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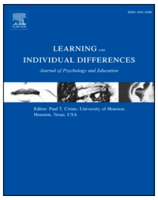

Tailoring explicit and implicit instruction methods to the verbal working memory capacity of students with special needs can benefit motor learning outcomes in physical education

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ABSTRACT

This study examined the effects of explicit versus implicit instructions and feedback methods on motor learning and perceived competence of 9-to 13-year old students with special educational needs practicing a balancing task during physical education. The aim was to test if and how the effects of type of instruction and feedback methods were influenced by students' verbal and visuospatial working memory capacities. The students significantly increased their balancing performance and perceived competence from pre- to posttest, with no differences between groups. The relation between type of instruction and feedback methods and learning outcomes was significantly influenced by verbal working memory capacity, not by visuospatial working memory capacity. Physical education teachers may need to align their instructions with verbal working memory capacity, by providing implicit instructions and feedback methods in students with low verbal working memory capacity and explicit instruction and feedback methods in students with high verbal working memory capacity.

1. Introduction

In primary education, it has become common practice to apply within-classroom differentiation. In a differentiated classroom, the teacher proactively plans and carries out varied approaches in anticipation of and response to the diverse learning needs of individual students (Tomlinson, 2001). This educational challenge is perhaps largest for teachers working with children with special (educational) needs. In the Netherlands, for example, classes in special primary education and the so-called ‘cluster 4’ primary schools typically comprise students with various learning difficulties and diverse behavioral and/or social problems (e.g., attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), reactive attachment disorder (RAD)).

Physical education (PE) teachers in the Netherlands aim to increase students' motor and perceived competence in order to encourage current and future engagement in physical activities (Brouwer et al., 2012; Mooij et al., 2011). According to Stodden et al. (2008), the interaction of actual motor competence and perceived competence is one of the most powerful mechanisms affecting engagement and persistence in physical activity (see also Robinson et al., 2015). Thereby, perceived competence is regarded as a motivational drive for motor learning (Stodden et al., 2008; Wulf & Lewthwaite, 2016). In line with this, motor learning methods that enhance expectancies of successful performance are shown to facilitate motor learning in children (Simpson et al., 2020). For teachers working in special education, it is challenging to accomplish this positive spiral of engagement, as the cognitive and behavioral problems that led to children's reference to special schools are associated with reduced motor ability (e.g. Lai et al., 2014; Tseng et al., 2004; Westendorp et al., 2011).

PE teachers in special education strive to organize the learning environment such that students gain positive experiences with physical activity and increase motor skills. The wide divergence in motor, cognitive, behavioral, and social abilities among the students within one class highlights the importance of within-classroom differentiation in special education PE lessons. One important aspect of the learning environment that allows differentiation is the verbal guidance given to individual students. In fact, in the last thirty years, motor learning research (e.g., Liao & Masters, 2001; Wulf, 2007) has demonstrated that

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changing the nature and amount of verbal guidance can induce different modes of motor learning (e.g., explicit and implicit motor learning), and thereby can affect learning outcomes.

One commonly used method of verbal guidance is to provide explicit, detailed step-by-step instructions about movement execution. By doing so, the teacher aims for the student to acquire declarative knowledge about the to-be-learned motor task, and use this knowledge to improve performance. This mode of learning is termed *explicit* learning (Berry & Dienes, 1993). Traditionally, explicit learning is thought to be especially beneficial for novice performers (Fitts & Posner, 1967); it provides them with verbal movement rules that they can use to approximate the desired movement execution (Willingham, 1998). Explicit learning is typically thought to strongly rely on (verbal) working memory processing (Buszard et al., 2016; Kleynen, Braun, et al., 2014; Masters et al., 2008). It is also possible to learn *implicitly*, and increase motor skill without (or with reduced) buildup and use of declarative knowledge (e.g., Masters, 1992; Willingham, 1998). For example, in an early laboratory study, Masters (1992) evoked implicit learning by having young healthy adults perform a secondary cognitive task (i.e., random letter generation) while concurrently practicing the motor skill of golf putting. Execution of the secondary task significantly limited the buildup of declarative knowledge, but learners still showed clear improvements in golf putting accuracy – indicating that motor skill learning did take place. This suggests that implicit motor learning is minimally reliant on (verbal) working memory processing.

Explicit and implicit learning can be considered as two ends of a continuum, with fully explicit learning (i.e. with substantial build-up of declarative knowledge and dependence on verbal working memory) at one end and fully implicit learning (i.e. without any build-up of declarative knowledge or verbal working memory involvement) at the other end (Kal et al., 2018; Kleynen et al., 2015; Kleynen, Braun, et al., 2014). Although the student population of special primary schools and cluster 4 schools is diverse, deficits in working memory capacities (WMCs) are common since children with mild intellectual disabilities (Van der Molen et al., 2009), ADHD (Martinussen et al., 2005; Willcutt et al., 2005) and ASD (Kercood et al., 2014; Wang et al., 2017) generally exhibit deficits in working memory. Even though DSM-V criteria for RAD do not include cognitive aspects, children with RAD often show behavioral and neurophysiolocal similarities with ADHD with deficits in executive functions, such as working memory (Dahmen et al., 2012; Menon et al., 2020; Salari et al., 2017) as a function of early pathogenic care. Given these deficits in working memory, it seems relevant that PE teachers in special education take individual differences in WMC into account in their choice to exploit a relatively more explicit or more implicit motor learning process.

There are different learning methods that PE teachers could use to promote implicit learning. One such method was proposed by Liao and Masters (2001) and is called analogy learning. In analogy learning, a teacher conveys the information about the desired movement execution by means of a single metaphor. This metaphor should provide a clear and meaningful mental image to the learner, and encompasses the complex rule structure of the to-be-learned movement. A second method to promote implicit learning is providing instructions that induce an external focus of attention, which directs the learners' attention to the effects of the movements on the environment (Wulf, 2007; Wulf et al., 1998). Hence, these two methods serve to circumvent the step-by-step processing (analogy learning) and internal focus (on body movements) strongly induced by explicit instruction methods. Indeed, both analogy learning and external focus learning methods exhibit characteristics of implicit learning, such as little accumulation of explicit knowledge and robust motor performance during dual-tasking (see e.g. Kal et al., 2013; Lam et al., 2009; Liao & Masters, 2001; Masters et al., 2008; Wulf et al., 2001). Although these two methods are typically examined separately in research, mechanisms underlying analogy learning and external focus learning are considered intertwined (Poolton & Zachry, 2007; Wulf & Lewthwaite, 2016) and can be easily -or maybe even preferably- implemented together in to evoke a more implicit learning process in practice (Poolton & Zachry, 2007).

Studies that examine effects of analogies on motor skill learning methods in students with learning or behavioral deficits are – at least to our knowledge – absent. A few studies have examined the effects of analogy learning in typically developing children, showing superior learning in sequential dancing (Sawada et al., 2002) and rope skipping (Tse et al., 2017) for analogy learning as compared to explicit learning. In the study of Tse et al. (2017), for instance, 5-to 7-year-old children practiced rope skipping during five lessons in a two-week period. They either received series of explicit instructions or instructions by analogy. Explicit instructions included, for example, ‘jump with both feet on the same spot’. Instead, children in the analogy learning group were told to ‘jump like a rabbit’. Both groups showed increases in successful skips across practice, but early in learning (i.e., the first practice session) the analogy instructions resulted in significantly more successful skips and better movement technique than the detailed explicit instructions. Moreover, when tested with a concurrent secondary task, children who received analogy instructions showed more robust rope skipping skill. This indicates that performance after learning with analogy instructions depended less on cognitive resources than after learning with explicit instructions.

Effects of external focus instructions in children with learning or behavioral problems are equivocal. Saemi et al. (2013) showed that 8- to 11-year old children with ADHD showed greater improvements in throwing accuracy after practicing with external focus instructions (i.e., children were told to focus on the ball) compared to internal focus instructions (i.e., with a focus on the motion of the throwing hand). Similarly, Chiviacowsky et al. (2013) found that 10- to 14-year old children with mild intellectual disability (IQ = 51–69), who received external focus instructions in a bean bag throwing task managed to maintain throwing accuracy in a transfer test, in which the distance towards the target was increased from two to three meters. By contrast, throwing accuracy of the children who received internal focus instructions decreased significantly from retention to transfer test. However, Tse (2019) conducted a study with a similar task and procedure as Chiviacowsky et al. (2013) in 9- to 12-year old children with ASD, and reported that children who had received internal focus instructions outperformed children who had received external or no focus instructions during retention and transfer. These inconsistencies in the effects of external versus internal focus instructions are also present in studies including children with typical development. Whereas some studies reported positive effects of external focus instructions compared to internal focus instructions (Abdollahipour et al., 2015, 2017; Brocken et al., 2016; Flores et al., 2015; Hadler et al., 2014; Krajenbrink et al., 2018; Roshandel et al., 2017; Teixeira da Silva et al., 2017), other studies failed to replicate these findings (Agar et al., 2016; Emanuel et al., 2008; Van Abswoude et al., 2018).

In sum, research on the effects of explicit and implicit instruction methods in children with special needs is scarce and does not provide clear-cut results in terms of motor learning. Instead, there seem to be pertinent individual (and/or group) differences in how children respond to different instructions (see also Simpson et al., 2020). What factors mediate these individual differences needs further examination.

As stated earlier, one particularly important factor could be working memory capacity (Brocken et al., 2016; Jongbloed-Pereboom et al., 2019; Krajenbrink et al., 2018; Van Abswoude et al., 2018, 2019; Van Cappellen-van Maldegem et al., 2018). Working memory refers to a limited capacity system, which allows for the temporary storage and manipulation of information necessary for performing complex tasks (Baddeley & Hitch, 1974). In its simplest form, working memory is viewed as a multicomponent system, with a central executive as attentional control system aided by two subsidiary systems: the phonological loop and the visuospatial sketchpad. The phonological loop, the verbal component, is assumed to hold and manipulate verbal and acoustic information, while the visuospatial sketchpad maintains and manipulates visuospatial information and is assumed to play an important role in spatial orientation and in the solution of visuospatial problems (Baddeley & Hitch, 2000). Students' learning abilities have been shown to be closely associated with verbal and visuospatial WMC (Gathercole et al., 2016). Jaroslawska et al. (2016), for example, reported that the verbal working memory component plays a key role in following instructions. Significantly, children with mild intellectual disabilities, ADHD or ASD exhibit deficits in both verbal and visuospatial working memory, with an emphasis on visuospatial deficits in children with ADHD (Martinussen et al., 2005) and ASD (Kercood et al., 2014; Wang et al., 2017) and an emphasis on verbal deficits in children with mild intellectual disabilities (Van der Molen et al., 2009).

Masters et al. (2013; see also Buszard et al., 2016; Steenbergen et al., 2010) argue that explicit learning likely relies strongly on the verbal component of working memory while implicit learning does not. This is because the detailed step-by-step explicit movement instructions used with explicit learning will require, and thus tax, verbal working memory processing. A study of Buszard et al. (2017) provides evidence for this contention. They found that typically developing 8 to 10-year-old children with high verbal WMC showed consistent improvements in a basketball shooting task when given multiple (i.e., five) internal focus instructions, whereas performance deteriorated in children with low verbal WMC. However, research that examined the relationship between children's verbal WMC and motor learning with internal focus instructions did not find such association (Brocken et al., 2016; Krajenbrink et al., 2018; Van Abswoude et al., 2018, 2019; Van Cappellen-van Maldegem et al., 2018). Yet, these latter studies may have insufficiently taxed working memory, because children received only one (Brocken et al., 2016; Van Abswoude et al., 2018) or three instructions (Krajenbrink et al., 2018). Implicit learning methods have been shown to lead to the accumulation of little explicit knowledge (e.g. Liao & Masters, 2001) and robust motor performance while performing a secondary task (e.g. Kal et al., 2013; Liao & Masters, 2001; Poolton et al., 2006; Wulf et al., 2001). This suggests that verbal working memory is minimally involved during implicit learning. Accordingly, several studies have reported that verbal WMC does not predict motor skill improvements with implicit learning (e.g. with external focus instructions; Van Abswoude et al., 2018; Brocken et al., 2016; Van Cappellen-van Maldegem et al., 2018; Krajenbrink et al., 2018).

As this brief overview shows, researchers have primarily focused on the verbal component of working memory. The role of visuospatial WMC in explicit and implicit motor control and learning has received less attention. One of the exceptions is a study of Buszard et al. (2016) that shows that visuospatial WMC of young adults with typical development was positively associated with implicit processes (i.e. low EEG coherence between T4-F3 and T4-F4 regions in the Beta1 and Alpha2 frequency domains) during the performance of a novel motor task. In line with this finding, we propose that implicit learning methods may rely on visuospatial WMC more strongly than explicit methods. For instance, analogy instructions require the learner to process a visual image and convert it into movement patterns, whereas external focus instructions typically emphasize the spatial relation of a learner's movement to the environment. Preliminary support for the latter contention comes from a study by Van Cappellen-van Maldegem et al. (2018). In this study, 7-year-old children with probable Developmental Coordination Disorder received external focus feedback about the movements of the ribbon or ball while doing a ‘slingerball’ task. Greater improvements in throwing performance were observed in children who had larger visuospatial WMC. Two other studies, however, did not confirm these observations (Krajenbrink et al., 2018; Van Abswoude et al., 2018).

It is important to note that the current literature on the relation between working memory and the gains of explicit or implicit learning methods has primarily focused on children with typical development and has been restricted to laboratory studies, in which children practiced individually with guidance of an experimenter in a tightly controlled setting including one implicit instruction method instead of a blend of implicit instruction methods. Probably, this setting is not representative for PE in special education (see also Van der Kamp et al., 2015). Furthermore, previous studies solely focused on motor- and not on motivational outcome measures. As already stated, (Dutch) PE teachers consider increasing students' perceived competence as an important vehicle for engaged participation in physical activities (Brouwer et al., 2012).

To address these issues in every aspect, the present study was set up and established in a process of co-creation with PE teachers and other stakeholders in special physical education, and embedded in regular PE lessons. The study aim was to assess the effects of more explicit learning methods versus more implicit learning methods on students' motor learning and perceived competence on a slacklining task, and to assess whether learning improvements were influenced by students' verbal and visuospatial WMCs. We hypothesized that the benefits of explicit and implicit instruction and feedback methods would depend on students' verbal and visuospatial WMC, respectively. More specifically, we did not expect differences between explicit and implicit methods per se but did hypothesize that students' verbal WMC would predict improvements in motor performance (i.e., motor learning) and perceived competence with explicit instructions and feedback, while visuospatial WMC would predict learning outcomes of the students who practiced with implicit instruction and feedback methods (i.e. external focus instructions and analogies).

2. Material and methods

2.1. Context of the study origin

This study was funded by the Netherlands Initiative for Education Research (NRO), which aims to contribute to innovation and improvements in education with an emphasis on linking educational practice and research. A consortium was formed by stakeholders of motor learning in special physical education. Besides researchers, this consortium consisted of PE teachers in special education, community service professionals with a focus on inclusive sport programs, developers of sport materials, and representatives of the National Association of PE and a PE teacher education faculty. In a series of meetings the research question, experimental task and design were discussed, chosen and operationalized. Hence, this study is a result of a process of co-creation by researchers and practitioners; the choices made have both theoretical and practical grounds.

2.2. Participants

A priori power-analyses (G*Power 3.1.9) showed that for a RM-ANOVA with within-between interaction, two groups, and three measurements, a minimum of 28 participants would be needed to detect a moderate effect of instruction method on learning outcomes ($\alpha = 0.05$, $\beta = 0.80$, expected $r = 0.50$, effect size $f = 0.25$). Furthermore, for a two-tailed multiple regression model with five predictors, a minimum of 68 participants would be needed to be able to detect a significant moderate ($f^2 = 0.15$) improvement in R^2 when adding two working memory by group interaction terms ($\alpha = 0.05$, $\beta = 0.80$). Accordingly, we recruited students from the four public primary schools for children with special educational needs that were part of the consortium. These were located in three small to moderate sized cities in the Netherlands (population: 15.000 to 150.000 inhabitants). In the Netherlands, there is no distinction between private and public schools, as all schools are government funded. The participating schools were so called SBO and/or cluster 4 schools, in which group sizes are smaller (approximately 15 students per class) than at regular schools, and the students get more tailor-made and specialised support. Students at SBO and cluster 4 schools encounter learning difficulties and/or behavioral or social problems, such as ADHD, ASD, and RAD, and are typically referred to these schools, because they were at risk of dropping out at regular schools. For this study, we included all grade 7 and 8 students at the participating schools, without any further in- or exclusion criteria. The local university's ethics committee approved the protocol of the study. We approached the parents of all grade 7 and 8 students of the four schools (11 classes consisting of 163 students) for active consent. We gained consent for 115 students (85 boys and 30 girls, $M_{age} = 11.7$ years, $SD_{age} = 0.7$ years) to participate in the study (i.e. 71% consent).

2.3. Task and apparatus

The to-be-learned task was to walk a slackline (length: 390 cm; width 35 mm; height: 31 cm), using as little support as possible. The slackline (slackstar 35 mm) was stretched as tight as possible on a slackrack (GIBBON slackrack classic) with help of a tension rattle (GIBBON power ratchet). The high tension permitted that also with the heaviest students standing at the middle of the line, the slackline did not touch the ground. Two upper parts of a vaulting box (height: 46–52 cm, depending on the vaulting box brand that was available at the schools) were placed in a longitudinal direction at each end of the slackline, serving as start- and endpoint for the cross over. A red circle (diameter: 20 cm., thickness: 4 mm.) was placed on each vaulting box to mark the start and end positions. Support was available from six metal rounders posts in bases (Janssen Fritsen, height: 155 cm), which were equally distributed on both sides of the line. The students could grab these rounders to remain in balance (Fig. 1).

Two Fuji film camera's (finepix XP60) were used during the pretest, second practice session, and posttest to record the students' balancing performances in a frontal (Fig. 1, camera 1) and sagittal (Fig. 1, camera 2) plane. To measure balancing outcome, we developed a scoring system (i.e., scores ranging between 1 and 14) in which the distance covered and amount of support were considered (Appendix A). Furthermore, a rating scale for balancing technique (i.e., range 0–14) was developed in cooperation with a slackline expert, based on existing literature on using slacklining in PE (Konijnenberg, 2013). The rating scale was consistent with the instructions that were provided during the practice sessions. It consisted of seven criteria for posture and walking (Appendix B). To establish the reliability of the scoring system for balancing technique, the experimenter and a research assistant independently rated 50 randomly selected trials. A single-measures, 2-way mixed, absolute-agreement ICC indicated good interrater reliability (ICC = 0.77, 95% CI [0.48, 0.89]).

WMC was assessed with two subtests of the Dutch version of the Wechsler Intelligence Scale for Children-V (WISC-V-NL; Wechsler, 2018a). The Digit Span subtest was used to measure verbal WMC. In this subtest, children listened to gradually increasing sequences of numbers, and were required to repeat them in the same order, reversed order, and in ascending order. Visuospatial WMC was assessed with the Picture Span subtest. For this subtest, children previewed (a growing set of) pictures and subsequently had to identify each of these among a larger set of pictures, and in the same order. The two subtests were digitally assessed using Q-interactive and two Bluetooth-connected iPads (iPad air, model MD787FD/A), one for the experimenter and one for the student. In both subtests, points were awarded for each correct answer, with a possible range of 0–54 for the Digit Span subtest and 0–49 for the Picture Span subtest. Furthermore, scaled scores were obtained in order

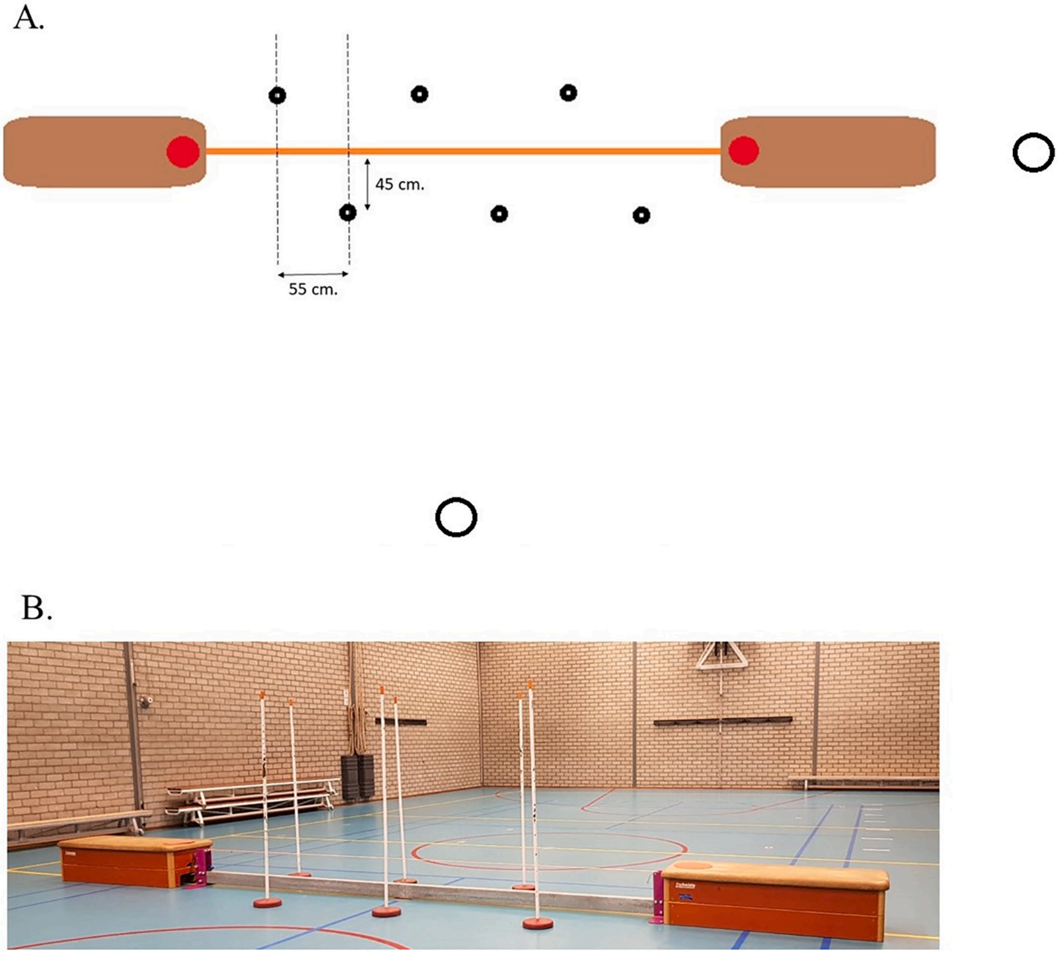

Fig. 1. Schematic top view (A) and photograph (B) of the slackline situation.

to compare these raw scores with children of the same age from a normative sample of 1038 Dutch children (Wechsler, 2018b). A scaled score of 10 reflects the mean of the age-related normative sample with 3 units as standard deviation. Reliability of the two subtests was previously found to be sufficient for the normative sample of Dutch children (Digit Span $\lambda^2 = 0.85$, Picture Span $\lambda^2 = 0.84$) and good for samples of children with learning problems, ADHD, and ASD (Digit Span $\lambda^2 =$ 0.88–0.93; Picture Span $\lambda^2 =$ 0.87–0.93; Wechsler, 2018b).

We assessed perceived competence using the subscale (5 items) of the Intrinsic Motivation Inventory (IMI; McAuley et al., 1989). According to Clancy et al. (2017), the IMI is a very flexible instrument that allows researchers to select and modify items to assess (subscales of) intrinsic motivation in any sport setting. The items were therefore translated into Dutch and modified for the slacklining task (Appendix C). Each of the five items of the perceived competence subscale was rated on a 7-point Likert scale (1–7 points), with a higher score indicating greater perceived competence. As a result, total perceived competence score ranged from 5 to 35.

Motor competence was assessed with the Athletic Skills Track (AST, Hoeboer et al., 2016). The AST has proven to be a reliable (test-rest reliability AST-2: ICC = 0.802) and valid (correlation age- and gender-related quotients of the Körperkoordination-Test für Kinder with AST-2: $r = -0.646$) assessment tool to assess motor skill competence among 4- to 12-year old children in a PE-setting (Hoeboer, Krijger-Hombergen, et al., 2018). Given the characteristics of the current participants, we administered an age-specific version of AST that was originally developed for children aged 6–9 (AST-2) instead of 9–12 (AST-3). This decision was made in consultation with the developer of the AST, and after the PE teachers had indicated that the AST-3 consisted of (combinations of) skills that would be too difficult for a considerable number of the current participants, for example a forward roll. AST scores refer to the amount of time (in seconds) a student needs to complete the track. Hence, a low AST score reflects high motor competence. In regular primary education, children aged 6–9 need on average 30.6 ± 7.3 s (boys) and 33.0 ± 7.9 s (girls) to complete the AST-2 (Hoeboer, Ongena, et al., 2018).

2.4. Procedure and design

The study was embedded in regular PE lessons. In the selected schools, students take two PE lessons of 45–60 min a week. For four weeks, one of these lessons included the slackline task, set up in part of the gym hall. The study design consisted of a pretest (week 1), two practice sessions (week 2 and 3), and a posttest (week 4), see Fig. 2. Different persons, with different roles and responsibilities were involved in conducting the experiment (Table 1). The experimenter and an extra PE teacher, who was only present during the two practice sessions, took care of the slackline activity. In total, four extra PE teachers were involved in guiding the students during the practice sessions. Each extra PE teacher guided the two practice sessions in 2 to 4 classes (i.e., 11 classes in total) and guided an equal number of students from both experimental groups. The PE class teacher supervised the PE lesson as a whole, and guided the other PE activities during the lesson. Group teachers or teacher interns were involved in guiding the students through the perceived competence subscale. Within each school, all activities took place in the same gym.

During the pre- and posttest, the students performed the slackline task individually. The experimenter explained the student that the task was to walk gently across the line to the opposite side, and that it was permitted to grab the rounders posts to achieve this. The experimenter added that the less the rounders posts were used, the better it was. After completing four trials, which were video recorded, a group teacher or

Table 1
Involved persons with their roles and responsibilities.

Persons/roles	Responsibilities
PE class teacher	• Supervision of PE lessons • Guide students through other (non-experimental) PE activities • Send students to experimental task • Keep track of time • Assess motor ability with AST-2 (during a non-slackline lesson)
Experimenter	• Supervision of experiment • Guide students through slackline pretest and posttest • Making video recordings
Extra PE teacher	• Guide students during experimental interventions (i.e. give instructions and feedback during practice session 1 & 2)
Group teacher/ teacher-intern	• Guide students through perceived competence subscale (pretest, practice session 2, posttest)
Research assistant 1	• Score balancing outcome and –technique based on video recordings
Research assistant 2	• Assess verbal and visuospatial WMC (during school time)

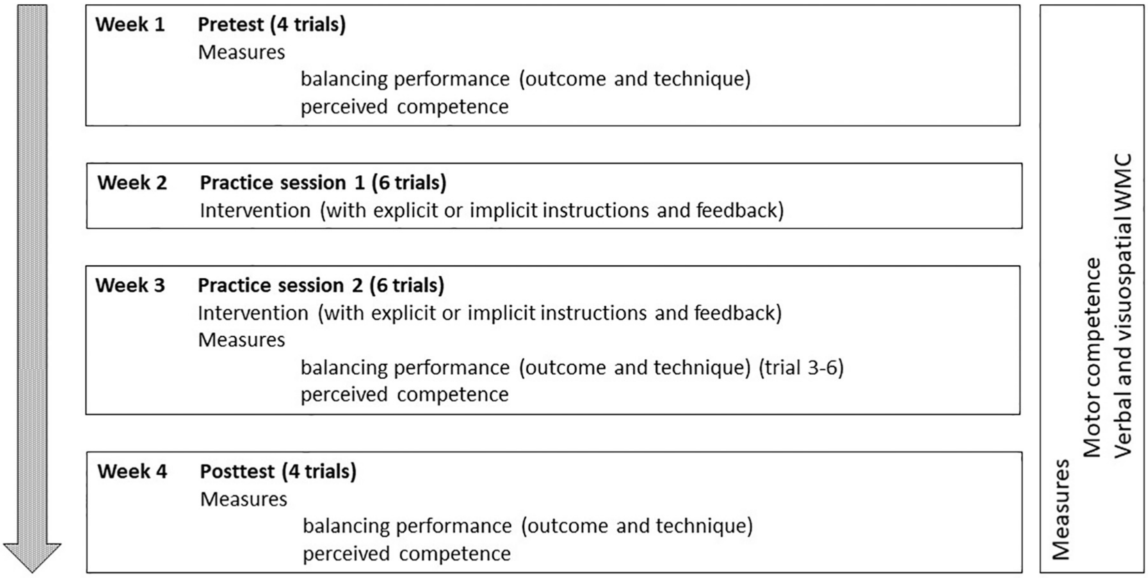

Fig. 2. Timeline of procedure.

teacher-intern went through the items of the perceived competence subscale together with the student, ensuring comprehension of the items, and completed the questionnaire in accordance with the student's answers.

After the pretest, students were ranked according to initial balancing outcome score in the pretest. Next, they were alternately allocated to one of the two instruction and feedback methods groups, following a pre-specified order, to ensure similar pretest balancing levels across the two groups. Any imbalances in boy/girl distribution between the groups were resolved by swapping a boy and girl with the same initial balancing outcome score. The two groups received different methods of instruction and feedback on balancing technique during the two practice sessions (week 2 and 3). The explicit instruction and feedback methods group (i.e., EIF-group) received detailed instructions and points of feedback with an internal focus of attention. Providing verbal information with an internal focus of attention is a learning method that is associated with evoking a (more) explicit learning process (e.g. Kal et al., 2018). The implicit instruction and feedback methods group (i.e., IIF-group) received instructions and points of feedback that were formulated as analogies or with an external focus of attention. These are learning methods that are associated with (more) implicit learning (e.g. Poolton & Zachry, 2007). Table 2 shows the exact phrases that were used as instructions (prior to the first practice trials) or points of feedback (after each subsequent practice trial). Hence, although the underlying content of the instructions and feedback in both conditions were similar, the way the instructions and feedback were expressed differed between the groups.

Before the first practice session, all students were introduced to the extra PE teacher who would provide guidance during both practice sessions. The students practiced in small groups of 2–3 students, who were assigned to the same experimental group. Before the first trial of the first practice session, the extra PE teacher explained they were going to practice slacklining and he or she would assist them in improving task performance by providing verbal instructions. The extra PE teacher restated that the task was to walk gently across the line to the opposite side, and that it was permitted to grab the rounders posts to achieve this, the fewer the better. Subsequently, the extra PE teacher provided the first two instructions on balancing technique (conform the experimental group, Table 2) and demonstrated the desired posture while standing on the floor. During each of the two practice sessions, each student completed six trials. After every trial, the extra PE teacher provided the most relevant point of feedback to the student. To this end, the teacher chose one out of the four pre-defined phrases (Table 2), she or he considered most critical for furthering the student's balancing. The extra PE teacher demonstrated the posture if the instruction was given the first time or when the extra PE teacher thought it would increase comprehension. Preceding trial 2–6, the extra PE teacher asked the student which point of feedback the student had been given in the previous trial. The PE teacher confirmed, reminded or reformulated the answer of the student conform the original point of feedback given. The procedures of practice session 2 were the same, except for three differences. Prior to the first trial, the PE teacher asked the students if they reminded and could explicate the instructions/points of feedback they had been given in the former session. The PE teacher then replicated the four instructions/points of feedback and demonstrated the accompanied postures conform the experimental group. Also, balancing performance was video recorded during the second practice session, and after the last trial, perceived competence was measured following the same procedure as in the pre- and posttests.

Table 2
Phrases used as instructions and points of feedback as applied in the two experimental conditions.

	Explicit instructions/points of feedback (internal focus)	Implicit instructions/points of feedback (analogies and external focus)
1.	*'Direct your eyes towards the end of the line'*	*'Focus on the red circle'*
2.	*'Keep your upper body in erect position and move your hands above your shoulders'*	*'Pretend as if you are a big tree, which branches are waving in the wind'*
3.	*'Place your feet straight on the line'*	*'Direct the tip of your shoe towards the red circle'*
4.	*'bend your knees slightly'*	*'Pretend as if you are sitting on a high chair'*

The first research assistant applied the scoring system for balancing outcome (Appendix A) for the pretest, posttest, and practice session 2. Scoring was performed based on the video recordings of all four trials in the pre- and posttests, and the last four trials (trials 3–6) in practice session 2. To minimize bias, videos were muted during scoring. Furthermore, at pre- and posttest, the videos were scored on alphabetic order of the students' last names, and therefore not related to experimental group. The two highest scores were summed and used for statistical analyses. Subsequently, the attempts with these highest scores on balancing outcome were assessed on balancing technique (Appendix B). Similar to balancing outcome, the two balancing technique scores were summed and used for statistical analyses. During the course of the study, the PE class teacher assessed AST-2 during another PE-lesson. Finally, during school time, the students were called one-by-one to the second research assistant to perform the Digit Span and Picture Span subtests of the WISC-V-NL.

2.5. Statistical analyses

All statistical procedures were performed using IBM Statistics SPSS, version 26. Statistical significance level was fixed at $p = .05$.

To verify whether stratification was successful and to identify possible confounding factors, separate independent t-tests were performed to assess whether the two experimental groups differed in age, verbal and visuospatial WMC, motor competence, and balancing outcome and technique scores in the pretest. A chi-squared test was performed to examine whether the distribution of gender differed between groups. Perceived competence measures were not normally distributed. Therefore, a Mann-Whitney U test was conducted to assess whether experimental groups differed at pretest.

Next, the effects of instruction and feedback methods on the outcome measures were assessed. Separate 2(Group: EIF, IIF) x 3(Test: pretest, practice session 2, posttest) ANOVAs with repeated measures on the second factor were performed to compare the two groups' improvements in balancing outcome and technique. Effect sizes were calculated with partial eta squared (η_p^2). Values of 0.01, 0.06, and 0.14 were considered as small, moderate, and large effect sizes (Cohen, 1988). To compare the levels of perceived competence of the experimental groups, a Friedman test of differences among repeated measures was conducted. When either gender, age, motor competence, balancing performance at pretest or perceived competence at pretest (tended to) significantly differ between experimental groups and was significantly related to improvement for a particular outcome measure, the variable was added as covariate in the respective ANOVA repeated measures analysis or Friedman test. Pairwise comparisons using Bonferroni adjustments were performed as post hoc analyses. Furthermore, separate Mann-Whitney *U* tests were used to assess whether the two experimental groups differed in perceived competence in practice session 2 and the posttest.

Subsequently, we assessed whether improvements due to learning (i.e., the differences between post- and pretest scores) in balancing outcome, -technique, and perceived competence were predicted by verbal and visuospatial WMC, and whether this differed for the EIF and IIF groups. To this end, three hierarchical three-stepped linear regression analyses were applied, following similar steps as Brocken et al. (2016). Instruction and feedback methods (i.e., EIF- vs. IIF-group) and possible covariates were entered on the first step. In the second step, verbal and visuospatial WMC scores were entered. Finally, the working

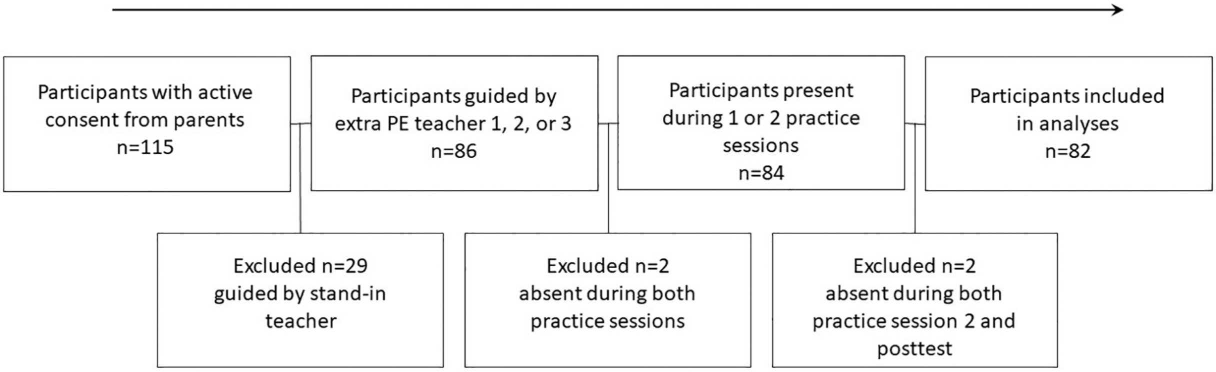

Fig. 3. Flowchart exclusion of participants during the study.

memory by instruction and feedback methods interaction terms were added in the third step. The interaction terms were regarded to be relevant only if they significantly improved model fit (R^2). For all regression analyses, the assumptions of homoscedasticity (i.e., by inspecting the standardized residuals by standardized predicted values plot), error-independence (Durbin-Watson = 1.568 > 1.624, the critical value of 80 students and five predictors), lack of multicollinearity, and normal distribution of errors (e.g., non-significant Kolmogorov-Smirnov) were verified.

3. Results

3.1. Flow of the study

Proceedings were uncomplicated during pre- and posttests. However, during practice sessions, one extra PE teacher encountered problems. This extra PE teacher, who did guide three classes, was originally not involved in the study. However, circumstances required that this extra PE teacher had to suddenly stand in for a colleague who was originally planned to be involved. The stand-in teacher was only quickly briefed on the study and requirements before practice session 1. Although this teacher largely managed to instruct students conform the procedure, there were serious problems keeping the students motivated and focused on the task. Pedagogical climate and students' engagement seemed to decline further throughout practice session 2, resulting in drop-outs, neglect, and (non)verbally demonstrated frustration. Eventually, the experimenter decided to intervene and take over the role of extra PE teacher. For the practice under the guidance of the other three extra PE teachers no irregularities were noted. The perceived competence scores of the students in practice session 2 were compared between the four extra PE teachers, to get an indication of the pedagogical climate during these practice sessions, and check whether it may have affected the intervention. A Kruskal-Wallis test showed that there was a statistically significant difference between teachers in students' perceived competence score after practice session 2, $\chi^2(3) = 25.28$, $p < .01$. The students who were guided by the stand-in extra teacher had a mean rank perceived competence score of 26.0, while the students who were guided by extra PE teacher 1, 2 and 3 had mean rank perceived competence scores of 62.1, 59.2, and 50.8, respectively. Bonferroni-corrected post hoc tests showed that perceived competence was significantly lower for the students who were guided by the stand-in teacher compared to students of two other teachers (adjusted $p < .01$), but not compared to students who were guided by a third teacher (adjusted $p = .07$). Furthermore, no significant differences were present at pretest, $\chi^2(3) = 4.18$, $p = .24$, with a mean rank perceived competence score of 49.41 for the students who would receive guidance from the stand-in teacher, and a mean rank perceived competence score of 50.42, 63.10, and 53.62 for the students who would receive guidance of the other extra PE teachers. We therefore concluded that the pedagogical climate was insufficiently conducive for engaged participation and learning for students guided by the stand-in teacher. Therefore, the 29 students who received guidance from the stand-in teacher were removed from further analyses.

From the remaining students, we excluded 4 students who had either missed both practice sessions or practice session 2 plus the posttest. Accordingly, of the originally recruited 115 students, a total of 82 students were included in analyses (Fig. 3).

3.2. Group characteristics

Group characteristics are shown in Table 3. There were no significant differences between the experimental groups with respect to gender, age, motor competence, verbal and visuospatial WMC, balancing outcome, -technique, and perceived competence at pretest. However, a non-significant difference was suggested for age, $t(80) = -1.85$, $p = .07$. Since age correlated significantly with improvements in balancing

Table 3
Group characteristics.

	Explicit instruction and feedback group	Implicit instruction and feedback group	Value test statistic	p-Value
N (gender)	39 (30 boys, 9 girls)	43 (27 boys, 16 girls)	$\chi^2(1) = 1.93$	p = .17
Age	11.72 ± 0.65 years	11.97 ± 0.56 years	t(80) = 1.85	p = .07
Motor competence (AST score)[a]	30.26 ± 10.19 s	32.29 ± 11.36 s	t(75) = 0.83	p = .41
Verbal working memory (raw score)[b]	19.44 ± 3.24	19.12 ± 2.97	t(80) = 0.47	p = .64
Verbal working memory (scaled score)[b]	6.46 ± 1.79	6.14 ± 1.74		
Visuospatial working memory (raw score)[c]	27.08 ± 6.16	27.28 ± 5.81	t(80) = 0.15	p = .88
Visuospatial working memory (scaled score)[c]	8.49 ± 2.45	8.53 ± 2.29		
Balancing outcome at pretest	18.10 ± 3.80	18.51 ± 3.23	t(80) = 0.53	p = .60
Balancing technique at pretest	8.56 ± 3.31	7.67 ± 3.31	t(80) = 1.22	p = .23
Perceived competence at pretest	25.05 ± 6.86	25.21 ± 6.52	U(80) = 848	p = .93

[a] A lower score on AST represents higher motor competence.
[b] Digit Span subtest, WISC-V-NL.
[c] Picture Span subtest, WISC-V-NL.

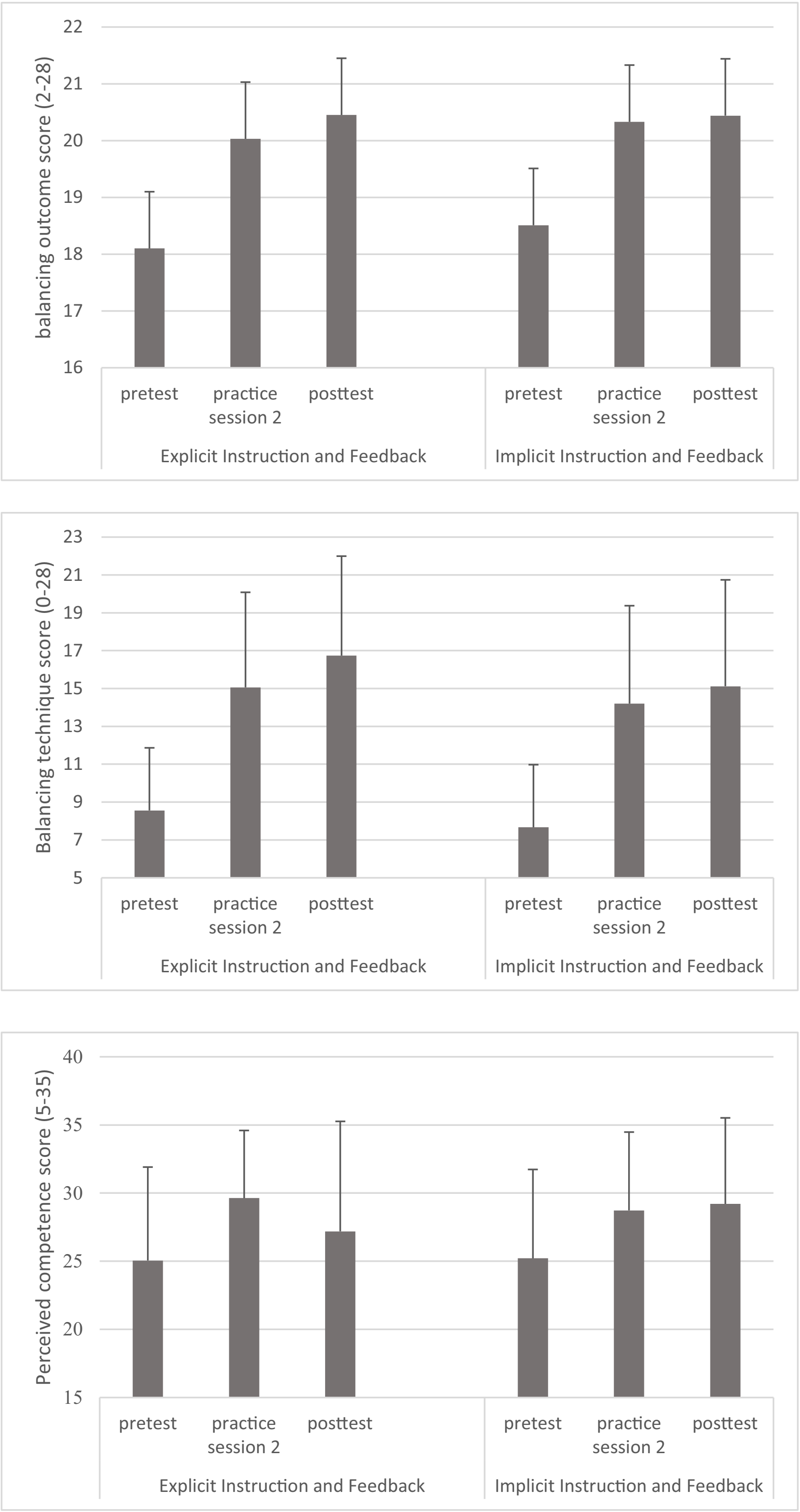

Fig. 4. Balancing outcome, balancing technique, and perceived competence scores as a function of group and test.

Table 4

Hierarchical regression models with improvements in balancing outcome (model 1), balancing technique (model 2), and perceived competence (model 3) as dependent variables. Bold values denote statistical significance at the $p < 0.05$ level.

Model 1						
Dependent variable	Balancing outcome (improvements from pre- to posttest)					
	B	β	[95% CI]	p	R^2	ΔR^2
Step 1					0.005 (p = .523)	
Constant	2.447					
Group (EIF vs. IIF)	−0.517	−0.072	[−2.122, 1.088]	.523		
Step 2					0.056 (p = .216)	0.051 (p = .133)
Constant	−0.419					
Group (EIF vs. IIF)	−0.571	−0.079	[−2.159, 1.017]	.476		
Verbal WMC	−0.055	−0.047	[−0.340, 0.229]	.700		
Visuospatial WMC	0.146	0.241	[−0.002, 0.293]	.053		
Step 3					0.187 **(p = .007)**	0.132 **(p = .004)**
Constant	3.465					
Group (EIF vs. IIF)	4.987	1.734	[2.525, 22.393]	**.015**		
Verbal WMC	0.190	0.353	[0.033, 0.789]	**.034**		
Visuospatial WMC	0.100	0.074	[−0.154, 0.243]	.656		
Verbal WMC by Group	0.269	−2.549	[−1.470, −0.400]	**.001**		
Visuospatial WMC by Group	0.139	0.730	[−0.094, 0.461]	.191		

Model 2						
Dependent variable	Balancing technique (improvements from pre- to posttest)					
	B	β	[95% CI]	p	R^2	ΔR^2
Step 1					0.058 (p = .097)	
Constant	29.704					
Group (EIF vs. IIF)	−0.284	1.091	[−2.456, 1.887]	.795		
Age	−1.842	0.891	[−3.617, −0.067]	**.042**		
Step 2					0.097 (p = .098)	0.038 (p = .205)
Constant	26.278		[4.526, 48.031]			
Group (EIF vs. IIF)	−0.163	1.084	[−2.323, 1.997]	.881		
Age	−1.812	0.885	[−3.575, −0.050]	**.044**		
Verbal WMC	0.325	0.189	[−0.052, 0.702]	.090		
Visuospatial WMC	−0.120	0.098	[−0.315, 0.076]	.226		
Step 3					0.098 (p = .249)	0.002 (p = .937)
Constant	26.544					
Group (EIF vs. IIF)	−0.932	−0.096	[−15.138, 13.274]	.896		
Age	−1.802	−0.228	[−3.596, −0.009]	**.049**		
Verbal WMC	0.263	0.168	[−0.277, 0.804]	.335		
Visuospatial WMC	−0.090	−0.110	[−0.374, 0.195]	.532		
Verbal WMC by Group	0.121	0.245	[−0.644, 0.886]	.753		
Visuospatial WMC by Group	−0.058	−0.171	[−0.455, 0.340]	.773		

Model 3						
Dependent variable	Perceived competence (improvements from pre- to posttest)					
	B	β	[95% CI]	p	R^2	ΔR^2
Step 1					0.015 (p = .274)	
Constant	2.378					
Group (EIF vs. IIF)	1.622	0.124	[−1.309, 4.552]	.274		
Step 2					0.049 (p = .276)	0.034 (p = .263)
Constant	−5.125					
Group (EIF vs. IIF)	1.770	0.135	[−1.156, 4.696]	.232		
Verbal WMC	0.398	0.188	[−0.123, 0.918]	.133		
Visuospatial WMC	−0.009	−0.008	[−0.279, 0.261]	.948		
Step 3						
Constant	−16.652				0.161 (**p = .022**)	0.111 (**p = .010**)
Group (EIF vs. IIF)	25.342	1.934	[6.823, 43.862]	**.008**		
Verbal WMC	1.166	0.552	[0.463, 1.870]	**.001**		
Visuospatial WMC	−0.136	−0.124	[−0.505, 0.233]	.464		
Verbal WMC by Group	−1.542	−2.307	[−2.535, −0.549]	**.003**		
Visuospatial WMC by Group	0.228	0.496	[−0.287, 0.742]	.381		

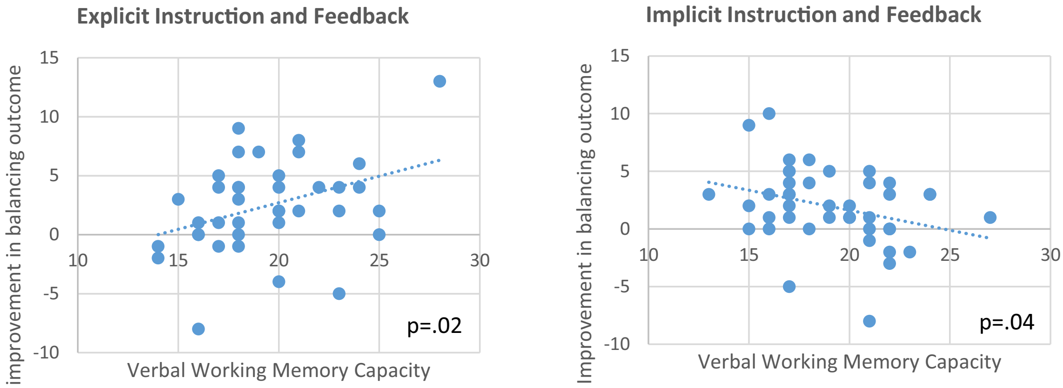

Fig. 5. Relation between verbal WMC score and improvements in balancing outcome from pre- to posttest for the EIF- and IIF-groups.

technique from pre- to posttest, $r = -0.24$, $p < .05$, it was decided to include age as covariate in analyses with balancing technique as dependent variable.

3.3. *Effects of instruction and feedback methods on motor learning and perceived competence*

Fig. 4 shows the scores of the EIF- and IIF-groups on balancing outcome, -technique, and perceived competence at pretest, practice session 2 and posttest. The RM-ANOVA revealed a significant main effect for test for balancing outcome, $F(1,72) = 26.0$, $p < .01$, $\eta_p^2 = 0.27$. Bonferroni-corrected post hoc paired-sampled *t*-tests indicated that balancing outcome scores were higher in practice session 2 and posttest than in the pretest, $t(74) = 4.04$, adjusted $p < .01$;$t(80) = 5.42$, adjusted $p < .01$, but balancing outcome scores between practice session 2 and posttest did not differ, $t(73) = 0.75$, adjusted $p = 1.36$. No significant effects for group, $F(1,72) = 0.003$, $p = .95$, $\eta_p^2 < 0.001$, and group x test were found, $F(1,72) = 0.10$, $p = .75$, $\eta_p^2 = 0.001$.

For balancing technique, the RM-ANCOVA with age as covariate failed to reach significance for test, $F(2,142) = 2.43$, $p = .09$, $\eta_p^2 = 0.03$. Furthermore, no significant differences were found for group, $F(1,71) = 1.68$, $p = .20$, $\eta_p^2 = 0.02$, or group x test, $F(2,142) = 0.20$, $p = .82$, $\eta_p^2 = 0.003$.

A non-parametric Friedman test revealed significant differences between pretest-, practice session 2-, and posttest for perceived competence score, $\chi^2(2) = 23.61$, $p < .01$. Post hoc analyses with Wilcoxon Signed rank tests indicated that perceived competence scores were higher in practice session 2 and posttest than in the pretest, $Z = 4.79$, adjusted $p < .01$; $Z = 4.22$, adjusted $p < .01$, but perceived competence scores between practice session 2 and posttest did not differ, $Z = 0.95$, adjusted $p = 1.00$. Furthermore, two separate Mann-Whitney *U* tests showed that the experimental groups did not differ on perceived competence at practice session 2, $U = 634$, $p = .48$, and posttest, $U = 886$, $p = .38$.

3.4. *Relationships with verbal and visuospatial WMC*

Table 4 summarizes the results of the three separate hierarchical regression analyses that were used to assess the influence of verbal and visuospatial WMC scores on improvements in balancing outcome, -technique and perceived competence.

Improvements in balancing outcome were not predicted by experimental group, verbal or visuospatial WMC (Table 4, Model 1). Inclusion of these variables did not lead to a significant prediction model. However, addition of the interaction terms (i.e., verbal WMC by group and visuospatial WMC by group) in step 3 did lead to a significant prediction model, $F(2,75) = 3.46$, $p = .007$ ($R^2 = 0.187$), due to a significant increase in model fit ($\Delta R^2 = 0.132$, $p = .004$). This seemed predominantly due to a significant interaction between verbal WMC and group ($B = 0.269$, $p = .001$), as the visuospatial by group interaction term was not significant ($p = .191$). When split by group, verbal WMC was positively related with increases in balancing outcome in the EIF-group, ($B = 0.45$, 95%CI [0.07, 0.83], $p = .02$). In contrast, a negative relationship between verbal WMC and balancing outcome improvements existed in the II-group ($B = -0.35$, 95%CI [−0.68, −0.02], $p = .04$), see Fig. 5.

Improvements in balancing technique were not predicted by experimental group, verbal WMC, visuospatial WMC or the interaction terms between verbal or visuospatial WMC and group. Inclusion of these variables did not lead to a significant prediction model (Table 4, Model 2). Age emerged as a significant predictor of differences in balancing technique between pre- and posttest. Thus, the older the students, the less progress they made from pre- to posttest on balancing technique.

Finally, the model with change in perceived competence from pre- to posttest as dependent variable (Table 4, Model 3) showed similarities with the balancing outcome model (Table 4, Model 1). Again, experimental group, verbal WMC, and visuospatial WMC separately did not predict changes in perceived competence; the overall model was not significant when these variables were included. Yet, similar to balancing outcome (Table 4, Model 1), adding the working memory by group interaction terms in step 3 led to a significant prediction model, $F(2,74) = 2.830$, $p = .022$ ($R^2 = 0.161$), and a significant increase in model fit ($\Delta R^2 = 0.111$, $p = .010$). Again, the verbal WMC by group interaction term was statistically significant ($B = -1.542$, $p = .003$), while the visuospatial by group interaction term was not ($p = .381$). When split by group, verbal WMC was significantly and positively related to changes in perceived competence in the EIF-group ($B = 1.05$, 95%CI [0.33, 1.77], $p = .005$), but not in the IIF-group ($B = -0.305$, 95%CI [−0.87, 0.26], $p = .28$), see Fig. 6.

4. Discussion

4.1. *Discussion of main findings*

The study aim was to assess whether the instruction and feedback methods provided during practice were related to improvements in students‘ motor performance (balancing outcome and –technique) and perceived competence, and whether learning improvements were influenced by students' verbal- and visuospatial WMCs. To ascertain representative design, the study was conducted as part of actual PE lessons.

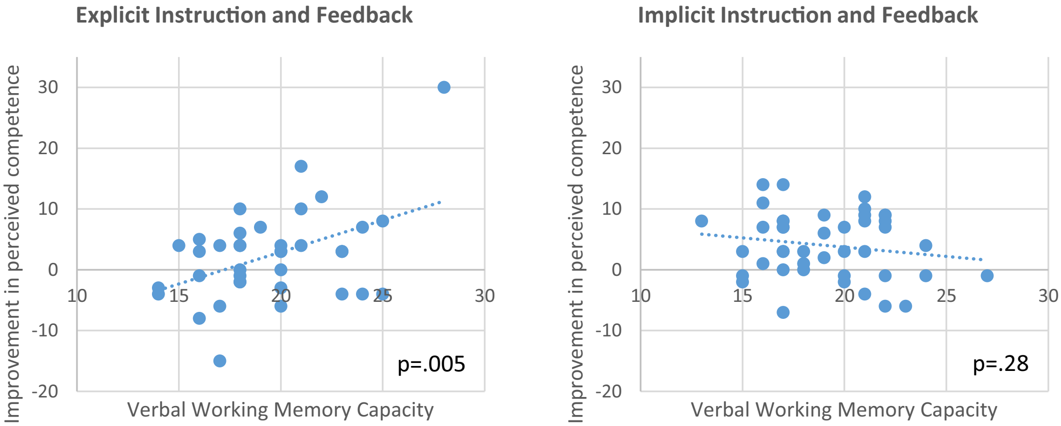

Fig. 6. Relation between verbal WMC score and improvements in perceived competence from pre- to posttest for the EIF- and IIF-groups.

Overall, the students improved their balancing skills through practicing with the instructions and feedback, as shown by significant increases in balancing outcome from pre- to posttest and a concomitant increase in students' perceived competence. The explicit and implicit instruction and feedback methods groups showed similar improvements overall. However, verbal WMC was found to influence the effect of instruction and feedback methods on learning outcomes. For the explicit methods group, greater verbal WMC was associated with greater improvements in balancing outcome and perceived competence. For the implicit methods group, verbal WMC was negatively associated with improvements in balancing outcome only. Finally, visuospatial WMC was not related to any of the learning outcomes in the two groups.

A pertinent finding of the present study was that verbal WMC positively predicted improvements in balancing outcome and perceived competence of students who received explicit methods of instructions and feedback. This finding is consistent with the study of Buszard et al. (2017) and provides evidence that learning with multiple internal focus instructions taxes verbal WMC. In the present study, students received 2–4 instructions prior to practice and one feedback point after each trial. Furthermore, the students could hear the instructions and feedback delivered to the peers in their practice group. Therefore, in the current study, students' verbal WMC may have been loaded more than participants' verbal WMC in previous studies (Brocken et al., 2016; Krajenbrink et al., 2018; Van Abswoude et al., 2018) in which children practiced individually and a maximum of 1–3 instructions were provided intermittently (i.e. every 5–20 trials). Furthermore, previous studies included children with typical development instead of students in special education. Accordingly, the scaled verbal WMC scores of the students in the current study show that they have low verbal WMCs relative to a normative Dutch sample. Therefore, besides the absolute strain, the relative strain on verbal WMC may have been high in the explicit instruction and feedback methods group of the current study. This could explain why in our study verbal WMC could act as a rate limiter for balance skill improvement in the explicit learning methods group, whereas this was not always found in these earlier studies.

We had not anticipated that verbal WMC was negatively associated with increases in balancing outcome in the implicit instruction and feedback methods group. In some students, most likely in those with ASD, the analogies may not have promoted motor execution due to comprehension problems. Children with ASD are known to have deficits in metaphor comprehension compared to children with typical development (Kalandadze et al., 2018). Accordingly, video stimulated interviews with 23 randomly selected participants of the current study about their perceptions of the delivered instructions and feedback showed that students reported difficulties with understanding the analogies and tended to take them literately (Van den Brink, 2019). Contrarily, most students said they understood the internal or external focus instructions and feedback. Possibly, the analogies did not provide all students with clear and meaningful visual images and/or a transparent link to balancing movements, which may have led to a reduction of visuospatial working memory engagement. Moreover, relatively high verbal WMC may have permitted students to ruminate on the (perhaps poorly understood) analogies during practice, which may have distracted attention away from the task and hindered motor learning. This premise is in line with evidence that children with greater verbal WMC are more likely to consciously control movements and ruminate about movement style (Buszard et al., 2013). This also seems to fit with the study of Tse and Van Ginneken (2017), who found that 10 year-old children with a high propensity for conscious control performed best in a transfer and delayed retention test when they had been guided with internal focus instructions (instead of external focus instructions) during practicing darts. Overall, our findings suggest that explicit – instead of implicit – instructions and feedback methods seem to be more helpful for students with high verbal WMC.

We expected that implicit instructions and feedback methods, especially analogies, would load visuospatial WMC. However, we did not find supporting evidence for this hypothesis. Our findings may indicate that practicing slacklining with implicit instructions and feedback did not load students' visuospatial memory resources sufficiently for it to become a rate limiting factor. Implicit instructions and feedback may have put little load on the visuospatial WMC, because retaining and manipulating the instructions and feedback may have not (fully) relied on visuospatial WMC. Another possibility is that the strain of implicit instructions and feedback on visuospatial working memory was limited due to the nature of the information. Hence, a meaningful analogy has been considered as a single information rich chunk, rather than separate bits of information that load working memory (Masters & Liao, 2003). Furthermore, in the present sample, WMC appeared to be greater for visuospatial WMC than for verbal WMC, as evidenced by significant differences between the scaled visuospatial and verbal working memory scores within participants ($p < .01$). This may have further contributed to a smaller relative strain on visuospatial working memory. Finally, another explanation for the absence of effects of visuospatial WMC concerns the used test for measuring visuospatial WMC. The study that did find a significant interaction between implicit (i.e. external focus) instructions and visuospatial WMC (Van Cappellen-van Maldegem et al., 2018) used the spatial recall subtest of the Automated Working Memory Assessment (AWMA, Alloway, 2007). Possibly, the applied Picture Span subtest (WISC-V) in the current study is a more indirect test of the spatial component of visuospatial WMC compared to the applied spatial recall test in Van Cappellen-van Maldegem et al. (2018). This seems predominantly relevant for external focus instructions and feedback since they emphasize the spatial relation of a learner's movement to the environment.

We showed that PE teachers can influence students' perceived competence, either through manipulating the pedagogical climate, or by tailoring instruction and feedback methods to the verbal WMC of the student. We assume that in the current study, the perceived competence scores predominantly followed the balancing outcome scores, as the experimental task afforded students a clear external referent of success (i.e. distance covered, number of touched rounders posts) and significant associations between balancing outcome and perceived competence scores were present on the pretest, $r = 0.43$, $p < .01$ and posttest, $r = 0.42$, $p < .01$. This is in line with the general notion that children's cognitive abilities to accurately assess their competence become established from 6 to 9 years of age (e.g. Robinson et al., 2015).

4.2. Strengths and limitations

The present study was an experimental field study in which the study design resulted from a process of co-creation between researchers and PE teachers. The involved PE teachers found it important, for example, to include all students of their classes in the experiment and going beyond disorder categories or labels (i.e. no focus on specific learning or behavioral deficits). This standpoint was based on their educational practice, in which they educate a diversity of students. Also, specific labels seem to suggest similarities or differences between students that may be of minor importance for motor learning or PE. Indeed, the findings of the current study suggest that the differentiation among students with special needs does not necessarily need to be based on their specific behavioral deficits. Another practical issue concerned that if teachers deliberately apply implicit motor learning methods in their lessons, the choice for the precise implicit learning method (e.g. analogy learning, learning with external focus, errorless learning) will often be a pragmatic one, with PE teachers more likely applying a blend of implicit learning methods. This is in line with Poolton and Zachry (2007) who state that analogies and external focus condition can easily be implemented together in practice. Accordingly, we chose to combine analogies and external focus instructions and feedback methods in the implicit condition in a task with errorless learning characteristics. Integrating the study in the context of PE allowed less tight experimental control. Even so, we still found significant relationships between verbal WMC and learning outcomes. The highly representative design of the study enhances the generalizability of these findings towards educational practice. In contrast to balance outcome, balancing technique did not improve with practice, and did not to show any relationship with working memory capacity. Although it was developed and scored based on expert judgment, and found to be reliable, the scoring method used may not have been sensitive enough to capture the variety of ways through which children could have improved their balancing outcomes (cf. Lee et al., 2014).

The study design also has some limitations. Our data did not permit discrimination between the specific effects of analogies and external focus instructions, nor between the effects on students with different learning or behavioral problems, such as ASD. This complicated the interpretation of the unexpected negative relationship between verbal WMC and implicit learning gains, for example. Also, we did not systematically validate the understanding and use of the involved instructions and feedback methods (cf. Van den Brink, 2019) or include manipulation checks such as a transfer test with a secondary task to assess if the purported learning processes were indeed induced. Therefore, the findings of this study exhibit the effects of explicit and implicit verbal guiding *methods* and their relation with WMCs, we did not examine whether these methods actually led to (more) explicit or (more) implicit *learning*. However, there is reason to believe that this was the case as the applied verbal guiding methods are associated to either implicit or explicit learning (see Kal et al., 2013; Lam et al., 2009; Liao & Masters, 2001). Furthermore, our results indicate a relatively greater reliance on verbal WMC for the EIF-group, which is most readily explained by learning having been relatively more explicit for this group than for the IIF-group.

4.3. Implications for future studies

Future studies on the relationship between WMC and outcomes of instruction and feedback methods should involve a variety of PE settings including different tasks and student populations. Furthermore, it would be worthwhile to validate the understanding, use and effects of the involved instructions and feedback a priori. Besides including the teachers input for designing the intervention (as was done in the present study), it would also be interesting to involve students' perceptions towards the applied instructions and feedback methods. Some studies (Jie et al., 2018; Poolton et al., 2007) already incorporated representatives of the study population to select appropriate analogies, for example. Also, studies that included stroke patients (Jie et al., 2018; Kleynen, Wilson, et al., 2014) adopted interventions during which appropriate analogies were chosen and adapted in cooperation with each participating patient, to ensure the analogies were meaningful and led to appropriate movement execution. Furthermore, it seems attractive to study the application of differentiated verbal guidance in which instruction and/or feedback delivery (e.g. timing and amount of feedback) is self-controlled by the students, since self-controlled feedback has been shown to increase motor learning (Chiviacowsky et al., 2008; Ste-Marie et al., 2013) and motivational beliefs (Kok et al., 2020; Ste-Marie et al., 2013) in children.

Verbal WMC influenced the effects of explicit and implicit instructions and feedback methods. Although this effect was statistically significant, the effect size was relatively small (i.e. the maximal amount of additional explained variance of the verbal WMC x group interaction was 11–13%). Therefore, next to verbal WMC, other individual characteristics may be relevant for applying effective within-classroom differentiation of learning methods. Individual characteristics such as individual preferences (Tse & Van Ginneken, 2017; Van Abswoude et al., 2018) or the executive attention component of working memory (Buszard et al., 2017) may also play a role in explaining explicit or implicit learning effects and deserve further study.

For PE teachers to successfully adapt verbal guidance to the verbal WMCs of their students, teachers need to be aware of how instruction and feedback methods induce different types of learning. Furthermore, they should gauge the verbal WMC of their students. Additional research is needed to assess whether PE teachers can adequately evaluate students' verbal WMC based on observation, or whether effective and time efficient practical tools or measures such as BRIEF (Gioia et al., 2000) or the working memory rating scale (Alloway et al., 2009) could be used or developed further for this purpose.

4.4. Final conclusion

The present study provides relevant information for PE teachers who want to make a deliberate choice (i.e. apply evidence based within classroom differentiation) on the precise formulation of instructions and feedback. Results of the current study imply that one factor that may influence this choice could be students' (individual) verbal WMC; doing so can result in increased motor learning and higher levels of perceived competence. Motor- and perceived competence are both important objectives in PE, and are considered as prerequisites for a positive spiral of students' engagement in physical activity (e.g. Stodden et al., 2008). PE teachers (in special education) could align their motor learning methods with verbal WMC by providing meaningful analogies and external focus instructions and feedback to students with a relatively low verbal WMC and internal focus instructions and feedback in students with a relatively high verbal WMC. Future studies should demonstrate whether the observed findings are representative for PE settings with different tasks and student populations, and further explore the role of visuospatial WMC and the relevance of other individual characteristics.

Acknowledgements

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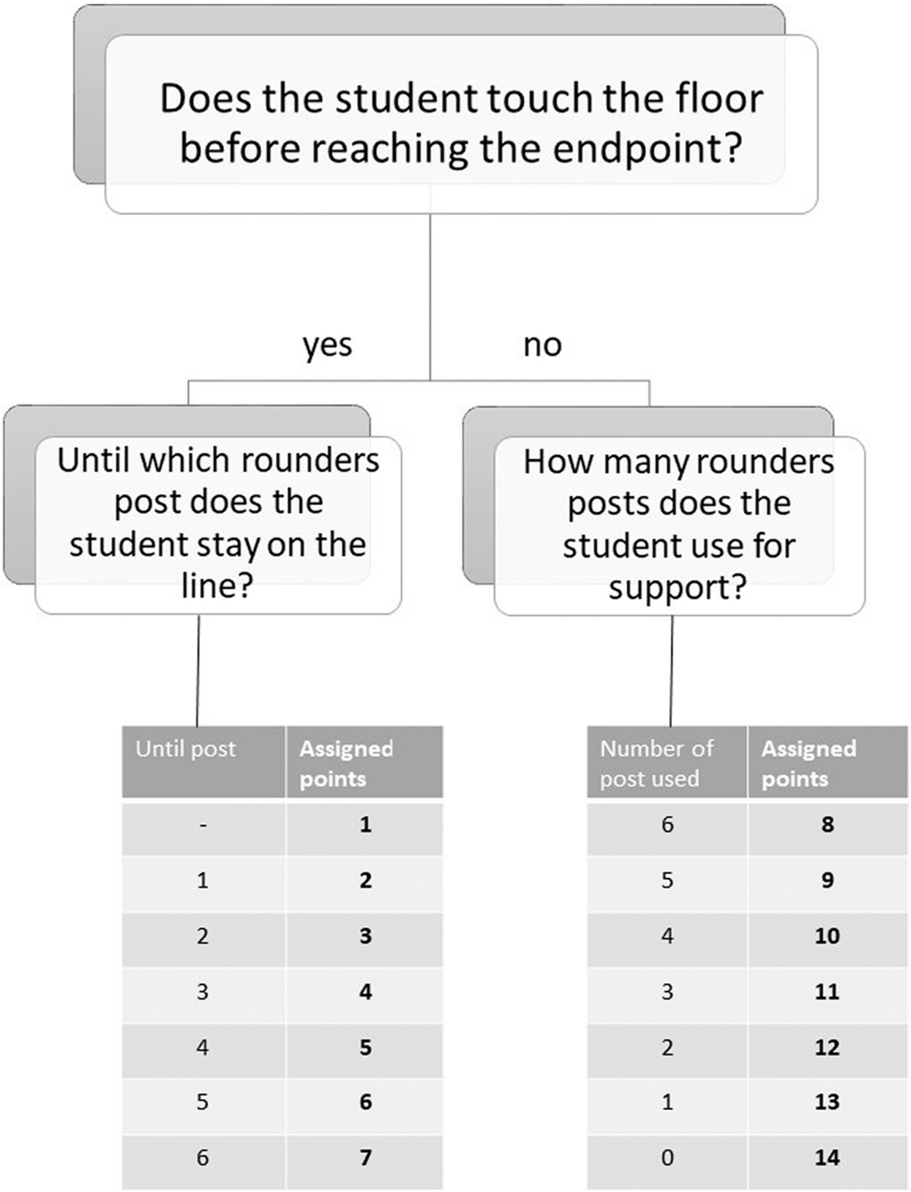
Appendix A. Scoring system balancing outcome


Does the student touch the floor before reaching the endpoint?

Until which rounders post does the student stay on the line?

Until post	Assigned points
-	**1**
1	**2**
2	**3**
3	**4**
4	**5**
5	**6**
6	**7**

How many rounders posts does the student use for support?

Number of post used	Assigned points
6	**8**
5	**9**
4	**10**
3	**11**
2	**12**
1	**13**
0	**14**

Appendix B. Rating scale balancing technique

Criterion 1	**Gaze direction (observed in frontal plane)**
0 points	Gaze is predominantly directed towards the feet/in downward direction/on the teacher/on practice surroundings
1 point	Gaze is intermittently directed towards the end of the slackline/red circle
2 points	Gaze is predominantly directed towards the end of the slackline/the red circle
Criterion 2	**Usage of arms for maintaining and regaining balance (observed in frontal plane)**
0 points	Arms are not or barely used for maintaining and regaining balance (with exception of grabbing the rounders posts)
1 point	Arms are intermittently used for maintaining and regaining balance
2 points	Arm are actively used for maintaining and regaining balance
Criterion 3	**Position of the hands (observed in frontal plane)**
0 points	Arms and hands are positioned along the body and move towards the rounders posts and back
1 point	Hands are predominantly positioned below shoulder height (but not along the body)
2 points	Hands are predominantly positioned above shoulder height
Criterion 4	**Foot placement (observed in frontal plane)**
0 points	Feet are extremely (approximately 45 degrees or more) pointing in- or outward, this also includes walking sideways
1 point	Feet are slightly (approximately between 10 and 45 degrees) pointing in- or outward
2 points	Feet are predominantly placed straight on the line (approximately between 0 and 10 degrees)
Criterion 5	**Knee angle (observed in sagittal plane)**
0 points	Knees are (almost) in straightened position
1 point	Knees are intermittently bent slightly
2 points	Knees are predominantly bent slightly
Criterion 6	**Upper body position (observed in sagittal plane)**
0 points	The upper body is extremely bent forward
1 point	The upper body is slightly bent forward
2 points	The upper body is in erect position
Criterion 7	**Walking manner (observed in sagittal plane)**
0 points	The student walks fast along the line, without seeking for balance and/or the student shuffles along the line with one foot maintaining front position and/or the student walks while holding two rounders posts simultaneously
1 point	The student walks calmly along the line, but starts to walk fast or quickly grabs a rounders post when balance is disrupted
2 points	The student balances calmly along the line with control, and tries to regain balance when necessary by calmly grabbing a rounders post or by moving the arms in a controlled fashion

Appendix C. Applied IMI subscale perceived competence in Dutch (and English)

Hieronder staan 5 uitspraken. Kruis voor elke uitspraak aan in hoeverre je het eens bent. *(Below are 5 statements. Please indicate per statement how true it is for you.)*

	1	2	3	4	5	6	7
	Helemaal niet eens *(Not at all true)*		Niet eens of oneens *(Somewhat true)*				Helemaal mee eens *(Very true)*
1. Ik denk dat ik best wel goed ben in slacklinen. *(I think I am pretty good at slacklining.)*	☐	☐	☐	☐	☐	☐	☐
2. Ik denk dat ik het slacklinen best wel goed deed vergeleken met andere leerlingen. *(I think I did pretty well at slacklining, compared to other students.)*	☐	☐	☐	☐	☐	☐	☐
3. Ik ben tevreden met hoe goed ik het slacklinen deed. *(I am satisfied with my slackline performance.)*	☐	☐	☐	☐	☐	☐	☐
4. Ik was best wel goed in slacklinen. *(I was pretty skilled at slacklining.)*	☐	☐	☐	☐	☐	☐	☐
5. Toen ik het slacklinen even had geoefend, voelde ik me er best wel goed in. *(After working at slacklining for a while, I felt pretty competent.)*	☐	☐	☐	☐	☐	☐	☐

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