Transportation Research Part F: Psychology and Behaviour 93 (2023) 55–67

Contents lists available at ScienceDirect

Transportation Research Part F: Psychology and Behaviour

journal homepage: www.elsevier.com/locate/trf

Psychological and experiential contributors to experienced cyclists' on-road cycling behaviour: A path analysis study

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A R T I C L E I N F O

Keywords:
Attentional control
Cycling self-efficacy
Distraction control
Errors
Negative experiences

A B S T R A C T

Cyclists' behaviour may be characterised as both positive and negative, although research has typically focused on the latter – notably, behaviours such as crashes, collisions, and errors. Cyclist distraction is often implicated in these negative behaviours. However, there is a dearth of research on the psychological correlates of errant cycling behaviours and distraction. We distributed an online survey that included a combination of established and novel measures to 191 experienced cyclists (155 M, 36 F; aged 18–80 yrs, *M* age = 57.03 yrs) to ascertain their self-reported cycling behaviour and experience, their attentional style, their cycling self-efficacy and their negative experiences whilst cycling. We conducted path analysis to explore relationships between these variables – specifically, to determine whether self-reported cycling behaviour and negative experiences would be predicted by attentional style, cycling self-efficacy, and cycling experience. Of the statistically significant relationships, Internal Distraction Control negatively predicted cyclists' self-reported errors (b = -0.235) and violations (b = -0.195). The cyclists' years of urban cycling positively predicted their errors (b = 0.068), violations (b = 0.046) and negative experiences (b = 0.05) when cycling. Cycling self-efficacy positively predicted violations (b = 0.003) and negatively predicted positive behaviours (b = -0.002). These results suggest that a combination of psychological and experiential factors explain some of the variance in self-reported cycling behaviours – particularly negative ones. Road user entropy in UK towns and cities is set to increase as micromobility usage increases. Formal assessment of cyclists' capabilities, particularly their ability to deal with distractions, may be crucial to mitigate the consequences.

1. Introduction

Cyclists' behaviour has been characterised in terms of both positive and negative behaviours (Useche, Montoro, et al., 2018; Wang et al., 2019; Wang et al., 2020) – but the latter has most frequently been the focus of research: widely used descriptors include *violations* (Fraboni et al., 2018), *errors* (Hezaveh et al., 2018), *collisions* (Isaksson-Hellman & Werneke, 2017) *crashes* (Vanparijs et al., 2016) and

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https://doi.org/10.1016/j.trf.2022.11.016
Received 5 August 2022; Received in revised form 22 November 2022; Accepted 28 November 2022
Available online 3 January 2023

near-misses (Warner et al., 2017). Collisions, crashes, and near-misses are clearly observable behaviours that often occur in relation to other road users, whereas many errors and violations, such as failing to notice a pedestrian in the road and cycling under the influence of alcohol respectively, are imperceptible. Collectively, these behaviours have been measured in a variety of ways, including remote observation (e.g., running red lights; Fraboni et al., 2018), lab-based simulations (Warner et al., 2017) insurance company reports (Isaksson-Hellman & Werneke, 2017; Vanparijs et al., 2016) and self-report measures (Feenstra et al., 2011). Despite their shortcomings (Furnham & Henderson, 1982), an advantage of self-report measures is that they can afford us some insight regarding cognitive, attentional, and perceptual contributions to cyclists' behaviours in the real world.

1.1. Measuring cycling behaviour

Of the few self-report measures designed to measure cyclists' behaviour, the Cycling Behaviour Questionnaire (CBQ; Useche, Montoro, et al., 2018) has been the most widely used since its creation. Like its predecessors (Feenstra et al., 2011; Hezaveh et al., 2018), the CBQ includes items relating to cyclists' *self-reported errors* (e.g., "Unintentionally hitting a parked vehicle") and *violations* (e.g., "Zigzag between vehicles when using a mixed lane"), with the addition of items relating to *positive behaviours* (e.g., "Keep a safe distance from other cyclists or vehicles"). Consistent with previous studies, data obtained via these subscales are correlated with demographic variables including age (Johnson et al., 2011), gender (Bernhoft & Carstensen, 2008) and weekly cycling volume (Martínez-Ruiz et al., 2014). Moreover, recent findings suggest that the factor structure of the CBQ is retained in French and Dutch language versions (Useche et al., 2021), and the 29-item version has recently been revalidated across 19 countries (Useche et al., 2022), although a recent validation of the CBQ in the UK suggests that the data derived from this measure added little to the variance already explained by cyclists' experience, age, and gender, when used to predict self-reported cycling collisions (McIlroy et al., 2022). Accordingly, McIlroy et al. (2022) highlighted the importance of identifying other factors that influence road safety outcomes and suggested that efforts should be made to consider not only *what* behaviours manifest, but *why* they manifest.

Recent research involving the CBQ suggests that older cyclists tend to exhibit more positive cycling behaviours and perceive risks more easily compared to younger cyclists – or at least report that they do. Useche, Alonso, et al. (2018) administered the CBQ, a Cyclist Risk Perception and Regulation Scale and questionnaires relating to traffic rule knowledge and distraction to 1,064 cyclists from 20 different countries spanning Latin America, North America, and Europe. Age was negatively associated with risky behaviours (i.e., errors and violations) and traffic crashes, and positively with risk perception, positive cycling behaviours, knowledge of traffic norms – but also distraction. However, of the eight distracters listed in the cycling distractions questionnaire, only one refers to internal distracters (*My own thoughts or concerns*), whereas seven are external, such as *the behaviour of other users of the road*. Moreover, experienced cyclists would be more cognisant of how other road users' behaviour impairs their cycling when answering the prefatory question, "Normally, do these factors distract you and/or impair your cycling performance during your journeys?", and so their responses may reflect their deeper knowledge rather than riskier behaviour. Moreover, the format of this double-barrelled nature of this question ("and/or") allows the respondents to answer in relation to impairment without acknowledging that they were distracted. It is noteworthy that 9 of the 15 items in the *Errors* subscale describe or imply failures of attention, of which distraction is one; for example, "Not realizing that a vehicle that was parked intends to leave and having to brake abruptly to avoid colliding with it". Hence, the negative correlation between age and scores on this subscale could be evidence for a reduction in distractability with age. More nuanced assessments of cyclists' distractability and behaviour – perhaps ones that are age-specific (e.g., the Adolescent Cycling Behaviour Questionnaire; Feenstra et al., 2011) – may enable us to understand the relationship between distraction and behaviour more effectively.

1.2. Measuring attention

Attention is a nebulously defined construct (Hommel et al., 2019), but many definitions incorporate the notion that our attentional focus can be directed internally or externally – and often both at the same time (Monaghan et al., 2022). Definitions also frequently include the concepts of top-down and bottom-up attentional processing. Top-down attention is goal-directed and controlled – i.e., we choose where to focus our attention, usually to achieve a desired goal – whereas bottom-up attention is characterised by reflexive orienting toward novel, unexpected, or particularly salient events (Corbetta & Shulman, 2002). Bottom-up orienting, also known as stimulus-driven orienting, has historically been examined using exogenous distracters (Koelewijn et al., 2009; Störmer et al., 2019). However, endogenous bottom-up capture – for example, by intrusive thoughts – has not been so extensively investigated, although it does feature in several measures of attention, both explicitly (Attentional Control Scale, Derryberry & Reed, 2002; Attentional Style Questionnaire, Van Calster et al. 2018) and implicitly (e.g., Mindful Attention Awareness Scale, Brown & Ryan, 2003; Emotional Style Questionnaire, Kesebir et al., 2019).

In a series of related studies, Van Calster et al. (2018) developed the Attentional Style Questionnaire (ASQ) using 17 items derived from the Tellegen Absorption Scale (Tellegen & Atkinson, 1974) and Encoding Style Questionnaire (Billieux et al., 2009). These items relate not only to internal and external orientation of attention, but also top-down and bottom-up attentional control. Exploratory and confirmatory factor analyses revealed a two-factor structure reflecting internally and externally oriented attention. In their final study, the authors showed that internal attentional style scores correlated positively with those on several related measures including the Cognitive Failures Questionnaire (Broadbent et al, 1982) and the Daydreaming Frequency Scale (Stawarczyk et al., 2012). Recently, Kraft et al. (2020) obtained data from 286 English-speaking participants to examine the 17-item ASQ's factor structure. A 15-item version emerged, which comprised two factors: *Distractability/Cognitive Avoidance* and *Focusing*. Scores on the Distractability/Cognitive Avoidance subscale correlated negatively with attentional control, and positively with perseverative thinking, rumination, and worry. These findings suggest that the ASQ may be a potentially useful measure of attentional control – especially for internal distracters, which includes cognitive slips and daydreaming.

Urban cycling is attentionally demanding, requiring rapid and simultaneous alternation between exogenous and endogenous events, and bottom-up and top-down processing, to detect hazards then respond to them appropriately. Failure to do so is frequently implicated in collisions involving cyclists (Salmon et al., 2022; Stimpson et al., 2013). For example, Boele-Vos et al. (2017) analysed database statistics for 41 single-bicycle and bicycle-bicycle crashes in the Netherlands and found that an overly narrow focus of attention was identified as a causal factor in 12–24 % of crashes involving cyclists over 75 years of age, and an element of distraction was implicated in 12–27 % of occasions. Although external distractions are commonplace in urban cycling (Useche, Alonso, et al., 2018; Wolfe et al., 2016), internal bottom-up capture of attention by internal distracters may be more pertinent for safe cycling. For example, a commuter cyclist may ostensibly scan their environment for ongoing and emergent hazards whilst maintaining a stable and predictable trajectory – but the sudden recollection that they forgot to lock their front door could momentarily divert cognitive resources, such that their gaze behaviour becomes more fixated (Engström et al., 2005) and their perception of peripheral emerging hazards is compromised as a result. The influence of endogenous distractions on cyclists' behaviour warrants further investigation and may be achieved using the ASQ (Van Calster et al., 2018) and CBQ (Useche, Montoro, et al., 2018).

1.3. Cycling experience and cycling behaviours

Cyclists' behaviour may differ according to their experiences of cycling (e.g., Martínez-Ruiz et al., 2014; Useche, Esteban, et al., 2021). As might be expected, those with more cycling experience, particularly in urban areas – for example, commuter cyclists – have been shown to report higher levels of perceived comfort, and this was associated with choosing safe, rather than risky, responses to the presence of a truck (Abadi et al., 2019). Commuter cyclists accrue higher weekly and annual mileage than their non-commuter counterparts and some evidence suggests they have more positive experiences while cycling (Hansen & Nielsen, 2014). However, Useche et al. (2021) conducted a survey of 577 commuter cyclists, who cycled an average of 7.7 h per week, with average journey times of 35.3 min. Using the CBQ (Useche, Montoro, et al., 2018) they compared the commuter cyclists' self-reported cycling behaviour to that of a group of non-commuter cyclists who rode for 5.0 h per week, with journey times of 65.3 min, on average. The commuter cyclists tended to experience greater psychological distress when cycling, were less aware of traffic norms, exhibited fewer positive behaviours and were involved in more traffic violations and crashes – they also reported significantly fewer distractions. In addition, age was positively associated with cycling distractions and negatively associated with traffic violations in the commuter cyclists. In fact, age was correlated in some way with all other variables in the analysis. Specifically, as age increased, self-reported educational level, cycling distractions, risk perception, knowledge of traffic rules and positive behaviours also increased; self-reported weekly cycling intensity, psychological distress and errors all decreased. The relationships between cycling experience, particularly urban cycling experience, and cycling behaviours are far from clear, so it would be prudent to explore other variables that might predict cycling behaviour.

1.4. Self-efficacy

Self-efficacy is a consistent predictor of positive behaviours in physical activity contexts (Bock et al., 2019; Cramer et al., 2014). For example, in a longitudinal study, Samendinger et al. (2019) examined the relationship between young adults' self-efficacy and their persistence in performing a cycle ergometer exergame task, over a series of 12 sessions; participants were free to quit cycling when they wanted to in each session. Not only did within-session self-efficacy predict the amount of time they spent cycling, but it became a stronger predictor as time went on, to the extent that it superseded the predictive effects of their persistence in previous sessions. Self-efficacy has demonstrated similar predictive and explanatory power in sport, regarding decision-making efficiency (Hepler & Chase, 2008), emotional responses to competition (Boardley et al., 2015), and fine motor skill improvements (Beauchamp et al., 2002). These cognitive, affective, and behavioural phenomena are potentially relevant for safe and effective cycling on urban roads.

Research explicitly examining the relationship between self-efficacy and on-road cycling behaviour is sparse, and has predominantly focused on the relationship between self-efficacy and use of cycling as a mode of active travel (Lois et al. 2015; Mertens et al., 2019). For example, Lois et al. (2015) used the Theory of Planned Behaviour as a framework for exploring social-cognitive mediators of intentions to cycle commute, in 595 Spanish adults who predominantly used other forms of transport for their daily commutes. As well as determining participants' attitudes towards cycling, their cycling habits and intentions to cycle, and subjective norms for cycling, the authors assessed the participants' identity as a cyclist (e.g., "I identify myself as a cyclist") and their cycling self-efficacy; for example, they rated their perceived capability to *ride a bicycle in traffic*, *repair a flat tyre* and *cycle uphill*.

Although they did not examine self-efficacy per se, in their examination of the relationship between cycling and walking behaviours and individuals' perceptions of their cycling abilities, McIlroy et al. (2022) asked survey respondents to rate their bicycle riding proficiency on a scale of one (*very bad*) to ten (*perfect*); they also collected data via the 29-item Cycling Behaviour Questionnaire (Useche, Esteban, et al., 2021), alongside information relating to cycling experience, collision involvement and helmet usage. They found a small negative correlation between self-reported bicycle riding proficiency and scores on the Errors subscale of the CBQ – although they also found that neither the Violations nor Positive Behaviours subscales possessed suitable internal reliability. Accordingly, scores from these subscales were not entered into a subsequent SEM analysis to investigate predictors of collision involvement. Interestingly, the cycling proficiency measure was also absent from the model, despite the small but significant relationship with self-reported errors, which also emerged as the strongest predictor of collision involvement – albeit still a weak one.

1.5. Aim and hypotheses

The aim of the present study was to examine the contributions of experienced cyclists' attentional control, cycling experience and cycling self-efficacy to their on-road behaviours and their experiences when cycling. To do so, we distributed an online survey that comprised the CBQ, the ASQ, a bespoke measure of cycling self-efficacy, questions relating to negative experiences while cycling, and items relating to various demographics, including weekly cycling volume and years of urban cycling experience; we used these latter two variables to characterise ongoing and historical experience of cycling, respectively. Given the established relationship between road user distraction and crashes involving cyclists (Salmon et al., 2022), we predicted that distraction control would be a negative predictor of errors, violations, and negative experiences; we made no prediction regarding positive behaviours, because none of the corresponding CBQ Errors subscale items implicate attentional lapses or distraction. Due to the currently nebulous relationship between cycling experience and cycling behaviours, we also made no predictions in this regard. Although the relationship between self-efficacy and cycling behaviour has not been extensively investigated, we tentatively predicted that cycling-specific self-efficacy would negatively predict self-reported errors (cf. McIlroy et al., 2022), violations, and negative experiences and would positively predict positive behaviours, consistent with findings from sport and physical activity research (e.g., Cramer et al., 2014; Hepler & Chase, 2008).

2. Method

2.1. Participants

Participants were 191 cyclists (155 M; 36 F) recruited via UK cycling club mailing lists and online fora. Their ages ranged from 18 to 80 years (M = 57.03 yrs, SD = 13.97 yrs). Ninety-seven percent of the sample had normal or corrected-to-normal vision, and 97.0 % had normal or corrected-to-normal hearing. The White UK ethnic group comprised 98.0 % of the sample; the remaining ethnicities comprised Asian British (n = 1), Black British (n = 2) and Hispanic (n = 1) individuals. Seventy percent of the sample belonged to a cycling club. 53.4 % of the sample had undergone formalised cycle training, at either beginner (37.7 %), intermediate (4.71 %) or advanced (11.0 %) levels. Table 1 summarises the sample's urban road cycling experience. Table 2 illustrates the frequency with which participants cycled in a variety of environments – specifically, country lanes, major roads, minor roads, busy urban roads, dual carriageways, cycle paths; the frequency with which they engaged in various types of cycling (recreational road cycling, recreational off-road cycling, commuting, time trialling, competitive long-distance cycling, and competitive off-road cycling); and the frequency with which they used safety equipment – namely, cycle helmets, high-visibility clothing, cycle-mounted reflectors and safety lights. The study was approved by the research ethics committee of the lead institution.

2.2. Measures

Qualtrics online survey software (Qualtrics, Provo, UT) was used to distribute an online survey comprising the CBQ, a modified version of the ASQ, six items to ascertain the frequency of participants' negative experiences when cycling, a bespoke cycling self-efficacy questionnaire, and demographic items. Participants gave their informed consent at the beginning of the survey.

2.2.1. Cycling behaviour questionnaire

We included all 29 items from the Cycling Behaviour Questionnaire (Useche, Montoro, et al., 2018) in the survey. Six items relate to participants' positive cycling behaviours (e.g., "I try to move at a prudent speed to avoid sudden mishaps or braking"), eight items relate to participants' cycling-related violations (e.g., "Crossing what appears to be a clear crossing, even if the traffic light is red") and fifteen items relate to cycling-related errors (e.g., "Fail to notice the presence of pedestrians crossing when turning"). All items are prefaced by the stem, "Estimate how often you do the following when cycling". Participants responded via a 5-point scale comprising the following points: 0 (Never), 1 (Hardly ever), 2 (Sometimes), 3 (Frequently) and 4 (Almost always).

Table 1
Participants' Urban Road Cycling Experience.

Years of Urban Road Cycling	Average miles cycled per week over preceding year						
	1–10 miles	11–20 miles	21–30 miles	31–40 miles	41–50 miles	51 + miles	TOTAL
1–5	4	3	2	2	2	2	**15**
6–10	2	2	3	1	2	9	**19**
11–15	1	1	5	1	2	7	**17**
16–20	1	1	2	2	1	9	**16**
21–25	2	1	–	4	3	5	**15**
26–30	–	–	1	2	3	2	**8**
31+	2	5	17	13	8	56	**101**
TOTAL	**12**	**13**	**30**	**25**	**21**	**90**	**191**

Table 2
Participants' cycling environments, cycling types and safety equipment usage, by frequency.

	Never	Infrequently	Frequently
Cycling Environments			
Rural lanes	6	17	162
Major roads	14	107	64
Minor roads	4	35	146
Busy urban roads	15	68	102
Dual carriageways	75	96	14
Cycle paths/routes	4	48	133
Cycling Types			
Recreational road cycling	2	22	161
Recreational off-road cycling	44	104	37
Commuting	72	31	82
Time trialling	164	19	2
Competitive long-distance cycling	153	26	6
Competitive off-road cycling	177	6	2

Note: 6 participants did not contribute data to these items; hence, n = 185.

2.2.2. Negative experiences

We included six survey items to determine the frequency with which participants had negative experiences with other road users, all of which shared the prefatory question, "How frequently do you have negative experiences with the following road users?" Six road user groups were represented: other cyclists, car/van drivers, bus drivers, lorry/HGV drivers, pedestrians, and motorcyclists. Participants responded on a 5-point scale comprising the following points: 0 (Never), 1 (Very infrequently), 2 (Occasionally), 3 (Frequently) and 4 (Very frequently). We included negative experiences as a novel criterion measure because, unlike the items on the Errors and Violations subscales of the CBQ, its constituent items do not implicate the respondent and so might have mitigated self-serving bias (Heider, 1958) in participants' responses, which may yield more accurate insights regarding their cycling behaviour.

2.2.3. Attentional style questionnaire

The original 17-item version of the ASQ (Van Calster et al., 2018) was distributed to assess participants' internal and external attentional control. The measure comprises 4 items assessing bottom-up external orientation of attention (e.g., "I have trouble concentrating when there is movement in the room I am in"), 5 items assessing top-down external orientation of attention (e.g., "I can be so absorbed by a line of thought that I become more or less unaware of my surroundings"), 5 items assessing bottom-up internal orientation of attention (e.g., "Sometimes I interrupt an activity to check an unrelated detail") and 3 items assessing top-down internal orientation of attention (e.g., "In general, I stay in control of my thoughts and do not let myself get distracted by interfering thoughts"). Participants respond on a 6-point scale ranging from 1 (In total disagreement) to 6 (In total agreement).

2.2.4. Cycling self-efficacy questionnaire

The cycling self-efficacy questionnaire comprised ten items shown in Table 3. Each item was prefaced by the stem, "Please indicate your confidence in your ability to…". The items may be categorised as shown in the second column of Table 3, but we selected them to collectively represent a global construct of *cycling self-efficacy* for several reasons: (a) a well-defined factor or construct must comprise at least 3 items in order to not be an incidental one (e.g., due to correlational relationships), (b) factors with more items tend to be better defined, and (c) the simplest factor structure is more parsimonious and has better validity properties (Kline, 2016). Participants responded on a percentage scale ranging from 0 (*Cannot do this at all*) to 100 (*Highly certain I can do this*).

Table 3
Cycling self-efficacy questionnaire items.

Item	**Category**
…cycle from a standing start, along a line that is 10 m long and 10 cm wide, without the front wheel veering from the line	Cycle Control
…cycle safely at 15 mph (24 kph) through a 75 cm-wide gap	
…judge the distance of a car behind you, using only your hearing	Auditory Perception
…safely avoid a pedestrian who steps out immediately in front of you, when you are travelling at 10 mph	Responding to Hazards
…come to a safe stop in the event of a blown front tyre when travelling at 15 mph	
…cycle safely in a busy urban street	Navigating Environment Safely
…cycle safely in a country lane	
…cycle safely entering a dual carriageway	
…cycle safely in a residential street with parked cars	
…cycle safely in a cycle path next to a road	

2.3. Data analysis

2.3.1. Cycling behaviour questionnaire

Although the *Errors* and *Violations* factor of the CBQ may be combined to form a fourth factor, *Risky Behaviours*, we elected to retain them as separate subscales in the present analysis, because of the varying extents to which attention misallocation and distraction are implicated in each of their constituent items: this is more prevalent for *Errors*.

2.3.2. Attentional style questionnaire – adaptation

We performed Multiple Item Response Theory (MIRT) analyses to determine the fit of each of the ASQ items for this sample of cyclists (Bishop et al., 2022). Somewhat overlapping with Van Calster et al.'s (2018) development of the ASQ, we found that items 4, 5, 6, 15 and 17 had very low factor coefficients and consequently, very low discrimination parameters; hence, these items were removed to leave a 12-item version comprising two factors, which we labelled *External Distraction Control* (5 items) and *Internal Distraction Control* (7 items).

2.3.3. Principal components analysis

We used R to conduct all our data analyses. Specifically, we used the parallel and principal functions in the psych package (Revelle, 2022). Because the items are on ordinal scales, we used polychoric correlations for factor analysis. Parallel analysis revealed that six factors need to be retained. Using oblique rotation (oblimin), principal components analysis (PCA) revealed support for six factors. These were attentional control (both internal and external), cycling self-efficacy, errors, violations, positive behaviours, and negative experiences. The items that we hypothesized to belong to each of these factors were the ones that indicated these factors. Although both internal and external attentional control were indicated to belong to a single factor, we decided to retain these as two separate factors because of their conceptual differences. Cronbach's alphas and McDonald's Omegas for the scales are given in Table 4. Table 5 shows descriptive statistics for all items.

2.3.4. Path analysis

We conducted path analysis using the lavaan package in R to test several hypotheses regarding the relationships between the scales. We used criteria set by Hu and Bentler (1999) to retain models that fit the data adequately well. These include the comparative fit index (CFI) $\geq$ 0.95, 0.05 $<$ the root mean square error of approximation (RMSEA) $\leq$ 0.08 for acceptable fit and $\leq$ 0.05 for good fit, and the standardized root mean squared residual (SRMR) $\leq$ 0.08. When the model did not have acceptable fit as deemed by these rules, we examined the modification indices and the standardised residuals for model modification suggestions. The research questions that we tested were as follows: (1) How do Internal and External Distraction Control, cycling miles per week, years of urban cycling, and cycling self-efficacy predict frequent cyclists' self-reported errors? (2) How do these variables predict frequent cyclists' self-reported violations? (3) How do they predict positive behaviours? and (4) How do they predict frequent cyclists' negative experiences when cycling? We did not include demographic information, such as gender and race, in the analysis because the data were highly skewed with incomparable group sizes. We also added age as a predictor to the model, but this model did not have an adequate fit. Consequently, age was not included as a predictor variable in the model.

3. Results

The path model was specified as given in Fig. 1. The exogenous variables were allowed to covary. In the lavaan package, the SEM function was used to fit the path model. We decided against fitting a structural equation model and instead used the total scores as latent variables because of the limited sample size. Although this is a limitation of the study, PCA has shown that these items do indicate these respective factors. Unstandardised and standardised parameter estimates are shown in Table 6. The sample size was 191 and there were 6 missing cases. Given that this missing data size was very low, the analysis was conducted with 185 cases. The model fit the data well with CFI = 1, RMSEA = 0 (90 % CI [0.00, 0.115]), SRMR = 0.018, $\chi^2 = 2.477$, df = 3, NFI = 0.98, and TLI = 1.041. The estimates of the regression coefficients are given in Table 6. Regarding the hypotheses:

Internal Distraction Control (*negative relationship*, b = -0.235) and years of urban cycling (*positive relationship*, b = 0.068) were statistically significant predictors of Errors. Internal Distraction Control (*negative relationship*, b = -0.195), cycling self-efficacy (positive, b = 0.02), and years of urban cycling (*positive relationship*, b = 0.046) were statistically significant predictors of Violations. Only cycling self-efficacy (*negative relationship*, b = -0.002) was a statistically significant predictor of Positive Behaviours. Only years of

Table 4
Internal consistency coefficients for the six scales.

Scale	Alpha	Omega
Violations	0.65	0.72
Positive Behaviours	0.53	0.66
Negative Experiences	0.73	0.82
External Distraction Control	0.79	0.85
Internal Distraction Control	0.82	0.86
Errors	0.86	0.88

Table 5
Descriptive statistics for all items.

Item	Factor	N	Mean	SD	Median
Unintentionally cross street	CBQ Errors	184	0.35	0.49	0
Collision/close to collision		184	0.38	0.52	0
Braking suddenly to cause accident		184	0.6	0.59	1
Not noticing pedestrians crossing		184	0.51	0.57	0
Hitting a parked vehicle		184	0.07	0.25	0
Not braking at stop sign		184	0.26	0.46	0
Distracted, no stop for pedestrian		184	0.59	0.71	0
Unaware of road conditions		184	0.9	0.7	1
No noticing vehicle moving off		184	0.83	0.68	1
Braking abruptly on slick surface		184	0.86	0.6	1
Almost hitting emerging passenger		184	0.67	0.66	1
Overtaking turning vehicle		184	0.26	0.48	0
Misjudging a turn		184	0.73	0.64	1
Misreading traffic signals		184	0.36	0.58	0
Misapplication of brakes		184	0.43	0.62	0
Under influence of alcohol etc.	CBQ Violations	188	0.59	0.73	0
Cycle against traffic		188	0.49	0.66	0
Zigzag between vehicles		188	0.93	0.9	1
Handle obstructive objects		188	0.77	0.95	0
Speeding		188	0.99	0.77	1
Cycle through red light		188	0.49	0.7	0
Carrying passenger illegally		188	0.06	0.3	0
Dispute with cyclist/driver		188	0.32	0.57	0
Prudent speed	CBQ Positive Behaviours	188	3.07	0.99	3
Not cycle in adverse weather		188	1.82	0.77	2
Not cycle tired or sick		188	2.9	0.74	3
Keep safe distance		188	3.59	0.66	4
Look both ways		188	3.65	0.75	4
Use correct lane		188	3.48	0.79	4
Negative Experiences (cyclists)	Negative Experiences	185	0.85	0.66	1
Negative Experiences (car/van)		185	2.31	0.93	2
Negative Experiences (bus drivers)		185	1.25	0.86	1
Negative Experiences (lorry/HGV)		185	1.35	0.8	1
Negative Experiences (pedestrians)		185	1.41	0.9	1
Negative Experiences (mtcyclsts)		185	0.95	0.81	1
External Distraction Control 1	External Distraction Control	185	3.58	1.17	4
External Distraction Control 2		185	3.32	1.23	4
External Distraction Control 3		185	2.98	1.23	3
External Distraction Control 4		185	2.94	1.12	3
External Distraction Control 5		185	2.74	1.12	3
Internal Distraction Control 1	Internal Distraction Control	185	2.83	1.37	3
Internal Distraction Control 2		185	2.79	1.33	3
Internal Distraction Control 3		185	2.81	1.2	3
Internal Distraction Control 4		185	3.53	1.26	4
Internal Distraction Control 5		185	3.01	1.14	3
Internal Distraction Control 6		185	3.01	1.23	3
Internal Distraction Control 7		185	2.57	1.21	2
Cycle Control	Cycling Self-Efficacy	185	67.43	28.47	79
Hearing Rearward Traffic		185	58.25	24.4	62
Pedestrian Avoidance		185	70.39	26.78	80
Gap Judgement		185	64.07	29.64	70
Safe Stopping		185	66.35	29.28	75
Navigating Urban Street		185	71.12	26.32	80
Navigating Country Lane		185	90.98	13.04	95
Navigating Dual Carriageway		185	69.16	30.49	79
Navigating Residential Street		185	82.03	19.08	89
Navigating Cycle Path		185	89.88	16.57	96

urban cycling was a statistically significant predictor of Negative Experiences (*positive relationship*, $b = 0.05$).

An alternate model was specified where cycling self-efficacy was predicted using positive behaviours, negative experiences, errors, and violations. However, this model could not be fitted because the data matrix was not positive-definite.

4. Discussion

We distributed an online survey to a sample of cyclists primarily composed of middle-aged and older men with considerable cycling experience, who cycled recreationally on roads for the most part – although nearly half of the sample commuted frequently. They also tended to cycle on roads commonly used by cyclists – i.e., rural lanes, minor roads, busy urban roads, and cycle paths/routes. The most

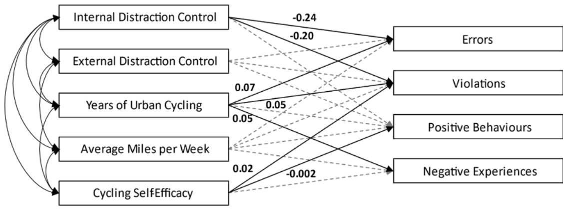

Fig. 1. Final Retained Path Model. Note: Statistically significant relationships are denoted using solid black lines and the remainder using dashed grey lines. Path coefficients are shown next to all significant relationships.

Table 6
Path analysis – parameter estimates.

Parameter	Unstd Estimate	Std.Err	z-value	P(>|z|)	Std Estimate	R^2
Errors	0.092					
Internal Distraction Control	−0.235	0.069	−3.413	**0.001**	−0.283	
External Distraction Control	−0.009	0.095	−0.09	0.928	−0.007	
Average miles Cycled Per Week	−0.007	0.022	−0.331	0.741	−0.024	
Years of Urban Cycling	0.068	0.034	2.036	**0.042**	0.149	
Violations						0.156
Internal Distraction Control	−0.195	0.043	−4.59	**<0.001**	−0.38	
External Distraction Control	0.025	0.059	0.419	0.676	0.034	
Cycling Self-Efficacy	0.003	0.001	2.346	**0.019**	0.156	
Average miles Cycled Per Week	−0.004	0.014	−0.268	0.788	−0.019	
Years of Urban Cycling	0.046	0.02	2.29	**0.022**	0.161	
Positive Behaviours						0.05
Internal Distraction Control	0.039	0.031	1.237	0.216	0.106	
External Distraction Control	−0.018	0.044	−0.402	0.688	−0.034	
Cycling Self-Efficacy	−0.002	0.001	−2.321	**0.02**	−0.171	
Average miles Cycled Per Week	−0.012	0.01	−1.166	0.244	−0.09	
Years of Urban Cycling	0.01	0.015	0.673	0.501	0.05	
Negative Experiences						0.055
Cycling Self-Efficacy	0	0.001	−0.124	0.901	−0.009	
Average miles Cycled Per Week	0.026	0.015	1.699	0.089	0.129	
Years of Urban Cycling	0.05	0.022	2.258	**0.024**	0.167	

prominent finding in the present data is that Internal Distraction Control, as measured using a modified version of the ASQ, strongly and negatively predicted cyclists' self-reported errors and violations, as identified using the CBQ. An unexpected and potentially serendipitous finding is that those considering themselves more capable also reported performing more cycling violations and fewer positive cycling behaviours – contrary to our predictions. We also observed that, as years of urban cycling experience increased, errors, violations and negative experiences while cycling also increased; this finding adds to a body of contradictory findings.

4.1. Distraction control and cycling behaviour

Nine of the items on the Errors subscale of the CBQ refer to attentional errors – the remaining 6 items implicate perceptual, decision-making and/or motor control errors. This may explain why Internal Distraction Control scores on the modified ASQ predicted self-reported errors on the CBQ, and arguably represents an initial step toward an examination of the concurrent validity of the Internal Distraction Control subscale. Indeed, there is clear overlap between some of the items on the two scales. For example, we might expect scores on the first Internal Distraction Control subscale item, "In general, I stay in control of my thoughts and do not let myself get distracted by interfering thoughts" to correlate negatively with those for the CBQ item "While you're distracted, you do not realize that a pedestrian intended to cross a crosswalk and so you do not stop to let him or her do so". Conversely, the External Distraction Control subscale item, "I can easily concentrate on a task, even when there is movement in the room I am in" does not correspond well with the CBQ Errors subscale item, "Fail to notice the presence of pedestrians crossing when turning". High scores on the former imply an ability to ignore movements in one's external environment – which would seem to manifest in high scores on the latter – and so the exact same trait is characterised as adaptive and maladaptive in these items, respectively. We tentatively suggest that the derivation of items for both measures is only partly empirically grounded, and so it may be pragmatic to create cycling-specific versions of the current ASQ Internal and External Distraction Control subscales.

Kraft et al., (2020) showed that their scores on their revised ASQ subscale, *Distractability/Cognitive Avoidance*, could predict psychopathology, including perseverative thinking, rumination, and worry, to some extent. Given its similarity to Kraft et al.'s delineation, the composition of our Internal Distraction Control subscale warrants further investigation. Although external distractions are commonly investigated in cycling research (e.g., Useche et al., 2018; Wolfe et al., 2016), future-oriented thoughts arise frequently throughout the day (e.g., thinking about upcoming errands; D'Argembeau et al., 2011) and so commuter cyclists may conceivably have several related thoughts during their journeys (Useche et al., 2021). Such thoughts inevitably place demands on working memory, which reduces the availability of cognitive resource for the primary task, i.e., cycling – although there is evidence that drivers can maintain primary task performance levels, albeit with increased cognitive load (Broadbent et al., 2022). Future research efforts should explore whether internal distraction control ability may mitigate deficits in cognitive resources, including attentional control, and ultimately improve cycling proficiency.

4.2. *Self-efficacy and cycling behaviour*

Whilst self-efficacy is typically a positive predictor of behaviour, not only in terms of physical activity and exercise (e.g., Bock et al., 2019; Samendinger et al., 2019), but also sports performance (e.g., Beauchamp et al., 2002; Hepler & Chase, 2008) and self-reported cycling behaviour (McIlroy et al., 2022), the present data suggest that it may have deleterious effects on-road cycling behaviour. For this reason, we tentatively suggest that some of the responses on our self-efficacy measure may in fact reflect participants' over-confidence. We should also acknowledge that, whilst there is some overlap between the items in our self-efficacy measure and those used previously (Lois et al., 2015), we included three highly novel and specific items to assess respondents' confidence in their ability to control their cycle and to detect rear-approaching vehicles using their hearing alone – and the data suggest high levels of confidence, if not overconfidence, for each of these items. For example, it could be argued that cycling at 15 mph through a gap that is only 75 cm wide is a perceptually and motorically demanding skill – but the median of participants' self-ratings on a percentage scale of their confidence was 70 ($M = 64.07$, SD = 29.64). Confidence in their ability to judge the distance of a car behind them was similarly high (Median = 62, $M = 58.25$, $SD = 24.40$). The potential overconfidence of cyclists and the effect on their cycling behaviour should be examined in future research.

Relatedly, the relationship of cycling self-efficacy to perceived level of comfort (PLOC; Abadi et al., 2019) in urban cycling settings is also worthy of further investigation. Experienced cyclists in Abadi and colleagues' study exhibited significantly higher PLOC than less experienced cyclists – particularly those with highly urbanised and/or commuter cycling experience. Comparable urban and commuting experience is evident in the present sample, and so their apparent overconfidence may reflect their greater comfort levels when describing their performance in the challenging cycling scenarios presented in our bespoke self-efficacy measure. An examination of the concurrent validity of our cycling self-efficacy measure relative to the items used by Abadi et al to assess PLOC may be prudent.

4.3. *Cycling experience and cycling behaviour*

The present findings indicate that years of cycling positively predicted errors, violations, and negative experiences. Given that age and cycling experience are related – i.e., we typically accrue experience as we age, of any given behaviour – these findings both contradict and support previous research, which has shown that older and more experienced cyclists are not only safer (Abadi et al., 2019; Useche, Alonso, et al., 2018) but also less safe (Boele-Vos et al., 2017; Useche et al., 2021) than younger and less experienced cyclists. For example, Useche, Alonso, et al. (2018) observed that age was negatively related to errors and violations, whereas Useche et al. (2021) showed that commuter cyclists, who completed an average of 7.7 h of cycling per week, were more likely to experience crashes, more likely to commit violations of traffic rules, and less likely to have positive experiences when cycling. Clearly, the relationship between age and cycling experience is nuanced and warrants closer scrutiny.

4.4. *Theoretical and practical implications*

The ASQ – or maybe the modified version used herein – may be a useful screening tool for determining individuals' capacity for safe urban cycling, and to identify where additional cycle training needs, such as training in cognitive control capacity, might be required. This may be particularly pertinent for individuals who have attention deficit hyperactivity disorder (ADHD), a condition which affects approximately 5 % of UK children and approximately 3–4 % of adults. It is 3–4 times more common in boys than girls (Hire et al., 2018), and is primarily manifested in hyperactivity, inattention, and impulsivity (Verkuijl et al., 2015). The DSM-V (American Psychiatric Association, 2013) criteria for inattention include "Often has trouble holding attention on tasks or play activities" and "Is often easily distracted" – clearly relevant for urban cycling contexts.

To our knowledge, the effect of ADHD on middle-aged and older adults' cycling performance has yet to be examined, but national database statistics suggest that children with ADHD are more inattentive around junctions (Nikolas et al., 2016) and are almost twice as likely to have a bike collision than children without the disorder (Grigorian et al., 2019a). Scores obtained from the Internal Distraction subscale of the modified version of the ASQ may highlight potential pathological differences in attentional control that may be modified with additional training and support.

Whilst the present ASQ items clearly have some predictive validity regarding self-reported cycling behaviours, few apply directly to cycling contexts. For example, Item 1 on the External Distraction Control subscale states "I have trouble concentrating when there is movement in the room I am in". Whilst this could afford some insight regarding a cyclists' ability to navigate urban environments, movement in such dynamic environments is inevitable. And the last item on the Internal Distraction Control subscale, "When I am working on my computer, I often go to the Internet to visit websites that are unrelated to my work" clearly does not apply to urban cycling whatsoever. However, a measure that encourages respondents to reflect on external and internal distractions during cycling may be challenging because these distractions are frequent and consequently not salient. A more prudent approach for determining a cause-effect relationship between endogenous distraction and cycling behaviour may be to use a think-aloud protocol, wherein cyclists would provide a continuous narrative as they navigate an urban environment; this can be achieved without adversely affecting task performance (Fox et al., 2011). Audio and/or visual prompts may facilitate this process, although there is some evidence that this can disrupt cyclists' performance (Kircher et al., 2015). Laboratory-based investigation of event-related potentials may be an even more viable method for gauging the frequency and intrusiveness of thoughts – and to identify where individuals' ability to suppress such thoughts can be trained (Chen et al., 2022).

The findings that those who rated themselves more proficient also reported more cycling violations and fewer positive cycling behaviours, and that more experienced individuals reported more errors, violations and negative experiences while cycling, are interesting and worthy of additional investigation. This may best be served by adopting a qualitative approach, using open-ended survey questions, interviews, focus groups or a combination of these, because the reasons are likely to be nuanced. For example, the participants might have conflated their cycling experience and proficiency when making their judgments of the latter, but to ascertain such relationships with only quantitative data is challenging.

It would also be appropriate to develop age-specific measures of cycling behaviour, as there are clearly some behaviours that younger cyclists might enact, but which older ones would avoid. For example, the Adolescent Cycling Behaviour Questionnaire, developed by Feenstra et al. (2011) to assess adolescents' risky cycling behaviours, comprises items such as "Use a cell phone whilst cycling". This behaviour is statistically less likely to occur in the present sample because only 55 % of UK adults aged 65 years and over own cell phones, compared to over 90 % of 16–54-year-olds (Ofcom, 2021); the same applies to the item "Ride a bicycle while under the influence of marijuana or other drugs", given the much higher prevalence of drug use by younger adults in the UK (Stripe, 2021). A cycling behaviour questionnaire designed specifically for older adults could comprise items that relate to risks more commonly taken by older adults (see below).

The variance in both positive and negative behaviours explained by the combination of predictors we included in our analysis is sufficiently sizeable that they could be used in future to identify cyclists for whom attention and/or estimations of ability are likely to be impaired; additional training or support could be provided for these individuals. For example, older adults tend to overestimate the time they have available to cross relative to vehicles approaching at high speeds relative to younger adults (Wilmut & Purcell, 2022). Measures like the self-efficacy measure we employed in the present study could be used to identify the extent of such overestimations, so that these vulnerable road users could receive training to recalibrate their judgements and consequently be safer when cycling on roads. Additionally, combined cognitive and physical training appears to improve executive function in children with ADHD (Liang et al., 2022), and so it would be worthwhile to examine the concurrent validity of our modified ASQ with existing assessments of ADHD symptoms (e.g., ADHD Rating Scale-5; DuPaul et al., 2016), so that these children may be screened and offered such training.

4.5. Limitations

First, we acknowledge the fallibility of the self-report measures used in all studies, including ours – not least the potential inaccuracy of retrospective recall (Howard, 2011). However, we have made suggestions for future research that might partially address this shortcoming – notably, using actual behaviour as an outcome measure, be it in a laboratory, a real-world setting, or both.

Second, the original ASQ wording, which we retained in our revised version, limits the applicability to cyclists somewhat. Therefore, another step for future research will be to develop a version that comprises cycling-specific items; for example, "During an activity, unrelated mental images and thoughts come to my mind" could become "During *cycling*, unrelated mental images and thoughts come to my mind". This may be particularly pertinent for external distracters: those included in a cycling-specific measure of external distraction control would arguably be more memorable and salient than those in the original ASQ – not least because many external distracters present an actual or imminent hazard, such as the engine noise of a rapidly approaching rearward vehicle.

And finally, our sample was small, which is why we resorted to conducting path analysis with total scores rather than a structural equation model with factor scores. However, the data were adequate for conducting PCA and path analysis; we also used polychoric correlations to account for the categorical nature of the data. The sample size limitation was further compounded by two facts. First, most of the items were on a categorical scale. Second, some items (e.g., on the cycling self-efficacy scale) were continuous. The first limitation requires a far greater sample size for convergence of models. The second limitation places the constraint that the variance of some of the items are extremely large compared to that of other items. This could potentially be overcome by using standardized scores. However, the data still are not sufficient to fit a full structural equation model. The demographic group sizes were disparate, preventing inclusion of some of the demographic variables in the model. A path model that included age as one of the predictors did not fit the data adequately well and was therefore not retained. The sample was also not diverse – although we should note that, in 2020, men made more than twice as many cycle trips as women and cycled an average of 127 miles per year compared to 50 miles per year for women. And in the same year, middle-aged and older adults cycled more frequently for leisure than did younger adults (Cycling, 2021). So, middle-aged males are not unrepresentative of the UK cycling population. Lastly, the data were only obtained online; men's online and in-person survey responses may be disparate (Barenboym et al., 2010).

4.6. Conclusion

Although we should be cautious not to overinterpret or overgeneralise the present findings, they suggest that experienced cyclists' behaviour may be influenced by a combination of their ability to control internal distractions, their cycling self-efficacy, and their cycling experience. Specifically, impaired distraction control, possible overconfidence in their cycling ability and years of urban cycling experience collectively predicted greater errors and violations, fewer positive behaviours, and an increased likelihood of negative experiences while cycling. Given the year-on-year increases in cycle journeys made in the UK (Department for Transport, 2021), and the increases in *road user entropy* this entails, formalised assessment of cyclists' perceptions of their abilities and attentional style may be prudent, to mitigate their errors, violations, and negative experiences with other road users.

CRediT authorship contribution statement

Daniel T. Bishop: Conceptualization, Methodology, Validation, Writing – review & editing. **David P. Broadbent:** Conceptualization, Methodology, Validation, Supervision, Writing – original draft. **Anna Graham:** Conceptualization, Methodology, Validation. **Prathiba Natesan Batley:** Methodology, Investigation, Formal analysis, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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