The instructions were presented before a practice session (with feedback) consisting of 16 stimuli (50% words). Performance was indexed by response accuracy (RA) and speed (RTs). RAs for words were examined as the number of correct button-presses and for nonwords as correct withdrawals. Overall performance was calculated as the number of correctly identified words plus nonwords. RTs (in ms) were assessed for correct responses to high and low-frequency words, and incorrect responses to pseudohomophones and real nonwords.

2.3. Statistical analyses

All analyses were performed using IBM SPSS Statistics, V26.0 (IBM Corp., 2019), with $p \leq 0.05$. All variables were first assessed for normality, and those with significant skewness or kurtosis were normalised by replacing outliers with mean value ±2SD for each variable (Field, 2009) (Tables 1–2).

Differences between native and non-native speakers in categorical variables were explored using Chi-Square, and in continuous variables using independent sample *t*-tests. Performance accuracy was analysed using a 4 (Stimulus-Type) × 2 (Sex) × 2 (Language) analysis of variance (ANOVA) with Stimulus-Type (high-frequency words, low-frequency words, pseudohomophones, real nonwords) as a within-subject factor, and Sex (males, females) and Language (native speakers, non-native speakers) as the between-subject factors. RTs to correct high and low-frequency words and incorrect pseudohomophones and real nonwords

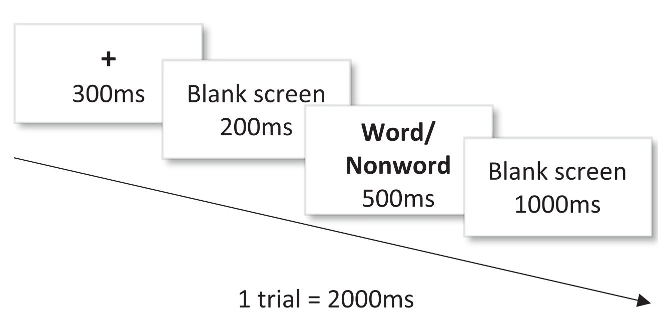

Fig. 1. Lexical decision task trial.

Table 1
Descriptive statistics for self-report psychopathology measures (N = 78).

	Mean (SD)	Observed min	Observed max	Maximum possible score
O-LIFE unusual experiences	10.4 (6.24)	0	25	30
O-LIFE cognitive distortions	13.3 (5.46)	0	24	24
O-LIFE introvertive anhedonia[a]	7.42 (4.63)	0	22	27
O-LIFE impulsive nonconformity	8.91 (3.30)	3	17	23
SRP-4-SF interpersonal[a]	13.8 (4.93)	7	28	35
SRP-4-SF affective	14.2 (4.68)	7	30	35
SRP-4-SF lifestyle	15.8 (5.00)	7	29	35
SRP-4-SF antisocial[a]	9.99 (2.24)	8	22	40
TriPM boldness	27.2 (8.26)	10	46	76
TriPM disinhibition[a]	14.8 (7.70)	1	34	80
TriPM meanness	13.2 (6.18)	1	27	76
BIS-11 attention[a]	10.8 (2.78)	6	20	20
BIS-11 cognitive instability	6.31 (2.24)	3	12	12
BIS-11 motor	14.4 (3.26)	7	22	28
BIS-11 perseverance[a]	7.15 (1.83)	3	14	16
BIS-11 self-control	13.2 (3.68)	7	21	24
BIS-11 cognitive complexity	11.2 (2.26)	6	16	20
S-UPPS-P negative urgency	8.77 (2.82)	4	15	16
S-UPPS-P lack of perseverance	7.46 (1.79)	4	11	16
S-UPPS-P lack of premeditation	7.36 (2.27)	4	12	16
S-UPPS-P sensation seeking	10.7 (2.86)	4	16	16
S-UPPS-P positive urgency	8.01 (2.71)	4	15	16
DASS-21 depression[a]	13 (4.71)	7	28	28
DASS-21 anxiety[a]	13.1 (4.54)	7	26	28
DASS-21 stress	14.7 (4.14)	7	24	28

[a] Normalised by replacing outliers (all had scores above mean + 2SD; no >6 people for any variable) with Mean ± 2SD. O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; SRP-4-SF = Self-Report Psychopathy Scale – Short Form; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale; S-UPPS-P = Impulsive Behavior Scale, Short Version; DASS-21 = Depression, Anxiety, and Stress Scale.

were analysed (separately) by 2 (Stimulus-Type: high and low-frequency words/pseudohomophones, real nonwords) × 2 (Sex) × 2 (Language) ANOVA with Stimulus-Type as a within-subject variable. The Greenhouse-Geisser correction was applied where Mauchly's Test indicated a significant sphericity violation.

Spearman's rank-order correlation coefficients (r_s) were used to examine psychopathology-LDT performance associations, first, across the whole sample, and then separately in native and non-native speakers, followed by the strength of the correlations in these two groups formally compared using Fisher's z transformation. Correction for multiple correlations was not applied because we wished to comprehensively explore the influence of all relevant trait dimensions, and expected, at best, small-to-moderate correlations. The overall LDT performance and RTs for incorrect real nonwords were associated, as shown in Table 3, with two or more traits (inter-relationships among various traits presented in Supplementary Table 2) and thus, analysed further using linear regression 'Stepwise' method. This method determines the final model based on a process of selecting/eliminating predictors one at a time depending on the outcome of the *t*-tests for the slope parameters, (i.e., partial F-tests) and the amount of shared and unique variance explained by these predictors.

3. Results

3.1. Sample characteristics

The mean age was 25.96 years (SD = 9.85) with no demographic difference between men ($n = 25$) and women ($n = 53$) (Supplementary Table 1). Native and non-native speakers did not differ in any demographic or self-report measures except anxiety (lower in natives: mean = 12.00, SD = 3.99; non-natives: 14.30, 4.89; $t = 2.29$; df = 76, p = 0.026). Table 1 presents descriptive statistics for all self-report measures.

3.2. LDT performance

3.2.1. Accuracy

There was a main effect of Stimulus-Type [$F(2.00,153.96) = 99.445$, p < 0.001, $\eta^2_p = 0.564$] (Fig. 2). Participants correctly identified significantly more high-frequency than low-frequency words [$t(77) = 11.148$, p < 0.001], pseudohomophones [$t(77) = 14.141$, p < 0.001], and real nonwords [$t(77) = 14.700$, p < 0.001], more low-frequency words than pseudohomophones [$t(77) = 6.234$, p < 0.001] and real nonwords [$t(77) = 6.449$, p < 0.001]; correct pseudohomophones and real nonwords did not differ [$t(77) = 0.111$, p = 0.912]. The main effect of Sex [$F(1,76) = 0.034$, p = 0.855] and Sex*Stimulus-Type interaction [$F(2.01,152.47) = 0.792$, p = 0.455] were non-significant.

Language had a significant main effect [$F(1,76) = 12.290$, p = 0.001, $\eta^2_p = 0.139$] and interacted with Stimulus-Type [$F(2.01,152.66) = 3.226$, p = 0.042, $\eta^2_p = 0.041$], indicating that natives were better than non-natives in distinguishing pseudohomophones [$t(76) = 3.000$, p = 0.004], and real nonwords [$t(76) = 2.307$, p = 0.024] but the groups failed to differ formally in recognition of high-frequency [$t(76) = 1.965$, p = 0.053] or low-frequency words [$t(76) = 1.867$, p = 0.066] (Table 2). The Sex*Language [$F(1,76) = 0.773$, p = 0.382] and Sex*Language*Stimulus-Type interactions [$F(2.02,149.29) = 0.309$, p = 0.736] were non-significant.

3.2.2. RTs

There was a significant main effect of Stimulus-Type for correct words [$F(1,74) = 240.166$, p < 0.001, $\eta^2_p = 0.764$] but not for incorrect nonwords [$F(1,74) = 3.594$, p = 0.062, $\eta^2_p = 0.046$]. Participants were significantly slower when identifying low-frequency than high-frequency words [$t(77) = 17.316$, p < 0.001] and slower when incorrectly identifying pseudohomophones over real nonwords [$t(77) = 2.440$, p = 0.017]. Sex or Language had no significant effect.

3.2.3. LDT Performance: speed-accuracy trade-off.

Longer RTs for incorrect real nonwords correlated with higher real nonword accuracy ($r_s = 0.254$, p = 0.025). When examined separately in native and non-native speakers, this was true only for non-natives (non-native: $r_s = 0.490$, p = 0.002; native: $r_s = 0.052$; $Z = 2.05$, p = 0.02). Furthermore, only in natives, longer RTs for high-frequency words correlated with their lower accuracy (native: $r_s = -0.395$, p = 0.010; non-native: $r_s = 0.118$; $Z = 2.27$, p = 0.012).

Table 2
Descriptive statistics for task performance for the entire sample and differences between native and non-native speakers.

	Entire Sample (N = 78)			Native speakers (n = 42)	Non-native speakers (n = 36)	Group differences (native versus non-native speakers)		
	Mean (SD)	Range	Maximum possible score	Mean (SD)	Mean (SD)	*t* (df = 76)	p	Cohen's *d*
Overall performance[a]	105.10 (7.35)	77–118	120	107.60 (5.70)	102.20 (8.04)	3.360	**<0.001*****	0.784
Correct words high-frequency[a]	29.81 (0.47)	25–30	30	29.90 (0.30)	29.70 (0.59)	1.876	0.053	0.446
Correct words low-frequency[a]	27.09 (2.16)	15–30	30	27.51 (1.98)	26.61 (2.28)	1.867	0.066	0.424
Correct pseudohomophones[a]	24.21 (3.55)	13–29	30	25.29 (2.78)	22.94 (3.95)	3.000	**0.004****	0.700
Correct real nonwords[a]	24.17 (3.52)	13–29	30	25.02 (2.75)	23.18 (4.07)	2.307	**0.024***	0.539
Correct words high-frequency RT	417.67 (35.02)	327–496	1000	415.87 (35.99)	419.78 (34.26)	0.488	0.627	0.111
Correct words low-frequency RT	478.93 (48.80)	357–621	1000	473.50 (50.96)	485.26 (46.07)	1.062	0.292	0.241
Incorrect pseudohomophones RT	449.08 (82.51)	297–635	1000	453.07 (83.87)	444.28 (81.84)	0.459	0.648	0.104
Incorrect real nonwords RT	429.58 (68.95)	293–579	1000	420.04 (56.33)	440.70 (80.66)	1.290	0.202	0.301

* p < 0.05; ** p < 0.01; *** p < 0.001. Significant differences are in **bold**.
[a] Normalised by replacing outliers (all had scores below mean-2SD; no more than six outliers for any variable) with mean-2SD.

3.3. Relationship between LDT performance and psychopathology dimensions

3.3.1. Correlations

Higher Unusual Experiences correlated with lower overall performance (Table 3). Higher psychopathy scores, especially SRP-4-SF Antisocial and TriPM Meanness, also correlated with lower overall performance (Table 3). Higher Antisocial scores correlated with lower word recognition. Higher SRP-4-SF Interpersonal, Affective, Antisocial, and TriPM Meanness correlated with lower correct pseudohomophones recognition. Higher TriPM Boldness and Meanness correlated with lower correct real nonwords recognition. No correlation coefficients in relation to schizotypy or psychopathy differed between native and non-native speakers.

Higher impulsivity correlated with poor LDT performance (Table 3). Specifically, higher S-UPPS-P Sensation Seeking correlated with lower overall performance, and with fewer correct real nonwords. Higher S-UPPS-P Positive Urgency correlated with lower low-frequency words recognition, and higher BIS-11 Motor and Self-Control with lower correct recognition of low-frequency words. For RTs, higher BIS-11 Lack of Perseverance correlated with longer incorrect real-nonword RTs.

Some Impulsivity-LDT correlations were different between native and non-native speakers (Table 4). Specifically, higher BIS-11 Cognitive Instability was associated with more correctly identified low-frequency words in natives only, with significant between-group differences in correlation coefficients ($Z = 2.47$, p = 0.013). Higher BIS-11 Perseverance correlated with a lower number of correct low-frequency words in non-natives only (between-group difference, Z = 2.5, p = 0.012). Higher BIS-11 Motor and higher S-UPPS-P Positive Urgency correlated with fewer correct low-frequency words in non-natives only (BIS-11 Motor, $Z = 3.22$, p = 0.001; S-UPPS-P Positive Urgency, $Z = 2.30$, p = 0.021). Overall, in non-natives, BIS-11 Motor impulsivity predicted 30% of the variance in correctly identified low-frequency words [$F(1,34) = 14.714$, p = 0.001, $R^2 = 0.302$]. In natives, only Cognitive Instability significantly predicted variance (14.7%) in low-frequency words [$F(1,40) = 6.878$, p = 0.012, $R^2 = 0.147$]. Other measures were excluded as non-significant.

Affective traits did not correlate with performance (Table 3).

3.3.2. The overall model: LDT and psychopathology traits

The stepwise regression model revealed that Meanness, Boldness, and Unusual Experiences predicted over 21% of the overall performance [$F(3,74) = 6.597$, p = 0.001, $R^2 = 0.211$], with Meanness accounting for nearly 12% [F(1,76) Change = 10.238, p = 0.002, R^2 Change = 0.119], and Boldness [$F(1,75)$ Change = 4.348, p = 0.040, R^2 Change = 0.048] and Unusual Experiences [$F(1,74)$ Change = 4.128, p = 0.046, R^2 Change = 0.044] accounting for about 4% each. Other traits did not change the predictive value of the overall model. For RTs for incorrect real nonwords, Boldness and BIS-11 Perseverance were entered as predictors, and only Boldness was significant, accounting for 12% of the variance [$F(1,76) = 3.243$, p = 0.002, $R^2 = 0.122$].

4. Discussion

As hypothesised, the link between poorer LDT performance and psychopathology-related traits was true for psychopathic traits (Meanness, Boldness) and marginally for positive schizotypy, but not for affective traits. Meanness significantly predicted pseudohomophone and real nonwords accuracy, and Boldness predicted the RTs for incorrect real nonwords. In the overall model, Meanness and Boldness were better predictors of the overall LDT performance than positive schizotypy. Additionally, only in non-native speakers, higher Motor Impulsivity was linked to poorer identification of low-frequency words.

4.1. Lexical decision performance: schizotypy versus psychopathy

Meanness (callous aggression and lack of empathy, mostly associated with the affective facet of Psychopathy Checklist-Revised) had the strongest association with LDT performance. Meanness is often elevated in forensic populations (Hare, 2006; Hare and Neumann, 2009) and is associated with criminal behavior whereas Boldness (fearless dominance) is often seen in successful psychopaths (Patrick et al., 2009). Previously, the impulsive-antisocial aspect (similar to TriPM Boldness) was found associated with lower LDT accuracy in highly psychopathic individuals, purportedly caused by reduced processing of changing demands (Heritage and Benning, 2013). Highly psychopathic individuals demonstrate deficits, relative to controls, in processing abstract words and are unable to integrate this information and modulate their behavior accordingly (Kiehl et al., 2004). Also, individuals with higher fearless dominance (Boldness) tend to respond instantaneously which could lead to mistakes in real nonword identification. It is possible that highly psychopathic individuals, especially those with traits associated with criminal behavior, are unable to modulate their responses and poor at integrating various reading skills at once when dealing with more complex lexical information.

In contrast to psychopathy, schizotypy (Unusual Experiences) was

Table 3
Spearman rank-order correlations (r_s) between LDT performance and schizotypy and psychopathy measures in the entire sample (N = 78).

Accuracy Measure	Overall performance accuracy	Correct words high-frequency	Correct words low-frequency	Correct pseudo-homophones	Correct real nonwords	Correct words high-frequency RTs	Correct words low-frequency RTs	Incorrect pseudo-homophones RTs	Incorrect real nonwords RTs
	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)
O-LIFE unusual experiences	−0.248* (0.028)	−0.130 (0.256)	−0.204 (0.073)	−0.196 (0.086)	−0.194 (0.089)	−0.029 (0.803)	−0.020 (0.860)	−0.040 (0.729)	0.019 (0.865)
O-LIFE cognitive distortions	0.035 (0.763)	0.022 (0.845)	−0.025 (0.827)	−0.007 (0.950)	0.077 (0.501)	−0.019 (0.870)	0.072 (0.529)	0.006 (0.956)	0.062 (0.591)
O-LIFE introvertive anhedonia	−0.054 (0.639)	0.002 (0.984)	−0.117 (0.309)	−0.081 (0.479)	0.022 (0.851)	−0.071 (0.538)	−0.049 (0.667)	−0.083 (0.472)	−0.057 (0.618)
O-LIFE impulsive nonconformity	−0.125 (0.277)	−0.081 (0.478)	0.022 (0.846)	−0.120 (0.295)	−0.108 (0.347)	−0.077 (0.504)	−0.155 (0.176)	−0.007 (0.954)	−0.028 (0.809)
SRP-4-SF interpersonal	−0.139 (0.223)	−0.020 (0.859)	0.066 (0.566)	**−0.244*** (0.032)	−0.048 (0.677)	−0.003 (0.976)	−0.122 (0.288)	−0.014 (0.905)	0.026 (0.822)
SRP-4-SF affective	**−0.247*** (0.029)	−0.011 (0.924)	−0.046 (0.690)	**−0.265*** (0.019)	−0.212 (0.062)	−0.074 (0.522)	−0.186 (0.103)	−0.133 (0.246)	−0.089 (0.436)
SRP-4-SF lifestyle	−0.222 (0.051)	−0.107 (0.350)	−0.087 (0.446)	−0.206 (0.070)	−0.178 (0.120)	0.003 (0.983)	−0.074 (0.518)	−0.038 (0.740)	−0.005 (0.968)
SRP-4-SF antisocial	**−0.318**** (0.005)	**−0.336**** (0.003)	**−0.244*** (0.032)	**−0.264*** (0.020)	−0.185 (0.105)	0.041 (0.723)	−0.049 (0.673)	**−0.254*** (0.025)	−0.189 (0.097)
TriPM boldness	**−0.242*** (0.033)	−0.073 (0.526)	−0.118 (0.302)	−0.061 (0.594)	**−0.320**** (0.004)	−0.068 (0.554)	−0.205 (0.072)	−0.135 (0.237)	**−0.294**** (0.009)
TriPM disinhibition	−0.198 (0.082)	−0.105 (0.359)	−0.151 (0.187)	−0.203 (0.074)	−0.151 (0.188)	0.050 (0.663)	−0.079 (0.492)	−0.136 (0.235)	−0.124 (0.278)
TriPM meanness	**−0.318**** (0.005)	−0.121 (0.291)	−0.115 (0.315)	**−0.257*** (0.023)	**−0.272*** (0.016)	0.015 (0.899)	−0.182 (0.110)	−0.050 (0.665)	−0.055 (0.632)
BIS-11 attention	0.016 (0.890)	−0.113 (0.324)	0.214 (0.060)	−0.037 (0.746)	−0.124 (0.281)	−0.092 (0.424)	−0.166 (0.146)	0.025 (0.831)	−0.112 (0.331)
BIS-11 cognitive instability	0.024 (0.838)	−0.006 (0.960)	0.212 (0.063)	−0.039 (0.734)	−0.053 (0.645)	−0.043 (0.711)	−0.081 (0.481)	0.055 (0.633)	0.078 (0.495)
BIS-11 motor	−0.214 (0.060)	−0.211 (0.064)	**−0.281*** (0.013)	−0.096 (0.403)	−0.157 (0.169)	0.088 (0.444)	−0.092 (0.423)	−0.105 (0.360)	−0.145 (0.204)
BIS-11 perseverance	0.018 (0.872)	0.105 (0.360)	0.082 (0.476)	0.058 (0.611)	−0.085 (0.457)	0.128 (0.265)	0.124 (0.279)	0.214 (0.060)	**0.239*** (0.035)
BIS-11 self-control	−0.134 (0.242)	−0.045 (0.695)	**−0.284*** (0.012)	−0.053 (0.647)	−0.055 (0.634)	0.051 (0.655)	0.009 (0.935)	0.001 (0.992)	−0.032 (0.778)
BIS-11 cognitive complexity	0.100 (0.382)	−0.109 (0.340)	−0.171 (0.133)	0.141 (0.219)	0.133 (0.247)	0.060 (0.600)	−0.049 (0.671)	0.031 (0.785)	−0.040 (0.729)
S-UPPS-P negative urgency	−0.121 (0.290)	−0.034 (0.765)	−0.077 (0.502)	−0.098 (0.393)	−0.103 (0.371)	0.006 (0.957)	0.052 (0.649)	−0.073 (0.525)	0.041 (0.721)
S-UPPS-P lack of perseverance	0.071 (0.539)	0.164 (0.151)	−0.084 (0.465)	0.026 (0.819)	0.196 (0.086)	0.054 (0.636)	0.117 (0.306)	0.161 (0.160)	0.199 (0.080)
S-UPPS-P lack of Premeditation	−0.047 (0.685)	−0.104 (0.365)	−0.122 (0.288)	−0.054 (0.638)	0.029 (0.798)	−0.050 (0.666)	−0.092 (0.424)	−0.043 (0.710)	−0.068 (0.555)
S-UPPS-P sensation seeking	**−0.293**** (0.009)	−0.082 (0.477)	−0.196 (0.086)	−0.118 (0.305)	**−0.324**** (0.004)	−0.099 (0.386)	−0.138 (0.227)	−0.038 (0.744)	−0.159 (0.165)
S-UPPS-P positive urgency	−0.203 (0.074)	−0.155 (0.175)	**−0.226*** (0.047)	−0.125 (0.277)	−0.160 (0.162)	0.034 (0.767)	−0.085 (0.458)	−0.089 (0.437)	−0.149 (0.193)
DASS-21 depression	−0.061 (0.593)	0.059 (0.607)	0.025 (0.825)	−0.172 (0.132)	0.004 (0.975)	−0.042 (0.714)	0.024 (0.832)	−0.031 (0.789)	0.062 (0.589)
DASS-21 anxiety	−0.219 (0.054)	−0.113 (0.324)	−0.165 (0.148)	−0.185 (0.105)	−0.161 (0.159)	−0.096 (0.401)	−0.048 (0.679)	−0.114 (0.321)	−0.035 (0.763)
DASS-21 stress	−0.005 (0.967)	−0.003 (0.977)	0.017 (0.882)	−0.074 (0.521)	0.057 (0.618)	0.021 (0.857)	0.039 (0.735)	−0.016 (0.892)	0.062 (0.588)

* $p < 0.05$; ** $p < 0.01$ (not corrected for multiple correlations). Significant correlations are in **bold**.
O-LIFE = Oxford-Liverpool Inventory of Feelings and Experiences; SRP-4-SF = Self-Report Psychopathy Scale – Short Form; TriPM = Triarchic Psychopathy Measure; BIS-11 = Barratt Impulsiveness Scale; S-UPPS-P = Impulsive Behavior Scale, Short Version; DASS-21 = Depression, Anxiety, and Stress Scale.

less strongly linked to LDT performance (explaining only about 4% of the variance in performance) and did not resemble the relationship seen in schizophrenia. Processes involved in lexical recognition, reading deficits, and dyslexia can be associated with genetic-neuropsychological aspects of schizophrenia as some deficits are also observed in high clinical risk for schizophrenia (Revheim et al., 2014; Whitford et al., 2018). However, normal-to-mildly elevated schizotypal scores without a presence of clinical diagnosis may not necessarily lead to alterations in lexical processing. The deficits in higher schizotypy in language-related tasks can be very subtle, dependent on the tested cohort and specific schizotypy dimensions, or not present at all (Schofield and Mohr, 2014). Furthermore, some of the reading skills deficits seen in schizophrenia may well be explained by medication (de Boer et al., 2020).

4.2. *Lexical decision, impulsivity and the role of language familiarity*

In non-native speakers, higher motor impulsivity was associated with lower accuracy of low-frequency words, but not nonword

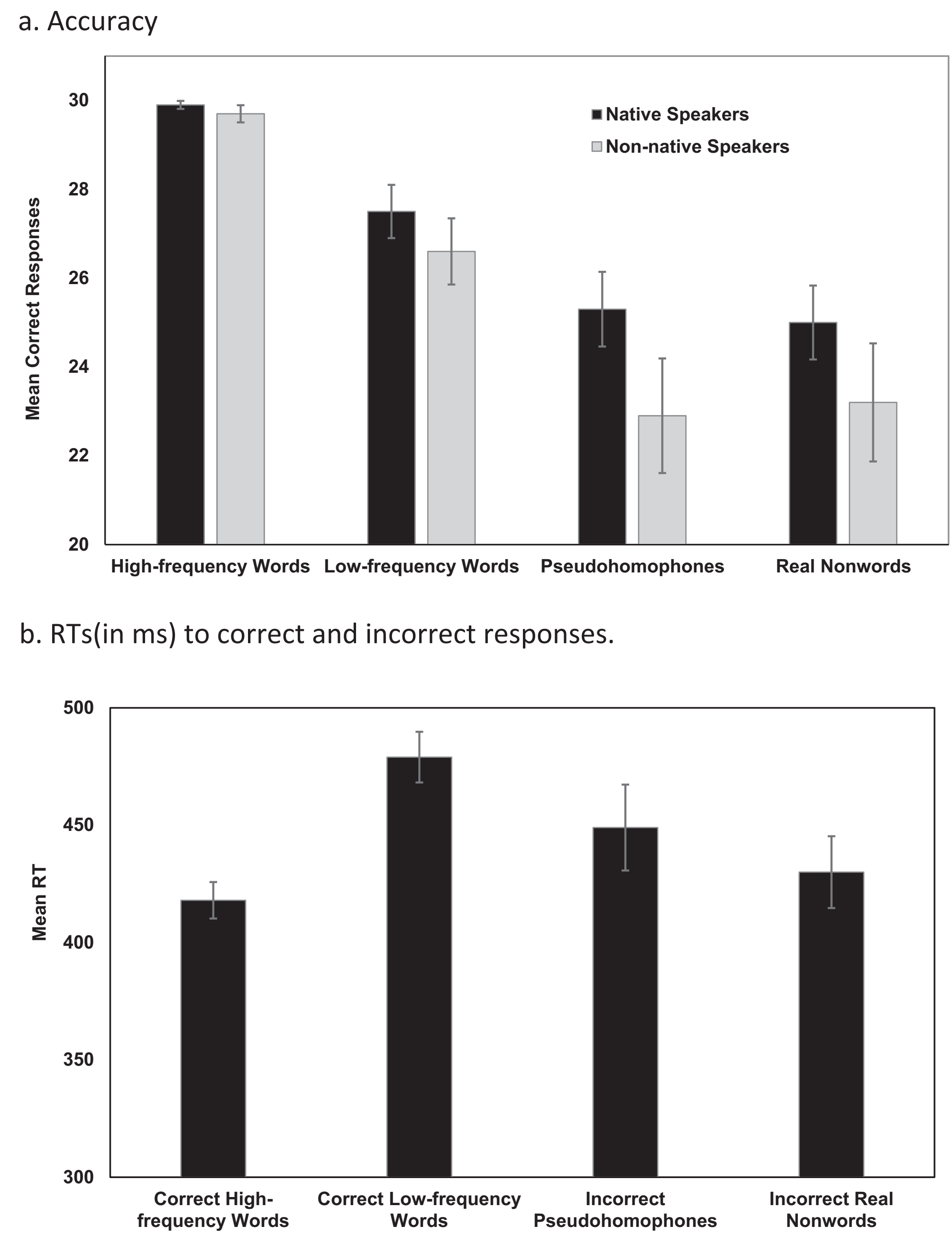

Fig. 2. Mean accuracy (2a) for different stimulus-types, and RTs (2b) for correct high and low-frequency words and incorrect pseudohomophones and real nonwords in native (n = 42) and non-native speakers (n = 36). Error bars display 95% confidence intervals.

recognition, suggesting that these individuals may opt for the first interpretation when facing an unfamiliar word and confound it as a nonword; they may "guess" the answer because of poor ability to suppress inadequate vocabulary representations (van der Schoot et al., 2004). Other data also suggest that impulsive individuals process language information less efficiently and often experience problems in processing complex lexical information (De Pascalis et al., 2009; Ku et al., 2020). Unexpectedly, in native speakers, Cognitive Instability, which captures impulsive, quickly changing thoughts (Patton et al., 1995), was associated with better identification of low-frequency words, possibly by helping them shift quickly between different lexical representations and select the correct one (with good knowledge of the language).

4.3. *Implications and limitations*

Our present findings show that elevated psychopathic traits and higher motor impulsivity in combination with non-native language proficiency are associated with poor lexical recognition. Considering previous findings of impaired reading skills in patients with psychopathy and/or a history of violence (Vanova et al., 2021), our results suggest the existence of a continuum of reading skill deficits related to elevated psychopathic traits and have implications for future research adopting a dimensional approach to psychopathology. Future research could establish whether the mechanisms underlying psychopathy/schizotypy-lexical recognition association in the normative population are shared with those underlying poor reading skills in clinical populations, what it means in terms of vulnerability to dyslexia, and clarify the roles of specific symptoms and illness-related factors (e.g., medication) (de Boer

Table 4
Relationship between LDT performance and self-reported impulsivity in the native and non-native speakers.

Measure	Overall performance		Correct words high frequency		Correct words low frequency		Correct pseudo-homophones		Correct real nonwords	
	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native	Native	Non-native
	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)	r_s (p)
BIS-11 attention	−0.021 (0.896)	0.042 (0.806)	−0.003 (0.983)	−0.237 (0.164)	0.206 (0.190)	0.268 (0.114)	−0.135 (0.395)	0.031 (0.858)	−0.089 (0.576)	−0.172 (0.317)
BIS-11 cognitive instability	0.038 (0.812)	−0.015 (0.929)	0.034 (0.831)	−0.079 (0.648)	0.451** (0.003)	−0.098 (0.570)	−0.182 (0.248)	0.023 (0.894)	−0.027 (0.868)	−0.104 (0.547)
BIS-11 motor	−0.192 (0.223)	−0.243 (0.153)	−0.212 (0.177)	−0.224 (0.189)	−0.003 (0.984)	−0.644*** (< 0.001)	−0.220 (0.161)	0.028 (0.871)	−0.208 (0.185)	−0.109 (0.528)
BIS-11 perseverance	−0.220 (0.162)	0.158 (0.358)	−0.034 (0.831)	0.184 (0.281)	−0.187 (0.235)	0.381* (0.022)	0.004 (0.980)	0.005 (0.977)	−0.275 (0.078)	0.044 (0.799)
BIS-11 self-control	−0.171 (0.279)	−0.121 (0.483)	0.175 (0.268)	−0.247 (0.146)	−0.254 (0.105)	−0.341* (0.042)	−0.113 (0.477)	−0.022 (0.898)	−0.116 (0.464)	0.008 (0.965)
BIS-11 cognitive complexity	0.182 (0.249)	−0.042 (0.808)	0.102 (0.522)	−0.304 (0.072)	−0.226 (0.151)	−0.149 (0.387)	0.245 (0.117)	−0.005 (0.975)	0.235 (0.134)	0.015 (0.933)
S-UPPS-P negative urgency	−0.196 (0.214)	0.053 (0.757)	−0.040 (0.799)	0.034 (0.845)	0.018 (0.909)	−0.151 (0.378)	−0.182 (0.248)	0.075 (0.665)	−0.264 (0.091)	0.121 (0.482)
S-UPPS-P lack of perseverance	−0.053 (0.740)	0.062 (0.721)	0.200 (0.204)	0.071 (0.681)	−0.111 (0.484)	−0.156 (0.362)	−0.052 (0.742)	−0.043 (0.803)	0.059 (0.709)	0.260 (0.126)
S-UPPS-P lack of premeditation	−0.112 (0.481)	−0.007 (0.967)	−0.095 (0.551)	−0.139 (0.418)	0.007 (0.967)	−0.303 (0.072)	−0.256 (0.102)	0.132 (0.444)	−0.041 (0.798)	0.107 (0.534)
S-UPPS-P sensation	−0.247 (0.115)	−0.352* (0.035)	0.067 (0.672)	−0.199 (0.245)	−0.173 (0.274)	−0.217 (0.204)	0.025 (0.875)	−0.266 (0.117)	−0.327* (0.035)	−0.310 (0.066)
S-UPPS-P positive urgency	−0.253 (0.106)	−0.202 (0.238)	−0.165 (0.295)	−0.193 (0.260)	−0.020 (0.901)	−0.511*** (0.001)	−0.249 (0.112)	−0.028 (0.871)	−0.297 (0.056)	−0.061 (0.723)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (*not corrected for multiple correlations*). Correlations in **bold** are significantly different between native and non-native speakers. BIS-11 = Barratt Impulsiveness Scale; S-UPPS-P = Impulsive Behavior Scale, Short Version.

et al., 2020). People with high psychopathy in forensic and non-forensic populations show impairments in various reading skills, including lexical recognition, and a high prevalence of dyslexia (Brites et al., 2015; Daderman et al., 2004; Selenius et al., 2006). Especially vulnerable are non-native speakers from an immigrant background (Svensson et al., 2015), a factor associated with a risk for schizophrenia (Selten et al., 2007). Vulnerability to dyslexia can negatively influence their socio-economic status and academic achievements (Hemphill and Tivnan, 2008). Our findings on psychopathic traits could help to better understand the cognitive challenges associated with these traits, their links with dyslexia, even in educated populations.

This study, however, had limitations, including (i) a relatively small sample size and limited range of schizotypal and psychopathy scores in the sample, (ii) unexpectedly, an influence of language familiarly in impulsivity-LDT association, (iii) use of a one-choice variant LDT (i.e., no RTs for correct nonwords), and (iv) no correction for multiple testing which could lead to Type-I error. Thus, our findings should be considered preliminary until replicated in future studies with larger samples and other LDT variants. Furthermore, this was a correlational study, thus, we cannot infer causation.

5. Conclusions

We found that psychopathic traits show stronger negative associations with lexical recognition than schizotypal traits, and impulsivity may differentially affect performance depending on language familiarity. There is, however, a need to replicate these findings, especially the influence of language familiarity in the impulsivity-performance relationship.

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CRediT authorship contribution statement

Martina Vanova: Conceptualization; Formal analysis; Data curation; Investigation; Methodology; Project administration; Visualization; Writing - original draft; Writing - review & editing. **Luke Aldrige-Waddon:** Project administration; Writing - review & editing. **Ben Jennings:** Formal analysis; Supervision; Writing - review & editing. **Leonie Elbers:** Project administration; Writing - review & editing. **Ignazio Puzzo:** Supervision; Writing - review & editing. **Veena Kumari:** Conceptualization, Methodology, Formal analysis, Resources, Writing - review & editing, Supervision, Funding acquisition.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scog.2021.100224.

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