



Ready for handwriting?

*Development of the Writing Readiness
Inventory Tool In Context (WRITIC) for
kindergarten children in the prewriting phase*

Margo van Hartingsveldt

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Development of the Writing Readiness Inventory Tool In Context (WRITIC)
for kindergarten children in the prewriting phase

Margo J. van Hartingsveldt

The studies presented in this thesis have been performed at the department of Rehabilitation and the Scientific Institute for Quality of Healthcare (IQ healthcare). These are part of the Radboud Institute Health Science (RIHS), one of the approved research institutes of the Radboud university medical center.

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Radboud Universiteit Nijmegen

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Development of the Writing Readiness Inventory Tool In Context (WRITIC)
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Publications in current thesis

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Chapter 1

General Introduction



Handwriting has given rise to a number of cultural practices, such as letter writing, and cultural forms such as diaries and Post-it notes. Moreover, handwriting is also an aesthetic category that we still uniquely associate with a manual craft: from calligraphy to urban graffiti, from tattooing to signing, the physical, the human hand is pivotal in the production of letters and texts. Handwriting emerged from an age-long tradition; the primal writing implement has been the stylus, a tool that started as a wedge to incise in sand, in clay, or in wax. Over time the stylus took on different shapes: as a brush, once turned around, became a quill, then a pencil, a pen, and a ballpoint pen. In all these forms the stylus was led by the hand, and its basic product was a line or a 'trait'.
(van Dijck & Neef, 2006).

1
Eleven 'Steve Jobs schools' will open in August in the Netherlands and at least 1,000 children aged four to 12 will attend these schools, without notebooks, books or backpacks. Each of them, however, will get an iPad, and will have constant access to their iPads, which they can take home, and where time spent on an educational app will count as school time. The children will choose what they wish to learn based on what they happen to be curious about. Arithmetic, reading skills and text comprehension are the core subjects in the elementary school. Good handwriting has been downgraded to a secondary skill, nice for industrious pupils but not truly relevant (15-07-2013).
(Evers, 2013)

Is handwriting still important?

Handwriting is an essential occupation from early childhood through adulthood. The handwriting of a person is very personal, it is a means of expressing language, leaves a permanent trace and it is called the 'Language by Hand' (Berninger, Abbott, et al., 2006). Handwriting is part of the daily live of people; it is used to make a shopping list, to write a birthday card, to take down a phone message, or to complete an assignment. Writing has a long history and it can be done in several manners, for example with a finger in the sand, with a ballpoint pen on a sheet of paper, or with a stylus on a tablet. On the one hand handwriting is a longstanding occupation that children still learn in first grade and that they will use throughout their school careers. Handwriting still remains important in education, employment and in everyday life. On the other hand, the use of computers, tablets and smart phones has dramatically changed the way people communicate through writing and the question now is if it is still necessary to master handwriting.

In addition to handwriting as a way of communication, handwriting is also essential for the learning of reading and spelling (Longcamp et al., 2008). Research shows that there are close functional relationships between reading and writing processes in the brain. Handwriting and reading are learned multimodal. In learning to write and read, the motor program used for writing, as well as the visual form of the letters and the associated kinaesthetic feedback are linked in such a way that a multimodal letter representation is developed in the brain (Longcamp, Anton, Roth, & Velay, 2003; Longcamp, Boucard, Gilhodes, & Velay, 2006). This is confirmed by research of multimodal brain activation, that has shown a grapheme–phoneme connection and has demonstrated an association between a print processing task in kindergarten and reading in second grade (Bach, Richardson, Brandeis, Martin, & Brem, 2013). Thereby, Longcamp et al. (2008) stated that handwriting movements produced during learning, influence the ability to discriminate between characters of letters and the learning of reading. This is in line with research by James and Engelhart (2012) that showed that brain activation during letter perception is influenced by previous handwriting experience. They stated that handwriting is important for the early conscription in letter processing of brain regions known to underlie successful reading and therefore, may facilitate reading achievement in young children (James & Engelhardt, 2012).

The acquisition of handwriting requires that children learn to produce the characteristic shape of each letter (Overvelde, 2013) by using the correct movement pattern. Learning to produce letterforms is part of the higher-order cognitive processes such as spelling words and producing written text. Cognitive skills and fine motor skills are both involved in the complex process of writing acquisition (Richards et al., 2011). If basic skills, such as fine motor handwriting skills, are not fluent, the letter representation in the brains and higher-level cognitive skills in the working memory can be attenuated, which can negatively influence text writing (Peverly, 2006). The proposed mechanism is that sufficient handwriting practice contributes to good orthographic–motor integration and

1 automatisisation of handwriting movements so that cognitive processes are free to focus on ideas and the knowledge of the subject of the written products (Berninger, Rutberg, et al., 2006; van Galen, 1991; Wallen, Duff, Goyen, & Froude, 2013).

Handwriting has added value compared to keyboard writing. Recent research with 300 primary school children from first to sixth grade shows that handwriting speed of children is consistently faster than keyboarding speed across all ages. Only a small minority of children age 5 and 6 have faster keyboarding than handwriting speed. This research showed that children's compositional quality of written text is superior in the handwritten scripts as opposed to the keyboarded scripts. The quality of the content and text structure from the keyboarded scripts were up to two years behind in development compared to the handwritten scripts (Connelly, Gee, & Walsh, 2007). This was confirmed by research by Berninger and colleagues (2009); they determined that children wrote longer essays with faster word production rate by pen than by keyboard. In their research, children in the fourth and sixth grade wrote more complete sentences when writing by pen than when writing by keyboard, moreover this relative benefit for sentence composing in text was not affected by spelling ability (Berninger, Abbott, Augsburger, & Garcia, 2009).

Taken together, it seems that handwriting is still an important occupation for children to learn during the first years of school and is essential for the child's participation in the regular classroom environment (Rosenblum, 2008). Handwriting remains a crucial part of elementary school curricula and is, for the time being, the primary way in which elementary school students demonstrate their knowledge in all academic areas. Handwriting is required when children complete class assignments, compose stories, complete written examinations, copy numbers for calculations, and write personal notes and messages (Schneck & Amundson, 2010).

During the school period, children are increasingly busy with writing. In kindergarten, children are engaged in paper and pencil tasks 20% of the day (Marr, Cermak, Cohn, & Henderson, 2003). Starting from the second grade, 30% to 60% of the school day is devoted to fine motor activities, with writing as the predominant occupation (McHale & Cermak, 1992).

Handwriting difficulties

Learning to master the complex skill of handwriting is not easy for all children: the prevalence of handwriting problems has been estimated to range between 5% and 30% depending on grade, selection criteria and assessment instruments used (Feder & Majnemer, 2007; S. Graham & Harris, 2005; Karlsdottir & Stefansson, 2003; Maeland, 1992; Overvelde et al., 2011; Smits-Engelsman, Niemeijer, & van Galen, 2001). Handwriting difficulty or dysgraphia, is defined as a disturbance or difficulty in the pro-

duction of written language related to the dynamics of handwriting (Hamstra-Bletz & Blote, 1993). Handwriting difficulties are related to poor writing legibility, low speed and complaints, such as experiencing pain, strain or discomfort while writing which can also evoke handwriting difficulty (Overvelde et al., 2011). Children with handwriting difficulties experience challenges in keeping up with the volume of written work required, which may impede academic progress (Feder & Majnemer, 2007). When students do not need to think about their handwriting, they can focus their cognitive resources on their ideas and knowledge of the subject (Berninger, Rutberg, et al., 2006). Repeated failures will likely lower the child's motivation resulting in a vicious circle. Moreover, handwriting difficulty is the most common reason to refer schoolage children to paediatric occupational therapy services (Marr & Cermak, 2003; Schneck & Amundson, 2010).

Development of handwriting

The close functional relationship between reading and writing can also be seen in the work of Berninger and colleagues (2006). They illustrate that multimodal language behaviour actually draws on four functional systems: a) language by ear (listening to aural language input); b) language by mouth (producing oral language output); c) language by eye (reading written language output); and d) language by hand (producing written language output) (Berninger, Abbott, Abbott, Graham, & Richards, 2002; Berninger, Abbott, et al., 2006). Each of these language systems is, on its own, a developmental trajectory, has its own internal organisation, interacts with the other language systems to some degree at different stages of development (Berninger, 2000) and results in a multimodal language system (Longcamp et al., 2008; Longcamp et al., 2006). Berninger, Abbott, et al. (2006) describes handwriting development in four stages in which the complexity of the motor tasks increases and is coupled to letterforms, see figure 1.1.

The first two stages depicted in Figure 1.1 cover tasks typically practiced by infants and toddlers, the third stage covers tasks typically practiced and often mastered during the kindergarten year and the fourth stage covers tasks typically mastered by the middle of the end of first grade.¹ The first two grades rely prominently on perceptual and motor skills and the integration of these skills. The last two stages rely on coordinating language (names of letters) with the act of writing alphabet letterforms. Early elementary school handwriting is an integration of orthographic codes (letterforms), phonological codes (names), and grapho-motor codes (output). It is language by hand (Berninger, 2000).

¹ Anglo-American first grade stands for the third group in the Netherlands; Anglo-American kindergarten stands for the second group in the Netherlands.

- 1
- Infant discovers that crayon leaves a mark on external world.
 - Infant explores use of crayon through scribbling.



- Toddler learns to imitate others using a crayon to make isolated strokes in horizontal and vertical directions.
- Toddler learns to imitate diagonal lines and circles using crayon.
- Toddler learns to imitate simple shapes made from straight lines and circular strokes using crayons.



- Kindergarten child learns to name alphabet letters.
- Kindergarten child learns motor control to use a pencil by connecting dots in drawings, staying in the line in mazes, and by tracing over alphabet forms.
- Kindergarten child learns to imitate adults in making alphabet letterforms.



- First grader learns to copy uppercase and lowercase alphabet letterforms accurately.
- First grader can name all the uppercase and lowercase alphabet letters when presented in random order.
- First grader writes dictated letters in both cases accurately from memory.
- First grader writes all lower case letters in alphabet accurately and automatically in correct order from memory.

Figure 1. Handwriting development – language by hand (Berninger, Abbott, et al., 2006).

Relationship between cognitive and motor skills in handwriting

Handwriting is a complex skill to master, it involves linguistic, cognitive and perceptual-motor components, all of which have to be coordinated into an integrated fashion. The literature describes two models concerning the relationship between cognitive and motor processes involved in the skill of handwriting. The process model by van Galen and Smits-Engelsman (Smits-Engelsman & van Galen, 1997; van Galen, 1991) is developed from a cognitive psychology perspective and the model by Berninger (Abbott & Berninger, 1993; Berninger et al., 1992) is developed from an educational perspective. Both models describe the relationship between the cognitive, linguistic and motor aspects of writing (Overvelde, Smits-Engelsman, & Nijhuis-Van der Sanden, 2013). The process model by van Galen and Smits-Engelsman emphasises the coherence between cognitive and motor processes during the performance of handwriting. In this model, it becomes clear that higher-order cognitive processes, such as intentions, semantic structures and syntactical processes need to be processed before writing comes into focus (see Figure 1.2). The architecture of this model is hierarchical in the sense that output from each stage forms input for the lower stage. This does not mean that parallel

processing does not exist; information is processed in different stages at the same time, and these processes influence each other.

Cognitive level	
Intentional level	I want to write something
Linguistic level	Semantic structures determine the order in the sentence and the plural forms
Lexical level	The dictionary of the memory
Auditive and visual synthesis	The synthesis of letters and sounds in words and vice versa
Phoneme-grapheme level	The transition of a sound in an allograph
Motor level	
Motor Programming	Activation of an general sequence of drawing strokes, irrespective of their size and irrespective of the musculature which will be used in their realisation
Parameterisation	The processing step by which the overall force level, tempo, and size of the task performance is regulated
Muscular intention	The process of neurological recruitment and muscular initiation of the motor units that are appropriate for a task in a given biomechanical context

Figure 2. Process model of van Galen and Smits-Engelsman (Smits-Engelsman & van Galen, 1997; van Galen, 1991).

The model of Berninger emphasises the cognitive and linguistic aspects of handwriting and describes fine motor skills as an important performance component of handwriting. This model displays that in learning ‘text writing’ two main processes are involved: the perceptual-motor process ‘handwriting,’ and the cognitive processes of ‘spelling’ and ‘composition’ (Abbott & Berninger, 1993; Berninger & Rutberg, 1992; Overvelde et al., 2013). We choose for this model of Berninger as basis for our conceptual model that we used to identify the factors related to handwriting readiness, whereby we in this thesis emphasis on the perceptual-motor components of handwriting readiness (see Figure 3). This emphasis we have integrated in an occupation-based assessment on handwriting readiness as explained further in this introduction.

Performance components and handwriting

Factors intrinsic to the child may impact on the capacity to develop effective handwriting skills. In the literature these factors are referred to using terms as performance components or perceptual motor components of handwriting (Wallen et al., 2013). In addition

to the performance component, fine motor, described by Berninger as a key component in the early stages of learning to write (Berninger, Abbott, et al., 2006; Berninger, Rutberg, et al., 2006), the literature mentions other performance components important for handwriting development. These components include visual perception, visual-motor integration, kinaesthesia and sensory modalities (Cornhill & Case-Smith, 1996; Denton, Cope, & Moser, 2006; Feder & Majnemer, 2007).

There are several studies that found that children with handwriting problems show a deficit in fine motor coordination (Cornhill & Case-Smith, 1996; Feder & Majnemer, 2007; Maeland, 1992; Smits-Engelsman et al., 2001; Smits-Engelsman & van Galen, 1997). Also visual motor integration is correlated with poor handwriting (Cornhill & Case-Smith, 1996; Maeland, 1992; Pienaar, Barhorst, & Twisk, 2013; Tseng & Cermak, 1993; Tseng & Chow, 2000; Volman, van Schendel, & Jongmans, 2006; Weintraub & Graham, 2000). Volman et al., (2006) presume that there are two different performance components in the development of handwriting in children: fine motor coordination and visual-motor integration. Fine motor coordination is defined as “performing the coordinated actions of handling objects, picking up, manipulating and releasing them using one’s hand, fingers and thumb” (WHO, 2007)(p.155) and visual motor integration is defined as “the degree to which visual perception and finger-hand movements are well coordinated” (Beery, Buktenica, & Beery, 2010)(p.13). Unfortunately, evidence regarding the relationship with handwriting abilities is not available for the performance components visual perception, kinaesthesia and sensory modalities (Feder, Majnemer, Bourbonnais, Blayney, & Morin, 2007).

Handwriting readiness is the stage before handwriting (Marr, Windsor, & Cermak, 2001; Schneck & Amundson, 2010). In Figure 3 we describe the conceptual model, based on the model of Berninger, used to identify the perceptual-motor and cognitive factors relating to handwriting readiness. In this model the reader should note that learning ‘text writing’ is based on different processes: the perceptual-motor process ‘handwriting,’ and the cognitive language processes of ‘spelling’ and ‘composition’ (Abbott & Berninger, 1993). In this study we focus on ‘writing readiness,’ which is composed of ‘orthographic coding,’ ‘visual-motor integration’ and ‘fine motor coordination.’ In the phase in which children learn the perceptual-motor skill of preliminary writing, ‘visual-motor integration’ and ‘fine motor coordination’ are important performance components (Volman et al., 2006). Orthographic coding, defined as ‘holding written words in memory while analysing letter patterns in them’ (Berninger, 2009) is a cognitive language process and therefore falls outside the scope of perceptual-motor focus on writing readiness.

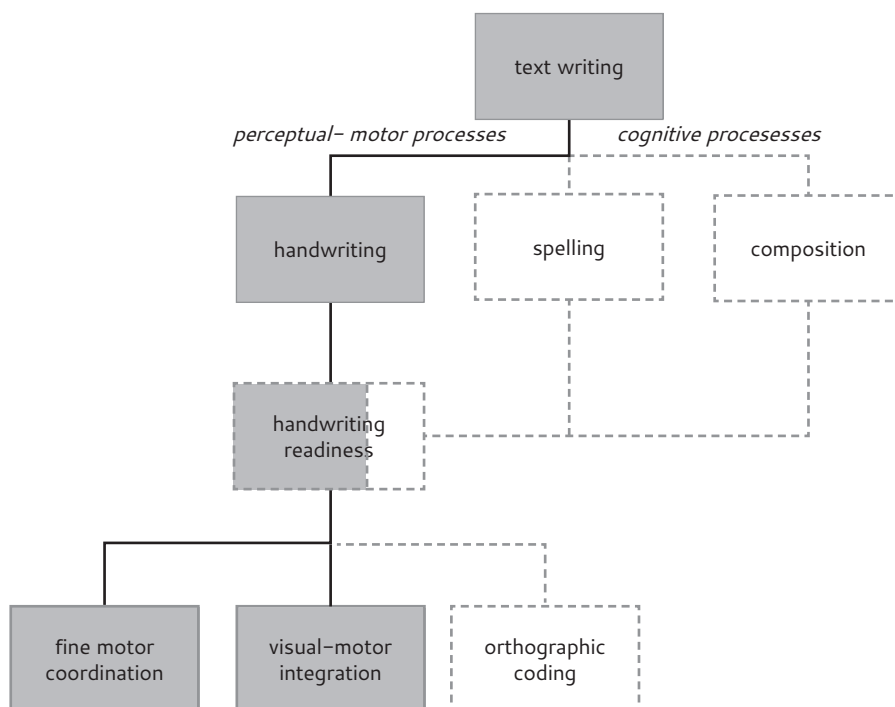


Figure 3. Conceptual model of handwriting readiness and its relationship to handwriting, text writing and performance components, based on the model of Berninger (Abbott & Berninger, 1993; Berninger et al., 1992; Marr et al., 2001; Overvelde et al., 2013; Volman et al., 2006).

Handwriting readiness

So far in this introduction we only have discussed the perceptual-motor and cognitive aspects of handwriting readiness. However Feder and Majnemer (2007) stated in their review on handwriting development that both intrinsic factors, which refer to the child's actual handwriting capabilities, and extrinsic factors, which are related to environmental components are related to the performance of paper-and-pencil tasks. In this thesis handwriting readiness is seen from the perspective of intrinsic factors of the child, extrinsic factors of the environment and the performance of paper-and-pencil tasks.

Handwriting readiness is defined as a developmental stage at which a child has the capacity to profit satisfactorily from the instruction given in the teaching of handwriting (Marr et al., 2001). It is not always clear when children are ready for formal handwriting instruction. Different rates of maturity, environmental experiences, and interest levels are all factors that can influence children's early attempts and success in copying letters.

Some children may exhibit handwriting readiness at 4 years of age, whereas others may not be ready until they are 6 years old (Schneck & Amundson, 2010). Mastering handwriting readiness before handwriting instruction is initiated facilitates the learning process. On the other hand, children who are taught handwriting before they are ready may become discouraged and develop poor writing habits that may be difficult to correct later (Benbow, 2006).

Intrinsic factors in the child

As written above, fine motor coordination is an evidence-based performance component of handwriting. Brushes, crayons, pencils, felt-tip markers, and pens are the primary tools used by children in their graphic endeavours. These tools form an extension of the hand, and their control and manipulation are needed in attaining skilled copying, drawing, and handwriting. A refinement of fine motor control is necessary to allow stability and controlled dynamic finger movement required for skilled handwriting (Ziviani & Wallen, 2006). Visual-motor integration is the other evidence-based performance component of handwriting. The development of visual-motor integration starts with children of two years that can imitate a vertical line, a horizontal line and a circle; a child of three years can copy a vertical line, a horizontal line and a circle; children of three and four years can copy a cross, right oblique line, a square, a left oblique line, and an oblique cross; and children of five and six years can copy a triangle (Beery et al., 2010). The authors of the Beery Developmental Test for Visual-Motor Integration (BeeryTMVMI) (Beery et al., 2010) suggest that instruction in handwriting has to be postponed until the child is able to master the first nine geometric figures of the BeeryTMVMI.

Besides the perceptual-motor and cognitive components, important for handwriting readiness explained in our conceptual model that was based on Berninger's model, there are more factors intrinsic to the child important for the mastery of handwriting, as there are sustained attention and motivation (Wallen et al., 2013).

Sustained attention is needed to enable the child to effectively perform a handwriting task for a prolonged period. Lowered sustained attention can limit practice of handwriting and can for instance lead to poor mastery of letter formation (Feder et al., 2007). Children with Attention Deficit Hyperactivity Disorder (ADHD) without comorbid autism and DCD experience handwriting difficulties that are related to their ADHD severity (Langmaid, Papadopoulos, Johnson, Phillips, & Rinehart, 2012). Also in a study by Schoemaker et al. (2005), decreased accuracy in figure copying was documented in children with ADHD who did not have coordination problems (Schoemaker, Ketelaars, van Zonneveld, Minderaa, & Mulder, 2005).

Mastering motivation is the driving force that provides children with the inspiration to independently act, explore, and attempt to master challenging tasks. It is predictive of both readiness to learn and attainment of tasks necessary for activities of daily living, social communication, and psychological well-being (Miller, Ziviani, Ware, & Boyd,

2014). Motivation is important in the mastery of handwriting, Graham (2012) stated that individual differences in motivation predict handwriting performance, and that motivation shapes handwriting (Steve Graham, Berninger, & Abbott, 2012).

Extrinsic factors

The context is the sum of factors that influences the performance of activities of the child (Polatajko et al., 2007). In the occupational therapy literature the term environment refers to the external physical environment (objects and structures), and social environment (classmates, teacher, interaction and relationships), which surrounds the child and is the environment in which the schoolactivities occur. The term context refers to a variety of interrelated conditions that are within and surrounding the client, such as the cultural context (expectations of other persons) and the temporal context (expectations relating to age and time). These interrelated contexts often are less tangible than physical and social environments but nonetheless exert a strong influence on performance (Dunn, 2005; Roley et al., 2008). In this thesis the terms environment and context are used interchangeable. Thereby we focus on the physical and social environment.

The physical environment, as there is the working station of the child, will influence the performance of paper-and-pencil tasks. Positioning and seated body posture is often the initial issue addressed by occupational therapists in a handwriting assessment. Children are encouraged to sit on a chair with their hips, knees and ankles at 90 degrees, and with their feet fully supported. Thereby they use desks that support the forearms comfortably (Pollock et al., 2009; Schneck & Amundson, 2010). Although such a workstation is believed to provide proximal stability and optimize fine motor control distally, there is only little evidence to support this (Smith-Zuzovsky & Exner, 2004).

The social environment in the classroom relates to personal and immediate aspects of social interaction (Polatajko et al., 2007). This influences the class climate, which can be a quiet or a more chaotic environment and this has also impact on the child performing his activities.

Paper-and-pencil tasks

The kindergarten period is especially focused on the achievement of handwriting readiness. Ergonomics, such as a sufficient pencil grip (Schwellnus et al., 2012, 2013) and sitting position (Pollock et al., 2009; Schneck & Amundson, 2010), are facilitators in the performance of the paper-and-pencil tasks, such as colouring, drawing, making prewriting patterns, writing one's own name and copying letters and numbers. Kindergarten is the most important period in which children learn to stabilise the wrist in an extension position and learn to use a dynamic pencil grasp. Between the ages of 3 and 6, most children develop from a transitional static grasp with wrist movements to a mature dynamic grasp with thumb and finger movements (Edwards, Buckland, & McCoy-Powlen, 2002). Thus, an evaluation of paper-and-pencil tasks in kindergarten evaluates if children can produce the different paper-and-pencil tasks and if they have adopted an adequate body position and pencil grip.

Interactive and occupational perspective of the development of handwriting

An important aspect in the assessment of handwriting readiness is the interactive perspective (Law et al., 1996; Shumway-Cook & Woollacott, 2007; Thelen & Smith, 1994). This perspective provides a framework for understanding human occupational development from the interaction of different systems: the person, the environment and the activities/tasks. In this perspective all systems contribute to handwriting development: genetics, maturation, learning and motivation as determinants of the child; physical, social, historical and cultural as determinants of the environment and possibilities, exposure and expectations as determinants of the activities/tasks (Davis & Polatajko, 2011; van Hartingsveldt & van den Houten, 2012).

In the Person–Environment–Occupation model (PEO model) (Law et al., 1996), frequently used in paediatric occupational therapy, three overlapping circles represent the dimensions of the model: person, environment and occupation (activities and tasks) with occupational performance as dynamic interaction between the three interacting circles (see Figure 4).

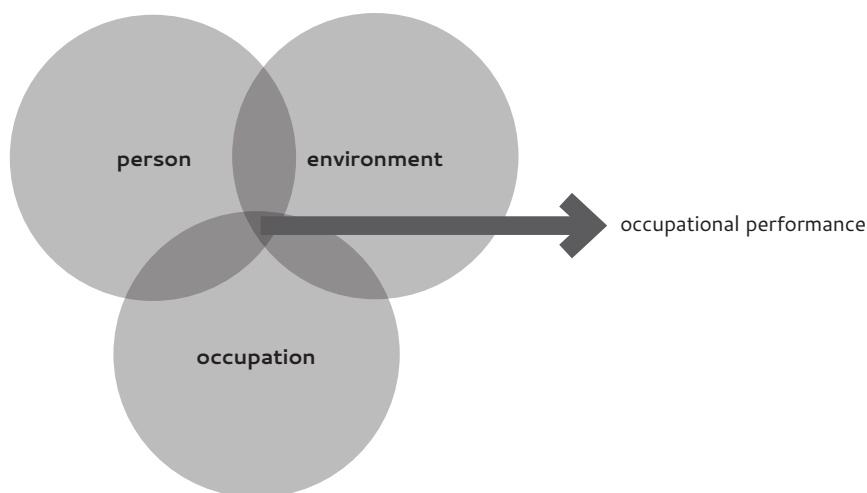


Figure 4. Person–Environment–Occupation model (Law et al., 1996).

In this thesis, the person is the 5–6 year old kindergarten child. The occupation contains the school-occupations of the kindergarten child such as the different paper-and-pencil tasks (e.g., colouring, making pre-writing patterns, writing own name and copying letters and numbers). These paper-and-pencil tasks should be performed by using an appropriate dynamic pencil grip (Schwellnus et al., 2012, 2013) and an adequate sitting posture (Pollock et al., 2009; Schneck & Amundson, 2010). The environment contains the physical and social environment of the classroom of the child.

Early evaluation of handwriting readiness

The negative effects of handwriting difficulties on a child's academic performance and self-esteem (Marr & Cermak, 2003; Ratzon, Efraim, & Bart, 2007) make early evaluation of handwriting readiness important in providing information regarding tailored interventions. Handwriting interventions are effective; a recent systematic review offers convincing evidence that interventions that involve handwriting practice twice per week for a minimum total of 20 sessions are effective for improving handwriting outcomes in children with handwriting difficulties (Hoy, Egan, & Feder, 2011). In addition, a co-teaching program for first-grade students shows significant gains in legibility, speed and writing fluency (Case-Smith, Holland, & Bishop, 2011; Case-Smith, Holland, Lane, & White, 2012). Co-teaching usually consists of a general educator paired with a special education teacher or related services professional (e.g., occupational therapist, speech-language pathologist) providing instruction to a class.

For the assessment of handwriting readiness the Scale of Children's Readiness in Printing (SCRIPT) (Marr, 2005; Marr & Cermak, 2002; Weil & Amundson, 1994) was developed in the USA. The SCRIPT is a letter shape-copying test developed for kindergarten children. In the Netherlands, the Screening Prewriting [Skills] Occupational Therapy (SPOT),² a standardised observation, has been developed. The goal of the SPOT is to evaluate handwriting readiness in five- and six-year-old kindergarten children (van Hartingsveldt, Cup, & Corstens-Mignot, 2006). In the SPOT, performance (quality of sitting posture and pencil grip) and product (quality of results) of seven paper-and-pencil tasks are observed. Additionally in the SPOT, three fine motor tasks are observed: cutting, in-hand manipulation and drawing large two-handed and one-handed patterns. The content and feasibility of SPOT have been evaluated and validated using the consensus technique through a Delphi survey of two expert rounds (van Hartingsveldt et al., 2006). Paediatric therapists and specialised teachers in the Netherlands and Belgium are extensively using the SPOT; this conclusion can be drawn based on the fact that more than 3,000 books about the SPOT observation have been sold in the last seven years. However, the SPOT is not a quantitative test with a clear cut-off point to evaluate the presence or absence of handwriting readiness.

Assessment of handwriting readiness

In the last ten years, the focus of assessment and intervention in occupational therapy has changed and has moved away from the traditional approach on performance components (Kennedy, Brown, & Stagnitti, 2013) to an occupation-based assessment in real-life situations, making the performance assessment contextual and meaningful (Brown & Chien, 2010; Coster, 1998; Hocking, 2001). This implies that handwriting readiness is preferably tested during pre-writing activities in the natural school setting of the child, taking into account the influence of the environment. Subsequent analyses of the

² In the Netherlands known by its Dutch name: Korte Observatie Ergotherapie Kleuters (KOEK)

assessment results can then consider how environmental features support or impede performance (Dunn, 2005). Goyen and Duff (2005) also advocate an occupation-based handwriting evaluation that includes an assessment of the actual process and output of handwriting generated under different conditions, including the classroom (Goyen & Duff, 2005). This means that during an occupation-based assessment the focus could be on the activities/tasks of the child in relation to the physical and social environment (Davis & Polatajko, 2011; van Hartingsveldt, Logister-Proost, & Kinébanian, 2010). They also urge responsible use of standardised assessments to compliment an occupation-based assessment. Assessments need to have adequate psychometric properties and should be used for the purposes intended (Wallen et al., 2013).

The aim and outline of this thesis

Because there are no occupation-based measurements of handwriting readiness, the overall aim of this research project is the development of an occupation-based measurement, the Writing Readiness Inventory Tool In Context (WRITIC). The tool is developed for 5 and 6 year old Dutch kindergarten children to evaluate handwriting readiness in the context of the classroom and to discriminate between children who are ready to learn handwriting and children who are not. We followed the steps in the development process according to Kielhofner (Kielhofner, 2006):

1. Identify the need for an instrument;
2. Identify the purpose and the intended population;
3. Specify the underlying construct;
4. Plan how the construct will be defined: develop items and supporting materials and pilot the instrument;
5. Empirically assess reliability and validity in successive stages.

To identify the need for an instrument we tested if an existing measure, the Peabody Developmental Fine Motor Scales second edition (PDMS-FM-2) (Folio & Fewell, 2000) was appropriate. We translated the test into Dutch and in **Chapter 2** we report the reliability and validity of the Dutch version of the PDMS-FM-2 in kindergarten children with mild fine motor problems. Because the PDMS-FM-2 was not sensitive enough for this population, we performed a systematic literature review to establish if there were psychometrically sound standardised tests or test items to assess handwriting readiness in 5 and 6 year old children on the levels of occupation, activities/tasks and performance components; the results of this literature review are reported in **Chapter 3**. In **Chapter 4** we describe the second, third and fourth step in test development, namely, deciding on the content, development of the items and pilot testing the instrument. In this chapter we also described the fifth step of determining content validity, construct validity and feasibility of the WRITIC. In **Chapter 5** the results of three cohort studies evaluating test-retest reliability, inter-rater reliability and convergent validity with the Developmental Test for Visual-Motor Integration (BeeryTMVMI) (Beery et al., 2010)

and the Nine-Hole Peg Test (9-HPT) (Smith, Hong, & Presson, 2000) are reported. **Chapter 6** presents the results of a longitudinal cohort study evaluating predictive validity of the WRITIC, 9-HPT and BeeryTMVMI, administered in kindergarten on the Systematic Screening for Handwriting Difficulties (Dutch abbreviation: SOS) (Smits-Engelsman, Stevens, Vrenken, & van Hagen, 2005) administered in first grade. **Chapter 7** provides a general discussion and reflects on the findings from the various studies. Conclusions are translated into suggestions for daily practice and recommendations for future research are formulated.

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Chapter 2

Reliability and validity of the fine motor scale of the Peabody Developmental Motor Scales–2



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ABSTRACT

This study examined the test–retest reliability, inter–rater reliability, convergent validity and discriminant validity of the Fine Motor Scale of the Peabody Developmental Motor Scales–second edition (PDMS–FM–2). Participants included two groups of 18 children between the ages of 4 and 5 years with and without mild fine motor problems. The PDMS–FM–2 was administered twice to 12 children and rated by two occupational therapists. The PDMS–FM–2 results were compared with scores on the Movement Assessment Battery for Children (M–ABC). In addition, the scores of the children with and without fine motor problems were compared. For the test–retest reliability and the inter–rater reliability, correlation coefficients varied from $r = 0.84$ to $r = 0.99$. These results suggest that PDMS–FM–2 has excellent test–retest and inter–rater reliability. Convergent validity with the fine motor section of the M–ABC and discriminant validity have been confirmed. Only 39% of the children in the group with problems in fine motor activities had fine motor problems according to the PDMS–FM–2. This finding seems to indicate that the PDMS–FM–2 may not be sensitive enough for this population.

INTRODUCTION

In paediatric occupational therapy, activities during play, self-care and school occupations are of prime importance (Law, Missiuna, Pollock, & Stewart, 2001) and fine motor skills are essential for the performance of children's occupations. Exner (2001) defines fine motor skills as those skills accomplished with hands to attain and manipulate objects. Through the use of a dexterous grasp, the manipulation of objects and the enabling of multiple tool functions, the child can engage in play, self-care and school occupations (A. Henderson & Pehoski, 1995). A study on kindergarten children in New York found that these children spend nearly one half (46%) of their in-class time in some type of fine motor activity (Marr, Cermak, Cohn, & Henderson, 2003).

The delayed development of fine motor skills in young children is frequently a cause for referral to school-based occupational therapists (Oliver, 1990). Most children in kindergarten do not experience difficulties in pre-school activities. However, a subgroup of children struggles with the acquisition of these activities. Currently the term developmental coordination disorder (DCD) is used when referring to children who exhibit mild motor problems not due to a medical condition, such as a neurological disorder. By definition, children with DCD demonstrate difficulties in motor coordination that negatively impact school performance and/or daily living (APA, 1994).

The occupational therapist serves as the specialist for the child when delays in the development of hand skills interfere with the ability to do pre-school activities, such as drawing, printing, fastening, constructing with blocks and toys, or manipulating small objects (Case-Smith, 1996, 2000; Case-Smith et al., 1998). The goal of school-based occupational therapy is to improve a child's performance of tasks and activities important for functioning in school (Case-Smith, Rogers, & Johnson, 2001). The delayed development of fine motor skills in young children is frequently a cause for referral to school-based occupational therapists (Oliver, 1990).

School-based occupational therapists in The Netherlands, who work with pre-school children with mild fine motor problems, lack a reliable and valid measure to assess fine motor skills. There are measures for pre-school children with major fine motor problems, such as the Quality of Upper Extremities Test (DeMatteo et al., 1992) and the Melbourne Assessment (Randall, Johnson, & Reddiough, 1999), which are used in The Netherlands. Both are developed for children with cerebral palsy. For children with DCD who experience motor problems, there is the Dutch version of the Movement Assessment Battery for Children (M-ABC) (S. E. Henderson & Sugden, 1992; Smits-Engelsman, 1998). This measure is frequently administered by physical therapists and occupational therapists in The Netherlands. Unfortunately, the fine motor section of this test consists of only three items. The authors of the M-ABC state that care must be taken when drawing a conclusion about only the fine motor section.

A literature review was conducted, searching for assessment tools that evaluate fine motor skills in pre-school children, between the ages of 4 and 6 years, with mild fine motor problems not caused by a neurological disorder. The assessment tools found during the literature search were evaluated on their test qualities as well as on the criteria for the assessment of the fine motor construct. The clinimetric qualities that were evaluated were: standardization, reliability, validity, norm referencing and whether a valid fine motor score was given. The criteria for the fine motor construct required that the test evaluated items requiring grasp, release, in-hand manipulation, bilateral hand use, tool use and dexterity. The Fine Motor Scale of the Peabody Developmental Motor Scales-second edition (PDMS-FM-2) (Folio & Fewell, 2000) appeared to be the only assessment tool that fulfilled both the clinimetric criteria and the criteria for the fine motor construct. The only aspect of the fine motor construct that is not assessed in the PDMS-FM-2 is in-hand manipulation.

2 The purpose of the study was to examine reliability and construct validity of the PDMS-FM-2 in pre-school children between the ages of 4 and 5 years with problems in fine motor skills. Construct validity is defined as the evidence that the measurement tool actually measures what it purports to measure (Feinstein, 1987). Folio and Fewell (2000) state that a test's validity must be investigated repeatedly until a conclusive body of data has accumulated. Construct validity was determined by assessing the convergent validity and the discriminant validity between two groups (Feinstein, 1987; Streiner & Norman, 1996).

The guiding questions for this study were as follows:

1. What is the test-retest reliability of the PDMS-FM-2?
2. What is the inter-rater reliability of the PDMS-FM-2?
3. What is the convergent validity in terms of a correlation between the PDMS-FM-2 and the fine motor section of the M-ABC?
4. What is the discriminant validity of the PDMS-FM-2, when comparing the test scores of children with problems in fine motor skills and children without problems in fine motor skills?

METHODS

Study design

A quantitative study was conducted to research the test qualities of the PDMS-FM-2.

Participants

For this study 18 children between the ages of 4 and 5 years were selected after meeting the following criteria: (1) They had mild fine motor problems as indicated by the school teacher, and (2) the mild fine motor problems were not caused by a neurological disorder, such as cerebral palsy. The fine motor problems were determined by the Checklist of Fine Motor Skills, which was specially composed for this research on the basis of Part I of the Checklist Movement ABC (Henderson & Sugden, 1992; Smits-Engelsman, 1998). Most of the children with fine motor problems ($n = 13$) came from the Pedological School, a special school for children with pedagogical problems and/or learning problems. Children from this school were chosen because there is a greater prevalence of children with developmental motor delays in special education as compared to children in regular education (Kalverboer, 1996). By choosing this school to recruit participants, the chance of obtaining a large enough sample size for this research project was expected. In The Netherlands, pre-school children reach the age of 6 years in the last pre-school year. Due to the fact that the maximum age for the PDMS-FM-2 is 71 months, there were not enough eligible pre-school children in the Pedological School. Therefore, the study group was supplemented with five children from regular schools who were referred by their teacher to occupational therapy for an assessment because of problems with fine motor activities.

Table 1. Comparison of the group of children with (presumed) fine motor problems and the group of children without problems.

Group	Mean age (month)	Age range (month)	Number of boys	Number of girls	Left handed	Left handed
(Presumed) fine motor problems ($n = 18$)	61.9	52-71	16	2	5	13
Without fine motor problems ($n = 18$)	62.7	53-72	16	2	3	15

This group of children with fine motor problems consisted of 16 boys and 2 girls aged 52 to 71 months (mean 61.9 months). Thirteen children were right-handed and five were left-handed. From this group, 12 children from the Pedological School took part in the reliability study. This group of children consisted of 11 boys and one girl aged 52 to 72 months (mean 61 months). Eight children were right-handed and four were left-handed. The control group included 18 children from a regular school without fine motor problems, according to their teachers. These children were matched for both age and gender to the group of children with fine motor problems. Table 1 provides details on age and gender of both groups. There were no significant differences between groups on age ($p > 0.73$) or gender. The parents of all children had given written informed consent for their children to participate in this study.

Instruments

PDMS-FM-2

The PDMS-2 is a standardized test, designed to evaluate both fine and gross motor skills in children from birth to 71 months of age. It is a reliable and valid assessment tool. This study focuses on the PDMS-FM-2, which consists of two subtests: Grasping, and Visual-Motor Integration (standard score range: 1–20). The Fine Motor Quotient (FMQ) is derived by adding the subtest standard scores and converting the sum to a quotient (range: 25–165). Standard scores and quotients can be transposed to percentile scores. The PDMS-FM-2 is a standardized test; for each item the instructions are described in full text. For this study, the text of the items and the examiner record booklet have been translated into Dutch. The standardized PDMS-2 test kit was used for the administration of the fine motor scales. The items not included in the kit were provided by the primary investigator.

M-ABC

The M-ABC consists of four age-related item sets. Each set is composed of eight items that measure different aspects of motor ability: three items measure manual dexterity, two measure ball manipulation skills and three measure static and dynamic equilibrium. In this study, only the items evaluating manual dexterity were used. Scores range from 0 to 5 on each item, so the total score for manual dexterity can vary from 0 to 15. The manual dexterity score can be converted to percentile scores. The 15th percentile score is used as cut-off point. The test has acceptable reliability and validity. Henderson and Sugden (1992) found a 62–100% agreement in classification (scores) between two measurements at a two-week interval. Smits-Engelsman et al. (1998) found 90–96% agreement of classification of motor performance between two measurements at a two-week interval. Smits-Engelsman et al. (1998) studied the relationship between the M-ABC test and the Körper KoordinationTest für Kinder (Kiphard & Schilling, 1974) in 202 children. A correlation of 0.62 and a Cramer's V of 0.56 was found for classification of motor performance (Smits-Engelsman, Niemeijer, & van Galen, 2001).

Procedure

To determine test–retest reliability, rater 1 administered the PDMS–FM–2 twice to 12 children with fine motor problems with an interval of 1 week. To determine inter–rater reliability, 12 children were videotaped during the administration of the PDMS–FM–2 by rater 1. Rater 2 viewed and scored the videotapes separately from rater 1 in random order. The subjects' test papers, obtained during the assessment for the drawing and cutting test items were available for rater 2. Basal and ceiling levels, as described in the manual, were not used because they could give rater 2 cues about how rater 1 scored the child. In order to decrease cueing that a ceiling level had been reached, rater 1 tested at random, 1, 2 or 3 items above ceiling level. For the basal level, rater 1 tested at random, 1, 2 or 3 items below basal level. The random order was established by picking up a card off a pile.

To determine convergent validity, the PDMS–FM–2 and the manual dexterity items of the M–ABC were administered to all 18 children with fine motor problems. To determine discriminant validity, the PDMS–FM–2 was also administered to the 18 children without fine motor problems. The scores of the children with problems in fine motor activities ($n = 18$) were compared to the scores of the children without problems ($n = 18$). The manual dexterity items of the M–ABC were also administered to the children without fine motor problems in order to compare the fine motor capabilities of both groups.

The test administrators were two occupational therapists with 18 and 14 years' experience in paediatric occupational therapy, respectively. The raters prepared for the data collection independently by following the training procedure as described in the test manual (Folio & Fewell, 2000).

Data analysis

To define the sample size, the Correlation Coefficient Power Calculator from the UCLA Department of Statistics (www.statpages.net) was used. For a correlation coefficient of 0.8, an $\alpha = 0.05$ and a power of 0.80, nine children had to participate. For the PDMS–FM–2, standard scores per subtest were calculated by rater 1. From the total standard score for the fine motor scales, the Fine Motor Quotient (FMQ) and percentiles scores were calculated.

From the M–ABC, raw test scores were computed in weighted scores allowing for the determination of a score for manual dexterity. This final cluster score was then used to examine whether or not the percentile score was below the 15th percentile. Data were analysed using the SPSS/PC+ Statistics Version 10.0 (SPSS Inc. Illinois, USA).

For test–retest reliability and inter–rater reliability, the data were analysed based on

the standard scores of the subtests and the FMQ of the PDMS-FM-2. Spearman's rho correlation coefficient was used. The Wilcoxon signed-ranks test was used to determine if there was an equal partition of the variables. To demonstrate test-retest reliability it was expected, on the basis of the outcomes of the study of Folio and Fewell (2000), that there would be an almost perfect agreement with a correlation coefficient between 0.81 and 1.0. For an evaluation of the expected agreement, the classification of Landis and Koch (1997) was used: 0.01–0.20 = slight; 0.21–0.40 = fair; 0.41–0.60 = moderate; 0.61–0.80 = substantial; 0.81–1.0 = almost perfect (Landis & Koch, 1997).

For convergent validity the standard score of the FMQ of the PDMS-FM-2 was compared with the cluster score of manual dexterity of the M-ABC. Spearman's rho correlation coefficient was used. A strong agreement between the outcomes on the two tests was expected, with a correlation coefficient between 0.61 and 0.80. For discriminative validity, the standard scores of the subtests and the FMQ of the PDMS-FM-2 were used as well as the cluster scores of manual dexterity of the M-ABC. The Mann-Whitney test for two independent samples was used to test whether there was a significant difference between the two groups. This test was also used to determine the difference in the two groups. Both the PDMS-FM-2 and the M-ABC have a cut-off point for children who are considered to have fine motor problems. The cut-off point of the PDMS-FM-2 is the 16th percentile and the cut-off point of the M-ABC is the 15th percentile. Significance level was set at the $\alpha = 0.05$ level for all analyses.

RESULTS

Test-retest reliability varied from $r = 0.84$ ($p < 0.001$) to $r = 0.98$ ($p < 0.001$). There is an equal partition ($0.33 < p > 0.48$) of the comparing variables. The inter-rater reliability varied from $r = 0.94$ ($p < 0.001$) to $r = 0.99$ ($p < 0.001$). There is also an equal partition ($0.20 < p > 1.00$) of the compared variables. See Table 2 for the outcomes of test-retest and inter-rater reliability.

Table 2. Correlation coefficients test-retest and inter-rater reliability (Spearman's rho) with the significance for equal partition (Wilcoxon signed rank test) with p -values ($n = 12$).

Scores PDMS-FM-2	Test-retest	p -value	Equa partition	Inter-rater	p -value	Equal partition
Fine Motor Quotient	0.98	< 0.001	$p > 0.39$	0.98	< 0.001	$p > 0.38$
Standard score Grasping	0.96	< 0.001	$p > 0.48$	0.94	< 0.001	$p > 0.20$
Standard Score Visual-Motor	0.84	0.001	$p > 0.33$	0.99	< 0.001	$p > 1.0$

For the convergent validity the correlation coefficient was $r = 0.69$ ($p = 0.002$). The discriminant validity is determined with the M-ABC and the PDMS-FM-2. For the M-ABC the mean rank of the fine motor section of the study group was 26 and the mean rank of the control group was 11. The Z -value of the statistic test on the M-ABC was 4.24 ($p < 0.001$). The difference in fine motor abilities between the two groups on the PDSM-FM-2 ranged from $Z = -4.59$ ($p < 0.001$) to $Z = -2.80$ ($p = 0.005$) (see Table 3).

Based on the percentile score of the PDMS-FM-2, a nominal outcome is established delineating having or not having fine motor problems. Of the group children with fine motor problems according to their teachers, 39% had fine motor problems as compared to 0% of the children in the group without fine motor problems. Based on the percentile score of the M-ABC, of the group of children with fine motor problems according to their teachers, 78% had fine motor problems according to the Dutch M-ABC norm data. When using the American M-ABC norm data 50% had fine motor problems. In the group of children without fine motor problems there were, according to the Dutch and American M-ABC norm data, 0% children with fine motor problems. Table 4 provides the nominal outcomes on both tests.

Table 3. Outcomes of PDMS –FM-2 on the Mann-Whitney test for two independent samples of the group with (presumed) fine motor problems ($n = 18$) and the group without fine motor problems ($n = 18$).

Scores	Group	Mean rank	Sum of ranks	Z-value	p-value
Fine Motor Quotient	With problems	10.75	193.50	-4.43	< 0.001
	Without problems	26.25	472.50		
Standard score Grasping	With problems	13.69	246.50	-2.80	< 0.005
	Without problems	23.31	419.50		
Standard Score Visual-Motor	With problems	10.50	189.00	-4.59	< 0.001
	Without problems	26.50	477.00		

Table 4. Comparison of children with fine-motor problems ($n = 18$) and without fine motor problems ($n = 18$) based on percentile scores of the PDFMS-2 and M-ABC.

Test	Group	Without fine motor problems	Wifh fine motor problems	Chi square	p-value
PDMS-FM-2	With problems	11 (61%)	7 (39%)	8.69	0.003
	Without problems	18	0		
M-ABC Manual dexterity NL norms	With problems	4 (22%)	14 (78%)	-22.91	< 0.001
	Without problems	18	0		
M-ABC Manual dexterity USA norms	With problems	9 (50%)	9 (50%)	12.00	< 0.001
	Without problems	18	0		

DISCUSSION

Based on the literature research, the PDMS-FM-2 is the only available test that meets the accepted criteria of reliability and validity and the criteria for the fine motor construct, except for in-hand manipulation. The purpose of this study was to examine if the PDMS-FM-2 was a reliable and valid assessment tool to be used with children, between the ages of 4 and 5 years, who have problems in the execution of fine motor activities.

The test-retest reliability and the inter-rater reliability were determined via analysis of the Fine Motor Quotient (FMQ) and the standard scores of the subtests Grasping and Visual-Motor Integration. This was done in order to be consistent with the analysis of Folio and Fewell (2000) who also determined the reliability based on these scores. The results indicated that, as was expected, reliability met the criteria ($r = 0.81-1.0$). The reliability was almost perfect, the correlation coefficients varied from $r = 0.84$ to $r = 0.99$. These values are comparable to the correlation coefficients of the reliability study in the manual of the PDMS-FM-2 (Folio & Fewell, 2000) which vary from $r = 0.73$ to $r = 1.00$.

A factor that contributed to the high reliability of the PDMS-FM-2 is the fact that most of the outcome scores were based on quantitative measures (Larkin & Cermak, 2002), such as buttoning, that must be done within 20 seconds. An additional factor that might have improved the inter-rater reliability values obtained in this study was the use of videotapes. The ability to review a child's performance may have increased inter-rater reliability (Gebhard, Ottenbacher, & Lane, 1994). Observers generally have greater agreement when they are aware that their observations are being assessed (Stokes, Deitz, & Crowe, 1990).

To determine the convergent validity, the manual dexterity items of the M-ABC were administered in addition to the PDMS-FM-2. To assess convergent validity, there must be another test administered which measures the same construct. The fine motor construct of the PDMS-FM-2 is composed of items concerning grasping and visual motor integration and the fine motor construct of the M-ABC is composed of items concerning manual dexterity. Although the items on the two tests are different, convergent validity can be assessed because grasping and visual motor integration are the basic necessities for manual dexterity. The correlation that was found between the PDMS-FM-2 and the M-ABC met the expected criteria ($r = 0.61-0.80$). The correlation coefficient $r = 0.69$ indicated a strong agreement between the tests. According to Streiner and Norman (1996) it is satisfying to have a strong correlation, especially because the PDMS-FM-2 is 'better', namely, it explains more findings and allows for more accurate judgement on the tested construct.

To determine discriminative validity, the PDMS-FM-2 was administered to a group of 18 children with problems in fine motor activities and to a group of 18 children with-

out fine motor problems. The presence of problems in fine motor activities was initially based on the opinion of the teacher. Although this is not a gold standard, it is what often occurs in daily practice. The teacher worries about the fine motor abilities and refers the child to an occupational therapist. By administering the manual dexterity items of the M-ABC to both groups, the teachers' opinion was validated by means of an objective score from the test. There was a difference in Z-value between the two groups of -4.24 ($p < 0.001$). The difference between the two groups is more than four standard deviations. Based on the percentile score of the M-ABC. A nominal outcome was established delineating having, or not having, fine motor problems. Of the group of children reported to have fine motor problems by their teachers, 78% had fine motor problems according to the Dutch M-ABC norm data. When using the American M-ABC norm data 50% had fine motor problems. In the control group of children none was found to have fine motor problems according to the Dutch and American M-ABC norm data. Upon evaluation of the M-ABC norm data, there was an obvious difference between the two groups, however the manual dexterity items of the M-ABC are not a 'gold standard'.

Through statistical analysis of the outcomes of the PDMS-FM-2 for the two groups, the Z-value varied from -4.59 to -2.80 (a contrast of 4.5 to 3 standard deviations was present, indicating a significant difference). When the contrast was based on the nominal outcome of the percentile scores of the PDMS-FM-2, there was an evident difference: 39% of the children in the study group had fine motor problems as compared to 0% of the children in the control group. However the discriminative validity that was found did not meet the expected criteria (80%).

The question is, what is the clinical relevance of the PDMS-FM-2 for children with problems in fine motor activities? It was expected that a minimum of 80% of the children in the study group would have fine motor problems according to the PDMS-FM-2. However this was not the case. Only 39% of the children with problems in fine motor activities had fine motor problems according to the PDMS-FM-2. This seems to indicate that the PDMS-FM-2 is not sensitive enough for this population. Larkin and Cermak (2002) also mentioned this limiting factor in current assessment tools for the identification of developmental coordination disorder. They also indicated that the lack of precision in an assessment could be a source of frustration for the practitioner. This was also experienced by the therapists administering the PDMS-FM-2 in this study. The quantitative outcomes on the test were within the norms, but during observation of the quality of performance, problems that were mentioned by the teacher could be identified. An example of this is observed during 'cutting a square'. The child might have met the quantitative norm and received the maximum score of 2, but performed the task in an uncoordinated and primitive way, with much difficulty.

As mentioned in the introduction, the only aspect of the fine motor construct that is not assessed in the PDMS-FM-2 is in-hand manipulation. In fact manipulative skills could differentiate between children with and without fine motor problems (Breslin & Exner,

1999; Exner, 1992). Despite the importance of these skills, none of the standardized assessments used by occupational therapists specifically measures the quality of children's in-hand manipulation skills. There is still a need for a reliable and valid test for in-hand manipulation. Because of the fact that the PDMS-FM-2 does not seem to be sensitive enough to identify this population, one could state that if the PDMS-FM-2 indicates fine motor problems, these children most likely would benefit from occupational therapy treatment. And the other children with mild problems, according to their teacher, would benefit from occupational therapy instructions to teacher and parents.

The results of this study should be treated with caution because, as stated earlier, there were significant differences in norms between American and Dutch children in the 4–5 year age group on the manual dexterity items of the M-ABC. For all other age groups and other parts of this test there are no significant differences between Dutch and American children. According to the Dutch norms of the M-ABC more children have fine motor problems. In this study, the norms that were used for the PDMS-FM-2 were the American norms. If Dutch norms for the PDMS-FM-2 were available the validity outcomes of this study would, perhaps, be different.

Nonetheless, due to the fact that in this study the PDMS-FM-2 was not sensitive enough to identify this population, the next question is, which reliable and valid assessment tool(s) can be used for the evaluation of Dutch pre-school children with fine motor problems? The most plausible answer is to use the manual dexterity items from the M-ABC. The M-ABC was normed for the Dutch population and on the basis of these Dutch norms, 78% of the children in the study group had fine motor problems. Unfortunately, the M-ABC has limitations. The test has only three manual dexterity items and therefore the author (Smits-Engelsman, 1998) recommends caution when interpreting and drawing conclusions based on the manual dexterity items only. With the manual dexterity items of the M-ABC only a small part of the fine motor construct is assessed. Therefore, it is important to complement the test outcomes of the M-ABC with observations of the fine motor skills. Larkin and Cermak (2002) state that reliable observations require highly trained observers with appropriate pre-planned observational strategies. In The Netherlands occupational therapists use a standardized observational tool for fine motor pre-school activities. However, the combined use of M-ABC and a standardized observational tool for fine motor pre-school activities is limited since the visual-motor integration items are missing. So, it seems a good idea to complete this assessment with the Developmental test for Visual-Motor Integration (VMI) (Beery, 1997). Different authors (Burgman, 1998; Exner, 2001; Larkin & Cermak, 2002; Richardson, 2001) state that an occupational therapy assessment should contain norm-referenced tests in combination with observations of functional skills. Therefore, the proposed assessment plan for Dutch pre-school children with fine motor problems would be the administration of the manual dexterity items of the M-ABC, the VMI and a standardized observational tool for fine motor pre-school activities, therefore incorporating norm referenced tests with standardized observation.

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Chapter 3

Standardized tests of handwriting readiness: a systematic review of the literature



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ABSTRACT

Aim: To establish if there are psychometrically sound standardized tests or test items to assess handwriting readiness in 5- and 6-year-old children on the levels of occupations, activities/tasks and performance components.

Method: Electronic databases were searched to identify measurement instruments. Tests were included in a systematic review if: (1) participants are 5 and 6 years old, (2) the focus was on handwriting-readiness, and (3) the measurement was standardized. In the second step a further electronic search was undertaken for selected relevant measurement instruments to evaluate the content, psychometric properties, and feasibility of these instruments.

Results: The search identified 1114 citations. In the final selection 39 articles with information about 12 tests were included. The content, feasibility, and psychometric properties of these 12 tests were evaluated and none of the instruments was satisfactory, according to the specific criteria.

Interpretation: None of the instruments include all necessary components to evaluate writing readiness. Therefore, the development of an all-encompassing assessment is necessary to test handwriting readiness and to make tailored interventions possible.

INTRODUCTION

Competent handwriting is one of the most important skills that children learn at school during their years at school (Feder, Majnemer, Bourbonnais, Blayney, & Morin, 2007; Feder et al., 2005). Handwriting is a major occupation in childhood that is essential for the child's participation in the classroom environment (Rosenblum, 2008). Thirty to sixty percent of the school day is devoted to fine motor activities, with writing as the predominant task (McHale & Cermak, 1992; Tseng & Chow, 2000). The prevalence of handwriting problems has been estimated to range between 5% and 27% depending on grade, selection criteria and instruments used (Karlsdottir & Stefansson, 2002; Maeland, 1992; Smits-Engelsman & van Galen, 1997; Volman, van Schendel, & Jongmans, 2006).

The transition from kindergarten to elementary school is an important period of childhood. Early school success and positive transition tends to translate into higher levels of social competence and academic achievement that remain stable over time (Bart, Hajami, & Bar-Haim, 2007; Hamre & Pianta, 2001; Pianta, Cox, Taylor, & Early, 1999). Reducing the problems in pre-writing skills in kindergarten children is crucial: research has shown that a child's healthy adjustment to school during these first years is a precursor to subsequent school success (Alexander, Entwisle, & Olson, 2001; Ratzon, Efraim, & Bart, 2007; Rimm-Kaufman & Pianta, 2000). Educators and paediatric therapists attempt to identify children who are at risk of writing problems at an early age in order to provide additional instruction or therapeutic intervention (Bart et al., 2007; Marr & Cermak, 2002; Ratzon et al., 2007). Kindergarten children are often referred to occupational or physical therapists for evaluation and/or treatment of poor fine motor performance, including difficulty with pre-writing skills. Therapy referrals made early in a child's academic career are considered to be beneficial to the child so that a deficit can be addressed – and hopefully corrected – before the student's academic performance is affected (Marr, 2005). In their review on handwriting remediation studies, Feder and Majnemer (2007) concluded that most studies on handwriting remediation provide evidence to support its effectiveness despite variations in the duration, frequency, and treatment approaches applied.

The negative effects of handwriting difficulties on a child's academic performance and self-esteem, as discussed in the literature (Marr & Cermak, 2002, 2003; Ratzon et al., 2007) make early evaluation of pre-writing skills is of major importance. Such early evaluations provide the kindergarten teacher with the opportunity to stimulate paper-and-pencil tasks and, if major problems in pre-writing skills are identified, to refer the child to a paediatric occupational or physical therapist.

Occupation-based assessment

A recent trend in occupational therapy is to focus assessment on real-life situations, making the performance assessment contextual and meaningful (Hocking, 2001). The strong shift to adopt an occupation-based approach in the assessment of children is based on the paradigm that the evaluation should determine how children participate in occupations in a relevant context (Coster, 1998). Therefore, pre-writing activities should be assessed in the natural school setting of the child where the influence of the environment can be taken into account. Subsequent analyses of the assessment results can then considered how environmental features support or create barriers. Each child reacts differently to environmental variables; what might support performance in one child can be a barrier to performance in another (Dunn, 2005).

In paediatric occupational therapy the focus of the intervention is on daily occupations in play, activities of daily living (ADL) and school. In occupational therapy, occupations are defined as a set of activities meaningful to the child in a specific context; the activities comprise a set of tasks, and the tasks consist of a set of performance components. This hierarchy is based on the Taxonomic Code of Occupational Performance (TCOP) (Polatajko et al., 2007; Polatajko et al., 2004). According to the TCOP, handwriting readiness can be assessed at the level of occupations, activities, tasks and performance components (Table 1).

Table 1. Levels of occupation-based assessment.

Level of complexity	Definition	Example
Occupation	An activity or set of activities that is given meaning by individuals in a specific context	Writing own name in the classroom
Activity	A set of tasks	'Drawing' the letters on a paper
Task	A set of functions	Grasping and positioning the pencil in the hand
Performance components	Perceptual-motor function	Fine motor coordination, visual motor integration

Adjusted to the Taxonomic Code of Occupational Performance (TCOP) (Polatajko et al., 2007; Polatajko et al., 2004)

Next to the occupation, at the level of activities and tasks, an assessment of writing readiness should contain an observation of ergonomic factors, such as body position and pencil grip. Parush et al. (1998) noted that children who had poor handwriting had an inferior pencil grip and paper and body positioning compared with children with good handwriting. Rosenblum et al. (2006) described a high correlation between body position and the fluency of handwriting. Subsequent studies, however, found that that grip affected neither

legibility (Koziatsek & Powell, 2003) nor the undertaking of writing long passages (Dennis & Swinth, 2001), although these studies did not take into account the dynamic aspect of the adopted grips (Ziviani & Wallen, 2006). Kindergarten is an important period for the development of wrist stabilization in extension position and a dynamic pencil grasp. Between the ages of 3 and 6 years, most children develop from a transitional static grasp with wrist movements to a mature dynamic grasp with thumb and finger movements (Edwards, Buckland, & McCoy-Powlen, 2002). Information about pencil grip and the position of the wrist and the forearm resting on the surface has to be evaluated because of early remediation. This is important to prevent correction of the inefficient wrist position and grip after it has been reinforced and kinesthetically locked in.

At the level of performance components, empirical evidence suggests that problems in handwriting relate to a deficit in perceptual-motor function. The motor and perceptual components related to poor handwriting performance may include fine motor control, visual motor integration, visual perception, kinesthesia, and sensory modalities (Cornhill & Case-Smith, 1996; Feder & Majnemer, 2007). Feder and Majnemer (2007) state in their review that the correlation between visual perception, kinesthesia and sensory awareness of the fingers with handwriting remains unclear. On the other hand, there is evidence for a correlation between fine motor control, visual-motor integration, and handwriting. Several studies have found that children with handwriting problems show a deficit in fine motor control (Cornhill & Case-Smith, 1996; Maeland, 1992; Smits-Engelsman, Niemeijer, & van Galen, 2001; Smits-Engelsman & van Galen, 1997), whereas in other studies, visual motor integration was found to contribute significantly to poor handwriting (Cornhill & Case-Smith, 1996; Maeland, 1992; Tseng & Chow, 2000; Tseng & Murray, 1994; Weintraub & Graham, 2000). Volman et al. (2006), in their study of 29 children in grades 2 and 3 with handwriting problems and 20 children without handwriting problems, support the concept that there are two different mechanisms underlying the quality of handwriting in children: fine motor coordination and visual-motor integration. The findings of this study suggest that the screening of the performance components of writing skills in kindergarten children should focus on these two underlying mechanisms (Volman et al., 2006).

In the Netherlands, a valid and reliable occupation-based assessment for writing readiness among kindergarten children is lacking. The aim of this systematic literature review was to investigate whether there are psychometric sound tests or test items to assess handwriting readiness in 5- and 6-year old kindergarten children at the level of occupations, activities/tasks and performance components.

METHOD

Search strategy

In November 2009 we undertook a comprehensive search of computerized bibliographic databases, including Pubmed (1966 – November 2009), Cumulative Index to Nursing and Allied Health Literature WebSPIRS (CINAHL; 1982 – November 2009), PsychINFO Web-SPIRS (1966 – November 2009) and Education Resources Information Center WebSPIRS (ERIC; 1966 – November 2009). Our broad search strategy included Medical Subject Headings (MeSH) or indexed terms as well as free-text words for 'standardized measurements' AND 'kindergarten children of 5 and 6 years old' AND 'school occupations' OR 'school activities' OR 'paper-and-pencil tasks' AND performance components such as 'fine motor coordination' OR 'visual motor integration' (Table SI, published online). Because we conducted a comprehensive review, with the purpose of finding as many references to different tests or test items as possible, we included all study designs, such as psychometric articles and intervention studies. The names of identified instruments were used as terms for a further search of the electronic databases. Additional potentially relevant publications were searched manually through citation and author tracking.

Inclusion and exclusion criteria

Tests or test items were included in the review if they met all of the following criteria: (1) participants are kindergarten children aged 5 and 6 years, (2) handwriting readiness specific (i.e. items on school occupations, school activities, paper-and-pencil tasks, fine motor coordination, and visual motor integration) and (3) a standardized measurement was mentioned in the publication. Tests or test items were excluded if they were not published in English, German, or Dutch and did not meet the inclusion criteria.

Data extraction

A preliminary selection, based on title and abstract, was performed independently by two of the reviewers (MvH, PA). Where there was disagreement, a decision was reached by consensus of the reviewers. Full-text articles that fit the inclusion criteria were retrieved for more detailed evaluation by the first author. Tests or test items were included after agreement by both raters, and conflicting viewpoints were discussed until agreement was reached. Assessment manuals were sourced, and a further electronic search was under-taken for included measures.

Criteria for evaluating psychometric properties of handwriting readiness measures

The quality criteria of Terwee et al. (2007) were used to assess the psychometric properties of the instruments. For each property, a sample size of at least 50 participants is considered adequate. In our study, we evaluated the following psychometric properties of an instrument (Terwee et al., 2007).

Internal consistency

A positive rating was given when factor analysis was applied and Cronbach's alpha was at least 0.70.

Content validity

A positive rating was given if a clear description was provided of the measurement aim, the target population, the concepts that were measured, and the item selection. In addition, the target population should have been involved during item selection.

Criterion validity

A positive rating was given if convincing arguments were presented that the criterion was at least 0.70.

Construct validity

A positive rating was given when hypotheses were specified in advance, and at least 75% of the results were in agreement with these hypotheses.

Reproducibility agreement

A positive rating was given when the smallest detectable change or the limits of agreement were smaller than the minimal important change. Because this is a relatively new approach, a positive rating was also given if authors provided convincing arguments that the agreement was acceptable.

Reproducibility reliability

A positive rating was given when the intraclass correlation coefficient (ICC) or the weighted kappa was at least 0.70.

Responsiveness

A positive rating was given if hypotheses were given in advance and at least 75% of the results were in accordance with the hypotheses, and if the minimal important change was greater than the smallest detectable change.

The criteria of Terwee et al. (2007) are based on classical psychometric testing. These do not include Rasch analysis, a method that has recently become very popular in psychometric research; therefore, this analysis was added to the reliability and validity items of

the Terwee et al. (2007) criteria. In addition to these established psychometric properties (Terwee et al., 2007) the presence of normative scores are of importance to determine whether a score reflects normal or abnormal behaviour.

RESULTS

Selection of assessment tools

The search resulted in 1316 citations (Fig. 1). Duplicates were removed, narrowing the citation pool to 1114 citations. The preliminary selection, based on the abstracts, contained 70 citations, with information about standardized tests on school occupations, paper-and-pencil activities/tasks, fine motor coordination and visual-motor integration in kindergarten children aged 5 and 6 years.

We were unable to retrieve 11 articles via the university library and seven of the 70 citations were dissertation reports; consequently, the preliminary selection was reduced to 52 full-text articles. Of these 52 articles: 26 were excluded because information about a test was lacking (five articles), the test included was not standardized (three articles), the test was not handwriting readiness specific (14 articles), or the participants were older than 6 years (four articles). Citation and author tracking resulted in an additional 14 articles being retrieved and three manuals of included tests (Beery & Beery, 2004; Fisher, Bryze, Hume, & Griswold, 2005; Henderson, Sugden, & Barnett, 2007). The final selection consisted of a total of 40 articles which included information about standardized assessments on writing readiness in kindergarten children aged 5 and 6 years.

We found 12 tests that assess aspects of handwriting readiness in this age group. The included measurements were (1) School Assessment of Motor and Process Skills (School-AMPS); (2) Scale of Children's Readiness in Printing (SCRIPT); (3) Writing Essential Skill Screener-Preschool version (WESS-P); (4) Test of In-Hand Manipulation-revised (TIHM-R); (5) Nine-Hole Peg Test (9HPT); (6) Beery Developmental Test of Visual-Motor Integration (Beery VMI); (7) Draw-A-Person: Quantitative Scoring System (DAP:QSS); (8) Motor Performance Checklist (MPC); (9) Movement Assessment Battery for Children, 2nd edition (M-ABC-2); (10) Maastricht's Motor Test (MMT); (11) Bruininks-Oseretsky Test of Motor Proficiency, 2nd edition (BOT-2); and (12) the Denver Developmental Screenings Test, 2nd edition (Denver II). We found information about the first and second editions of the M-ABC and BOT. We have chosen to include the second edition of these tests in this review.

These 12 assessment tools were grouped according to target population, objective, sub-scales, number of items (total and handwriting readiness specific), number of response options, time to administer, required course, required materials, and citations in Pubmed, PsychINFO, CINAHL and ERIC (Table 2).

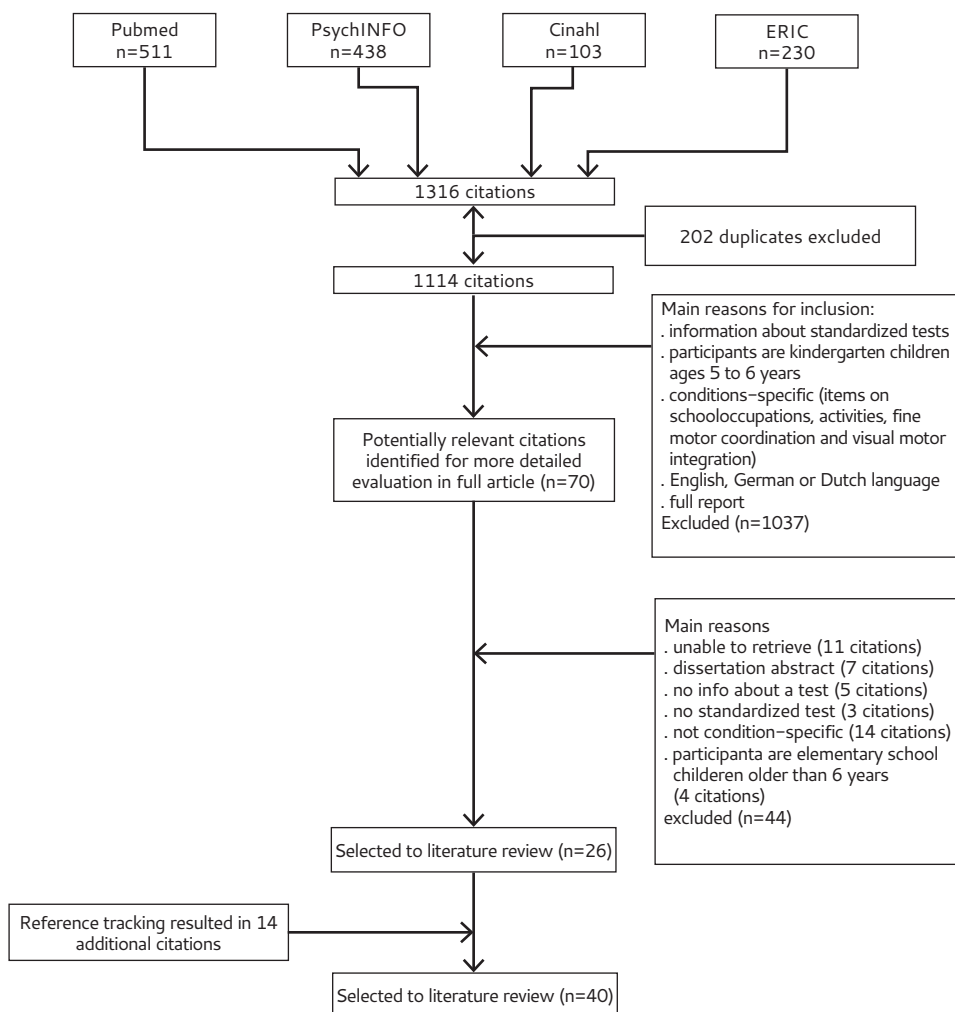


Figure 1. Flowchart showing the selection of articles about standardized tests for writing readiness.

Characteristics of assessment tools

The 12 instruments were grouped according to the TCOP (Polatajko et al., 2007; Polatajko et al., 2004) at the level of occupation, activities/tasks, and performance components (Table 3).

There is only one occupation-based test that assesses the aspects of handwriting readiness on the different levels of the TCOP. The School AMPS examines the interaction

between a student, a schoolwork task and a classroom environment and evaluates the quality of the student's schoolwork task performance, measured at the level of complex activity and occupation. Motor and process components of schoolwork performance are evaluated by an occupational therapist through observation in the classroom setting (Fingerhut, Madill, Darrah, Hodge, & Warren, 2002; Fisher, Bryze, & Atchison, 2000). From the performance components perspective, only the aspect of fine motor coordination is assessed.

Paper and pencil tasks

There are two instruments that involve one single paper-and-pencil task: the SCRIPT (Marr, 2005; Marr & Cermak, 2002) and the DAP:QSS (Abell, VonBriesen, & Watz, 1996; Hall & Case-Smith, 2007; Hilgert & Adams, 1989; Pianta & McCoy, 1997; Rae & Hyland, 2001; Short-DeGraff & Holan, 1992). The SCRIPT is a letter shape copying test developed for kindergarten children (Weil & Amundson, 1994). The child has to copy all 26 lowercase letters and eight uppercase letters, namely, A, K, M, N, V, W, Y, and Z. The DAP:QSS is a figure drawing assessment with a quantitative scoring system.

One instrument was found that evaluates writing readiness at the level of paper-and-pencil tasks and visual-motor integration: the WESS-P (Erford, 1997). The WESS-P consists of four activities reflecting pre-writing skills and conceptual development and includes copying simple geometric shapes, copying speed, copying letters and numbers, and name writing.

Fine motor coordination

Two instruments were found that consist only of a fine motor coordination task: the TIHM-R (Bazyk et al., 2009; Exner, 1993; Pehoski, Henderson, & Tickle-Degnen, 1997a, 1997b; Pont, Wallen, Bundy, & Case-Smith, 2008) and the 9HPT (Poole et al., 2005; Smith, Hong, & Presson, 2000). Both tests use a time procedure with pegboard and pegs. In the TIHM-R the pegs must be used in in-hand manipulation tasks, such as translation and rotation with stabilization; in the 9HPT, the pegs must be used in a onehanded aiming task.

Visual motor integration

One test for the assessment of visual-motor integration for this population was found: the Beery VMI (Daly, Kelley, & Krauss, 2003; Feder & Majnemer, 2007; Feder et al., 2005; Marr & Cermak, 2002; Rodger et al., 2003; Short-DeGraff & Holan, 1992; Weil & Amundson, 1994).

General motor tests

Five general motor tests designed to measure fine and gross motor skills in children were found: MPC (Gwynne & Blick, 2004; Gwynne, Blick, & Hughes, 1996), M-ABC-2 (Brown & Lalor, 2009; Henderson et al., 2007), MMT (Kroes et al., 2004), BOT-2 (Deitz, Kartin, & Kopp, 2007; Duger, Bumin, Uyanik, Aki, & Kayihan, 1999; Feder et al., 2007; Feder

Table 2. Classification of tests that assess aspects of readiness in 5- and 6-year-old kindergarten children.

Test	Target population	Objective	Subscales	Number of items (nr of items on writing readiness)	Number of response options	Time to administer (min)	Training needed	Materials	ERIC Psych-INFO	Cinahl	Pubmed
Scale of Children's Readiness in Printing (SCRIPT)(Marr, 2005; Marr & Cermak, 2002; Weil & Amundson, 1994)	Kindergarten children	Measure a child's ability to copy manuscript alphabet letters.	Only one	34 (34)	0/1		no	Test booklet and pencil	5	0	4
Beery developmental test for Visual Motor Integration (Beery VMI) (Daly et al., 2003; Feder & Majnemer, 2007; Feder et al., 2005; Marr & Cermak, 2002; Short-DeGraff & Holan, 1992; Weil & Amundson, 1994)	2-18 y	Screening for visual motor deficits that can lead to learning, neuropsychological, and behavior problems.	<ul style="list-style-type: none"> Visual motor integration Visual perception Motor coordination 	90 (90)	0/1	25	no	Test booklets and pencil	262	38	49
Test of In-hand Manipulation - Revised (THIM-R) (Exner, 1993; Pehoski et al., 1997a, 1997b)		Measure a child's ability of in-hand manipulation skills (translation and rotation).	Only one	3 (3)	Timed task	10	no	Pegboard	2	1	5
Bruininks-Oseretsky Test of Motor Proficiency - second edition (BOT-2) (Deitz et al., 2007; Wuang, Lin, & Su, 2009; Wuang & Su, 2009)	4-21 y	Individually administered measure of gross and fine motor skills.	<ul style="list-style-type: none"> Fine manual control Manual coordination Body coordination Strength and agility 	53 (20)		45 - 60	no	Test kit	4	79	109
Movement Assessment Battery for Children-Second Edition (Movement ABC-2) (Brown & Lalor, 2009; Henderson et al., 2007)	3-16 y	Identifies, describes, and guides treatment of motor impairment.	<ul style="list-style-type: none"> Manual dexterity Ball manipulation skills Static and dynamic equilibrium 	8 (3)	6-point rating scale	20 - 40	no	Test kit	124	86	179

Test	Target population	Objective	Subscales	Number of items (nr of items on writing readiness)	Number of response options	Time to administer (min)	Training needed	Materials	ERIC Psych-INFO	Cinah	Pubmed
School Version of the Assessment of motor and Process Skills (School AMPS) (Fingerhut et al., 2002; Fisher et al., 2000)	3 - 12 y	Evaluation tool for student's school-work task performance in typical classroom settings.	<ul style="list-style-type: none"> . Pencil writing . Drawing/coloring . Cutting/pasting . Computer writing . Manipulative tasks 	2 (2)	4-point rating scale	60-80	1 week course and pencil	Test booklet and pencil	7	6	4
Motor Performance Checklist (MPC)(Gwynne & Blick, 2004; Gwynne et al., 1996)	5 y	Screening for gross and fine motor problems.	Only one	12 (3)	0/1	5	No	Checklist and pencil	1	0	2
Draw A Person: A Quantitative Scoring System (DAP:QSS) (Abell et al., 1996; Hall & Case-Smith, 2007; Planta & McCoy, 1997; Rae & Hyland, 2001; Short-DeGraff & Holan, 1992)	3 - 15 y	Measure of mental ability.	Only one	1 (1)	Counting body parts	15	No	Test booklet, paper and pencil	1034	17	181
Denver Developmental Screenings Test - 2nd edition (Denver II) (Bayoglu et al., 2007; Frankenburg et al., 1992)	0 - 6 y	Screening tool designed for children at risk with developmental problems.	<ul style="list-style-type: none"> . Gross motor . Language . Fine motor-adaptive . Personal-social 	125 (28)	0/1	20-30	No	Checklist, Interview, Observation	32	62	352
Writing Essential Skill Screener - Preschool Version (WESS-P) (Erford, 1997)	4 - 5 y	Screening for pre-school writing skills.							1	0	0
Nine Hole Peg Test (9HPT) (Poole et al., 2005; Smith et al., 2000)	5 - 11 y	Measures fine motor dexterity.	Only one	1 (1)	Timed task	5	No	Pegboard with 9 pegs	24	117	122
Maastricht's Motor Test (MMT) (Kroes et al., 2004)	5 - 6 y	Objectify qualitative and quantitative aspects of movement	<ul style="list-style-type: none"> . Static balance . Dynamic balance . Diadochokinetic . Manual dexterity 	70 (28)	3-point rating scale	30	No	Computer Test booklet	1	0	1

et al., 2005; Miyahara, Piek, & Barrett, 2006; Miyahara, Piek, & Barrett, 2008; Tseng & Chow, 2000), and the Denver II (Bayoglu, Bakar, Kutlu, Karabulut, & Anlar, 2007; Frankenburg, Dodds, Archer, Shapiro, & Bresnick, 1992). These tests evaluate fine and gross motor skills and include items of writing readiness.

Table 3. Results classified on level of occupation according to the TCOP.

	Occupations	Paper-and-pencil activities	Performance components	
			Fine motor coordination	Visual-motor integration
School-AMPS				
SCRIPT				
WESS-P				
TIHM-R				
9-HPT				
VMI				
DAP:QSS				
MPC				
M-ABC-2				
MMT				
BOT-2				
Denver-II				

BOT-2, Bruininks-Oseretsky Test of Motor Proficiency– second edition; Denver-II, Denver Developmental Screenings Test – 2nd edition; MMT, Maastricht’s Motor Test; MPC, Motor Performance Checklist; Preschool Version; DAP:QSS, Draw-A-Person: Quantitative Scoring System; School-AMPS, School Assessment of Motor and Process Skills; SCRIPT, Scale of Children’s Readiness in Printing; TIHM-R, Test of In-Hand Manipulation – Revised; VMI, Developmental test of Visual Motor Integration; WESS-P, Writing Essential Skill Screener – Preschool version; 9-HPT, Nine Hole Peg Test;

Psychometric properties of assessment tools

The psychometric properties for these 12 measures, which are based on an extensive and systematic literature search, are described in Table 2. The psychometric properties of an instrument are described according to the criteria of Terwee et al (Terwee et al., 2007; van de Ven-Stevens, Munneke, Terwee, Spauwen, & van der Linde, 2009). Based on the accepted criteria, none of the instruments demonstrated satisfactory results for all properties (Table 4). The BOT-2 and the Beery VMI showed the most satisfactory results in terms of psychometric properties.

Feasibility

Feasibility was evaluated according to the amount of administration time needed to complete the test, the equipment required, and the reliability of the recommended training time to administer the test. These items are summarized in Table 2. The School AMPS is the most time-consuming approach because it consists of an interview with the teacher, observation of two activities in the classroom, and interpretation of the scores. Training is required only for the School-AMPS.

Table 4. Description of psychometric properties of selected instruments

School-AMPS	
content validity	<ul style="list-style-type: none"> Fisher et al. (2000): two unidimensional scales are defined: a motor scale and a process scale ($MnSq \leq 1.4$, $z < 2$) ($n = 208$ children, 81 typically developing, 103 educational-related disabilities and 24 identified 'at risk' by their teacher, 3–15 years);
Intrarater reliability	<ul style="list-style-type: none"> Atchison et al. (1998): examination of the rater goodness-of-fit-statistics indicated strong intrarater reliability ($MnSq = 1.0$, $z = 0$) ($n = 54$ children, 22 typically developing and 32 identified disabled, 3–7 years); Fisher et al. (2000): five of the six raters demonstrated acceptable goodness-of-fit ($MnSq \leq 1.4$, $z < 2$) ($n = 208$ children, 81 typically developing, 103 educational-related disabilities and 24 identified 'at risk' by their teacher, 3–15 years);
construct validity	<ul style="list-style-type: none"> Fingerhut et al. (2002): Pearson correlation coefficients with the School-AMPS motor scale and the PDMS-FM: $r = .45$ and the School-AMPS process scale with the PDMS-FM: $r = .35$ ($n = 42$ typical developing children 5–7 years); Munkholm and Fisher (2008): Typically developing students scored significantly higher for school motor quality of performance measures compared to students with mild disabilities (mean difference = 0.49, $P < 0.001$, $d = 0.89$). Typically developing students also scored significantly higher for school process ability compared to students with mild disabilities (mean difference = 0.58, $P < 0.001$, $d = 1.09$) ($n = 350$, 175 typically developing students and 175 students with mild disabilities, 4–11 years);
Norm scores	<ul style="list-style-type: none"> Fisher et al. (2005) have collected normative data in children age between 3 and 21 years ($n = 1592$).
SCRIPT	
construct validity	<ul style="list-style-type: none"> Daly et al. (2003): Pearson correlation coefficient was used, and a significant relationship between the SCRIPT and the VMI was obtained with a $r = .64$, $p < 0.01$ ($n = 54$ typically developing children 4.9–5.9 years); Weil and Amundson (1994): Pearson correlation coefficient revealed a moderate correlation ($r = 0.47$, $p < .001$) between performances on the VMI and SCRIPT ($n = 59$, typical developing children, 5.3 – 6.2 years); Daly et al. (20043): Kruskal-Wallis test was used to demonstrate that students who copy the first nine forms on the VMI had significant higher scores on the SCRIPT (2-tailed, $p < 0.00$) ($n = 54$ typically developing children 4.9–5.9 years); Marr and Cermak (2002): Independent sample t test was used to demonstrate that students who copy the first nine forms on the VMI had significant higher scores on the SCRIPT ($n = 101$, typical developing children mean age 5.6 years); Weil and Amundson (1994): Mann-Whitney U-test was used to demonstrate a significant difference between groups of children in kindergarten who are able to copy the first nine forms of the VMI and children who are not able to copy the first nine forms of the VMI and their scores on the SCRIPT (2-tailed, $p = 0.02$) ($n = 59$, typical developing children, 5.3 – 6.2 years).
WESS-P	
internal consistency	<ul style="list-style-type: none"> Erford (1997): Kuder-Richardson-Formula 20 (KR-20) was used resulting in a total scale coefficient of 0.95 ($n = 563$, children 4–5 years old);
test-retest reliability	<ul style="list-style-type: none"> Erford (1997): Pearson correlation coefficient was 0.91 for the 30-day test-retest reliability ($n = 85$, children 4–5 years old);
construct validity	<ul style="list-style-type: none"> Erford (1997): Pearson correlation coefficient was used, and the significant relationship between the WESS-P and the VMI was $r = .82$, $p < 0.001$ and with the WESS-P and the Test of Early Written Language (TEWL) was $r = .85$, $p < 0.001$ ($n = 125$ children, 4–5 years old).
TIHM-R	
test-retest reliability	<ul style="list-style-type: none"> Pont et al. (2008) plotted the error bands of ability measure (measure score ± 1 SE) for each child

for the first and second TIHM-R testing occasions. Error bands for 22 of the 29 ability measures (75.86%) overlapped. Because this overlap was substantially lower than the desired 95%, adequate test-retest reliability of the TIHM-R was not supported ($n=45$ typically developing children, 5.5–6.5 years);

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| interrater reliability | – Pont et al. (2008) plotted the error bands of ability measure awarded by each rater to determine whether any differences in scores were likely to be the result of differences in the severity of the raters. The measure bands of all children overlapped when scored by two or more raters. Fortysix of the 100 data sets were given exactly the same overall ability measure by two or more raters. Very high interrater reliability of the TIHM-R was established ($n=45$ typically developing children, 5.5–6.5 years); |
| construct validity | – Pont et al. (2008) used Rasch modelling to have evidence for adequate construct validity, the goodness of item fit statistics for the TIHM-R with the collapsed rating scale revealed that all but one item (94.4%) conformed to the expectations of the Rasch model, which we deemed acceptable. |

9-HPT

- | | |
|-------------------------|--|
| Internal consistency | – not relevant, because the test consist of only one item;
Smith et al. (2000): correlation coefficients for the dominant and nondominant hand of r equal to 0.81 and 0.79, respectively, $p < 0.001$ ($n=503$ children, 5–10y); it is not described what correlation is calculated; |
| test-retest reliability | – Smith et al. (2000): correlation coefficient ($r=0.99$; $p<0.001$) for both hands ($n=416$ children, 5–10y); again, it is not clear what correlation is calculated; |
| interrater reliability | – Poole et al (2005): ICC equal to 0.98 for the dominant hand and 0.96 for the non-dominant hand ($n=20$, typically developing children 4–19 years); |
| construct validity | – Smith et al. (2000): significant inverse correlations were obtained ($r=-0.80$ and $r=-0.74$ for the dominant and non-dominant hand, respectively) between scores of the 9-HPT and the Purdue Pegboard Test ($n=236$ children 6, 8 and 10y); |
| Norm scores | – Smith et al. (2000) have collected normative data in children age between 5 and 10y ($n=826$);
– Poole et al. (2005) have collected normative data in children age between 4 and 19y ($n=53$). |

Beery-VMI

- | | |
|-------------------------|---|
| content validity | – Beery & Beery (2004): the Rasch-Wright results indicate high content reliability for the Beery VMI; its total group item separation was 1.00, and its total group person separation was 0.96 ($n= 50$ children, 3–17 years); |
| Internal consistency | – Beery & Beery (2004): the overall coefficient alpha results of 0.82 ($n=750$, children, 2–17 years); |
| test-retest reliability | – Beery & Beery (2004): the overall test-retest 10-day raw score coefficients were 0.89 for the Beery VMI, 0.85 for Visual Perception, and 0.86 for Motor Coordination, it is not described what correlation is calculated ($n=115$ children, 5–11 years); |
| interrater reliability | – Beery & Beery (2004): the interscorer reliabilities between two raters were 0.92 for the Beery VMI, 0.98 for Visual Perception, and 0.93 for Motor Coordination, it is not described what correlation is calculated ($n=100$ children, age is not described); |
| construct validity | – Beery (1997): a significant relationship between the Beery VMI and the WRAMA of $r=0.52$ and a significant relationship between the Beery VMI and the DTVP-2 Copying of $r=0.75$, and between the Beery VP and the DTVP-2 Position in Space of $r=0.62$, and between the Beery MC and the DTVP-2 Eye-hand Coordination of $r=0.65$ ($n= 122$ typical developing children, 5–11 years);
– Beery & Beery (2004): a significant relationship between the Beery VMI and the WISC-R Full IQ is $r=0.62$, and the Beery VP and the WISC-R Full IQ is $r=0.54$, and the Beery MC and the WISC-R Full IQ is $r=0.51$ ($n=17$ children with learning disabilities, 6–12 years);
– Beery (1997): a significant relationship between the Beery VMI and the CTBS Overall Total is $r=0.63$, and between the Beery VP and the CTBS Overall Total is $r=0.29$, and between the Beery MC CTBS Overall Total is $r=0.40$ ($n=44$ typically developing children 4th and 5th grade);
– Daly et al. (2003): Pearson correlation coefficient was used, and a significant relationship between the VMI and the SCRIPT was obtained with a $r=.64$, $p<0.01$ ($n=54$ typically developing children 4.9–5.9 years) |

- Weil and Amundson (1994): Pearson correlation coefficient revealed a moderate correlation ($r = 0.47$, $p < .001$) between performances on the VMI and SCRIPT ($n=59$, typical developing children, 5.3 – 6.2 years);
- Daly et al. (2003): Kruskal–Wallis test was used to demonstrate that students who copy the first nine forms on the VMI had significant higher scores on the SCRIPT (2-tailed, $p < 0.00$) ($n=54$ typically developing children 4.9–5.9 years);
- Marr and Cermak (2002): Independent sample t test was used to demonstrate that students who copy the first nine forms on the VMI had significant higher scores on the SCRIPT ($n=101$, typical developing children mean age 5.6 years);
- Weil and Amundson (1994): Mann–Whitney U–test was used to demonstrate a significant difference between groups of children in kindergarten who are able to copy the first nine forms of the VMI and children who are not able to copy the first nine forms of the VMI and their scores on the SCRIPT (2-tailed, $p = 0.02$) ($n=59$, typical developing children, 5.3 – 6.2 years);
- Beery & Beery (2004): have collected normative data in children age between 1 and 18 year ($n=2512$).

DAP:QSS

- | | |
|--------------------|---|
| Construct validity | <ul style="list-style-type: none"> - Saklofske and Tamaoka (1996): Results of this study indicated that that a general developmental trend was apparent ($n=400$, typically developing Japanese children, 6 – 12 years); - Saklofske and Tamaoka (1996): Correlation Coefficient between the MAT-SF and the DAP:QSS was for the DAP Man 0.52 ($P < 0.05$), for the DAP woman 0.47 ($P < 0.05$), for the DAP self 0.53 ($P < 0.05$) and for the DAP total score 0.56 ($P < 0.05$) ($n=400$, typically developing Japanese children, 6 – 12 years); - Saklofske and Tamaoka (1996): A factor analysis was conducted to: two factors accounted for 84% of the variance. First factor was Facial Features and the second factor was Upper Body and Clothing; |
| Norm scores | <ul style="list-style-type: none"> - Naglieri (1983): has collected normative data in 2587 North American children age between 5 and 17 year ($n=2512$). |

MPC

- | | |
|------------------------|--|
| Intrarater reliability | <ul style="list-style-type: none"> - Gwynne and Blick (2004): Pearson correlation coefficient was 0.77 ($P, 0.001$). A moderate correlation of 0.58 ($P, 0.01$) was found between the gross motor subscales and a high correlation of 0.73 ($P, 0.001$) was found between the fine motor subtotals ($n=19$, typical developing children, 5 years); |
| Interrater reliability | <ul style="list-style-type: none"> - Gwynne and Blick (2004): Pearson correlation coefficient between seven raters ranged between 0.79 and 0.99 with a mean of 0.93 ($n=19$, typical developing children, 5 years); |
| Construct validity | <ul style="list-style-type: none"> - Gwynne et al. (1996): Pearson correlation coefficient between the total score of the BOTMP and the MPC was 0.64 ($P < 0.005$) ($n=30$, typically developing children, 5 years); - Gwynne and Blick (2004): Pearson correlation between the total scores from the BOTMP and the MPC was 0.72 ($P < 0.01$). Pearson correlation between the gross motor subtest scores on the two tests was 0.58 ($P < 0.001$), and between the fine motor subtests was 0.60 ($P < 0.001$) ($n=141$, typically developing children, 5 years); - Gwynne and Blick (2004): Pearson correlation between scores below the composite standard score of 55 on the BOTMP and the MPC was 0.85 ($P < 0.001$) ($n=39$, typically developing children, 5 years); - Liljestrand et al. (2009): children who 'failed' the MPC had 7–10 point lower in the WPPSI-R subscales ($P < 0.001$), 9–10 points lower mean on the VMI-4 subscales ($P < 0.001$) ($n=339$, typically developing children and children whose total serum bilirubin level was at least 25 mg/dL in the first 30 days after birth and children who had been rehospitalised with dehydration within 15 days of birth recharge, 5 years) (Liljestrand et al., 2009). |

M-ABC-2

- | | |
|------------------|---|
| Content validity | <ul style="list-style-type: none"> - Henderson et al. (2007): was established by input of an expert panel. According the test manual, the expert panel was unanimous that the MABC-2 contents/items were representative of the |
|------------------|---|

	motor domain it was intended to evaluate;
Interrater reliability	– Chow et al. (2002): ICC varied from 0.92 to 1.0 (n=31, Chinese adolescents, 11–16 year);
	– Faber and Nijhuis-van der Sanden (2004): ICC was 0.79 (n=64, young adults);
Intrater reliability	– Faber and Nijhuis-van der Sanden (2004): ICC was 0.79 (n=64, young adults)
Test–retest reliability	– Visser and Jongmans (2004): Pearson Product Moment Correlation results ranged from 0.49 to 0.70 (n=55, typically developing children, 3 years);
	– Chow et al. (2002): ICC varied from 0.62 to 0.92 (n=31, Chinese adolescents, 11–16 year);
	– Henderson et al. ⁵³ : Pearson Product Moment Correlation results ranged from 0.86 to 0.91 for the three manual dexterity tasks while the Aiming and Catching tasks were less reliable with coefficients of 0.48 and 0.68 (n=20, typically developing children, 3 years);
	– Henderson et al. (2007): Pearson Product Moment Correlations for the three age bands were 0.77 (Manual Dexterity), 0.84 (Aiming and Catching), 0.73 (Balance) and 0.80 (total test score). This indicates reasonable test–retest reliability for the MABC–2 (n=60, typically developing children, 20 from each age-band);
	– Henderson et al. (2007): children identified who having motor impairment using the M-ABC and were re-assessed using the M-ABC–2 and continued to demonstrate motor impairment (n=20, children with motor impairment, age wasn't mentioned);
Construct validity	– Frijters et al. (2010): Correlation between the BSID-II-NL-M and the M-ABC–2 is $r_s=0.70$ ($P<0.01$) (n=28, typically developing children);
	– Jelsma et al. (2010): Correlation between the BOT–2 and M-ABC–2 is $r_s=0.58$ ($P<0.001$) (n=80, typically developing children);
	– Van Beek et al. (2010): Correlation between the KTK and the M-ABC–2 is $r_s=0.62$ ($P<0.001$) (n=49, typically developing children, 11–16 year);
	– Henderson et al. (2007): have collected normative data in children age between 3 and 16 year (n=1172).

MMT

Intrater reliability	– Kroes et al. (2004): ICC varied from 0.95 for the qualitative score, 0.93 for the quantitative score, to 0.96 for the total score (n=42, typically developing children and children with ADHD and ODD/CD, 5–6 years);
Interrater reliability	– Kroes et al. (2004): ICC varied from 0.92 for the qualitative score, 0.97 for the quantitative score, to 0.96 for the total score (n=24, typically developing children and children with ADHD and ODD/CD, 5–6 years);
Test–retest reliability	– Kroes et al. (2004): ICC varied from 0.61 for the qualitative score, 0.74 for the quantitative score, to 0.74 for the total score (n=43, typically developing children and children with ADHD and ODD/CD, 5–6 years);
Construct validity	– Kroes et al. (2004): Mann Whitney U test was used to demonstrate discriminative validity between children with deviant performance (according to the school doctor's judgment) and children with a normal performance: the normal group scored significantly better ($P<0.001$) on total quality, total quantity and total score (n=487, typically developing children and children with ADHD and ODD/CD, 5–6 years).

BOT–2

Content validity	– Deitz et al. (2007): was examined using Rasch Analysis and factor analysis: items were retained, revised and deleted. Further evidence was provided by the developmental progression of medial subtest scores across age groups. As expected, the greatest increases were noted during the early years (the number and age of the population were not mentioned);
Internal consistency	– Deitz et al. (2007): was examined using the stratified alpha method for each composite and the split-half method for each subtest. These were high (≥ 0.93) for the Total Motor Composite. For the Short Form, these were generally acceptable (≥ 0.80) for all age groups, except for the 4 and 8 year old. For the subtests for individual age groups, internal consistency were borderline to high and correlations range from 0.60 to 0.92 (n=1520, typically developing children, 4–21 years);
	– Wang and Su (2009): Cronbach's alpha of the BOT–2 total score was excellent: 0.92, coefficient alpha ranged from 0.81 to 0.88 for the subtests and 0.87–0.88 for the composites (n=100,

Interrater reliability	children with intellectual disabilities (IQ<70), 4–12 years);
	– Deitz et al. (2007): Pearson correlation coefficient using two raters were good for the Short Form and for all Complete Form subtests and composites. With one exception (the Fine Motor Precision subtest, $aa\ jr=0.86$), they were all >0.90 ($n=47$, typically developing children, 4–21 years);
Test–retest reliability	– Deitz et al. (2007): Pearson correlation coefficient were ≥ 0.80 for the Total Motor Composite, the Short Form (with knee push-ups) and the Short Form (with full push-ups), for three of the composites (Fine Manual Control, Manual Coordination, and Body Coordination) and for their related subtests were highly variable, with 7 of the 9 correlations, <0.80 for the composites and 16 of the 18 correlations, <0.80 for the subtests. The reliability coefficients for the remaining composites (Strength and Agility with knee-pus-ups and full push-ups) and their related subtests were all >0.80 ($n=134$, typically developing children, 4–21 years);
	– Wuang and Su (2009): ICC varied between 0.88 and 0.99 for the subtests and the composites, the ICC for the total score was 0.99 ($n=100$, children with intellectual disabilities (IQ<70), 4–12 years);
Construct validity	– Deitz et al. (2007): correlation between the BOTMP and the BOT–2 was strong: $aa\ jr=0.80$, the correlation between the fine motor composite on the BOTMP and the BOT–2 was moderate: $aa\ jr=0.60$ ($n=49$, Typically developing children, 6–14 year);
	– Deitz et al. (2007): correlation between total scores on the BOT–2 scores and PDMS–2 scores were moderate to strong: $aa\ jr=0.73$, fine motor scores on both tests: $aa\ jr=0.51$ ($n=38$, typically developing children, 4–5 years);
	– Deitz et al. (2007): adjusted correlation between the BOT–2 fine motor integration and the TVMS–R Visual Motor Skills was 0.74 ($n=56$, typically developing children, 4–13 years);
Responsive–ness	– Wuang and Su (2009): The BOT–2 total score had an SRM of 0.54 and ES of 0.67. The SRM for the composites ranged from 0.31 to 0.73, with lower SRM for body coordination composite. The ESs are of similar magnitude to the SRMs. The MDC (90%CI) for the total score was 4.18, implying that in 90% of the cases we can state that a change of a child's total score with less than 4 points is just a result of measurement error. The MDC–values for the subtests ranges from 0.67 to 1.70 and 1.36–1.87 for the composites ($n=100$, children with intellectual disabilities (IQ<70), 4–12 years);
Norm scores	– Bruininks and Bruininks (2005): have collected normative data in children age between 4 and 21 year ($n=1520$).

Denver–II

Interrater reliability	– Frankenburg et al. (1992): to determine if agreement was better than change the K statistics was calculated: $K \geq 0.75$ ($n=34$, typically developing children, age is not described)
Test–retest reliability	– Frankenburg et al. (1992): for the 7– to 10 days test–retest reliability, 59% of the Denver–II items had excellent agreement: $K \geq 0.75$, and 23% were in the fair to good range: $K \geq 0.40$ ($n=34$, typically developing children, age is not described)
Construct validity	– Was not performed because the Denver–II is not a test of some hypothetical construct ⁶¹
Norm scores	– Frankenburg et al. (1992): have collected normative data in children age between 0 and 6 y ($n=2096$)

Note: if no information was available on the psychometric properties of an instrument, this property is not mentioned.

9–HPT, Nine Hole Peg Test; BOTMP Bruininks–Oseretsky Test of motor Proficiency; BOT–2 Bruininks–Oseretsky Test of motor Proficiency–second edition; BSID–II–M, Bayley Scales of Infant Development–second edition Motor Scale; CTBS, Comprehensive Test of Basic Skills; Denver–II, Denver Developmental Screenings Test – 2nd edition; DTVP–2, Developmental Test of Visual Perception – second edition; DAP:QSS, Draw–A–Person: Quantitative Scoring System; KTK, Körper Koordinationstest für Kinder; M–ABC–2, Movement Assessment Battery for Children; MAT–SF, Matrix Analogies Test–Short Form; MMT, Maastricht's Motor Test; MPC Motor Performance Checklist; PDMS–FM, Peabody Developmental Motor Scales – Fine Motor; School AMPS, School Assessment of Motor and Process Skills; SCRIPT, Scale of Children's Readiness in Printing; TEWL, Test of Early Written Language; TIHM–R, Test of In–Hand Manipulation – Revised; VMI, Developmental test of Visual Motor Integration; WESS–P, Writing Essential Skill Screener – Preschool Version; WISC–R, Wechsler Intelligence Scale for Children – Revised; WRAYMA, Wide Range Assessment of Visual Motor Ability

Table 5. Summary evaluation of psychometric quality.

Instrument	Internal consistency	Agreement	Test-retest Reliability	Intrarater Reliability	Interrater Reliability	Content Validity	Construct Validity	Criterion Validity	Responsiveness
School AMPS	0	0	0	+R	0	+R	+	0	0
SCRIPT	0	0	0	0	0	0	+	0	0
WESS-P	+	0	?	0	0	0	?	+	0
TIHM-R	0	0	-	+R	0	0	+R	0	0
9-HPT	?	0	?	0	?	0	?	0	0
Beery-VMI	+	0	?	0	?	+	+	0	0
DAP:QSS	0	0	0	0	0	0	+	0	0
MPC	0	0	0	?	?	0	+	0	0
M-ABC-2	0	0	?	?	?	+	+	0	0
MMT	0	0	+	+	?	0	+	0	0
BOT-2	+	0	+	0	+	+	+	0	?
Denver-II	0	0	?	0	?	-	0	0	0

NOTE In conformation with the quality criteria for measurement properties of Terwee et al29: rating: +, positive rating; ?, indeterminate rating (doubtful design); -, negative rating; 0, no information available. NB Doubtful design or method equals the lacking of a clear description of the design or methods of the study, sample sizes smaller than 50 subjects (should be at least 50 in every [subgroup] analysis), or any important methodological weakness in the design or execution of the study.

+*Design and results are adequate, but $30 \leq n \leq 50$

+R established with Rasch-analysis

9-HPT, Nine Hole Peg Test; BOT-2, Bruininks-Oseretsky Test of motor Proficiency-second edition; Denver-II, Denver Developmental Screen-ings Test - 2nd edition; DAP:QSS, Draw-A-Person: Quantitative Scoring System; M-ABC-2, Movement Assessment Battery for Children; MMT, Maastricht's Motor Test; MPC Motor Performance Checklist; School AMPS, School Assessment of Motor and Process Skills; SCRIPT, Scale of Children's Readiness in Printing; TIHM-R, Test of In-Hand Manipulation - Revised; Beery VMI, Developmental test of Visual Motor Integration; WESS-P, Writing Essential Skill Screener - Preschool Version;

DISCUSSION

This two-step systematic review of tests to assess handwriting readiness in 5- and 6-year-old kindergarten children identified 12 measures with the School-AMPS as the only occupation-based assessment. None of the tests reviewed fulfilled all of the criteria outlined against the TCOP, psychometric properties and feasibility.

The School-AMPS is the only test that assesses paper-and-pencil tasks at the level of occupation, activities and performance components, according to the levels of the TCOP. The importance of children's participation in life situations is gaining greater attention in the area of paediatric allied health care (Sakzewski, Boyd, & Ziviani, 2007). Therefore, we searched the literature for an occupation-based assessment of pre-writing activities useful in the natural school setting where the environmental context can be evaluated (Dunn, 2005). Unfortunately, the School-AMPS does not comply with all the levels of the TCOP. There is no opportunity in the School-AMPS to assess the qualitative ergonomic factors of paper and pencil tasks, such as information about a static or dynamic pencil grasp and information on an eventually forced arm/hand position, which are important factors to evaluate during this developmental period of pencil grip and wrist pattern (Edwards et al., 2002). Furthermore, the School-AMPS does not evaluate visual-motor integration, which is another important underlying component of writing readiness, identified in the literature (Volman et al., 2006).

From the three tests which evaluated paper-and-pencil tasks, copying ability, the domain of the SCRIPT, plays an influential role in the primary stages of learning letter formation (Weil & Amundson, 1994). Copying letters is believed to represent the majority of handwriting activities performed by children in kindergarten (Marr, Cermak, Cohn, & Henderson, 2003), so this task should be included in an evaluation of writing readiness. Own name writing, an item in the WESS-P, is an important early measure of emergent writing skill (Cabell, Justice, Zucker, & McGinty, 2009). Children learn how to print letters from their experience of writing their own name (Levin, Both-De Vries, Aram, & Bus, 2005). Consequently, own name writing should be a specific part of the assessment of writing readiness.

The DAP:QSS, a figure drawing assessment, is used as an indicator of cognitive level, socio-emotional development, and personality (ter Laak, de Goede, Alewa, & van Rijswijk, 2005), as well as an indicator of intelligence (Abell et al., 1996). The test was not developed to be an indicator of early writing readiness; therefore, we do not recommend that the DAP:QSS should be part of a writing readiness assessment.

The two tests of fine motor coordination at the level of performance components that assess dexterity are the 9HPT and TIHM-R. Time as duration of a task is the most widely used index of dexterity and, therefore the 9HPT is easy to use as a dexterity test (Smith et al., 2000). In-hand manipulation is considered to be an qualitative essential component of

fine motor skills (Ziviani & Wallen, 2006). A positive relation between in-hand manipulation and the performance of functional activities such as handwriting, and the use of scissors and cutlery, has been widely hypothesized (Breslin & Exner, 1999). Case-Smith (1991, 1993) found that the time taken to rotate and translate pegs could be used to distinguish between children with and without fine motor delay (Case-Smith, 1991, 1993). Because the TIHM-R evaluates fine motor coordination in a qualitative and quantitative way, this test should be part of the assessment of writing readiness.

The Beery VMI is a test often used internationally for the evaluation of visual-motor integration. This test has been demonstrated to be particularly useful for the assessment of writing readiness in 5- and 6-year-old children (Marr & Cermak, 2002). Therefore, this test should be part of the assessment of writing readiness.

General motor tests, such as the MPC, M-ABC-2, MMT, BOT-2, and Denver II, evaluate fine and gross motor skills, including items of writing readiness. Only the M-ABC-2 and the BOT-2 have sub-tests with a total score on fine motor, an important performance component of writing readiness. The BOT-2 has eight items on fine motor skills whereas the M-ABC-2 has only three, suggesting that the fine motor score of the BOT-2 is more stable. This attribute has been confirmed by the authors of the M-ABC-2, who recommend caution in drawing conclusions based solely on manual dexterity items (Henderson et al., 2007). The fine motor part of the BOT-2 and the M-ABC-2 should be a part of the assessment of writing readiness. The MPC, MMT and Denver II all have some items on fine motor and paper-and-pencil tasks. If these items are to be used as part of a writing readiness evaluation, research must be carried out to validate their effectiveness as part of such an assessment.

Based on content, the following seven tests should be useful in an assessment of writing readiness: the School-AMPS, SCRIPT, WESS-P, TIHM-R, Beery VMI, the M-ABC-2 and the fine motor part of the BOT-2.

Feasibility is one of the most significant variables influencing the actual use of an outcome measure in daily practice (Law, King, & Russell, 2005). A quick, inexpensive, and nonintrusive assessment can be implemented in daily practice without impediment and is feasible for therapists. However, the only occupation-based assessment in this review, the School-AMPS, does have a problem: to become a reliable and validated administrator of the School-AMPS, occupational therapy practitioners have to participate in a 1-week training course and become calibrated as a reliable rater. Rater calibration is a procedure that allows the AMPS Project International to determine each rater's competency and whether or not they are scoring the School-AMPS in a valid and reliable manner. This is a time-consuming and financially burdensome criterion that may be a barrier for some practitioners in daily practice.

In terms of psychometric properties, none of the instruments demonstrate satisfactory

results for all properties, according to the described criteria (Terwee et al., 2007). From the seven tests that can be useful in an assessment of writing readiness, the BOT-2 and the Beery-VMI show the most satisfactory results on psychometric properties. All seven instruments that can be used to assess aspects of writing readiness describe research on construct validity. Only the BOT-2 shows positive ratings on test-retest and inter-rater reliability, and the M-ABC-2 and the Beery VMI show doubtful scores on these aspects. Inter-rater and test-retest reliability are both very important aspects of the stability of a test and the basis for further psychometric research (Streiner & Norman, 2008). However until further reliability and validity studies are completed, therapists should be cautious in coming to clinical decisions related to writing readiness of children based solely on SCRIPT, WESS-P and TIHM-R results.

There are several potential limitations to this review. Articles were included only if they were published in English, German or Dutch. Therefore, some assessments may have been excluded. The first selection was made on abstracts; thus, it is theoretically possible that a handwriting readiness test could have been missed. However, we checked the reference lists from the included articles so this is unlikely. The search revealed very well-known tests that have proven useful for assessing parts of the components of writing readiness. Finally the rating for Table 4 was performed only by the first author and, therefore, may be potentially biased.

CONCLUSION

The results of this systematic review identified only one occupation-based assessment that assesses different aspects of writing readiness suitable for kindergarten children aged 5 and 6 years, namely the School-AMPS. However, the School-AMPS does not evaluate important aspects of the activity and performance component level, such as the ergonomic aspects of arm/hand position and pencil grip and visual motor integration, and it requires training to administer. Therefore, an all-encompassing, feasible assessment instrument needs to be developed in order to enable testing of the writing readiness at all the levels of the TCOP and to allow tailored advice and interventions. The results of this systematic review identify test items, which may be useful in the development of a comprehensive evaluation tool of writing readiness in children.

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Chapter 4

Development of the Writing Readiness Inventory Tool In Context (WRITIC)



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ABSTRACT

This article describes the development of the Writing Readiness Inventory Tool In Context (WRITIC), a measurement evaluating writing readiness in Dutch kindergarten children (5 and 6 years old). Content validity was established through 10 expert evaluations in three rounds. Construct validity was established with 251 children following regular education. To identify scale constructs, factor analysis was performed. Discriminative validity was established by examining contrast groups with good ($n = 142$) and poor ($n = 109$) performers in paper-and-pencil tasks. Content validity was high with 94.4% agreement among the experts. Two reliable factors were found in the performance of paper-and-pencil tasks with Cronbach's alphas of 0.82 and 0.69 respectively. The contrast groups differed significantly in two WRITIC subdomains: "Sustained attention" and "Task performance". Our findings indicated that the WRITIC is feasible for use in the classroom.

INTRODUCTION

Handwriting is an important skill to learn during the first years at school. It is essential for the child's participation in school and is closely related to learning to read and spell (Longcamp et al., 2008). The functional skill of handwriting supports the academic task of writing and allows students to convey written information legibly and efficiently while accomplishing written school assignments in a timely manner (Berninger & May, 2011). The prevalence of handwriting problems has been estimated to range between 5% and 30% depending on grade, selection criteria and the assessment instruments used (Overvelde et al., 2011). Handwriting difficulties can have a negative effect on a child's academic performance and self-esteem (Ratzon, Efraim, & Bart, 2007). Learning the mastery of handwriting requires sufficiently developed performance components, such as visual-motor integration and fine motor coordination (Overvelde et al., 2011; Volman, van Schendel, & Jongmans, 2006). A recent systematic review provides evidence that interventions that involve handwriting practice are effective in improving handwriting in children (Hoy, Egan, & Feder, 2011).

In the Netherlands, 5–6 years old children learn prewriting skills in kindergarten. In this phase, they learn to produce different writing patterns, to use an appropriate dynamic pencil grip and an adequate sitting posture. In grade one children receive instruction in unjoined cursive script and later on with joined cursive script. A few years ago, we developed a Dutch structured observation: Screening Prewriting [Skills] Occupational Therapy (SPOT) for 5- and 6-year-old kindergarten children. In SPOT, seven paper-and-pencil tasks are observed on performance (quality of sitting posture and pencil grip) and on product (quality of results). Thereby three motor tasks are observed: cutting, in-hand manipulation, and crossing midline of the body. The content and feasibility of SPOT have been evaluated and validated using the consensus technique through a Delphi survey of two expert rounds (van Hartingsveldt, Cup, & Corstens-Mignot, 2006). Although SPOT is extensively used by pediatric occupational and physical therapists in the Netherlands and Belgium, there is a lack of an international quantitative valid assessment for writing readiness which can be used in the prewriting phase. An instrument is needed which has a clear cut-off point that evaluates writing readiness in the context of the classroom, and is able to discriminate between children who are ready to learn the mastery of handwriting and children who are not. Therefore, we started to develop an occupation-based, valid, reliable, and evaluative quantitative instrument to assess writing readiness. In case of not ready for handwriting according to this instrument, therapists can give tailored advice to teachers to support children or they can offer an intervention. Interventions to support the child's participation include adaptations in the child's physical and social environment, task-oriented training with enough practicing time and demonstrating strategies that enhance participation of children in paper-and-pencil tasks (Hoy et al., 2011; Missiuna et al., 2012). This way the child becomes more ready for handwriting and potential negative influences caused by writing difficulties may be prevented.

Development of the Writing Readiness Inventory Tool In Context (WRITIC)

Kielhofner (2006) distinguished five steps in test development: (1) Identify the need for an instrument, (2) Identify purpose and population, (3) Specify the underlying construct, (4) Plan how the construct will be defined: develop items and supporting materials and pilot the instrument, and (5) Establish content validity and empirically assess reliability and validity.

For the first step, a systematic literature review was performed to find psychometrically sound standardized tests to assess handwriting readiness in 5- and 6-year-old children on the levels of occupations, activities/tasks, and performance components. Although we found 12 tests, most focused on visual-motor integration and fine motor skills; none of the instruments included all the components necessary to assess writing readiness. We concluded that a feasible, valid, and reliable occupation-based assessment to screen writing readiness was lacking (van Hartingsveldt, Aarts, de Groot, & Nijhuis-Van Der Sanden, 2011).

In the second step, the purpose of the new instrument was defined: evaluating writing readiness and discriminating between children who are ready to learn handwriting and children who are not. The instrument should be feasible and easy to administer by pediatric therapists. The target population includes those kindergarten children aged 5 to 6 years old whose teachers judged that they might not be ready to learn handwriting. In the Netherlands, children pass into Grade 1 in the year they reach the age of six.

In the third step, the underlying construct was specified. Based on the interaction perspective, as proposed in the Person Environment Occupation (PEO) Model (Law et al., 1996), the instrument contains three domains: 'Child', 'Environment', and 'Paper-and-pencil tasks'. These correspond with the three interacting circles 'Person', 'Environment', and 'Occupation' of the PEO model. When these circles overlap, there is a goodness of PEO fit that refers to optimal occupational performance. The focus of WRITIC is on specific testing in the domain 'Paper-and-pencil tasks', the other two domains are generally screened. Based on the Taxonomic Code of Occupational Performance (TCOP) (Polatajko et al., 2007), writing readiness is assessed at the level of 'occupation', 'activity', and 'task'.

In the fourth step, the construct was defined by developing the content of the test on basis of SPOT extended with knowledge related to the theoretical construct. For each domain the items and supporting materials were developed: the manual, the writing booklet, the standardized instruction, and the scoring booklet.

Two pilot studies were performed in kindergarten children of 5 and 6 years old with drafts of WRITIC. A proof of principle in discriminative validity ($n = 40$) using the extreme group design showed that the domain 'Paper-and-pencil tasks' significantly distinguished between groups with well-developed and poorly developed writing readiness ($p = .008$)

(Vries, Wright, & Lovelock, 2009). In addition, two reliability studies were carried out (both $n = 40$) using the method of Bland and Altman. The first study showed good and the second showed variable inter-rater reliability (Stroomer et al., 2010). Due to these pilot studies, WRITIC was revised; the latter version is used in this study.

The purpose of this study was to examine content validity, construct validity, and the feasibility of using WRITIC with kindergarten children, 5 and 6 years old.

METHOD

Research design

A two-phased study was carried out to evaluate content and construct validity and feasibility. Content validity indicates whether the instrument samples all the relevant or important content or domains (Streiner & Norman, 2008). Content validity was established using the Delphi technique, including anonymous evaluation, consecutive rounds of questions with controlled feedback and a statistical group outcome (Powell, 2003). Construct validity refers to the capacity of an instrument to measure the intended underlying construct (Streiner & Norman, 2008). Construct validity was established with factor analysis and discriminative validity with an extreme-groups design (Streiner & Norman, 2008). Feasibility involves the time taken, the child burden, and the impact on the class climate. (Dekker, Dallmeijer, & Lankhorst, 2005). Therefore, feasibility was assessed by recording administration time, the opinions of the children on a three-point scale, and by asking about the experience of the teacher. All participants provided informed consent.

Content validity

Participants

Ten Dutch experts in handwriting were approached: four paediatric occupational therapists, three occupational therapy researchers, one paediatric physical therapist, one developmental psychologist, and one specialized classroom teacher in elementary school. All agreed to participate.

Instrument

The Writing Readiness Inventory Tool In Context (WRITIC) is a quantitative measurement to be administered in the classroom while the child is sitting at his/her own school desk and using his/her own pencils. WRITIC contains three domains: (1) Child, (2) Environment, and (3) Paper-and-pencil tasks (see Figure 1):

1. The 'Child' domain contains six questions for the child regarding frequency, interest and perceived competence of drawing/colouring and handwriting and an item scored by the tester on sustained attention during performance of the WRITIC. All items are scored on a three-point scale (2 = good, 1 = doubtful, 0 = insufficient).
2. The 'Environment' domain contains three items, two on physical environment (desk height and chair size) and one regarding the social context (class climate), all scored on a three-point scale (2 = good, 1 = doubtful, 0 = insufficient).
3. The 'Paper-and-pencil tasks' domain contains 14 items on performance (quality of sitting posture and pencil grip) and seven items on product (quality of results). The child is asked to complete a drawing booklet containing five paper-and-pencil tasks. One task requires arm movements (tracing double-line paths), two tasks require wrist movements (colouring and making prewriting patterns), and two tasks require movements of the thumb and fingers (printing own name and

copying numbers and letters). The tester scores performance on the items while observing the child. As all items are scored three times (movements of the arm, movements of the wrist, and movements of the thumb and finger) on a three-point scale, these scores are summarized on a seven-point scale (0 to 6). The items on product are scored afterwards on a three-point scale (2 = good, 1 = doubtful, 0 = insufficient).

A higher score indicates a better performance for each subdomain of the WRITIC.

Domains WRITIC	Subdomains WRITIC	
Child	Interest Questoinnaire 6 items 3-point scale Range 0-12	Sustained attention Scored by tester 1 items 3-point scale Range 0-2
Environment	Physical Scored by tester 2 items 3-point scale Range 0-4	Social Scored by tester 1 items 3-point scale Range 0-2
Paper-and-pencil tasks	Task Performance† Scored by tester 7 items 3-point scale 6 items 7-point scale Range 0-50	Intensity of performance Scored by tester 4 items 7-point scale Range 0-24

† norm-referenced part of the WRITIC

Figure 1. Overview of (sub)domains of the Writing Readiness Inventory Tool In Context with their amount of items, sort of scale and range.

Procedure

In three rounds, online closed questions with an opportunity for remarks were sent to the experts. Using a four-point scale, they rated relevance, coverage and clarity of the potential WRITIC domains, items and scoring criteria. After each round, the percentage agreement among participants was calculated for each item. Two researchers processed the comments of the participants. Every round new questions were included based on the textual changes that were made. Thereby, we processed controlled feedback to the experts, comprising a summary of the percentage agreement, textual changes and an explanation of the choices (Powell, 2003).

Data analysis

Descriptive statistics were used to calculate agreement in each Delphi round. We aimed to reach a consensus with a minimum of 80% agreement (Powell, 2003).

Construct validity

Participants

To recruit participants, we sent letters to the heads of elementary schools to ask for participation in our studies. Once we received consent, we asked kindergarten teachers of these schools to select children. In this study, 252 kindergarten children, 5- and 6-years-old, were selected; 33 teachers in the west and east of the Netherlands selected four children and 20 teachers in the east of the Netherlands selected six children with either good or poor performance in paper-and-pencil tasks based on their own professional opinion. Following the selection of the children, we asked the teachers to fill in the Checklist of Fine Motor Skills (van Hartingsveldt, Cup, & Oostendorp, 2005) for each child, so we could validate that we had two different groups. This checklist includes items on prewriting and fine motor skills. Children with a diagnosis of visual/auditory impairment, influencing completion of WRITIC, were excluded.

Formal ethical approval was provided by the local ethical committee. The studies were in full compliance with the Committee on Research Involving Human Subjects (known by its Dutch initials, CMO) of the Arnhem and Nijmegen area.

Procedure

Children were individually assessed in the classroom during the time that all children were doing different tasks in small groups. The test administrators included seven occupational therapy students, three paediatric physical therapists and one paediatric occupational therapist. To become competent in administering WRITIC, they: (1) attended training provided by the first author, (2) practiced WRITIC with two children with typical development, and (3) checked their administration of WRITIC against a videotaped administration with the first author.

Data analysis

Descriptive statistics were used to characterize participants' demographic attributes. Construct validity was examined in two ways. To identify scale constructs, a principal component analysis (PCA) with orthogonal rotation (varimax) was performed. PCA is a multivariate technique for identifying the linear components of a set of items and how each item might contribute to the established factor. Orthogonal rotation is a statistical technique to ensure that the items are loaded maximally to only one factor (Field, 2009). We did the PCA on the 21 items of the domain 'Paper-and-pencil tasks' because we expected this to be the discriminative part. Cronbach's alpha was calculated for the established factors; a value above 0.7 was considered appropriate.

Discriminative validity of WRITIC and the Checklist of Fine Motor Skills were established using the Mann–Whitney test for two independent samples. The p values were set at $\leq .05$. We expected significant differences in the domains 'Child' and 'Paper-and-pencil tasks', but not in the domain 'Environment'. The analysis was performed using SPSS 16.0.

Feasibility

The feasibility of using WRITIC was established with a subgroup of 60 children, 35 boys and 25 girls. Feasibility was assessed by recording administration time and by evaluating to what extent children liked WRITIC with a three-point scale: very much, a little, or not at all. Teachers were asked for the impact on the class climate. Descriptive statistics were used in the analysis.

RESULTS

Content validity

All 10 experts returned the three online questionnaires. Most remarks concerned the clarity of the scores. A few items judged as inappropriate during the first expert round were removed from WRITIC. Consensus regarding the content of WRITIC (relevance, coverage and clarity of items) increased from a mean of 86.2% in the first round, and 92.0% in the second round, to a mean of 94.4% in the last round, with a consensus of 94% for the 'Child' domain, 95% for the 'Environment' domain, and 95% for the 'Paper-and-pencil tasks' domain.

Construct validity

Participants

After parents signed informed consent, 251 children were included. Only one child could not be included because of missing informed consent. The teachers selected two contrast groups; neither group was equal, since teachers sometimes selected more children with good performance ($n = 142$) as opposed to children with poor performance ($n = 109$). In the group of poor performers, 80% were boys ($n = 87$) and 20% were left-handed ($n = 22$). In the group of good performers, 31% were boys ($n = 44$) and 11% were left-handed ($n = 16$) (see Table 1).

Table 1. Descriptive data for the total group with poor and good performers^a ($N = 251$).

Group	Mean age (months)	Age range months)	Number of boys	Number of girls	Left- handed	Right- handed	Variable handed
Total group) ($n = 251$)	69.4	56–86	131 (52%)	120 (48%)	38 (15%)	210 (84%)	3 (1%)
Poor performers ($n = 109$)	69.1	56–86	87 (80%)	22 (20%)	22 (20%)	86 (79%)	1 (1%)
Good performers ($n = 142$)	69.6	56–78	44 (31%)	98 (69%)	16 (11%)	124 (87%)	2 (2%)

^a Poor and good performers as rated by the teacher

Factor analysis and internal consistency

A PCA revealed six factors with eigenvalues over 1.0 accounting for 59% of the cumulative variance. Eigenvalues are calculated. An eigenvalue is a mathematical index showing how the variance in the factor matrix is distributed (Field, 2009). The screen plot revealed that although the six factors had eigenvalues higher than 1, the eigenvalue dropped dramatically after the extraction of the first two decisive factors (eigenvalues of the first and second

factors were 4.97 and 2.48, respectively). The remaining four other factors were too small and not clinically relevant. Based on the initial PCA with two decisive factors, a two-factor structure was explored. Varimax rotation with a two-factor solution explained 35.5% of the existing variance. The two factors that emerged retained 17 of the 21 items (see Table 2). The first factor, named 'Task performance', accounted for 24% of the variance, containing all items on products of the paper-and-pencil tasks and six items on performance. The second factor, named 'Intensity of performance', accounted for 12% of the variance, containing four items associated with a relaxed versus forced position. Coefficient alpha was calculated to determine the internal consistency for each of the two factors which were $\alpha = 0.82$, and $\alpha = 0.69$ respectively, and the overall Cronbach's alpha was 0.73 (see Table 2). On the basis of the factor analysis two subdomains were defined: 'Task performance' and 'Intensity of performance'.

Table 2. Rotated component matrix domain 'Paper-and-pencil tasks' ($N=251$).

Items	Component 1 Task performance	Component 2 Intensity of performance
Copying numbers and letters	0.732	
Distal vs. proximal movement	0.673	
Tracing double-line paths	0.667	
Writing name	0.662	
Making spiral movements	0.650	
Making garlands	0.602	
Forearm position	0.600	
Type of pencil grip	0.599	
Coloring the picture	0.564	
Making arcades	0.525	
Sitting posture	0.455	
Wrist position	0.443	
Other hand	0.425	
Intensity of pencil grip		0.774
Pencil pressure		0.747
Shoulder position		0.613
Distance nose – table		0.572
Eigenvalues	4.97	2.48
Total variance explained	23.70	11.80
Reliability: Cronbach's alpha	0.82	0.69

Discriminative validity with extreme-groups methods

On the Checklist of Fine Motor Skills the score of poor performers ($Mdn = 6$) differed significantly ($U = 893.50$, $p < .001$) from good performers ($Mdn = 0$). On WRITIC the

difference in writing readiness between the poor performers ($Mdn = 37$) differed significantly ($U = 11.78$, $p < .001$) from good performers ($Mdn = 43.5$) (see Table 3 and Figure 2) for the items in the subdomain 'Task performance'. Also, for the subdomain 'Sustained attention' we found a significant difference ($U = 9.54$, $p < .001$), where 93% of the good performers versus 64% of the poor performers had a good score on "Sustained attention".

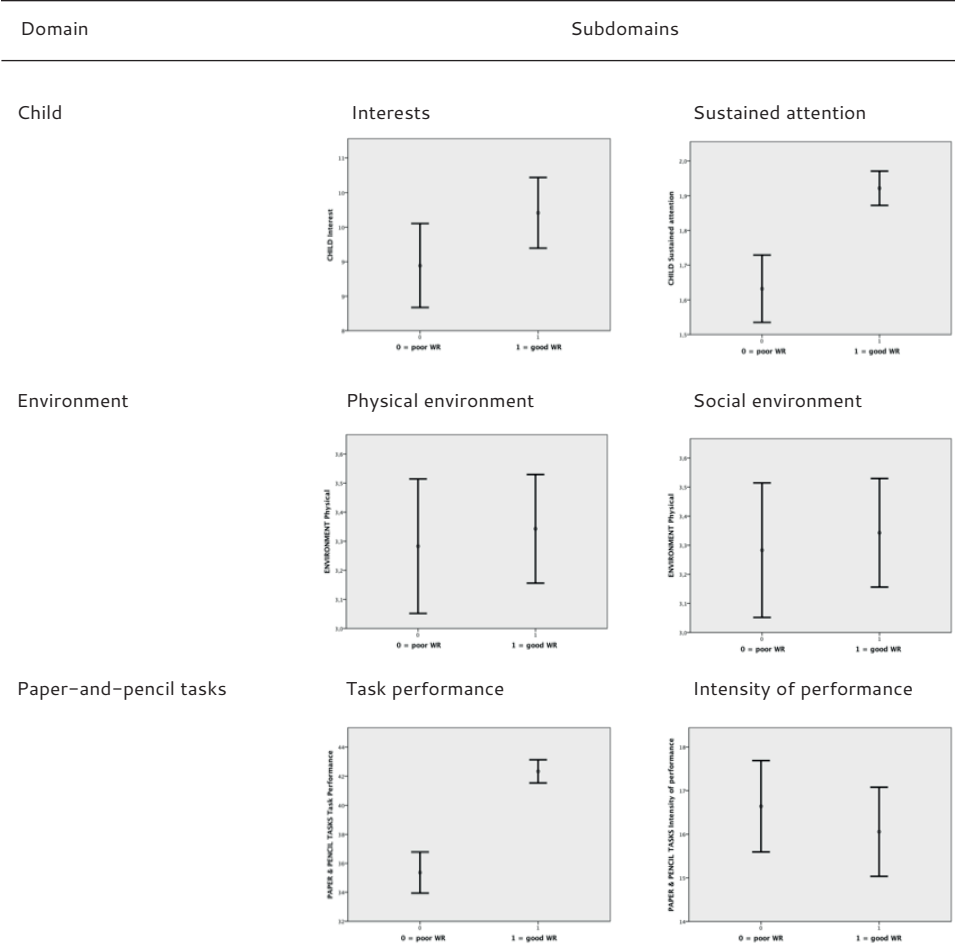
Feasibility

The mean time for administering WRITIC was 20 min (range 12 to 28). The seven items evaluating the products could be scored afterwards in about 5 min by the examiner. After finishing WRITIC, children were asked whether they liked the assessment. Fifty children (83%) liked it very much, six children (10%) liked it a little, and four children (7%) did not like it. There was a fair correlation between how much the children liked the assessment and their level of success in the subdomain 'Task performance' of WRITIC ($r_s = 0.25$, $p = .005$). Although WRITIC was administered in the classroom, teachers did not perceive it as a disturbance of their normal class routines.

Table 3. Comparison of WRITIC scores of children identified as poor performers ($n=109$) and good performers^a ($n=142$).

	Median poor per- formers	Range poor per- formers	Median good per- formers	Range good per- formers	Mann- Whitney U	p-value Mann Whitney
Checklist of Fine motor skills	6.0	0–23	0	0–25	893.50	<0.001
WRITIC Child Interest	9.0	1–18	10.0	3–17	8.44	0.062
WRITIC Child Sustained attention	2.0	0–2	2.0	0–2	9.54	<0.001
WRITIC Environment Physical	4.0	0–4	4.0	0–4	7.46	0.924
WRITIC Environment Social	2.0	0–2	2.0	0–2	7.57	0.752
WRITIC Paper-and-pencil tasks Task performance	37.0	16–48	43.5	27–49	11.78	<0.001
WRITIC Paper-and-pencil tasks Intensity of performance	18.0	2–24	17.0	0–24	7.09	0.551

^a Poor and good performers as rated by the teacher



^a Poor and good performers as rated by the teacher; please pay attention to the fact that the scale divisions are different in the six figures

Figure 2. Error bars discriminative validity visualizing the difference between the groups of poor performers ($n = 109$) and good performers ($n = 142$)^a

DISCUSSION

Based on Feder and Majnemer's review (2007), we included evaluation of the actual performance of paper-and-pencil tasks, intrinsic factors (the domain 'Child') and external factors (the domain 'Environment') in the first proposal of WRITIC. We were able to reach a high agreement within the expert panel suggesting that WRITIC is a robust instrument which covers the aspects of writing readiness. The three Delphi rounds were crucial for the evaluation and quality improvement of WRITIC as the experts made extensive efforts to evaluate the content validity of the test.

The content of the test is in line with Magalhaes, Cordoso, and Missiuna's (2011) review, which concluded that standardized measurements for handwriting should also include the participants' perspective and relevant environmental factors (Magalhaes, Cardoso, & Missiuna, 2011). Based on factor analysis the domain 'Paper-and-pencil tasks' contained two subdomains: 'Task performance' and 'Intensity of performance'. Factor analysis was only done on this domain because we expected this to be the discriminative part. The subdomain 'Task performance' covered seven items on quality of results and six items on quality of performance and showed good internal consistency. Both quality and quantity items are loaded on this factor and this indicated that the performance and product of paper-and-pencil tasks are interwoven constructs. The subdomain 'Intensity of performance' contained four items associated with a relaxed versus forced position or grip. A forced position may lead to discomfort during the performance of paper-and-pencil tasks. The internal consistency of the subdomain 'Task performance' ($\alpha = 0.82$) was high according to Field (2009), who indicates a cut-off point of 0.7 for ability tests. The internal consistency of the subdomain 'Intensity of performance' is almost high at 0.69.

The domain 'Person' was reflected by two subdomains: 'Sustained attention' and 'Interest'. 'Sustained attention' was able to distinguish between children with good and poor writing readiness. A low attention span can limit practice of handwriting and can lead to poor mastery of letter formation in 6- and 7-year-old children (Feder & Majnemer, 2007). Also, in children with ADHD decreased accuracy in figure copying was found not to be due to coordination problems but to problems with sustaining attention (Schoemaker, Ketelaars, van Zonneveld, Minderaa, & Mulder, 2005). In the subdomain 'Interest' children with good and poor writing readiness did not differ in frequency, interest, and perceived competence of drawing/colouring and "handwriting". Apparently, children 5 and 6 years old are less aware of their level of performance, as was also found in a study with 260 Canadian kindergarten children (mean age 5 years 9 months) (LeGear et al., 2012). Although motor skills levels were quite low, the children in this study had positive perceptions of their physical competence on the Pictorial Scale of Perceived Competence and Social Acceptance for Young Children. LeGear et al. (2012) indicate that these positive perceptions provide a window of opportunity for fostering skillfulness. The subdomain 'Child' gives important criterion-referenced information to consider when advising the teacher.

The two extreme groups consisted of children from the same classes and the same environment, therefore, no significant difference was found in the domain 'Environment'. In this study, 30% (32/109) of the poor and 31% (44/142) of the good performers were seated in chairs with inappropriate postural support. Especially for children with poor writing readiness, seating position is important criterion-referenced information to consider when advising the teacher. A study on the effect of seating position quality in typical 6- and 7-year-old children suggests that the fit of the furniture to the child's size may have an impact on complex in-hand manipulation skills (Smith-Zuzovsky & Exner, 2004).

In the domain 'Paper-and-pencil tasks', the score on 'Task performance' differed significantly between good and poor performers. The two contrasting groups were formed based on the opinion of the teacher and WRITIC confirmed their judgment. Hammerschmidt and Sudsawad (2004) found that the opinion of the teacher concerning handwriting is mostly based on the written product (Hammerschmidt & Sudsawad, 2004). Apparently, the items regarding the quality of product correlate with the teachers' opinion and contribute to the discriminative ability of the subdomain 'Task performance'. This subdomain also contains six items on quality of performance. In addition, the discriminating ability of the items on quality of performance is in accordance with the literature (Rosenblum, Goldstand, & Parush, 2006). In the subdomain 'Intensity of performance', in both groups a forced performance was found. A forced grip may lead to discomfort during the long-term performance of paper-and-pencil tasks, such as cramp or pain (Sassoon, 2006). Therefore, we judged this criterion-based information as important for advice and intervention in general.

The Checklist of Fine Motor Skills (van Hartingsveldt et al., 2005) was used to establish whether the selection procedure functioned properly. On this checklist the two groups differed significantly. The value of WRITIC above and beyond this checklist lies in the construct of determining writing readiness. The subdomain 'Task performance' should be the norm-referenced part of WRITIC and the other multiple components provide criterion-referenced information, essential for advice and intervention supporting writing readiness.

Our findings indicate that WRITIC is quick to administer, children like it, and it was not perceived as a disturbance by the teachers. Feasibility is one of the most significant variables influencing the actual use of an outcome measure in daily practice. A feasible instrument for use by professionals should be quick and non-intrusive and be implemented in daily practice without impediment (Dekker et al., 2005).

Boys were over-represented in the group of children with poor handwriting performance. Boys with handwriting difficulties are represented 3:1 compared to girls (Overvelde et al., 2011); in our study, the ratio was 4:1. The two groups were formed on basis of the opinion of the teacher, who chose from every class two or three children with poor and two or three children with good performance on paper-and-pencil tasks. We checked the selection with the Checklist of fine motor skills (van Hartingsveldt et al., 2005). However,

we also know from the literature that maturation of fine motor skills seems to be later in boys than in girls, so it is reasonable that not all of these children will develop hand-writing problems. As far as we know no data are available on prewriting skills to use for comparison.

Limitations

There are some limitations in this study. Firstly, establishing the feasibility according to the teachers was not done in a standardized and anonymous way. After administration of WRITIC in the class, the administrators had asked the teachers if this had been disturbing. Because this was done orally, we do not have descriptive data and therefore the conclusion about this part of feasibility is not robust. Another possible limitation is the use of 10 different raters: there could be a bias between them. However, in a parallel study (van Hartingsveldt, Cup, de Groot, & Nijhuis-Van der Sanden, 2014) we evaluated inter-rater reliability of WRITIC and this was sufficient.

Another limitation is that the WRITIC is developed with 5–6 years old children in Dutch Kindergarten to test handwriting readiness at the end of the prewriting phase. The results can be generalized to Dutch children. The test can be used in other countries at the end of the prewriting phase, although validation will be necessary to adapt to different learning environments and possible differences in ages.

CONCLUSION

The WRITIC is a new assessment of writing readiness in 5 and 6-year-old children. It is intended to be used in children whose teachers are worried about their writing readiness. WRITIC fills the gap as a quantitative measurement for writing readiness. Our findings support content validity, construct validity, and the feasibility of using WRITIC with kindergarten children, 5 and 6 years old.

Further research is recommended to assess the reliability, convergent validity and predictive validity of WRITIC.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

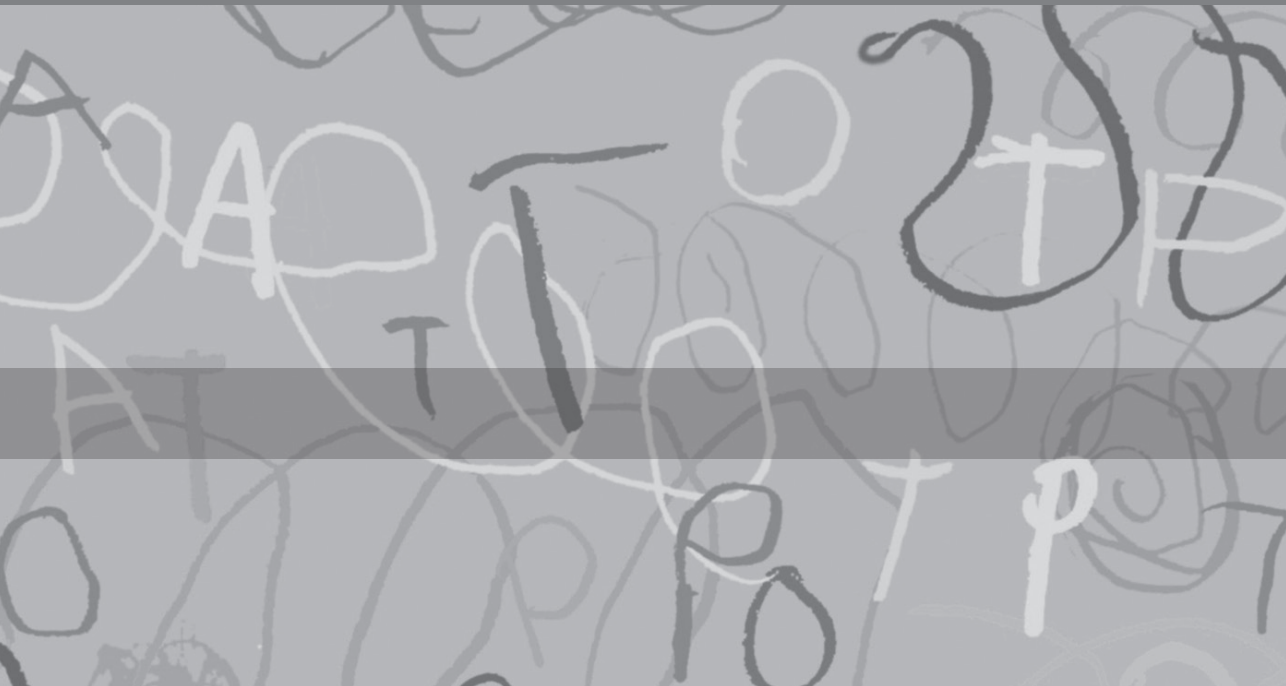
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Chapter 5

The Writing Readiness Inventory Tool In Context (WRITIC): Reliability and convergent validity



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ABSTRACT

Background/aim: This study examined the reliability and convergent validity of the Writing Readiness Inventory Tool In Context, a measurement evaluating writing readiness in kindergarten children (aged from five to six years).

Methods: Test-retest reliability was established with 59 children, inter-rater reliability with 72 children and convergent validity with 119 children. All participants were typically developing kindergarten children. Convergent validity was examined with the Beery-Buktenica Developmental Test of Visual-Motor Integration and the Nine-Hole Peg Test.

Results: We found excellent test-retest and inter-rater reliability on the future norm-referenced subdomain 'Task performance' of Writing Readiness Inventory Tool In Context with intra-class correlation coefficient ranging from 0.92 to 0.95. On the other criterion-referenced subdomains, we found fair to good reliability with intra-class correlation coefficient ranging from 0.70 to 1.0 and weighted Kappa ranging from 0.30 to 0.89. Correlations with the Beery-Buktenica Developmental Test of Visual-Motor Integration and the Nine-Hole Peg Test were moderate with r_s ranging from 0.34 to 0.40 and these are comparable with correlations in other handwriting studies.

Conclusion: Writing Readiness Inventory Tool In Context is an assessment of writing readiness that is stable over time and between raters. The expected moderate correlations with the Beery-Buktenica Developmental Test of Visual-Motor Integration and the Nine-Hole Peg Test support the construct of writing readiness.

INTRODUCTION

Handwriting is one of the most important skills for children to learn during the first years at school and is essential for the child's participation in the regular classroom environment (Rosenblum, 2008). Despite increased availability of computers, tablets and smart phones, handwriting remains the primary tool for written communication and knowledge assessment for students in the classroom (Cahill, 2009). Handwriting is part of the higher order cognitive processes required to learn to spell words and produce written text. Cognitive skills and fine motor skills are both involved in the complex process of writing acquisition (Richards et al., 2011). In learning to write and read, the motor programme used for writing, as well as the visual form of the letters and the associated kinaesthetic feedback are linked, so that a multimodal letter representation is built up (Longcamp, Anton, Roth, & Velay, 2003). Handwriting is a pre-condition to learn reading and spelling (Longcamp et al., 2008). If basic skills, such as fine motor skills, are not fluent, the use of higher-level cognitive skills in the working memory can be attenuated, which can negatively influence text writing (Peverly, 2006). The prevalence of handwriting problems has been estimated to range between 12% and 33% (Overvelde et al., 2011). Handwriting difficulties have negative effects on a child's academic performance and self-esteem (Ratzon, Efraim, & Bart, 2007). To prevent handwriting difficulties we developed the Writing Readiness Inventory Tool In Context (WRITIC), an early screening instrument for writing readiness (van Hartingsveldt, de Vries, Cup, de Groot, & Nijhuis-Van Der Sanden, 2014). In case of non-writing readiness according to WRITIC tailored advice and intervention can be given so these children have the possibility to start the mastery of handwriting without delay. A recent systematic review offers convincing evidence that interventions that involve handwriting practice are effective in improving handwriting in children with handwriting difficulties (Hoy, Egan, & Feder, 2011). This article studies the reliability and validity of WRITIC.

Writing readiness

'Writing readiness' is the stage before handwriting (Marr, Windsor, & Cermak, 2001; Schneck & Amundson, 2010). It is defined as a developmental stage at which a child has the capacity to profit satisfactorily from the instruction given in the teaching of handwriting (Marr et al., 2001). According to Donaghue (1975) and Lamme (1979) (in Schneck & Amundson, 2010) six prerequisite skills are necessary to profit from handwriting instruction: (1) development of intrinsic hand muscles; (2) eye-hand coordination; (3) letter perception, including the ability to recognise forms; (4) ability to hold utensils; (5) ability to form basic strokes smoothly; and (6) orientation to printed language. The first two prerequisite skills are related to fine motor coordination, which is needed to allow the stability and controlled dynamic finger movement, important for the mastery of skilled handwriting (Cornhill & Case-Smith, 1996). Dynamic finger movement is important to evaluate, because only 50% of the five- and six-year-old children have a dynamic pencil

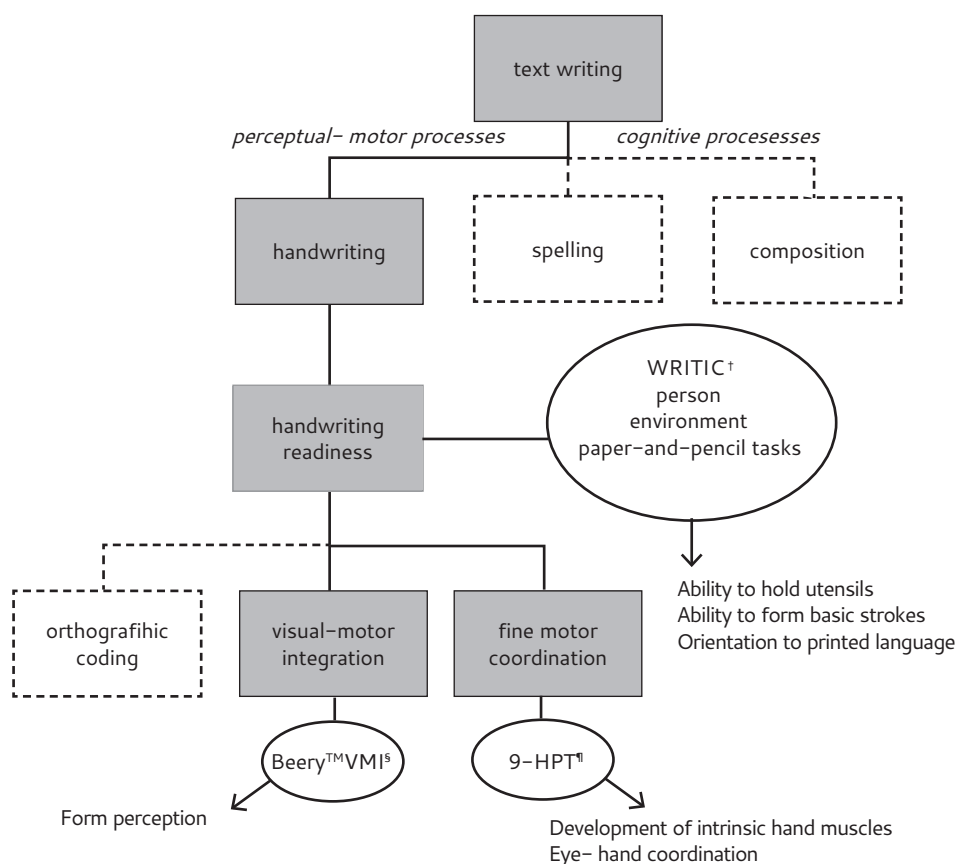
grip (Schneck & Henderson, 1990). To evaluate fine motor coordination, the Nine-Hole Peg Test (9-HPT) (Smith, Hong, & Presson, 2000) is frequently used (van Hartingsveldt, Aarts, de Groot, & Nijhuis-Van Der Sanden, 2011).

The third prerequisite skill is related to recognising forms, as part of visual-motor integration. This can be evaluated with the Beery Developmental Test for Visual-Motor Integration (Beery™VMI) (Beery, Buktenica, & Beery, 2010). This test is strongly related to kindergarten children's ability to copy letterforms (Daly, Kelley, & Krauss, 2003; Weil & Amundson, 1994) and is frequently used internationally (van Hartingsveldt et al., 2011).

The last three prerequisite skills are evaluated with WRITIC. The 'ability to hold utensils' is evaluated in items on pencil grip, the 'ability to form basic strokes smoothly' is evaluated in items on tracing, and 'orientation to printed language' is evaluated in items on copying letters and numbers.

In Figure 1 we describe the conceptual model used to identify the factors relating to writing readiness. In this model it is pointed out that learning 'text writing' is based on different processes: The perceptual-motor process 'handwriting', and the cognitive language processes of 'spelling' and 'composition' (Berninger, 2009; Richards et al., 2011). In this study, we focus on 'writing readiness', the stage before handwriting (Marr et al., 2001; Schneck & Amundson, 2010). Writing readiness is composed of 'orthographic coding', 'visual-motor integration' and 'fine motor coordination'. In the phase in which children learn the perceptual-motor skill of preliminary writing, 'visual-motor integration' and 'fine motor coordination' are important performance components (Volman, van Schendel, & Jongmans, 2006). Orthographic coding, defined as 'holding written words in memory while analysing letter patterns in them' (Berninger, 2009) is a cognitive language process and falls therefore outside the scope of our perceptual-motor focus of writing readiness. Regarding fine motor coordination, it is hypothesised that automation of the motor process is important for children to be able to use their working memory to learn multimodal letter (and later word) representation (Longcamp et al., 2003; Peverly, 2006).

Richards et al. (2011) stated that next to handwriting readiness skills, child variables (e.g. interest) and environmental variables matter in writing acquisition. Therefore we also included these variables in WRITIC. These three perspectives (handwriting skills, child variables and environment variables) form the domains of WRITIC and are based on the Person-Environment-Occupation model (PEO model) (Law et al., 1996).



† Writing Readiness Inventory Tool In Context; § Beery-Buktenica Developmental Test of Visual-Motor Integration; ¶ Nine-Hole Peg Test

Figure 1. Conceptual model of writing readiness and its relation to handwriting, writing and performance components (Berninger, 2009; Marr et al., 2001; Overvelde et al., 2011; Richards et al., 2011; Schneck & Amundson, 2010; Volman et al., 2006).

Writing Readiness Inventory Tool In Context

A systematic literature review on psychometrically sound standardised tests to assess handwriting readiness at the levels of occupations, activities/tasks and performance components resulted in 12 tests. Most measurements focussed on performance components, none of the instruments was occupation-based and included all components to assess writing readiness (van Hartingsveldt et al., 2011). Therefore, we developed WRITIC, an occupation-based measure to assess writing readiness in five- and six-year-old children

to be administered in the pre-writing phase. The goal of WRITIC is to discriminate between children who are ready for instruction in handwriting and children who are not (van Hartingsveldt et al., 2014). In case of non-writing readiness according to WRITIC, tests on fine motor coordination and visual-motor integration can be administered and therapists can give tailored advice to teachers to support these children or therapists can offer an intervention to practice pre-writing skills. This way the child becomes more ready for handwriting.

Domains WRITIC	Subdomains WRITIC	
Child	<p>Interest Questionnaire</p> <p>6 items 3-point scale Range 0-12</p>	<p>Sustained attention Scored by tester</p> <p>1 items 3-point scale Range 0-2</p>
Environment	<p>Physical Scored by tester</p> <p>2 items 3-point scale Range 0-4</p>	<p>Social Scored by tester</p> <p>1 items 3-point scale Range 0-2</p>
Paper-and-pencil tasks	<p>Task Performance[†] Scored by tester</p> <p>7 items 3-point scale 6 items 7-point scale Range 0-50</p>	<p>Intensity of performance Scored by tester</p> <p>4 items 7-point scale Range 0-24</p>

[†] norm-referenced part of the WRITIC

Figure 2. Overview of (sub)domains of the Writing Readiness Inventory Tool In Context with number of items, sort of scale and range.

WRITIC is to be administered in the classroom, where the influence of the context can be taken into account. First the child’s interests in paper-and-pencil tasks is evaluated. After that, the child is encouraged to complete a drawing booklet with five paper-and-pencil tasks including tracing, colouring, making pre-writing patterns, name writing and copying letters and numbers.

WRITIC contains three domains and every domain is composed of two subdomains. For the domain ‘Child’ these are ‘Interest’ and ‘Sustained attention’, for the domain ‘Environ-

ment' these are 'Physical environment' and 'Social environment', and for the domain 'Paper-and-pencil tasks' the subdomains are 'Task performance' and 'Intensity of performance' (see Figure 2).

The content validity of WRITIC was determined in expert consultations with 94,4% agreement. Previous research has confirmed that the subdomain 'Task performance' has high internal consistency after factor analysis and discriminates between children with good and poor performance on paper-and-pencil tasks. WRITIC is feasible to administer in the natural school context (van Hartingsveldt et al., 2014).

The subdomain 'Task performance' will be developed to the norm-referenced part of WRITIC and in the future reference norms will be collected. The other subdomains are criterion-referenced and provide valuable information for advice and intervention.

Occupation-based assessment

In an occupation-based or top-down assessment, according to the Taxonomic Code of Occupational Performance (TCOP) (Polatajko et al., 2007), an assessment starts at the level of occupation, determining how children participate in occupations in a relevant context. Thereafter activities, tasks and performance components are assessed. In the assessment of writing readiness, WRITIC is administered at the level of occupation, activities and tasks. In case of not ready for handwriting, performance components are assessed with 9-HPT and Beery™VMI.

In clinical decision-making good reproducibility of a test is crucial. It should be stable and consistent between raters and over time. Therefore the inter-rater and test-retest reliability of WRITIC needs to be determined (Streiner & Norman, 2008). To establish its relation to visual-motor integration and fine motor coordination, convergent validity with Beery™VMI and 9-HPT is determined. Visual-motor integration has a moderate relation to copying letterforms in kindergarten children (Daly et al., 2003; Marr et al., 2001; Weil & Amundson, 1994). Both performance components have a moderate correlation to handwriting performance (Volman et al., 2006). Our hypothesis is that both performance components have a moderate correlation with WRITIC.

METHODS

Three observational cohort studies were carried out to evaluate the reliability of WRITIC and its convergent validity with BeeryTMVMI and 9-HPT.

Participants

To recruit participants we sent letters to the heads of elementary schools to ask for participation. Once we received consent, we asked kindergarten teachers to select two or three children, aged five or six, with good performance, and two or three with poor performance on paper-and-pencil tasks. Moreover, the teachers completed the Checklist of Fine Motor Skills (van Hartingsveldt, Cup, & Oostendorp, 2005) for each selected child, to validate the subjective selection. In this way heterogeneous groups were formed for all three studies. We selected 60 children for the test-retest reliability study, 72 children for the inter-rater reliability study, and 120 children for the correlation study. Different children participated in the three studies. For the reliability studies, we formed groups larger than 50 as recommended by Terwee et al. (2007). For the convergent validity study we recruited 120 children. Children were excluded if they were not able to perform paper-and-pencil tasks due to a medical diagnosis or visual or auditory impairment. After parents gave informed consent, children were asked to participate. The ethical committee of the Radboud University Medical Centre provided formal ethical approval. The studies were in full compliance with the Committee on Research Involving Human Subjects (known by its Dutch initials, CMO) of the Arnhem-Nijmegen area.

Measures

The BeeryTMVMI includes 24 geometric figures progressing from simple to complex, which the child has to copy. In the Visual Perception (VP) test, the child has to choose the correct geometric form out of two to seven alternatives. In the Motor Coordination (MC) test, the child traces with a pencil a trail within progressively smaller paths while staying within the confines of a boundary derived from geometric figures. Raw scores were calculated. This test has excellent inter-rater reliability and strong concurrent and construct validity. Normative data have been collected from a US sample (Beery et al., 2010).

The 9-HPT is a simple, commercially available timed test of fine-motor coordination, in which pegs are inserted and removed from nine holes in a peg-board. Children were asked to complete the task with their 'writing' hand and the best time score was used. The 9-HPT has excellent inter-rater and test-retest reliability and strong construct validity. Normative data have been collected from a United States sample (Smith et al., 2000).

Procedure

WRITIC was administered individually in the classroom, during a time when all the children were doing different tasks in small groups. BeeryTMVMI (VMI, VP and MC) and 9-HPT were administered outside the classroom in a one-to-one situation (Beery et al., 2010; Smith et al., 2000).

To determine test-retest reliability, WRITIC was administered twice with intervals of 7–14 days (Streiner & Norman, 2008).

Inter-rater reliability was based on the observations of two raters in the classroom. Rater 1 administered and scored the WRITIC and rater 2 observed and scored the WRITIC simultaneously. Four different raters were involved. All raters fulfilled the role as administrator or observer in random order, resulting in 12 combinations (A-B; B-A; A-C; C-A; A-D; D-A; B-C; C-B; B-D; D-B; C-D; and D-C).

The test administrators included four occupational therapy students (inter-rater reliability study), three occupational therapy students (test-retest reliability study), and three paediatric physical therapists and one paediatric occupational therapist (correlation study). To become competent in administering WRITIC, they all: (1) attended a training session of three hours from the first author; (2) practised WRITIC with two typically developing children; and (3) checked their procedure of the administration of WRITIC, which was video recorded, with the first author.

Data analysis

Descriptive statistics were used to describe participants' demographic characteristics. For WRITIC, raw scores per subdomain were used. For the reliability studies we used all subdomains and for the convergent validity study only the subdomain 'Task performance'. For the subtests of BeeryTMVMI and for 9-HPT raw scores were used.

For the subdomains 'Task performance', 'Interests', 'Physical environment' and 'Intensity of performance', we used the intra-class correlation coefficient (ICC) and corresponding 95% confidence interval between the two measurements. We chose the ICC agreement (two-way random effects model, single measures), including systematic differences between therapists (Terwee et al., 2007). Because of the three-point scale in the subdomains 'Sustained attention' and 'Social environment' the weighted Cohen's Kappa was used as well as the percentage agreement. We used Fleiss criteria: excellent $r > 0.75$; fair to good $r = 0.40-0.75$ and poor $r < 0.40$ (Fleiss, 1981). An ICC or Kappa of 0.70 or higher was considered to indicate acceptable reliability (Terwee et al., 2007).

Spearman rank correlation coefficients were used to establish correlations between the subdomain 'Task performance' and the raw scores on the Beery™VMI and 9-HPT. We used Andresen criteria: strong $r_s > 0.60$; moderate $r_s = 0.30-0.60$ and weak $r_s < 0.30$ (Andresen, 2000). On the basis of other studies (Daly et al., 2003; Feder et al., 2005; Volman et al., 2006), our hypothesis is that both performance components have a moderate correlation, between 0.30 and 0.50, with WRITIC. Statistical analyses were performed using SPSS 19.0 (IBM SPSS Statistics, Amsterdam, the Netherlands), all tests were applied two-tailed and the significance level was set at $P < 0.05$.

RESULTS

For the study of test-retest validity, 59 children from 15 kindergarten classes in the west of the Netherlands were included; one child could not be followed up because of an incomplete dataset. The mean age was 66 months, 57% were boys ($n = 34$), 88% were right-handed ($n = 52$), 9% were left-handed ($n = 5$) and 3% ($n = 2$) had a variable hand use. For the study of inter-rater reliability, 72 children from 18 kindergarten classes in the east of the Netherlands were included. The mean age was 70.5 months, 50% were boys ($n = 36$), 81% were right-handed ($n = 58$) and 19% were left-handed ($n = 14$).

In the correlation study, 119 children from 20 kindergarten classes in the middle and east of the Netherlands were included. One child was not included because of lack of informed consent. The mean age was 70.5 months, 50% were boys ($n = 60$), 84% ($n = 100$) were right-handed, 15% ($n = 18$) were left-handed and 1% ($n = 1$) had a variable hand use.

The mean outcomes in the three studies varied for the subdomain 'Task performance' from 32.3 to 41.5. For the other subdomains outcomes varied for 'Interest' from 8.6 to 11.7, for 'Sustained attention' from 1.6 to 1.9, for 'Physical environment' from 3.0 to 3.1, for 'Social environment' from 1.4 to 1.8, and for 'Intensity of performance' from 13.0 to 17.8 (see Table 1).

For the subdomain 'Task performance' the ICC test-retest was 0.92 ($p < 0.001$) and the ICC inter-rater was 0.95 ($p < .001$). For the other subdomains the ICC test-retest varied from 0.70 to 0.83 ($p < 0.001$) and the ICC inter-rater varied from 0.82 to 1.00 ($p < 0.001$). The weighted Kappa for test-retest varied from 0.53 to 0.69 ($p < 0.001$) with a percentage agreement varying from 75% to 90%. The weighted Kappa for inter-rater varied from 0.30 ($p = 0.005$) to 0.89 ($p < 0.001$) within both cases with a percentage agreement from 94% (see Table 2).

The subdomain 'Task performance' showed fair cross-sectional correlations with Beery™VMI: $rr_s = 0.36$ ($p < 0.001$) for the VMI; $r_s = 0.34$ ($p < 0.001$) for 'Visual perception'; and $r_s = 0.39$ ($p < 0.001$) for 'Motor coordination'. With 9-HPT we found a correlation of $r_s = -0.40$ ($p < 0.001$).

Table 1. Descriptives of the mean outcomes and standard deviations of the three sub studies per subdomain of the Writing Readiness Inventory Tool In Context.

	Child		Environment		Paper-and-pencil tasks	
	Interest	Sustained attention	Physical	Social	Task performance	Intensity of performance
Test-retest reliability study (<i>n</i> = 59)	11.7 (4.3)	1.6 (0.5)	3.0 (3.0)	1.8 (0.4)	32.3 (7.8)	17.8 (3.7)
Inter-rater reliability study (<i>n</i> = 72)	8.6 (2.0)	1.9 (0.2)	3.1 (1.2)	1.6 (0.5)	41.8 (3.9)	13 (6.4)
Convergent validity Study (<i>n</i> = 119)	8.6 (2.2)	1.8 (0.5)	3.6 (0.8)	1.4 (0.6)	41.5 (5.2)	17.6 (5.5)

Values are expressed as mean (SD)

Table 2. Intra-class coefficients and weighted Kappa’s test-retest (*n* = 59) and inter-rater reliability (*n* = 72) of the Writing Readiness Inventory Tool In Context with *p*-values.

Domain Subdomain	Test-retest	<i>p</i> -value	95% CI	Inter-rater	<i>p</i> -value	95% CI
ICC						
Child Interests	0.70	<0.001	0.54–0.80	1.00	–	1.00–1.00
Environment Physical	0.91	<0.001	0.86–0.95	0.95	<0.001	0.92–0.97
Paper-and-pencil tasks Task performance	0.92	<0.001	0.87–0.95	0.95	<0.001	0.68–0.86
Paper-and-pencil tasks Intensity performance	0.83	<0.001	0.73–0.89	0.82	<0.001	0.80–0.92
Domain Subdomain	Test-retest	<i>p</i> -value	% agree-ment	Inter-rater	<i>p</i> -value	% agree-ment
Weighted Kappa Child Sustained attention	0.63	<0.001	75%	0.30	0.005	94%
Environment Social	0.69	<0.001	90%	0.89	<0.001	94%

DISCUSSION

The results in this study show that the newly developed WRITIC has excellent test-retest and inter-rater reliability at the future norm-referenced subdomain 'Task performance' while the criterion-referenced subdomains had fair to excellent reliability. The results also demonstrated moderate convergent validity of WRITIC with BeeryTMVMI and 9-HPT, which are comparable with handwriting studies (Volman et al., 2006).

The outcomes on reliability for 'Task performance' were excellent and above the criteria of Terwee et al. (2007). The excellent inter-rater reliability indicates that the administration and interpretation of the scoring of this subdomain is robust and well standardised and provides stable outcomes over time and over raters. An excellent agreement is particularly interesting because the items of 'Task performance' are observational which makes inter-rater agreement more difficult. Furthermore inter-rater reliability is based on four testers in different pairs, which makes the potential inter-rater variance higher. A reason for the excellent inter-rater agreement may be the fact that our raters received three-hour intensive face-to-face training, practised WRITIC with two typically developing children, and checked their administration procedure with the use of a video recorded administration with the first author before starting testing on their own. All raters of the reliability studies were occupational therapy students and lacked the experience of a paediatric professional. WRITIC thus appears to be a feasible efficient instrument that can be implemented by therapists in school-based practice (Law, King, & Russell, 2005).

The inter-rater reliability of the criterion-referenced subdomains was poor for 'Sustained attention'. By evaluating the data, it became clear that in this study only two scores of the three-point scale were used. The low outcome was the result of the skewed distribution of the data. On the scale from 0 to 2, '0' was not scored, '1' was scored only in 6% of the cases, in all of the other cases '2' was scored. This resulted in a high percentage of agreement between the two raters. This has to be interpreted cautiously because of the high chance of score 2. It was only in this study on inter-rater reliability ($n=72$) that there was such a skewed distribution on 'Sustained attention'. In the test-retest reliability study, 2% scored 0, 37% scored 1 and 61% scored 2, and in the validity study 2% scored 0, 18% scored 1 and 80% scored 2.

As hypothesised that BeeryTMVMI is related to kindergarten children's ability to copy letterforms, we found a moderate correlation between WRITIC and BeeryTMVMI. This is comparable to other studies where a moderate correlation was found (Daly et al., 2003; Marr et al., 2001; Pienaar, Barhorst, & Twisk, 2013). Volman et al. (2006) also found a moderate correlation in children from second and third grade between BeeryTMVMI and a handwriting test. Similar relations were also found in other studies (Feder & Majnemer, 2007; Maeland, 1992).

The hypothesised correlation with fine motor coordination was also confirmed. Volman et al. (2006) found also a moderate correlation between fine-motor coordination and the quality of handwriting. Similar correlations were found in other studies (Feder et al., 2005; Pienaar et al., 2013; Weintraub & Graham, 2000). Thus BeeryTMVMI and 9-HPT are partly correlated with WRITIC. Our moderate correlation is comparable to the correlation of these performance components with handwriting in older children, which underpins the construct of writing readiness as stage before handwriting, although this hypothesis needs to be confirmed in a future prospective study. The fact that BeeryTMVMI and 9-HPT are partly related to WRITIC suggests that both measurements are assessing another construct. It also suggests that these instruments are valuable additional instruments to WRITIC. In the case of non-writing readiness, according to WRITIC, it is recommended to assess performance components in a second step with 9-HPT and BeeryTMVMI.

The outcomes on the WRITIC in the three studies were similar. The 'Task performance' score was lower in the test-retest reliability study than in the other two studies. The reason could be the date of administration. The test-retest reliability study was administered in the first semester with a mean age of the children of 66 months, while the other two studies on intra-rater reliability and convergent validity were administered in the second semester with older children with a mean age of 70.5 months. The latter children had likely improved in their pre-writing abilities.

Strengths, limitations and directions for further research

The strengths of this study are the relatively large sample sizes of more than 50 participants (Terwee et al., 2007) and the stable outcomes on WRITIC in the different studies. A limitation is that we did not check inter-rater reliability in using point-by-point agreement before data were collected (Richardson, 2010). However in our inter-rater reliability study with four raters we found sufficient scores after training in administering WRITIC, so that is also expected in the other studies.

Further studies are recommended to assess the predictive validity of WRITIC, collect reference norms and determine a clear cut-off point regarding writing readiness.

CONCLUSION

The newly developed WRITIC has demonstrated excellent test-retest and inter-rater reliability on the future norm-referenced subdomain 'Task performance'. On the criterion-referenced part, we found fair to excellent reliability. The moderate convergent validity with the BeeryTMVMI and the 9-HPT underpins the construct of writing readiness. In an occupation-based assessment on writing readiness, WRITIC can be used in the first step, assessing at the level of occupation, activities and tasks. In case of non-readiness for writing

according to the WRITIC, in the second step, performance components can be assessed with BeeryTMVMI and 9-HPT. WRITIC is a stable assessment of writing readiness in five- and six-year old children over time and between raters, and WRITIC can be administered reliably in the educational environment of the child after a relatively short training of three hours.

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Predictive Validity of kindergarten assessments on handwriting readiness



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& Nijhuis-Van Der Sanden MWG. Predictive Validity of a kindergarten assessment
on handwriting readiness.

ABSTRACT

We investigated the predictive value of a new kindergarten assessment of handwriting readiness on handwriting performance in first grade as evaluated by the Systematic Screening for Handwriting Difficulties (Dutch abbreviation: SOS). The kindergarten assessment consisted of the Writing Readiness Inventory Tool In Context (WRITIC), the Beery-Buktenica Developmental Test of Visual-Motor Integration (BeeryTMVMI) and the Nine-Hole Peg Test (9-HPT). The WRITIC evaluates in kindergarten children (aged 5–6 years) prewriting skills, the BeeryTMVMI and 9-HPT evaluate visual motor integration and fine-motor coordination, all elements important for handwriting readiness. In kindergarten, 109 children (55 boys; mean age 70 months, SD 4.8 months) were tested with the WRITIC, BeeryTMVMI and 9-HPT and one year later in first grade (mean age 85 months, SD 4.5 months) with the SOS. A multivariable linear mixed model was used to identify variables that independently predict outcomes in first grade (SOS): baseline scores on the subdomain 'Task performance' of the WRITIC (WRITIC-TP), BeeryTMVMI, 9-HPT, 'sustained attention,' 'gender,' 'age' and 'intervention in the intermediate period. The results showed that WRITIC-TP, BeeryTMVMI, and 9-HPT, 'sustained attention,' 'gender' and 'intervention' had all predictive value on the handwriting outcome. Thereby WRITIC-TP was the main predictor for outcome of SOS-Quality, and BeeryTMVMI and 9-HPT were the main predictors of SOS-Speed. This kindergarten assessment of WRITIC-TP, BeeryTMVMI, and 9-HPT contributes to the detection of children at risk for developing handwriting problems.

INTRODUCTION

Despite the increased availability of computers, tablets, and smartphones, handwriting still remains an important tool for written communication and knowledge assessment for students (Cahill, 2009). Skilled handwriting is vital for children to learn during the first years at school because writing is learned multimodal and is strongly related to reading and spelling (Longcamp et al., 2008; Longcamp, Zerbato-Poudou, & Velay, 2005). Therefore, early detection of possible problems in the perceptual-motor learning process of handwriting is important for the prevention of handwriting problems at a later age.

Handwriting problems are related to poor writing legibility, low speed and complaints as experiencing pain, strain or discomfort during writing. The prevalence of handwriting problems in children from 6 to 12 years ranges between 15% and 33% (Overvelde et al., 2011). Handwriting problems have a negative effect on a child's academic performance and self-esteem (Ratzon, Efraim, & Bart, 2007). Therefore, early evaluation of prewriting skills is of major importance to indicate the need for tailored advice and intervention (Ratzon et al., 2007). These prewriting skills are predominantly trained during the kindergarten period, and therefore, this period seems the most efficient period for intervention (Heckman, Stixrud, & Urzua, 2006).

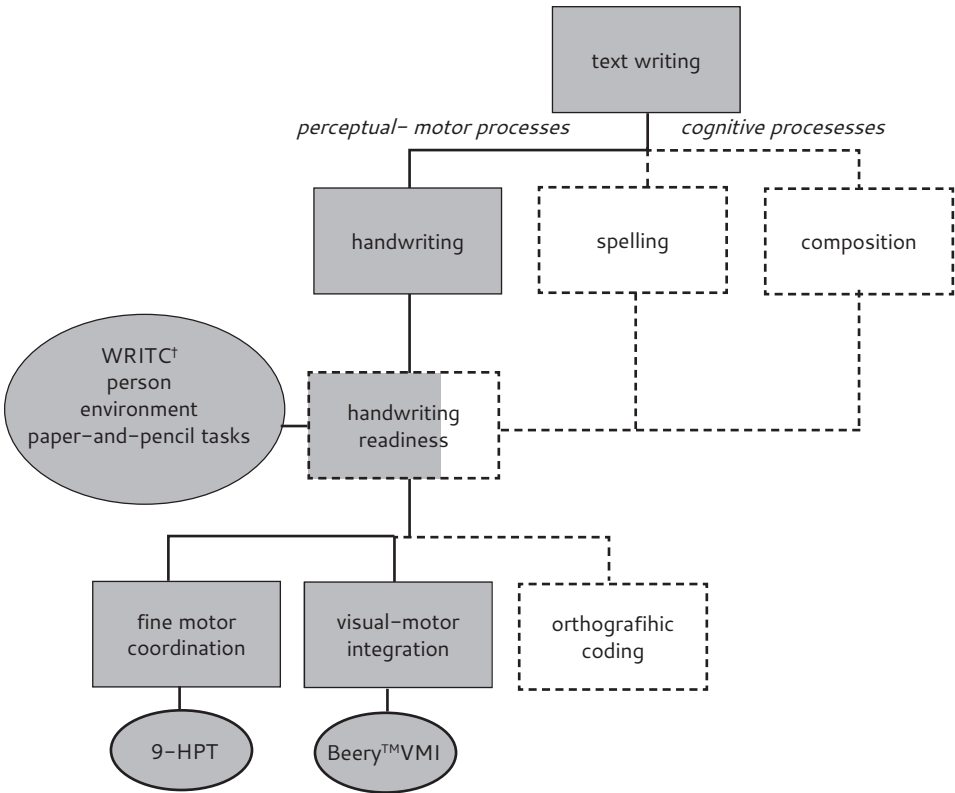
Children learn prewriting skills in kindergarten (in The Netherlands at the age of 5–6 years). In this phase, they learn to produce different writing patterns with an appropriate dynamic pencil grip and an adequate sitting posture. After this period, children start in grade one with unjoined cursive script and later on with joined cursive script. Although in different countries children start at different ages with learning prewriting and handwriting skills, the order of the skills to be learned is the same. Children learn first the prewriting skills (letter like patterns like garlands) and later the handwriting skills in manuscript or (un) joined cursive script.

In Figure 1, we describe the conceptual model used to identify the factors related to writing readiness. This model displays that in learning 'text writing' two main processes are involved: the perceptual-motor process 'handwriting,' and the cognitive processes of 'spelling' and 'composition' (Berninger, 2009; Overvelde et al., 2011; Richards et al., 2011). If handwriting skills are not fluent and automated, the use of higher-level cognitive skills in the working memory can be attenuated, which can negatively influence text writing (Peeverly, 2006; Wallen, Duff, Goyen, & Froude, 2013).

In this study, we focus on the perceptual-motor processes of 'handwriting readiness' (Marr et al., 2001; Schneck & Amundson, 2010). Handwriting readiness is defined as a developmental stage at which a child has the capacity to profit satisfactorily from the instruction given in the teaching of handwriting (Marr et al., 2001). In this study handwriting readiness is measured as having a proper seating posture (Pollock et al., 2009; Schneck & Amundson, 2010), a mature pencil grasp (Schwellnus et al., 2012, 2013) and performing

age-appropriate colouring, writing patterns, writing own name and copying letters and numbers. Children who are taught handwriting before they are ready may become discouraged and develop poor writing habits that may be difficult to correct later, e.g. a static pencil grip that leads to cramp or forced handwriting (Benbow, 2006).

Two performance components are identified by the literature related to the perceptual-motor process of handwriting (readiness): fine motor coordination, (Berninger, 2009; Feder et al., 2005) and visual-motor integration (Daly, Kelley, & Krauss, 2003; Marr et al., 2001; Volman et al., 2006).



† WRITC - Writing Readiness Inventory Tool In Context; Beery™VMI - Beery-Buktenica Developmental Test of Visual-Motor Integration; 9-HPT - Nine-Hole Peg Test

Figure 1. Adjusted Conceptual model of handwriting readiness and its relation to handwriting, text writing and performance components (Berninger, 2009; Marr, Windsor, & Cermak, 2001; Overvelde et al., 2011; Richards et al., 2011; Schneck & Amundson, 2010; van Hartingsveldt, Cup, de Groot, & Nijhuis-Van der Sanden, 2014; Volman, van Schendel, & Jongmans, 2006).

Fine motor coordination or 'fine hand use' (d 440) according to the International Classification for Functioning, Disability and Health, is defined as "performing the coordinated actions of handling objects, picking up, manipulating and releasing them using one's hand, fingers and thumb" (WHO, 2007). Beery, Buktenica, and Beery (2010) defined visual motor integration as "the degree to which visual perception and finger-hand movements are well coordinated" (p.13). Outside the scope of this article falls 'orthographic coding'; Berninger (2009) defined this as "holding written words in memory while analyzing letter patterns in them" (p.70), which is part of the cognitive process of handwriting readiness.

In the absence of assessments to evaluate the perceptual-motor skills in the pre-writing phase (van Hartingsveldt, Aarts, de Groot, & Nijhuis-Van Der Sanden, 2011), we developed the Writing Readiness Inventory Tool In Context (WRITIC). Predictive validity (Streiner & Norman, 2008) is important in professional decision making to determine the need for interventions in children. In the case of not ready for handwriting, therapists can give tailored advice to teachers to support children, who have minor problems. When children have major problems, referral to school-based occupational therapy or paediatric physical therapy, is indicated. Interventions to support the child's participation include adaptations in the child's physical and social environment and task-specific training (Hoy, Egan, & Feder, 2011; Missiuna et al., 2012).

In previous studies, we found WRITIC to be a valid, reliable, and feasible measure to assess handwriting readiness in 5- and 6-year-old children (van Hartingsveldt, Cup, et al., 2014; van Hartingsveldt, de Vries, Cup, de Groot, & Nijhuis-Van Der Sanden, 2014).

The WRITIC aims to discriminate between children who are ready to start with handwriting and those who are not. This measurement should only be assessed in children whereby teachers are worried about the handwriting readiness of the child. To increase ecological validity, the WRITIC has to be administered in the classroom. First, the child's interest in paper-and-pencil tasks is evaluated. Thereafter, the child is encouraged to complete a drawing booklet with five paper-and-pencil tasks (tracing double-line paths; colouring; making prewriting patterns; printing own name; copying letters and numbers) while an assessor observes the performance of the tasks, the sitting position and the pencil grip. The WRITIC is based on the Person-Environment-Occupation (PEO) Model (Law et al., 1996) and contains three domains: 'Child,' 'Environment' and 'Paper-and-pencil tasks.' The PEO-model provides a framework for understanding human development from the interaction perspective. In the WRITIC the person is the 5-6 year old kindergarten child with his interest and sustained attention; the environment contains the physical and social environment of the child; and the occupation contains the paper-and-pencil tasks.

Every domain of the WRITIC is composed of two subdomains. The 'Child' domain includes the subdomains 'Interest' and 'Sustained attention.' The 'Environment' domain contains a 'Physical' and 'Social' section. The 'Paper-and-pencil tasks' includes the subdomains 'Task performance' and 'Intensity of performance' (see Figure 2). The subdomain 'Task

performance’ contains six items on performance (quality of sitting posture and pencil grip) and seven items on product (quality of results). This subdomain will be the future norm-referenced part of WRITIC, while the other subdomains are criterion-referenced and provide valuable information for advice and intervention.

WRITIC Domains	WRITIC Subdomains	
Child	<p>Interest <i>Questoinnaire</i></p> <p>colouring/drawing/ handwriting . how often? . how nice? . how well do you think you're doing</p>	<p>Sustained attention <i>1 item scored by tester</i></p> <p>. focused . encouragement needed . encouragement no effect</p>
Environment	<p>Physical <i>2 item scored by tester</i></p> <p>. chair height . table height</p>	<p>Social <i>1 item scored by tester</i></p> <p>. quiet class . less quiet class . chaotic class</p>
Paper-and-pencil tasks	<p>Task Performance* <i>13 item scored by tester</i></p> <p>. product of the tasks . pencil grip . body position</p>	<p>Intensity of <i>4 item scored by tester</i></p> <p>. distance nose-table . shoulder position . intensity pencil grip . pencil pressure</p>

*norm-referenced part of the WRITIC

Figure 2. Overview of the content of the (sub)domains of the Writing Readiness Inventory Tool In Context (WRITIC)

To complete our kindergarten assessment of handwriting readiness, we added two measurements to evaluate performance components. For the assessment of fine motor coordination, the Nine-Hole Peg Test (9-HPT) (Smith, Hong, & Presson, 2000) was selected and for the assessment of visual-motor integration the Beery-Buktenica Developmental Test of Visual-Motor Integration (BeeryTMVMI) (Beery, Buktenica, & Beery, 2010) was used. Both instruments are reliable and valid and norm references are available for children (Beery et al., 2010; Poole et al., 2005; Smith et al., 2000).

Fine motor (writing) ability in preschool is a strong predictor of academic achievement in second grade (Dinehart & Manfra, 2013) and an important school readiness indicator (Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010). In addition, visual-motor integration in

kindergarten, as measured by the BeeryTMVMI, is closely related to handwriting, as a basic academic skill required in the first formal school year, especially among learners in low Social Economic Status (SES) type schools (Pienaar, Barhorst, & Twisk, 2013).

Based on the conceptual model and above mentioned literature, we hypothesized that the subdomain 'task performance' of the WRITIC, the BeeryTMVMI and the 9-HPT will have predictive value on handwriting performance in grade 1, administered with Systematic Screening for Handwriting Difficulties (Dutch abbreviation: SOS) (Smits-Engelsman, Stevens, Vrenken, & van Hagen, 2005) and therefore could be used as measurements in detecting children at risk for developing handwriting problems.

Because the literature indicates that 'sustained attention,' measured in kindergarten, is an important school readiness indicator (Cameron et al. 2012; Grissmer et al., 2010) and boys are more at risk than girls in developing handwriting problems (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008; Berninger et al., 1997; Feder, Majnemer, Bourbonnais, Blayney, & Morin, 2007), the variables 'sustained attention' and 'gender' will be tested as independent variables. Moreover 'age' and 'intervention in the intermediate period' were also included as independent variables.

METHODS

Design

A prospective longitudinal observational cohort study with two moments of measurement was carried out, evaluating the predictive validity of the subdomain 'task performance' of the WRITIC (WRITIC-TP), 9-HPT, and BeeryTMVMI administered in kindergarten and the SOS administered in first grade. 'Sustained attention,' 'gender,' 'age' and 'intervention in the intermediate period' were also evaluated as independent variables.

Participants

We recruited 120 typically developing kindergarten children aged 5 to 6 years, in the middle and east of the Netherlands, by sending letters to the heads of elementary schools. After obtaining commitment, we asked 20 kindergarten teachers to select six children, three with good and three with poor performance on paper-and-pencil tasks, based on their own professional opinion, to guarantee contrast in the study sample. Following selection, the teachers completed the Checklist of Fine Motor Skills (van Hartingsveldt, Cup, & Oostendorp, 2005) for each child, to check afterwards the difference between the groups of children with good and poor performance. When written informed consent of the parents was received, we asked the children for their agreement. Children who were not able to complete paper-and-pencil tasks were excluded.

At the first point of measurement, 119 children out of 120 children from 20 kindergarten classes were included; one child did not give informed consent. It appeared that not all teachers selected three children with good performance and three children with poor performance (sometimes the selected four good and two poor) leading to an unequal number of children per group. Demographics are shown in Table 1. In first grade, 109 (92%) of the 119 children were reassessed. The children came from 22 classes with a mean of 23 (range 15 – 33) children per class. From the dropouts, 50% ($n = 5$) were boys and 50% ($n = 5$) were poor performers. The scores of the dropouts on the kindergarten assessment were not significantly different relating to the scores of the total first grade group. The reason for withdrawal was repeating a class (eight children) and illness on the day of administration (two children). For demographics see Table 1. Four different Dutch writing methods were used. Handwriting instruction started in September (94%) or October (6%) and there was a large range in the average time spent per week on teaching handwriting. In the intermediate period, 20 children (18%) received an intervention: 29% of the poor performers got a period of physical or occupational therapy with attention to fine motor skills and handwriting skills, and 16% of the poor performers and 4% of the good performers got a period of extra handwriting exercise at school (Table 1).

The local ethical committee provided formal ethical approval. The studies were in full com

Table 1. Descriptive data of the total group and of the subgroups with poor and good performers in kindergarten and in first grade.

	Total group K-garten (<i>n</i> = 119)	Poor ^a perform. K-garten (<i>n</i> = 43)	Good ^a perform. K-garten (<i>n</i> = 76)	Total Group 1th grade (<i>n</i> = 109)	Poor ^a perform. 1th grade (<i>n</i> = 38)	Good ^a perform. 1th grade (<i>n</i> = 71)
Mean age in month (range)	70.4 (60–86)	70.1 (63–86)	70.6 (60–78)	85.0 (73–97)	84.4 (79–97)	85.1 (73–97)
Number of boys	60 (50%)	36 (84%)	24 (32%)	55 (50%)	32 (84%)	23 (23%)
Number of girls	59 (50%)	7 (16%)	52 (68%)	54 (50%)	6 (16%)	48 (68%)
Left-handed	18 (15%)	9 (21%)	9 (12%)	14 (13%)	7 (18%)	7 (10%)
Right-handed	100 (84%)	34 (79%)	66 (87%)	95 (87%)	31 (82%)	64 (90%)
Variable-hGanded	1 (1%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)
Mean children per class (range)	–	–	–	23 (15–33)	23 (15–33)	23 (15–33)
Writing method ^b	–	–	–	A – 63% B – 19% C – 10% D – 8%	A – 66% B – 18% C – 13% D – 3 %	A – 60% B – 20% C – 9% D – 11%
Start handwriting Sept.	–	–	–	103 (94%)	38 (100%)	65 (92%)
Start handwriting Oct.	–	–	–	6 (6%)	0 (0%)	6 (6%)
Mean time writing/week	–	–	–	128 (90–240)	130 (90–240)	127 (90–240)
Extra PT or OT	–	–	–	11 (10%)	11 (29%)	0 (0%)
Extra handwriting exercise at school	–	–	–	9 (8%)	6 (16%)	3 (4%)

Perform. – Performers; ^a Poor and good performers as rated by the teacher; ^b A = Pennenstreken (Penstrokes); b = Schrijftaal (Written language); C = Schrijven in de basisschool (Writing in elementary school); D = Schrift (Scripture); Sept. = September; Oct. = October; PT, Physical therapy; OT, Occupational Therapy

pliance with the Committee on Research Involving Human Subjects (Dutch abbreviation: CMO) of the Arnhem–Nijmegen area.

Measures

Systematic Screening for Handwriting Difficulties (SOS)

The SOS (Smits–Engelsman et al., 2005; van Waelvelde, Hellinckx, Peersman, & Smits–Engelsman, 2012) is a test in which the child has to copy a piece of text adapted to their age and learning stage, in cursive letters, for 5 minutes. To evaluate the quality of handwriting (SOS–Quality), the first five lines are analyzed using seven criteria: (a) letter form, (b) fluency of letter formation, (c) fluency in connections between letters, (d) letter height, (e) regularity of letter height, (f) space between words, and (g) straightness or regularity of the sentence. We used raw scores as the dependent variable, the range of the items is 0 – 5, except the item 'letter height' that has a score range of 1 – 9. The third criterion is not used in children in first grade who did not yet learn to write in continuous cursive script. Therefore, the total raw score ranged from 0 to 39. The writing speed (SOS–Speed) was measured by counting the number of letters produced in 5 minutes. SOS–Quality has excellent intra-rater reliability (ICC = 0.88), good inter-rater reliability (ICC = 0.77), and moderate test-retest reliability (ICC = 0.69). SOS–Speed has excellent intra-rater reliability (ICC = 1.00), excellent inter-rater reliability (ICC = 1.00), and moderate test-retest reliability (ICC = 0.66). Convergent validity ($r = 0.70$) with the Concise Assessment Methods of Children Handwriting (Dutch abbreviation: BHK) (Hamstra–Bletz, Bie, & Brinker, 1987) was confirmed. The SOS showed significant discriminative validity between typically developing children and children in special education, males and females, and different age groups (van Waelvelde et al., 2012).

Subdomain 'Task performance' of WRITIC (WRITIC–TP)

The main predictive variable for handwriting ability in the current study is WRITIC–TP (score range 0 – 50). This subdomain contains seven items scoring the quality of the paper-and-pencil tasks results using a 3-point scale (2 = good, 1 = doubtful, 0 = insufficient) and six items scoring the quality of sitting posture and pencil grip during performance using a 7-point scale (all items are scored three times on a 3-point scale along with the performance of three different handwriting tasks, these scores are summarized on a 7-point scale from 0 to 6). Within every item the criteria for a good, doubtful and insufficient score are clearly described. For instance within the item pencil grip a child gets 2 points for a dynamic mature pencil grip, 1 point for a static transitional pencil grip and 0 points for an immature pencil grip. Previous research confirmed high internal consistency of the WRITIC–TP ($\alpha = 0.82$), significant ability to discriminate between children with good and poor performance on paper-and-pencil tasks ($U = 11.78$, $p < 0.001$), and excellent test-retest and inter-rater reliability, with ICC's of 0.92 and 0.95 respectively. "All raters of the reliability studies were occupational therapy students and lacked the experience of a paediatric professional. The WRITIC thus appears a feasible instrument that can be im-

plemented by therapists and special teachers in school-based practice" (van Hartingsveldt, Cup, et al., 2014; van Hartingsveldt, de Vries, et al., 2014).

Beery-Buktenica Developmental Test of Visual-Motor Integration

The Beery™VMI is also a predictive variable for handwriting ability; the VMI part of this test includes 24 geometric figures progressing from simple to complex, which the child has to copy. Raw scores were calculated on the number of correct responses (score range 0 – 30). Inter-rater and test-retest reliability are excellent with correlation coefficients of 0.92 and 0.93 respectively. Concurrent and construct validity were confirmed. Normative data in a United States (US) sample were collected in children between 1 and 18 years old ($n=1,737$) (Beery et al., 2010).

Nine-Hole Peg Test

The 9-HPT is a predictive variable and is a simple, commercially available timed test of fine motor coordination in which nine pegs are inserted and removed in a peg-board with a time-score in seconds. Normative data in children were collected in two studies, the first study with children between 5 and 10 years old ($n=826$) (Smith et al., 2000), and the second study with children between 4 and 19 years old ($n=53$) (Poole et al., 2005). The 9-HPT has high inter-rater reliability (r ranges from 0.96 to 0.99) and good test-retest reliability (r ranges from 0.79 to 0.81). Construct validity was confirmed with the Purdue Pegboard test (r ranges from 0.74 to 0.80) (Poole et al., 2005; Smith et al., 2000).

Subdomain 'Sustained attention' of the WRITIC

The item of the subdomain 'Sustained attention' of the WRITIC is tested using a 3-point scale (2 = good, 1 = doubtful, 0 = insufficient). The child gets 2 points when it is focused on the paper-and-pencil tasks, 1 point when the child is not focused and needed encouragement to finish the paper-and-pencil tasks, and 0 points when the child is not focused, encouragement has no effect, and is not finishing the paper-and-pencil tasks. Previous research confirmed significant discriminative validity between children with good and poor performance on 'Sustained attention' ($U = 9.54$, $p < 0.001$), and weak to moderate test-retest and inter-rater reliability with weighted Kappas of .63 and .30 respectively (van Hartingsveldt, Cup, et al., 2014; van Hartingsveldt, de Vries, et al., 2014)

Procedure

In April/May 2011, the WRITIC, Beery™VMI, and 9-HPT were administered in the kindergarten class-room. In May/June 2012, the SOS was administered in the first grade classroom. The WRITIC and SOS were administered individually in the classroom, during the lessons. The Beery™VMI and 9-HPT were administered outside the classroom. All tests were administered according to the literature (Beery et al., 2010; Smith et al., 2000; Smits-Engelsman et al., 2005). The results of the first assessment were not reported back to the teachers and no intervention advice was given based on the outcome. In first grade,

we used a questionnaire for teachers to list the writing method used, the time handwriting instruction started, mean time per week spent on handwriting, and if additional intervention (remedial teaching, occupational therapy, or physical therapy) was provided during the past year.

Test administrators included five paediatric physical therapists and one paediatric occupational therapist. Most children ($n=85/78\%$) had different assessors in kindergarten and first grade. To become competent in administering WRITIC, all testers: (a) attended a training of 3 hours from the first author; (b) practiced with two typically developing children; and (c) checked with their administration regarding use of a videotaped interview with the first author.

Data Analysis

Descriptive statistics were used to characterize the study group by age, gender, writing hand, number of children per class, writing method, time when handwriting instruction started, time per week spent on writing, and if additional intervention was provided during the past year described (Table 1).

Spearman correlation coefficients were calculated between the outcomes of WRITIC-TP, BeeryTMVMI and 9-HPT in kindergarten and SOS-Quality and SOS-Speed in first grade. We used Spearman's correlation coefficient, because the data were not normally distributed and WRITIC-TP outcomes are at an ordinal level.

An univariable linear mixed model for multilevel data was used to evaluate the predictive ability of the variables measured in kindergarten on the SOS outcomes in first grade. The dependent variable was SOS-Quality and SOS-speed in first grade, respectively. The independent variable was the baseline score on WRITIC-TP, BeeryTMVMI, 9-HPT, 'sustained attention,' 'age,' 'gender,' and 'intervention in the intermediate period', respectively.

As number of children per class, writing method, time when handwriting instruction started and time per week spent on writing in the first analyses proved not to be a significant variables in predicting handwriting attainment in first grade, the intercept of each class was treated as a random variable to account for the correlated data between children in the same class. Note that each univariable model consisted of one independent variable and one independent fixed variable and one random variable.

The regression coefficient in each univariable model with the 95% confidence interval (CI) is presented.

A multivariable linear mixed model for multilevel data with selection procedures was used to identify those variables measured in kindergarten that simultaneously predicted the

SOS-outcome in first grade, separately. The dependent variable was SOS-Quality and SOS-speed in first grade, respectively. Variables that reached a p -value < 0.10 in the uni-variable analysis were used in the backward selection procedure (i.e. independent variables were omitted from the model one by one regarding the most non-significant p -value). Differences between the models were evaluated using the Likelihood-Ratio test. Because selection procedures do not identify the other important variables, we also studied close alternatives to the variables selected. The adjusted regression coefficients, with the 95% CI of the final models are presented, i.e. adjusted for all other variables that still remained in the model.

Statistical analyses were performed using SPSS® version 19.0 for Windows (SPSS Inc., Chicago, IL, USA) and SAS® version 9.2 for Windows (SAS Institute Inc., Cary, NC, USA). The critical level for statistical significance was set at $p < 0.05$.

RESULTS

The results of the tests in kindergarten and first grade are reproduced in Table 2.

Table 2. Descriptives of the outcome data.

Variable	A high score corresponds to	Kindergarten		First grade	
		Mean (SD)	Median (range)	Mean (SD)	Median (range)
WRITIC Task performance	good writing readiness	41.15 (5.19)	43 (26–48)	–	–
WRITIC Sustained attention	good sustained attention	1.78 (0.45)	2 (0–2)	–	–
9–HPT	poor fine motor coordination	26.34 (3.65)	26 (19.0–37.6)		
Beery™VMI	good visual motor integration	14.55 (3.61)	15 (8–23)		
SOS–Quality	poor handwriting performance	–	–	18.99 (6.37)	19 (3–34)
SOS–Speed	low handwriting speed	–	–	82.79 (21.23)	78 (47–151)

WRITIC, Writing Readiness Inventory Tool In Context; TP, Task Performance; SA, Sustained Attention; 9–HPT, Nine–Hole Peg Test; Beery™VMI, Developmental Test for Visual Motor Integration; SOS, Systematic Screening for Handwriting Difficulties; '–' indicates the item was not as–sessed

Table 3. Spearman Correlation Coefficient Matrix of WRITIC–TP, 9–HPT and Beery™VMI as measured in kindergarten and, SOS–Quality, and SOS–Speed as measured in first grade.

	WRITIC–TP Kindergarten	9–HPT Kindergarten	Beery™VMI Kindergarten	SOS–Quality Grade 1	SOS–Speed Grade 1
WRITIC–TP Kindergarten	1.00	–0.40**	0.36**	0.22*	0.16
9–HPT Kindergarten		1.00	–0.27*	0.35**	–0.18
Beery™VMI Kindergarten		–	1.00	–0.30**	0.27**
SOS–Quality First grade		–	–	1.00	–0.28**
SOS–Speed First grade		–	–	–	1.00

WRITIC–TP, subdomain 'task performance' of the Writing Readiness Inventory Tool In Context; 9–HPT, Nine–Hole Peg Test; Beery™VMI, Developmental Test for Visual Motor Integration; SOS, Systematic Screening for Handwriting difficulties

* p < 0.05; ** p < 0.01

In kindergarten, WRITIC-TP showed a cross-sectional correlation of $r_s = 0.36$ ($p < 0.001$) with BeeryTMVMI and of $r_s = -0.40$ ($p < 0.001$) with 9-HPT. In first grade, SOS-Quality showed a cross-sectional correlation of $r_s = -0.28$ ($p = 0.007$) with SOS-Speed (Table 3).

The unadjusted and the adjusted regression coefficients of the factors, assessed in kindergarten, to predict the outcomes in first grade, using univariable multilevel analyses and multivariable multilevel analyses with backward selection procedures, respectively, are presented in Table 4. All variables assessed in kindergarten, except age, were statistically significantly related to each of the two outcomes on handwriting in first grade (SOS-Quality and SOS-Speed).

Regarding SOS-Quality in first grade, we found that the WRITIC-TP assessed in kindergarten and the intervention were independent and sufficient variables to predict SOS-Quality in first grade. When we took out the children who received an intervention, WRITIC-TP was the main independent variable. More specifically, a higher value of 5 to 10 in WRITIC-TP resulted in a lower value of 1.1 to 0.6 in SOS-Quality in first grade. The best (similar) alternative to WRITIC-TP was 9-HPT.

Regarding SOS-Speed in first grade, we found that the BeeryTMVMI and 9-HPT assessed in kindergarten were independent variables predicting SOS-Speed in first grade. No close alternative model was found (Table 4).

Table 4. The unadjusted and adjusted regression coefficients of the factors assessed in kindergarten, to predict outcomes on SOS–Quality, SOS–Speed in first grade, using univariable multilevel analyses and multivariable multilevel analyses with backward selection procedures, respectively.

	Total (n=109)		Total (n=109)		Without Interv (n=89)	
	Unadjusted		Adjusted		Adjusted	
	b	(95% CI)	b	(95% CI)	b	(95% CI)
<i>SOS–Quality</i>						
Predictive factors						
WRITIC–TP	–0.15	(–0.25; –0.06)	–0.11	(–0.21; –0.01)	–0.14	(–0.27; –0.02)
Beery™VMI	–0.24	(–0.39; –0.09)	–	–	–	–
9–HPT	0.21	(0.07; 0.34)	–	–	–	–
Sustained attention (no)	1.74	(0.52; 2.97)	–	–	–	–
Gender (male)	2.16	(1.27; 3.04)	–	–	–	–
Age (years)	–0.07	(–0.19; 0.04)	–	–	–	–
Intervention ^a (yes)	–2.01	(–3.24; –0.79)	–1.49	(–2.78; –0.20)	–	–
<i>SOS–Speed</i>						
Predictive factors						
WRITIC–TP	0.60	(–0.18; 1.38)	–	–	–	–
Beery™VMI	2.15	(1.03; 3.27)	1.79	(0.64; 2.95)	2.05	(0.68; 3.43)
9–HPT	–1.63	(–2.68; –0.58)	–1.17	(–2.23; –0.11)	–1.55	(–2.95; –0.15)
Sustained attention (no)	–8.90	(–18.73; 0.94)	–	–	–	–
Gender (male)	–12.67	(–19.96; –5.39)	–	–	–	–
Age (years)	0.05	(–0.85; 0.95)	–	–	–	–
Intervention ^a (yes)	5.95	(–4.12; 16.02)	–	–	–	–

SOS, Systematic Screening for Handwriting Difficulties; WRITIC–TP, Writing Readiness Inventory Tool In Context – Task performance; Beery™VMI, Developmental Test for Visual Motor Integration; 9–HPT, Nine–Hole Peg Test; Interv, Intervention; CI, Confidence Interval; “–” indicates the item was not selected;

^ahaving had an intervention before the assessment in first grade

DISCUSSION

The present study demonstrates that WRITIC-TP, BeeryTMVMI and 9-HPT, administered in kindergarten, are the main predictors of outcome on SOS-Quality and SOS-Speed in first grade. 'Sustained attention,' 'gender' and 'intervention' in the intermediate period also have predictive values on handwriting attainment of first grade children.

WRITIC-TP is the main predictor of outcomes on SOS-Quality and the 9-HPT was the best-fit alternative to WRITIC-TP on SOS-Quality. This is in line with a recent study, which found that fine motor skills (paper-and-pencil tasks and fine motor coordination) should be considered a valuable indicator of school readiness (Dinehart & Manfra, 2013). In their study, Dinehart and Manfra (2013) found that the effects of fine motor writing (paper-and-pencil tasks) were disentangled from fine motor skills related to the manipulation of objects (fine motor coordination) and stronger effects were yielded for paper-and-pencil tasks compared to fine motor coordination. This is in accordance with our results.

The characteristics of handwriting are determined by quality (legibility) and speed (Smits-Engelsman et al., 2005). WRITIC is the main predictor on quality, and BeeryTMVMI and 9-HPT were the main predictors on SOS-speed. Because the last two tests predict handwriting speed instead of quality we can conclude that the BeeryTMVMI and 9-HPT are complementary to the WRITIC.

In kindergarten, we found moderate correlations between WRITIC-TP, BeeryTMVMI and 9-HPT. These moderate correlations with handwriting readiness are confirmed by the literature, for the BeeryTMVMI (Daly et al., 2003; Volman et al., 2006) and for fine motor coordination (Feder et al., 2005). Since all instruments have proven to be reliable and valid, these correlations could be explained as measuring different aspects of handwriting readiness. This underpins the content of the kindergarten assessment containing these three complementary measurements.

The strength of the predictive validity of WRITIC-TP, BeeryTMVMI and 9-HPT must be seen in the perspective of variability. The participants of this study were from 22 classes with different teachers, classmates, writing methods, and time spent on writing, variable developmental maturation (age), different expectations by parents and teachers for handwriting performance, and the influence of computer use both at home and at school (Marr, 2005). As such, we used a linear mixed model for multilevel data, whereby we treated the intercept of each class group as a random variable to account for the correlated data between children in the same class group. The variability makes it difficult to establish predictive validity. However, we still found statistically significant predictive validity with the WRITIC-TP on SOS-Quality and with the BeeryTMVMI and 9-HPT on SOS-Speed.

In the multivariable analysis on SOS-Quality, the best-fit models were with WRITIC-TP,

9-HPT and intervention. Intervention was a confounder, as almost half of the poor performers received some intervention in the intermediate period. This negatively influenced the predictive value of our assessment, as poor performers were trained on handwriting and thus, subsequently scored better on the tests in first grade. Therefore, we also determined the best-fit model without the children who received intervention.

From the univariable analysis, it became clear that the independent variables 'sustained attention,' 'gender' and 'intervention' also had predictive value on handwriting attainment. 'Sustained attention' as a predictor, is in line with the literature: a low attention span can limit the practice of handwriting in 6- and 7-year-old children (Feder et al., 2005), and slow hand writers were poorer in sustained attention (Tseng & Chow, 2000). 'Gender' as a predictor, corresponds with other studies (Berninger et al., 2008; Berninger et al., 1997; Feder et al., 2005), which have reported that girls out-perform boys. Although many first grade teachers believe that children with later birthdays are less ready for handwriting instruction, this study shows that chronological age in first grade was not a predictor. This finding is in line with that of Berninger et al. (Berninger et al., 1997).

An intervention time in the intermediate period was significantly related to handwriting attainment. Three good performers (4%) and 17 poor performers (45%) received an intervention of OT, PT or remedial teaching. Because nearly half of the poor performers received an intervention without advice based on the outcome of the assessment, we can state that the kindergarten teachers made a fairly good selection in forming the two groups for the heterogeneous sample. The surplus value of administering the WRITIC is the task specificity of WRITIC-TP, combined with the overall assessment of the other subdomains that gives valuable criterion-referenced information for advice and intervention.

The subdomains, 'Task performance' and 'Sustained attention' of WRITIC, both have predictive values for handwriting attainment. This is in line with two recent studies (Dinehart & Manfra, 2013; Grissmer et al., 2010). One study established that fine motor skills and attention, measured at kindergarten, are important school readiness indicators. This study also indicates that kindergartners' paper-and-pencil tasks may be a stronger predictor of academic success in middle school than other types of fine motor tasks (Dinehart & Manfra, 2013). Another study on predictive indicators for kindergarten achievement pointed out that that executive function (including attention) and fine motor skills (including coping shapes and drawing a man) make independent contributions to children's kindergarten success as well as improvement from fall to spring of kindergarten (Cameron et al., 2012). Their study used six standardized assessments, we found predictive validity on SOS-Quality with one assessment: the WRITIC.

The potential limitations of this study include: the selection of the teachers in forming the two groups was not performed according to the instruction given with as result that we did not have two same-sized contrast groups. The instructions were apparently unclear to the

kindergarten teachers. As a result, unfortunately, there were fewer children in the group of poor performers. Another limitation is that, for ethical reasons we could not prevent an intervention in the intermediate period and 45% of the poor performers received an intervention. Therefore, it is plausible that the children in this group became better performers, which biased the predictive validity of WRITIC-TP. Hence; the predictive validity of WRITIC-TP is likely to be stronger than the outcome on the multivariable analysis based on our data. Continuing research with a larger group is necessary to further investigate the added value of the WRITIC.

The kindergarten assessment of the WRITIC, BeeryTMVMI and 9-HPT contributes to the detection of children at risk for developing handwriting problems. Based on the findings of current study and the study of Dinhart & Manfra (2013), regarding to the WRITIC, we can conclude that:

- WRITIC is a valuable indicator for (non) writing readiness;
- Tailored advice based on WRITIC can be given to teachers at school;
- Tailored advice based on WRITIC will contribute to the prevention of writing problems in later grades.

The newly developed WRITIC will be published in the Netherlands and Dutch norms will be collected. However, at a later stage, the WRITIC can be translated and tested internationally. The WRITIC needs further development in the form of establishing norm values for cut-off points for at-risk children.

CONCLUSIONS

The results of this study show that the WRITIC-TP, BeeryTMVMI and 9-HPT all have a predictive value on handwriting attainment. The kindergarten assessment, containing three complementary tests, contributes to the detection of children who are at risk for developing handwriting problems. Sustained attention again proved to be an important co-factor that can be measured with the WRITIC. In addition, teachers should be more concerned about boys and children with attention problems, because these variables also have predictive values for handwriting attainment. We recommend this kindergarten assessment be used to assist in achieving the goal of timely intervention for 5- and 6-year-old children and thus, prevent handwriting problems in later grades.

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Chapter 7

General discussion and conclusions



INTRODUCTION

The overall aim of this research project was to develop an occupation-based, psychometrically sound and predictive measurement for five and six year old kindergarten children to evaluate handwriting readiness and to discriminate between children who are ready to learn handwriting and children who are not; this resulted in the Writing Readiness Inventory Tool In Context (WRITIC).

In a university course on clinimetrics, the first thing the lecturer said about developing a measurement was: “don’t start with it.” One of the main reasons was the huge amount of work for the researcher and, eventually, the burden for the target-group. This is in agreement with the statements of Streiner and Norman (2008) who mention in the introduction of their book ‘Health Measurement Scales, a practical guide to their development and use:’ “we must emphasize that the research enterprise involved in developing a new method of measurement requires time and patience” and “nevertheless the most common error is to dismiss existing scales and embark on the development of a new instrument” (Streiner & Norman, 2008)(p.5).

The first two studies presented in this thesis were performed in accordance with this view and with the first step in test development by Kielhofner (2006): ‘identify the need for an instrument.’ The WRITIC was not developed without awareness of existing tests. First, an existing test was evaluated (Chapter 2). As this test appeared not suitable for the identified purpose, a systematic review was carried out to find an occupation-based and psychometrically sound instrument to assess handwriting readiness in five- and six-year-old kindergarten children (chapter 3).

Looking back on the process of development of the WRITIC, the statement by Streiner and Norman (2008) that developing a measurement requires time and patience can be confirmed. In our case, there was little burden for the target group. As described in the fourth chapter, most children liked performing the WRITIC, only seven per cent of the children did not.

The process of measurement development in perspective of new insights

The research on the Peabody Developmental Fine Motor Scale – second edition (PDMS-FM-2) (chapter 2) was accomplished in 2003, ten years ago. At that time, the focus of the assessment was to evaluate fine motor coordination as a performance component of pre-writing skills. Assessments that focus on performance components tend to examine separate components of the child’s skills. These tests were frequently administered in a standardised context, which was not meaningful for the child and was often isolated from relevant daily life contexts (Brown & Chien, 2010). The Korte Observatie Ergotherapie Kleuters (KOEK) in English Screening Prewriting [skills] Occupational Therapy (SPOT)

(van Hartingsveldt, Cup, & Corstens-Mignot, 2006) was a precursor of the WRITIC and was also developed in this paradigm. For instance, cutting with scissors was one of the items included in the fine motor section of the SPOT because the literature suggested that it was a preparatory task in learning to use both hands differently during task performance, which at that time was thought to be important for handwriting (Benbow, 2006).

Over the last decade, there has been a shift in thinking from the process-oriented perspective with a focus on underlying performance components, such as perceptual motor training, toward the task-oriented approach with a focus on the training of the actual activities and tasks (Kennedy, Brown, & Stagnitti, 2013; Mandich, Polatajko, Missiuna, & Miller, 2001; Polatajko & Cantin, 2005; Smits-Engelsman et al., 2013; Wallen, Duff, Goyen, & Froude, 2013). In this approach, assessment and intervention are both focused on the task and based on the interaction between the person, the task, and the environment (Law et al., 1996; Thelen & Smith, 1994). Based on this task-oriented approach, the WRITIC only includes paper-and-pencil tasks and pre-writing tasks as opposed to the SPOT which also included performance components such as fine motor items (e.g., cutting) (van Hartingsveldt et al., 2006). In accordance with the emerging occupation-based perspective in assessment, occupational performance is increasingly evaluated in real-life contexts as opposed to a clinical context and also seeks the child's perspective instead of relying only on the professional perspective (Hocking, 2001; Weinstock-Zlotnick & Hinojosa, 2004). This shift in perspectives was also the case in handwriting (readiness) evaluation (Goyen & Duff, 2005). Therefore, the WRITIC was developed as an occupation-based measurement to evaluate the performance of five different paper-and-pencil tasks. WRITIC is administered in the real-life context of the classroom and evaluates the child's interests in paper-and-pencil tasks.

Our assessment of handwriting readiness contains two steps. In the first step, the WRITIC is administered to assess if the child is ready for the mastering of handwriting. In case a child is not ready for handwriting according to the WRITIC, the second step is administered in which performance components are assessed with the Nine-Hole Peg Test (9-HPT) (Poole et al., 2005; Smith, Hong, & Presson, 2000) and the Beery-Buktenica Developmental Test of Visual-Motor Integration (BeeryTMVMI) (Beery, Buktenica, & Beery, 2010). This is in line with Hocking (2001) and Kennedy et al. (2013) who proposed that occupational therapy assessments need an occupation-based approach that starts with seeking to understand the meaning, function and form of an occupation in the child's life, which may then be followed by a measurement that seeks to understand how performance components influence the child's occupational performance. After the WRITIC assessment of handwriting readiness in which the outcome is that the child is not ready for the mastering of handwriting, a therapist may suspect that a child has a problem with visual-motor integration and/or fine motor coordination. Then the use of the BeeryTMVMI or 9-HPT may be indicated for further investigation of performance components. However, there is still debate about the need to assess performance com-

ponents in writing assessment. Wallen et al. (2013) state that occupational therapists' continuing use of assessments of visual-motor integration and fine motor coordination requires discussion. Her advice is that performance components no longer need to be assessed. On the other hand, recent research has shown that fine motor (including visual-motor integration) and academic skills are related (Cameron et al., 2012; Dinehart & Manfra, 2013; Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010). Therefore, we have decided to still include performance components in our occupation-based assessment of handwriting readiness as the second step in the assessment. This decision is underpinned by the outcome of our research on predictive validity: subdomain 'Task performance' of the WRITIC, BeeryTMVMI and 9-HPT all have predictive value on handwriting attainment.

Why is there a need for the WRITIC?

We developed the WRITIC as an occupation-based measure to evaluate the perceptual-motor part of handwriting readiness in kindergarten children whose teachers have doubts about whether or not they are ready to learn handwriting. To facilitate a good transition from kindergarten to first grade, the kindergarten period is essential to recognise problems and avoid further derailment. Early school success and positive transitions tend to translate to higher levels of social competence and academic achievement that remain stable over time (Pianta & Cox, 1999; Bart et al., 2007). Research, which explored the long-term consequences of interventions, concluded that the early school years are the most cost-effective time to intervene (Heckman, Stixrud, & Urzua, 2006). This is in accordance with an epidemiologic study on writing disorders, that promote to increase the efforts to identify, and provide timely intervention for children to prevent the burden of handwriting difficulties in later life (Katusic, Colligan, Weaver, & Barbaresi, 2009). In the same way Cameron et al. (2012) state that successful intervention depends on identifying the readiness skills that predict long-term achievement and on interventions that can improve these skills early in the school trajectory.

Transcription skills consist of handwriting and spelling (Berninger, 2009). These skills play a crucial role in early written expression. When children lack adequate transcription skills, they consciously devote their attention to forming letters and spelling words, taking away considerable intentional and cognitive resources from composing text (Peverly, 2006). In the same way, it is determined that sufficient handwriting practice contributes to good transcription skills so that cognitive processes are free to focus on ideas and the knowledge of the subject of the written products (Berninger et al., 2006; van Galen, 1991; Wallen et al., 2013). In addition, Puranik and AlOtaiba (2012) examined the contribution of handwriting and spelling in beginning writers. The findings of their study support the theoretical proposition that handwriting and spelling are important ingredients in early writing development. They determined that of these two variables, handwriting accounted for the most unique variance in young children who are mastering text writing. Another important implication of that study is the need to identify children

who may be at risk for writing difficulties (Puranik & Alotaiba, 2012). This underpins the value of the development of the WRITIC: to detect children at risk for developing handwriting problems.

Another perspective is that Overvelde and Hulstijn (2011) found that children with handwriting problems, according to the Concise Evaluation Scale for Children’s Handwriting (Dutch acronym BHK) (Hamstra-Bletz, Bie, & Brinker, 1987), continued to show significant and substantial improvement during grades 2 and 3. In their study, handwriting problems decreased from 37% to 17% in grade 2 and diminished further to a low and stable rate of 6% in grade 3 (Overvelde & Hulstijn, 2011). However, children whose handwriting problems diminished in later grades often struggled in mastering handwriting in first grade. Therefore, early detection of handwriting difficulties with WRITIC is also important for these children. The children can then be encouraged and supported to develop their pre-writing skills to diminish the struggle and burden in mastering handwriting.

Psychometric properties of the WRITIC

The psychometric properties of the WRITIC were rated using the ‘quality criteria for measurement properties of health status questionnaires’ (Mokkink, Terwee, Knol, et al., 2010; Terwee et al., 2007). Mokkink, Terwee, Knol, et al. (2010) recommend using their criteria as an aid in the design and reporting of studies on the development of measures. Psychometric properties were determined using classical test theory. In our studies more than 50 children were included, which is an important criterion in psychometric research (Terwee et al., 2007) and positive results were found on most measurement properties (Table 1). The psychometric studies on content validity and reliability were performed on all subdomains of the WRITIC. The studies on internal consistency, construct validity and criterion validity were only performed on the subdomain ‘Task performance’ of the WRITIC (WRITIC-TP).

Table 1. Summary of psychometric properties of WRITIC according to the criteria of Terwee et al. (2007) in typically developing kindergarten children (5 – 6 years).

	Content validity	Internal consistency	Construct validity	Reliability	Criterion validity	Responsiveness	Floor or ceiling effect	Interpretability
WRITIC	+	+	+	+	+	0	+	0

+ = positive; ? = doubtful rating; 0 = no information available

There are some points for discussion, including the fact that criterion validity with a golden standard was not studied. A golden standard is the traditional way to determine criterion validity and is also called concurrent validity, whereby the administering of the two

measures at the same time. According to the outcome of our systematic review (Chapter 3), there is no golden standard to determine concurrent validity. Another form of criterion validity is predictive validity, whereby the criterion is administered in the future (Streiner & Norman, 2008). Predictive validity is important in professional decision making to determine the need for interventions in children, in our case, that are at risk of handwriting problems (Harris, Backman, & Mayson, 2010). We determined predictive validity by examining whether the outcome on the subdomain 'Task performance' of WRITIC administered in kindergarten predicted the scores on the performance of handwriting in first grade, administered with Systematic Screening for Handwriting Difficulties (Dutch abbreviation: SOS) (van Waelvelde, Hellinckx, Peersman, & Smits-Engelsman, 2012). In a multivariable linear mixed model analysis, WRITIC-TP was the main predictor for outcomes of the Quality part of the SOS (Chapter 6). This will be discussed later.

The COSMIN checklist, developed by Mokkink, Terwee, Patrick, et al. (2010), to evaluate the methodological quality of studies on measurement properties, suggests that construct validity will be assessed by testing predefined hypotheses, e.g., about expected correlations between measures (convergent validity) or expected differences in scores between 'known' groups (discriminative validity) (Streiner & Norman, 2008). In evaluating discriminative validity, as part of construct validity, it is less relevant whether these differences are statistically significant (depending on the sample size) than whether these differences are as large as could be expected (Mokkink, Terwee, Patrick et al., 2010). A weakness is that we did not hypothesise the extent of the difference. Therefore, we propose to collect norm values. Based thereon, cut-off points can be established; then the WRITIC can fulfil its aim as a decision-making tool to identify whether interventions are needed to achieve handwriting readiness.

Responsiveness and minimal important change (MIC) are not yet established. This is because we developed the WRITIC as a discriminative measurement and therefore determining responsiveness is not necessary. When WRITIC will be used in school-based practice, future research will be needed to evaluate the effect of the intervention based on the outcome of the WRITIC.

From the data in the total group ($n = 251$), it became clear that 7.5% of the participants had the highest two scores and 8% had the two lowest scores on the subdomain 'Task performance.' This was in line with the Terwee criteria on floor and ceiling effects. This means that the range is large enough and variability in scores is present (Mokkink, Terwee, Knol et al., 2010; Mokkink, Terwee, Patrick et al., 2010; Terwee et al., 2007).

Interpretability, the degree to which one can assign qualitative meaning to quantitative scores, was not determined by our research.

The WRITIC as norm-referenced and criterion-referenced instrument

The WRITIC is a norm-referenced as well as a criterion-referenced measurement (Richardson, 2010) (see Figure 1). In addition to the future norm-referenced information from the subdomain 'Task performance' (WRITIC-TP), administering the WRITIC gives valuable criterion-referenced information by evaluating the child factors, environmental factors and task specific factors. This is important for advice and intervention to optimise the occupational performance of the child. How to interpret the results on these factors is further discussed below.

WRITIC Domains	WRITIC Subdomains	
Child	Interest <i>Questionnaire</i> colouring/drawing/ handwriting . how often? . how nice? . how well do you think you're doing	Sustained attention <i>1 item scored by tester</i> . focused . encouragement needed . encouragement no effect
Environment	Physical <i>2 item scored by tester</i> . chair height . table height	Social <i>1 item scored by tester</i> . quiet class . less quiet class . chaotic class
Paper-and-pencil tasks	Task Performance* <i>13 item scored by tester</i> . product of the tasks . pencil grip . body position	Intensity of <i>4 item scored by tester</i> . distance nose-table . shoulder position . intensity pencil grip . pencil pressure

*norm-referenced part of the WRITIC

Figure 1. Overview of (sub)domains of the WRITIC with their content.

Child

- The subdomain 'Interest' focuses on the child's perspective by evaluating the child's interest, frequency and perceived competence in paper-and-pencil tasks. The child perspective is important in occupational therapy focusing on enabling occupation of the child. An occupation is defined as a personally constructed, individual experience of the child (Pierce, 2001). The subdomain 'Interest' is part of the WRITIC and gives information to better interpret the performance of the

child; this information can be used in planning advice or interventions that better match the child's needs.

Regarding the competence part of interest, it has become clear from the literature that kindergarten children, compared to older children, are less aware of their level of competence. At this age, the perception of competence is often more positive than the actual level of performance. However, their positive perceptions provide a "window of opportunities for fostering skilfulness" (LeGear et al., 2012)(p.9).

- The subdomain 'Sustained attention,' consisting of one item, discriminates between children with good and poor performance (Chapter 4) and is a predictor for handwriting attainment in first grade (Chapter 6). This is in line with other studies on school readiness. Grissmer et al. (2010) found that attention, next to fine motor skills and general knowledge, was a strong predictor of school readiness (Grissmer et al., 2010). In the same way Cameron et al. (2012) found that attention, as part of executive function as well as fine motor skills, both contribute to kindergarten achievement (Cameron et al., 2012). This is in line with a study of 527 first grade children in a Northern Florida community. In this study it became clear that attentiveness of children was uniquely related to the two dimensions of written expression, namely the substantive quality of the written composition and transcription skills (e.g. spelling and handwriting), even after accounting for other influencing variables (Kim, Otaiba, Sidler, & Gruelich, 2013). These findings are consistent with the study by Thomson et al. (2005), which showed that attentiveness was related to reading and writing (Thomson et al., 2005). The results of these studies suggest that in order to improve the mastery of handwriting in children, sustained attention needs to be assessed.

From our research it became clear that 'Sustained attention' is an important prerequisite of handwriting readiness. Because the WRITIC was developed as a screening instrument, this subdomain is evaluated with one item and reliability was insufficiently determined (chapter 5). In a future version of the WRITIC, this subdomain needs to be adapted so that it contains more items and reliability has to be determined again. In addition, a search for another measurement evaluating 'sustained attention' can be considered.

Environment

- The subdomain 'Physical environment' evaluates the seating posture of the child. Handwriting authorities state that school furniture configurations affect handwriting outcomes in children (Feder & Majnemer, 2007). School-based therapists encourage children to sit in the school chairs with their hips, knees and ankles at 90° with their feet fully supported, and to use desks that support the forearms comfortably (Pollock et al., 2009; Schneck & Amundson, 2010).

Although furniture designed this way is believed to provide proximal stability and optimise fine motor control distally, little empirical evidence exists regarding the relationship between ergonomic factors and handwriting (Overvelde et al., 2011). There are indications in only one study, on the effect of seating position quality in typical developing six- and seven-year-old children, that suggest that the fit of the furniture to the child's size may have an impact on complex in-hand manipulation skills, such as handwriting (Smith-Zuzovsky & Exner, 2004). This is in line with research which determined that children who had poor handwriting had an inferior body position compared to children with good handwriting (Parush, Levanon-Erez, & Weintraub, 1998). In addition, another trial described a high correlation ($r = .75$) between body position and the fluency of handwriting (Rosenblum, Goldstand, & Parush, 2006). Wallen et al. (2013) are critical and state that research has failed to find an association between aspects of handwriting and biomechanical factors considered to contribute to handwriting. In our study on discriminant validity we found that 30% of the poor and good performers were seated in chairs with inappropriate support. Therefore, despite the fact that there is contradictory evidence, it seems that especially for children with poor handwriting skills, optimising environmental factors such as the seating position can be helpful to optimise the learning process and therefore, criterion-referenced information appears to be relevant to consider when advising the teacher and the start of training in most ideal circumstances.

- The subdomain 'Social environment' evaluates the classroom climate. In a culture that regards (in)attention as an individual attribute, Milman (2008) states that often the valuable information regarding how students and teachers collectively produce behaviour during everyday interactions in the classroom is missed (Milman, 2008). This is especially true for children with poor sustained attention; evaluation of the class climate provides criterion-referenced information, which helps to understand the struggle of the child to maintain attention and gives advice to the teacher on interactions with the class. Kim et al. (2013) suggest that teachers' interaction with students may be an important factor to consider in stimulating sustained attention and facilitating children's writing development. This is in line with the emphasis in occupational therapy to evaluate and treat in the environment, so-called context therapy (Darrah et al., 2011). This contextual approach focuses on changing factors in the task and environment rather than on remediating a child's (motor) impairment. This is fundamentally different from other task-oriented approaches focusing on child factors described in the literature because in context therapy the therapist focuses on changing task or environmental constraints (Darrah et al., 2011).

Paper-and-pencil tasks

- The subdomain 'Task performance' offers criterion-referenced information about paper-and-pencil tasks, pencil grip and body position. This subdomain has seven items on the quality of product of paper-and-pencil tasks and these items are scored on the actual results of the performance of the task, important as a task-oriented measurement.

This subdomain 'Task performance' also includes six items on pencil grip and body position. Pencil grip is evaluated in terms of mature (dynamic), transitional (static) or immature (static) grips. There is a lot of research done on the relationship of pencil grip with legibility and speed. Subsequent studies, however, found that grip affected neither legibility (Koziatsek & Powell, 2003) nor the undertaking of writing long passages (Dennis & Swinth, 2001), although these studies did not take into account the static or dynamic aspect of the adopted grips (Ziviani & Wallen, 2006). Recent research (Kushki, Schwellnus, Ilyas, & Chau, 2011; Schwellnus et al., 2012, 2013) confirmed that different mature (dynamic) pencil grips did not influence handwriting speed or legibility in fourth-grade students. However, students in this trial that were classified in the category 'not mature and not dynamic' were all dysgraphic writers. These students all had poor legibility scores and had a static grasp whereby letter formation was achieved via wrist movements. Although this sample was too small for statistical analysis, future comparisons of writing speed and legibility between dynamic and static pencil grasp are recommended (Schwellnus et al., 2012).

- The subdomain 'Intensity of performance' appeared not to discriminate between good and poor performers. This subdomain contains four items on forced body posture: distance nose-table, shoulder position, intensity of pencil grip and pencil pressure. Kushki et al. (2011) indicated that more children tended to adapt forward-leaning postures as the writing progressed. This change in posture may have partially contributed to increased muscle tension and force on the pen and writing surface to stabilise the forward-leaning body. A forced grip may lead to discomfort during the long-term performance of paper-and-pencil tasks, such as a cramp or pain (Sassoon, 2006). Thus, despite the fact that this subdomain does not discriminate between good and poor performers, it offers criterion-referenced information for advising the teacher on how to stimulate non-forced pencil grip and body position.

Predictive value of the WRITIC

In Chapter 6 it was established that the outcome on the subdomain 'Task performance' of the WRITIC (WRITIC-TP), administered in the pre-writing phase, predicts scores on handwriting in the first grade, evaluated with the Quality part of the Systematic Screen-

ing for Handwriting Difficulties (Dutch abbreviation: SOS) (Smits-Engelsman, Stevens, Vrenken, & van Hagen, 2005) in conjunction with the BeeryTMVMI (Beery et al., 2010) and the 9-HPT (Smith et al., 2000) that have predictive value on SOS-Speed. This supports the idea that the BeeryTMVMI and 9-HPT are complementary to the WRITIC and could be administered in a second step in case of a child not being ready for handwriting according to the WRITIC.

Predictive validity was established despite large variability. The participants in this study were from 22 classes with different teachers, classmates, handwriting methods, and time spent on handwriting. Thereby multiple factors, including parental beliefs and practices, sociocultural factors, and child characteristics, contributed to children's skills and this variability (Skibbe, Hindman, Connor, Housey, & Morrison, 2013). This variability makes it difficult to establish predictive validity. However, we still found statistically significant predictive validity with the WRITIC-TP on SOS-Quality and with the BeeryTM-VMI and 9-HPT on SOS-Speed.

The predictive value of the subdomain 'Task performance' and the subdomain 'Sustained attention' as predictive variables on handwriting readiness are in line with outcomes of other studies on school readiness indicators. Cameron et al. (2012) found that executive function (including attention) and fine motor skills (including copy shapes and drawing a man) make independent contributions to children's kindergarten achievement as well as improvements from Fall to Spring of the kindergarten year. The researchers advise an increase in children's opportunities for fine motor paper-and-pencil tasks in kindergarten. In the same way, Grissmer et al. (2010) established that fine motor skills and attention, measured at kindergarten, are important school readiness indicators. This study also indicates that kindergartners' paper-and-pencil tasks may be a stronger predictor of academic success in middle school than other types of fine motor tasks. In accordance with this study, Dinehart and Manfra (2013) determined that fine motor writing ability in preschool is a stronger predictor of academic achievement in second grade than is fine motor manipulation. They suggest a possible explanation that handwriting provides children with the opportunity to create internal models for the symbol necessary to succeed in academic disciplines. This is in line with the research of Longcamp, Zerbato-Poudou, & Velay (2005), whereby two groups of 4-year old children were compared; one group learned words by keyboarding and the other group by handwriting. Children in the handwriting group outperformed the children in the typing group, suggesting that writing letters by hand helped children develop an internal model of the alphabetic character (Longcamp, Zerbato-Poudou, & Velay, 2005). Thus, it seems to be important that children learn to write letters regardless of whether or not this is with a pencil on paper or with a stylus on a tablet.

There are also other findings in the literature regarding the lack of relationship between fine motor performance and academic readiness. In a study by Piek, Dawson, Smith, and Gasson (2008) in 33 children they found that fine motor trajectory information did not

account for a significant proportion of the variance in school aged fine motor performance or cognitive performance. In this research, fine motor was evaluated by timed performance of transferring beads into a box, and beads onto a rod, finger tapping, turning a nut on a bolt, and sliding a peg on a rod as slowly and smoothly as possible. The difference between this research and our research with the WRITIC-TP is that in their research no items on paper-and-pencil tasks were included as apposed to our task-oriented assessment. On the other hand, gross motor information was a significant predictor (Piek, Dawson, Smith, & Gasson, 2008) of academic readiness.

Next to the WRITIC-TP, BeeryTMVMI, 9-HPT and 'sustained attention' as measured with the WRITIC, 'gender' is also a predictive variable of handwriting attainment in the first grade. 'Gender' as a predictor of handwriting corresponds with other studies (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008; Berninger et al., 1997; Feder et al., 2005), which have reported that girls outperform boys. In a recent epidemiological study of written language disorders it was found that boys have two to three times more hand-writing problems than girls (Katusic et al., 2009). Berninger et al. (2008) stated that the gender gap could be narrowed if more schools were proactively screening to identify boys, who are especially at risk for handwriting problems. Identified boys could then be provided with additional support and task specific training.

Second step in the assessment of handwriting readiness

In case of a child not being ready for handwriting according to the WRITIC, children who are at risk can be further assessed with the BeeryTMVMI and the 9-HPT. These two tests are both feasible to administer in a short period of time and are part of the screening assessment on handwriting readiness. In children, who have more spatial problems, e.g., in producing the characteristic shape of letters and numbers, the BeeryTMVMI gives additional information. In children, who have more trouble with the fine motor aspects of pre-writing, such as using a static pencil grip or struggling with the coordination of performing lines, the 9-HPT can give additional information. The information from these tests is important in giving advice and in planning interventions.

In Chapter 5 moderate correlations between the BeeryTMVMI and WRITIC-TP were found. This is in line with other studies which found a moderate correlation between the BeeryTMVMI and the ability of kindergarten children to copy letterforms (Daly, Kelley, & Krauss, 2003; Marr, Windsor, & Cermak, 2001; Weil & Amundson, 1994). This correlation declines in children of second and third grade (Goyen & Duff, 2005; Overvelde & Hulstijn, 2011).

The choice selection for these tests on performance components is based on the results of the systematic review (Chapter 3). In our review, two tests were found to evaluate fine motor coordination; the Nine-Hole Peg Test (9-HPT) (Smith et al., 2000) and the Test

of In-Hand Manipulation Revised (TIHM-R) (Pont, Wallen, Bundy, & Case-Smith, 2008). The decision to choose the 9-HPT was made on the basis of the psychometric qualities of this test. The 9-HPT has high inter-rater reliability (r ranges from 0.96 to 0.99) and good test-retest reliability (r ranges from 0.79 to 0.95). Construct validity was confirmed with the Purdue Pegboard test (r ranges from 0.74 to 0.80) and the Bruininks-Oseretsky Test (r ranges from -0.87 to -0.89) (Poole et al., 2005; Smith et al., 2000; Wang et al., 2011).

Berninger and Rutberg (1992) used the fine motor test 'finger succession task' or 'sequential finger movements' and determined that the sequential finger movements have, in relation to other fine neuro-motor tasks, the best correlation to handwriting ($r = .32$). This moderate correlation is the same as we found between the WRITIC-TP and the 9-HPT (Chapter 5). In this 'finger succession task' the child has to touch the thumb with each finger, in sequential order, beginning with the little finger and moving to the index finger, as quickly as possible (Berninger & Rutberg, 1992). Because the 'finger succession task' falls outside the scope of the definitions of fine motor coordination of Exner (2010) and the International Classification of Function Disability and Health for Children and Youth (ICF-CY) (WHO, 2007), we did not include this in our systematic review and research on fine motor tests. In the ICF-CY, patterns of fine hand use are described separately as: picking up, manipulating and releasing (WHO, 2007) and Exner (2010) describes the different fine motor patterns as simple patterns (reach, grasp, carry and voluntary release) and complex patterns (in-hand manipulation and bilateral hand use). In an occupation-based assessment the emphasis is on measurements that are highest in the hierarchy of the Taxonomic Code of Occupational Performance (TCOP) (Polatajko et al., 2007). The Timed-THIM and 9-HPT are higher in that hierarchy than the 'finger succession task.' Thus, that is why the 9-HPT was chosen. Studies are needed to evaluate if the 'finger succession task' has a significant correlation with the 9-HPT, the Timed-TIHM and WRITIC-TP.

On the basis of the screening assessment of the WRITIC, the BeeryTMVMI and the 9-HPT, therapists can give tailored advice to teachers to support these children. In addition, therapists can offer an intervention to practice pre-writing skills, which can contribute to the readiness of the child for handwriting. The evaluation of the effect of the intervention of a paediatric therapist is a topic for future research.

Is the WRITIC a measurement for therapists or teachers?

The WRITIC is developed as a screening instrument to evaluate handwriting readiness in the pre-writing phase in the classroom context. The established excellent reliability indicates that the administration and interpretation of the scoring of the norm-referenced subdomain 'Task Performance' is robust and well standardised and provides stable outcomes over time and between raters (see Chapter 4). This excellent agreement is particularly interesting because all raters of the reliability studies were students

and lacked the experience of a paediatric occupational or physical therapy professional. WRITIC thus appears to be a feasible efficient instrument that also can be implemented by non-therapists, for example specialized teachers in school-based practice. For further implementation of the WRITIC in the Netherlands, it is of added value when specialised teachers can administer the WRITIC in the school setting. Future research is needed to evaluate if our training, which consists of three-hour intensive face-to-face training, practicing the WRITIC with two typically developing children, and evaluating interrater reliability, will suffice for teachers in administering the WRITIC with satisfactory inter-rater reliability.

The WRITIC as measurement of school-based therapy

In the international literature on school-based occupational therapy, occupational therapists have recognised the need to move away from one-on-one, direct model of service delivery towards a more collaborative approach that supports students in the classroom by providing consultation to teachers and parents. Occupational therapy for children in school settings focuses more and more on capacity building through collaboration and coaching in context. In this approach, an occupational therapist works with teachers in the classroom on supporting children's everyday functioning in school (Campbell, Missiuna, Rivard, & Pollock, 2012; Missiuna et al., 2012). In the Dutch situation, we have school-based occupational therapy in special education; however, in regular education school-based occupational therapy is lacking. Paediatric community-based occupational therapists are working with children in regular school-settings, but in the Netherlands there is a lack of availability due to restrictions on allowed number of visits. With the introduction of the law on inclusive education (in Dutch: Wet passend onderwijs) in August 2014, the focus is on early identification of children as well as to build teachers' capacity to manage learning problems based on disabilities over the long term (OCW, 2013). Thereby it is indicated that teachers need to increase their awareness of students' occupational needs (Wehrmann, Chiu, Reid, & Sinclair, 2006). A measurement like the WRITIC fits in well with this development, especially when specialised teachers can administer the WRITIC in the school context. When the WRITIC is published, the manual will contain the state of the art advice on the different possible problems that will be evaluated by this future norm-referenced and criterion-referenced measurement. This will be an update of the content of the manual of the SPOT (van Hartingsveldt et al., 2006). When children have minor problems according to the WRITIC, the teacher will be supported by recommendations in the manual. When children have major problems, school-based occupational therapy is indicated in which the occupational therapist works collaboratively with the teacher. Interventions to support the child's participation include adaptations in the child's physical and social environment, task-oriented training with enough practicing time and demonstrating strategies that enhance participation of children in paper-and-pencil tasks (Hoy, Egan, & Feder, 2011; Missiuna et al., 2012; Overvelde, 2013).

The WRITIC in different educational cultures

The WRITIC was developed to evaluate handwriting readiness in the pre-writing phase. In the Netherlands, children start with the mastery of handwriting in first grade. Thus, in our situation, administering the WRITIC halfway through kindergarten, allows enough time to give advice to the classroom-teachers to support these children or if needed to offer an intervention to practice pre-writing skills. This way the child becomes more ready for learning the mastery of handwriting in the first grade. In other countries, the pre-writing phase is in an earlier grade (North America) or later grade (Scandinavian countries), however each child will have the same learning stages in the mastery of handwriting. Thus, the time point for administering the WRITIC would be adapted to the educational settings in a country. When the WRITIC will be used in other countries, there is a need for a culturally sensitively translation (Wild et al., 2005). This is extremely important when the WRITIC will be used in countries where they use characters, such as in China and Japan or where they use another alphabet and writing direction such as in Israel and the Arab countries. After a culturally sensitive translation of the WRITIC, the psychometric properties of the translated version of the WRITIC need to be determined.

The kindergarten screening of handwriting readiness

With the kindergarten screening of handwriting readiness, consisting of the WRITIC, the BeeryTMVMI and the 9-HPT, it becomes clear which children are at risk to develop handwriting difficulties. With the outcome of this screening, kindergarten classroom-teachers can be supported in coaching the children in the mastery of handwriting to prevent handwriting difficulties in higher grades. This will help children develop an automatically produced handwriting, so they will have enough capacity for idea generation, spelling and composing of their written work (Medwell, Strand, & Wray, 2009; Peverly, 2006; Wallen et al., 2013).

In the Evidence Statement (ES) Motor handwriting problems in children, five profiles of handwriting problems are distinguished on handwriting (readiness) difficulties: a) in combination with (fine) motor problems; b) based on cognitive and/or behavioural problems; c) based on didactic problems at school; d) as a combination of motor, cognitive and/or behaviour problems; and e) based on motor problems and underlying pathology (Overvelde, 2013; Overvelde et al., 2011). Our hypotheses are that:

- a. Children with profile A will not be ready for handwriting according to the WRITIC-TP in combination with fine motor problems according to the 9-HPT and/or the BeeryTMVMI;
- b. Children with profile B will not be ready for handwriting according to the WRITIC-TP, for example in combination with a low score on the subdomain 'Sustained attention' in children with attention deficit/hyperactivity disorder. Children with profile B could also not be ready for handwriting according to the

- WRITIC-TP in combination with a Learning Disability (LD) based on a cognitive weakness indicated by the BeeryTMVMI and intelligence tests;
- c. Children with profile C will not be ready for handwriting according to the WRITIC-TP because of insufficient practising time in school;
 - d. Children with profile D are a combination of the description of profile A and B;
 - e. Children with profile E are children who are not ready for handwriting according to the WRITIC-TP and who have a medical diagnosis.

With a screening of handwriting readiness, consisting of the WRITIC, the BeeryTMVMI and the 9-HPT, children with profile A, B, C and D could be evaluated and on the basis of the outcomes and advice and/or intervention in the school context can be recommended and planned. Children with profile E could also be screened on handwriting readiness. This is a starting point for further evaluation and intervention in the school context and/or an individual physical or occupational therapy intervention (Hoy et al., 2011; Missiuna et al., 2012; Overvelde, 2013). In future research, our hypotheses on the different profiles need to be explored. Then attention can be given to these different profiles of children who are not ready for handwriting, in assessment and intervention (Overvelde et al., 2011).

Conclusions and implications for practice

- The systematic review of tests that assess aspects of handwriting readiness of 5- and 6-year-old children provided an overview of the content, feasibility and psychometric properties of these tests in view of an occupation-based assessment;
- The WRITIC, a new assessment of handwriting readiness in 5- and 6-year-old children has been developed. It is meant to be administered in the pre-writing phase, approximately half a year before children start with the mastery of handwriting, in children whereby teachers are worried about their handwriting readiness;
- The WRITIC contributes to the evaluation of handwriting readiness. Children who are not ready for handwriting are at risk of developing handwriting difficulties. They thus benefit from an early assessment in order to prevent the negative influences caused by handwriting difficulties;
- The WRITIC includes a section that can be used to sample norm-referenced data as well as a criterion-referenced section. The norm-referenced section (WRITIC-TP) aims to evaluate if the child is ready for the attainment of handwriting. The criterion-reference section (the other subdomains) provides valuable information for paediatric therapists and specialised teachers in advising or planning an intervention;
- The WRITIC is a stable assessment of handwriting readiness in 5- and 6- year old children over a time period of one or two weeks and between raters;
- The WRITIC can be administered in the educational environment of the child after a relatively short training of three hours;

- The Beery™VMI and the 9-HPT give additional information about handwriting readiness;
- Teachers need to be more concerned about boys and children with attention problems, because these variables also have predictive value for handwriting difficulties.

Recommendations for further research

- Norms will be collected in Dutch children and cut-off points for at-risk children need to be established.
- The subdomain 'Sustained attention' needs modification in a future version of the WRITIC, so that it contains more items and is more robust. Afterwards, reliability needs to be re-established.
- Future research is recommended to test if the described training to administer the WRITIC will be enough for specialised teachers and also to examine if they can administer the Beery™VMI and the 9-HPT and interpret these results in advising the class-teacher.
- Future research is needed to evaluate the responsiveness of the WRITIC after an intervention period of supporting the teacher based on the state of the art advice in the manual and on the paediatric therapy intervention in children with major problems.
- In future research, attention needs to be given to the different profiles of children who are not ready for handwriting in assessment and intervention.
- When the WRITIC will be used in other countries, a cultural sensitive translation is recommended; the translated WRITIC needs to be tested psychometrically and norm values and cut-off points should be established. Special attention is needed when there is another education culture with a pre-writing phase in an earlier or later grade and the WRITIC is to be administered in children of another age.
- With the growing use of tablets in the school situation, in the future, the WRITIC could be adapted for stylus-and-tablet tasks and a psychometrically sound digital version of the WRITIC could be developed.
- Future research of the WRITIC will be focused on children with special needs such as children with developmental coordination disorder (DCD), mild cerebral palsy (CP) and children with other neurological disorders with mildly impaired hand function to evaluate if the WRITIC can be used with children with special needs.

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Summary



The main objective of this thesis was the development of a measurement instrument to assess handwriting readiness in five- and six-year-old children: the Writing Readiness Inventory Tool In Context (WRITIC). To guide the developmental process, Kielhofner's Steps in Test Development were followed (**Chapter 1**). During this process, several studies were conducted between 2008 and 2012. In this chapter a summary of all consecutive studies is described. The first study, described in **Chapter 2**, was conducted before this period in the context of my master thesis. This study was performed to evaluate the psychometric properties of the Dutch translated Peabody Developmental Fine Motor Scales second edition (PDMS-FM-2). The conclusion of this study was that this test was not sensitive enough to evaluate typical developing children with problems with paper-and-pencil tasks. This study and the absence of a standardised test that evaluates handwriting readiness in the prewriting phase, was the trigger to start the search for an instrument to evaluate handwriting readiness. In **Chapter 3**, the first step in test development was described: 'identifying the need for an instrument.' A systematic review showed that an occupation-based test to evaluate handwriting readiness was not present and therefore the development of the WRITIC was started. In **Chapter 4**, the development of the WRITIC and studies on content validity, construct validity and feasibility of the WRITIC were described. In **Chapter 5**, three cohort studies were reported to determine test-retest reliability, inter-rater reliability and convergent validity with the Developmental test for Visual-Motor Integration (BeeryTMVMI) and the Nine-Hole Peg Test (9-HPT). **Chapter 6** described a prospective longitudinal cohort study with the WRITIC, the BeeryTMVMI and the 9-HPT to evaluate predictive validity. Finally in Chapter 7, the main findings were discussed followed by conclusions and recommendations.

Chapter 1 is a general introduction and provides background information on handwriting, handwriting readiness and occupation-based assessment (an assessment focused on the performance of activities in a relevant context). It addresses the evidence that practising handwriting is important for the learning of reading and spelling and therefore still vital in our current time even with the increased availability of computers, tablets and smartphones. Descriptions are given of a developmental model and two process models of handwriting. The state of the art of the performance components of handwriting is described with the conclusion that visual motor-integration and fine motor coordination are both evidence-based performance components. Handwriting readiness is explained as a necessary construct for the mastering of handwriting. In this thesis handwriting readiness is seen from the perspective of intrinsic factors of the child, extrinsic factors of the environment and the performance of paper-and-pencil tasks. The interactive perspective in theories of development, which becomes clear in the Person-Environment-Occupation (PEO) Model, is a theoretical assumption of this thesis. As there are many children with handwriting problems, the importance of an early evaluation of handwriting readiness is emphasised. Occupation-based assessments focus on real-life situations and the evaluation of handwriting readiness focuses on the way children participate in school as the most relevant context. Finally, an outline of the thesis is provided.

The study reported in **Chapter 2** evaluates the psychometric properties of the second edition of the Dutch translated Peabody Developmental Fine Motor Scales (PDMS-FM-2) in typically developing children of four- and five-years-old. Excellent test-retest reliability and inter-rater reliability was established and convergent validity with the manual dexterity part of the Movement-Assessment Battery for Children (M-ABC) was confirmed. Discriminative validity was determined with two groups of 18 children with and without mild fine motor problems. Groups were formed based on the opinion of the teacher, determined by the checklist of Fine Motor skills, specially composed for this research. Only 39% of the children in the group with fine motor problems had 'problems' as defined by the PDMS-FM-2; comparatively, 78% of these children had fine motor problems according to the Dutch norms of the M-ABC. The conclusion was that the PDMS-FM-2 was not sensitive enough for typically developing children with fine motor problems as determined by their teacher. The M-ABC was indeed sensitive for this population, but because it consists of only three items, it should be complemented by another test or observation. This resulted in a recommendation for an assessment for Dutch kindergarten children, including a) the standardised observation Screening Prewriting skills Occupational Therapy (SPOT); b) the dexterity items of the M-ABC; and c) the Developmental test for Visual-Motor Integration (Beery-VMI). This study and doubts about psychometric characteristics of the SPOT, was the trigger to start the search for a reliable and valid instrument to evaluate handwriting readiness in five- and six-year-old children and to begin the development of the WRITIC.

Chapter 3 describes a systematic literature review to find psychometrically sound standardised tests to assess handwriting readiness in five- and six-year-old children on the levels of occupations, activities/tasks and performance components. In the first step of this systematic review a comprehensive search was undertaken in Pubmed, CINAHL, PsychINFO en ERIC. Tests were included in the review if: a) participants were 5-6 years old; b) the focus was on handwriting readiness; and c) the measurement was standardised. The search resulted in 1,114 citations; in the final selection 39 articles with information about 12 tests were included. These 12 tests were grouped according to levels of the Taxonomic Code of Occupational Performance (TCOP). In the second step, a further electronic search was undertaken for the selected 12 measurement instruments to evaluate the psychometric properties and the feasibility of these instruments. With the information of the literature from the extended search we established that none of the instruments were completely satisfactory in psychometric properties, according to the quality criteria established by Terwee (2007). This systematic review identified only one occupation-based measurement: the school-AMPS. Nevertheless, this measurement does not evaluate important aspects of body position and pencil grip and requires a training course of a week, only accessible for occupational therapists, to be competent to administer this test. Thus, the school-AMPS is not suitable as a screening instrument for handwriting readiness that can be administered by paediatric therapists and specialised teachers. In conclusion, internationally there is no occupation-based and psychometric sound instrument for the evaluation of handwriting readiness. As such, with this systematic review the need for an instrument was identified. The results of the second step of this systematic review were

used in the development of the new assessment.

Chapter 4 describes the development of the Writing Readiness Inventory Tool In Context (WRITIC). The purpose of the WRITIC is defined as evaluating handwriting readiness and discriminating between children who are ready to learn handwriting and children who are not. The instrument should be feasible and easy to administer by paediatric therapists and specialised classroom teachers. The target population includes those kindergarten children aged five to six, whose teachers judged that they might not be ready to learn handwriting. The underlying construct of the WRITIC is the Person–Environment–Occupation (PEO) Model. The domains 'Child,' 'Environment' and 'Paper-and-pencil tasks' are based on this model. The Taxonomic Code of Occupational Performance (TCOP) is the other underlying theory. Handwriting readiness in the WRITIC is assessed at the level of 'occupation,' 'activity' and 'task.' The content of the test was further based on the literature that was included in the systematic review and was based on experiences with the Screening Prewriting skills Occupational Therapy (SPOT) in daily practice. For each domain, the items and supporting materials were developed: manual, writing booklet, standardised instruction and scoring booklet. Thereby, two pilot studies were performed with drafts of the WRITIC. As a result of the pilot studies, the WRITIC was revised.

The definite WRITIC contains three domains and every domain is composed of two sub-domains. For the 'Child' domain 'Interest' and 'Sustained attention,' for the 'Environment' domain 'Physical environment' and 'Social environment' and for the 'Paper-and-pencil tasks' domain 'Task performance' and 'Intensity of performance.' WRITIC should be administered in the classroom. First, the child's interests in paper- and pencil tasks are being evaluated. After that, the child is encouraged to complete a drawing booklet with five paper-and-pencil tasks while an assessor observes the performance. The subdomain 'Task performance' (WRITIC-TP) will be the future norm-referenced part of the WRITIC. The other subdomains are criterion-referenced and provide valuable information for advice and intervention.

In the next step, the reliability and validity was assessed in successive stages.

Content validity was established with ten experts in three Delphi rounds. Consensus regarding the content of the WRITIC (relevance, coverage and clarity of the items) was high, with 94.4% agreement among the experts.

Factor analysis was performed to identify scale constructs within the domain Pa-

per-and-pencil tasks. Two reliable factors were found: 'Task performance' and 'Intensity of performance' with Cronbach's alphas of 0.82 and 0.69 respectively. These factors define the subdomains of the domain Paper-and-pencil tasks. The subdomain 'Task performance' is an interwoven construct and contains seven items on product of paper-and-pencil tasks and six items on performance of paper-and-pencil tasks. The subdomain 'Intensity of performance' contains four items associated with a relaxed versus forced pencil grip and body position.

Discriminative validity was established by examining contrast groups with good ($n = 142$) and poor ($n = 109$) performers, according to their teacher. These groups differed significantly in two WRITIC subdomains: 'Sustained attention' (domain 'Child') and 'Task Performance' (domain 'Paper-and-pencil tasks'). Because the two groups consisted of children of the same class environment, there were no differences found on the subdomains 'Physical environment' and 'Social environment.' There was also no significant difference on the subdomain 'Interest' (domain 'Child'). This could be due to the fact that kindergarten children are less aware of their level of performance. In both groups (good and poor performers according to the teacher), there were children with a forced position during the performance of paper-and-pencil tasks and so there was no significant difference found on the subdomain 'Intensity of performance' (domain 'Paper-and-pencil tasks').

Feasibility was established by recording time and by evaluating to what extent children liked the WRITIC. The mean time for administering the WRITIC with the child was 20 minutes (range 12 to 28 minutes). Thereafter, five minutes were required for the finishing of the scoring. The percentage of children who liked the administering of the WRITIC was 83%, 10% liked it a little and 7% did not like it. Although WRITIC was administered in the classroom, teachers did not perceive it as a disturbance to their normal class routines. It was concluded that this measurement is feasible for use in the class-room.

In **Chapter 5** the total assessment on handwriting readiness is described. An occupation-based assessment starts at the level of the occupation, determining how children participate in occupations in a relevant context. Thereafter, activities, tasks and performance components are assessed. In our assessment on handwriting readiness the first step is the assessment of the WRITIC (occupations, activities and tasks). The administering of the WRITIC starts with an evaluation of the child's interest in paper-and-pencil tasks and then the child is encouraged to complete a drawing booklet with five paper-and-pencil tasks. In the second step, performance components could be assessed with the BeeryTMVMI and the 9-HPT.

In clinical decision-making, good reproducibility of a test is crucial. Therefore, test-retest reliability of the WRITIC was established with 59 children and inter-rater reliability was established with 72 children. Excellent test-retest and inter-rater reliability was found on the future norm-referenced subdomain 'Task performance' of the WRITIC with intra-class correlation coefficient's (ICC's) ranging from 0.92 to 0.95 ($p < 0.001$). On the other crite-

tion-referenced subdomains, we found fair to good reliability with ICC's ranging from 0.70 to 1.0 ($p < 0.001$) and weighted Kappa ranging from 0.30 ($p = 0.005$) to 0.89 ($p < 0.001$). Thus, WRITIC is an assessment that is stable over time and between raters.

Convergent validity was established with 119 children with the BeeryTMVMI and the 9-HPT. Correlations were moderate with r_s ranging from 0.34 to 0.40 ($p < 0.001$), which are comparable with correlations in other handwriting studies. These correlations support the construct of handwriting readiness of the WRITIC.

The aim of **Chapter 6** was to investigate the predictive validity of the kindergarten assessment consisting of the WRITIC, the BeeryTMVMI and the 9-HPT. A prospective longitudinal cohort study was carried out to examine whether the outcomes on the subdomain 'Task performance' of the WRITIC (WRITIC-TP), the BeeryTMVMI and the 9-HPT administered in the pre-writing phase predict handwriting performance in first grade as evaluated by the Systematic Screening for Handwriting Difficulties (Dutch abbreviation: SOS). In kindergarten, 119 children (60 boys; mean age 70 months) were tested with the WRITIC, BeeryTMVMI and 9-HPT and one year later 109 children from the same cohort in first grade (mean age 85 months) with the SOS. A multivariable linear mixed model was used to identify variables that independently predict outcomes in first grade (SOS): baseline scores on WRITIC-TP, BeeryTMVMI, 9-HPT, 'sustained attention,' 'gender,' 'age' and 'intervention in the intermediate period. The results showed that WRITIC-TP, BeeryTMVMI, and 9-HPT, 'sustained attention,' 'gender' and 'intervention' had all predictive value on the handwriting outcome. Thereby WRITIC-TP was the main predictor for outcome of SOS-Quality, and BeeryTMVMI and 9-HPT were the main predictors of SOS-Speed. This kindergarten assessment of WRITIC-TP, BeeryTMVMI, and 9-HPT contributes to the detection of children at risk for developing handwriting problems.

In **Chapter 7**, the main findings of our studies are discussed in relationship to recent literature. The process of measurement development is placed in perspective of new insights. In accordance with the emerging occupation-based perspective of the assessment, the WRITIC is task-oriented, is administered in a real-life context and evaluates the child's interest in paper-and-pencil tasks.

The administering of the WRITIC in kindergarten is based on a well-timed evaluation of hand-writing readiness. In the case of children who are not ready for handwriting according to the WRITIC, in the second step of the assessment on handwriting readiness, the administering of the BeeryTMVMI or 9-HPT is indicated for further investigation of performance components. On the basis of the outcomes, timely interventions can start to improve handwriting readiness skills early in the school trajectory to prevent struggles and burdens in handwriting. The early school years are the most cost effective to intervene.

The psychometric properties of the WRITIC were rated using the 'quality criteria for measurement properties of health status questionnaires' developed by Terwee (2007)

and positive ratings were found on most measurement properties, except responsiveness. (see Table 1).

Table 1. Summary of psychometric properties of WRITIC according to the criteria of Terwee et al. (2007) in typically developing kindergarten children (5 – 6 years).

	Content validity	Internal consistency	Construct validity	Reliability	Criterion validity	Responsiveness
WRITIC	+	+	+	+	+	0

+ = positive; 0 = no information available

After reference norms are collected on the future norm-referenced subdomain 'Task performance' (WRITIC-TP), cut-off points can be established. Then the WRITIC can be used as a decision-making tool to clarify if interventions are needed to become ready for handwriting.

The content of the criterion-referenced information from the different subdomains of the WRITIC are discussed. The subdomain 'Sustained attention' is especially important because this domain discriminates between children with good and poor performance and is a predictor for handwriting attainment in first grade. Recent literature indicates that 'sustained attention' is an important prerequisite of handwriting readiness.

The predictive value of the WRITIC is in line with outcomes of most other studies on school readiness indicators. Because gender and sustained attention also have predictive values, teachers need to be more alert to boys and children with attention problems.

With the introduction of the law on inclusive education (in Dutch: Wet passend onderwijs) in August 2014, the focus is on early identification of children as well as to build teachers' capacity to manage learning problems based on disabilities over the long term. A measurement, such as the WRITIC, fits well in this development, especially when specialised teachers can administer the WRITIC in the school context.

Conclusions and recommendations

The WRITIC, a new standardised, valid, reliable and predictive assessment of handwriting readiness in 5- and 6-year-old children has been developed. It will be administered in the pre-writing phase, to children whose teachers are worried about their handwriting readiness. The future norm-referenced subdomain aims to evaluate if the child is ready for the attainment of handwriting. The other criterion-referenced subdomains provide valuable information for paediatric therapists and specialised teachers in advising or planning

an intervention. The BeeryTMVMI and the 9-HPT can further assess at-risk children, who are not ready for handwriting according to the WRITIC.

Recommendations regarding future research include:

- Performance of psychometric studies on:
 - a. Collecting norm values and cut-off points for at-risk children;
 - b. Reliability and validity of the WRITIC in children with special needs;
 - c. Responsiveness of the WRITIC after a period of intervention;
- With the growing use of tablets in the school situation, the WRITIC could be adapted for stylus-and-tablet tasks and a psychometrically sound digital version of the WRITIC should be developed.

Samenvatting



Dit proefschrift beschrijft de ontwikkeling van een nieuw meetinstrument: de Writing Readiness Inventory Tool In Context (WRITIC). Dit meetinstrument evalueert of oudste kleuters van vijf en zes jaar startklaar zijn voor het schrijfonderwijs in groep 3. In het Engels noemt men dit *handwriting readiness*. Het onderzoek naar de ontwikkeling van de WRITIC is gebaseerd op de fasen van testontwikkeling die door Kielhofner zijn beschreven (**hoofdstuk 1**). Hiervoor zijn in de periode van 2008 tot en met 2012 verschillende studies uitgevoerd. Een eerdere studie, uitgevoerd in het kader mijn master thesis in 2003, is beschreven in **hoofdstuk 2**. In deze studie zijn de klinimetrische eigenschappen van de in het Nederlands vertaalde Peabody Developmental Fine Motor Scales second edition (PDMS-FM-2) onderzocht. De conclusie van deze studie was dat de PDMS-FM-2 onvoldoende sensitief is voor het vaststellen van problemen in de fijne motoriek bij kleuters die moeite hebben met papier- en pentaken. De uitkomst van deze studie was de reden om in de literatuur te zoeken naar een test die *handwriting readiness* bij deze doelgroep evalueert. In **hoofdstuk 3** wordt een systematisch review beschreven waarbij in de internationale literatuur is gezocht naar een meetinstrument dat 'handwriting readiness' van oudste kleuters in de klas evalueert. Een dergelijk meetinstrument is niet gevonden en daarom is gestart met het ontwikkelen van de WRITIC. **Hoofdstuk 4** bevat een beschrijving van de ontwikkeling van de WRITIC en van de studies naar inhoudsvaliditeit, constructvaliditeit en bruikbaarheid van het meetinstrument. In **hoofdstuk 5** zijn drie cohortstudies beschreven. Twee daarvan zijn uitgevoerd om de testhertest- en inter-beoordelaarsbetrouwbaarheid te bepalen, en de derde om de convergente validiteit van de WRITIC met de Developmental test for Visual-Motor Intergration (BeeryTMVMI) en de Nine-Hole Peg Test (9-HPT) vast te stellen. Hoofdstuk 6 beschrijft een prospectieve longitudinale cohortstudie van de WRITIC, de BeeryTMVMI en de 9-HPT naar de voorspellende waarde van deze meetinstrumenten op de schrijfvaardigheid in groep 3. In **hoofdstuk 7** zijn de belangrijkste resultaten uit de verschillende onderzoeken bediscussieerd, met afsluitende conclusies en aanbevelingen.

Hoofdstuk 1, de introductie van deze thesis, bevat achtergrondinformatie over schrijven, de voorwaarden om te leren schrijven en de processen die daarbij betrokken zijn. Daarnaast wordt ingegaan op de evaluatie van *handwriting readiness* van oudste kleuters. Bij deze evaluatie staat de uitvoering van de activiteiten in de context centraal. Het hoofdstuk start met een uiteenzetting van het belang van het leren schrijven in deze tijd van computers, tablets en smartphones. Uit recent onderzoek komt naar voren dat de motorische handeling van het schrijven een positieve invloed heeft op verschillende cognitieve functies en ook van belang is voor het leren lezen en spellen van kinderen. In onze (digitale) tijd blijft het daarom belangrijk dat kinderen leren schrijven op de basisschool. Een model over de ontwikkeling van het schrijven en twee relevante procesmodellen betreffende het schrijven worden beschreven en toegelicht. Het hoofdstuk zet de 'state of the art' ten aanzien van de verschillende voorwaarden voor het schrijven op een rijtje. Uit de literatuur wordt duidelijk dat fijnmotorische coördinatie en visueel-motorische integratie beide voorwaarden zijn met een bewezen relatie met schrijven. Het hoofdstuk zet uiteen waarom *handwriting readiness* belangrijk is op het moment dat kinderen starten met het

schrijfonderwijs. Het bekijkt *handwriting readiness* vanuit het perspectief van het kind, de factoren in de omgeving en de daadwerkelijke uitvoering van de papier- en pentaken. Het interactieperspectief, een algemeen aanvaard principe in het denken over ontwikkeling, staat centraal in het Person-Environment-Occupation (PEO) model en vormt een theoretische basis in deze thesis. Omdat veel kinderen schrijfproblemen hebben, is een vroege evaluatie in groep 2 van belang om vast te stellen of kinderen startklaar zijn voor het schrijfonderwijs in groep 3. In de ergotherapie staat het handelingsgericht assessment centraal, dat gericht is op de uitvoering van dagelijks activiteiten in de context. De evaluatie van *handwriting readiness* is daarom gericht op het uitvoeren van de papier- en pentaken in de klas, omdat dát de context is, waarin deze activiteiten voor kinderen plaatsvinden. De introductie wordt afgesloten met een overzicht van de opbouw en inhoud van deze thesis.

In de studie die beschreven wordt in **hoofdstuk 2** zijn de klinimetrische eigenschappen van de in het Nederlands vertaalde Peabody Developmental Fine Motor Scales second edition (PDMS-FM-2) onderzocht. Dit onderzoek is uitgevoerd bij normaal ontwikkelende kinderen van vier en vijf jaar oud. Uit dit onderzoek kwam naar voren dat de PDMS-FM-2 ook bij deze doelgroep een zeer goede test-hertest- en interbeoordelaars-betrouwbaarheid heeft. Daarnaast is in dit onderzoek de convergente validiteit met het onderdeel handvaardigheid van de Movement-Assessment Battery for Children (M-ABC) bepaald. De discriminatieve validiteit van de PDMS-FM-2 is onderzocht door twee groepen kinderen met elkaar te vergelijken: een groep kinderen mét, en een groep kinderen zónder problemen in de fijnmotorische kleutervaardigheden. Deze groepen werden op basis van het oordeel van de leerkracht samengesteld en verschilden significant op de 'Checklist Fijne motoriek kleuters', die speciaal voor dit onderzoek was ontwikkeld. Slechts 39% van de kinderen uit de groep met problemen in de fijnmotorische kleutervaardigheden scoorde onder de norm op basis van de normen van de PDMS-FM-2. In vergelijking met 78% van de kinderen uit deze groep die onder de norm scoorde op basis van de Nederlandse normen van M-ABC. De conclusie van dit onderzoek is dat de PDMS-FM-2 niet sensitief genoeg is voor deze doelgroep. Uit dit onderzoek blijkt dat de M-ABC wel sensitief is voor deze groep kinderen. Omdat het onderdeel handvaardigheid van de M-ABC echter slechts uit drie items bestaat, is het van belang dit aan te vullen met een andere test of observatie. Dit heeft geresulteerd in een aanbeveling voor een assessment fijnmotorische kleutervaardigheden voor kinderen van vijf en zes jaar dat bestaat uit: de gestandaardiseerde Korte Observatie Ergotherapie Kleuters (KOEK), het onderdeel handvaardigheid van de M-ABC en de BeeryTMVMI. Deze studie, en het feit dat de in Nederland en België veel gebruikte KOEK een observatie is en geen betrouwbaar en valide meetinstrument, was de aanleiding om te starten met een systematisch review.

In **hoofdstuk 3** wordt een systematisch review beschreven waarbij in de internationale literatuur is gezocht naar een meetinstrument dat *handwriting readiness* van oudste kleuters in de klas evalueert. Op basis van de ergotherapie taxonomie '*Taxonomic Code of Occupational Performance*' (TCOP) is gezocht naar meetinstrumenten op het niveau van het handelen, de activiteiten, de taken en de voorwaarden voor het schrijven. In de eer-

ste stap van dit systematisch review is er een uitgebreid zoekactie uitgevoerd in Pubmed, CINAHL, PsychINFO en ERIC, hetgeen 1.114 referenties opleverde. Meetinstrumenten werden geïncorporeerd in de review als: a) participanten vijf en zes jaar oud waren; b) het doel van het meetinstrument gericht was op *handwriting readiness*; en c) het meetinstrument was gestandaardiseerd. In de uiteindelijke selectie bleven er 39 artikelen over met informatie over 12 meetinstrumenten. In de volgende stap van deze systematische review werd een tweede zoekactie uitgevoerd naar informatie over de klinimetrische eigenschappen en de bruikbaarheid van de gevonden 12 meetinstrumenten. De resultaten van deze systematische review laten zien dat de klinimetrische eigenschappen van geen van deze meetinstrumenten volledig voldoen aan de kwaliteitscriteria die vastgesteld zijn door Terwee et al. (2007). Uiteindelijk is er één meetinstrument gevonden dat in de relevante context afgenomen wordt: de school-AMPS. Helaas evalueert dit meetinstrument niet de pengreep en uitgangshouding, aspecten die van belang zijn voor *handwriting readiness*. Daarnaast is er, om competent te worden in het afnemen van deze test, een scholing van een week noodzakelijk, die alleen toegankelijk is voor ergotherapeuten. Daarom is de School-AMPS niet geschikt als screeningsinstrument voor de evaluatie van *handwriting readiness*, die afgenomen kan worden door kindertherapeuten en gespecialiseerde leerkrachten. De conclusie is dan ook dat er geen geschikt meetinstrument gevonden is en maakt duidelijk dat er behoefte is aan de ontwikkeling van een meetinstrument om *handwriting readiness* te evalueren bij oudste kleuters van vijf en zes jaar oud.

Hoofdstuk 4 bevat een beschrijving van de ontwikkeling van de Writing Readiness Inventory Tool In Context (WRITIC) en van de studies naar inhoudsvaliditeit, constructvaliditeit en bruikbaarheid van het meetinstrument. Het doel van de WRITIC is de evaluatie van *handwriting readiness* bij oudste kleuters van vijf en zes jaar waarbij er onderscheid wordt gemaakt tussen kinderen die de vaardigheden hebben om te starten met het schrijfonderwijs en kinderen die deze vaardigheden nog niet hebben. De doelpopulatie van de WRITIC is de oudste kleuter van vijf of zes jaar oud, waarvan de leerkracht zich zorgen maakt of hij/zij mee kan doen met het schrijfonderwijs in groep 3. Het onderliggende construct van de WRITIC is het PEO-model. De domeinen 'Kind', 'Omgeving' en 'Papieren pentaken' zijn gebaseerd op dit model. Een ander onderliggende theorie van de WRITIC is de TCOP: *handwriting readiness* in de WRITIC wordt geëvalueerd op het niveau van het handelen, de activiteiten en de taken. De inhoud van de WRITIC is gebaseerd op de praktijkervaringen met de gestandaardiseerde observatie KOEK en op de informatie uit de systematisch review. Voor elk domein zijn de items en de bijbehorende materialen ontwikkeld: de handleiding, het tekenboekje, de instructie en het scoreformulier. De WRITIC kan in de toekomst gebruikt worden door kindertherapeuten en gespecialiseerde leerkrachten in het basisonderwijs.

De inhoudsvaliditeit is vastgesteld met tien experts in drie Delphi-rondes. Consensus over de inhoud van de WRITIC (relevantie, inhoud en duidelijkheid van de items) was hoog met een overeenstemming van 94.4% tussen de experts.

Met het eerste concept van de WRITIC zijn twee pilot-studies uitgevoerd en op basis hiervan is de WRITIC aangepast.

De definitieve WRITIC bestaat uit drie domeinen, elk bestaande uit twee subdomeinen. Het domein 'Kind' bestaat uit 'Interesse' en 'Volgehouden aandacht'; het domein 'Omgeving' bestaat uit 'Fysieke omgeving' en 'Sociale omgeving' en het domein 'Papier- en pentaken' bestaat uit 'Taakuitvoering' en 'Intensiteit van uitvoering'. De WRITIC wordt afgenomen in de klas. Eerst wordt de interesse van het kind in de papier- en pentaken geëvalueerd middels een vragenlijst. Daarna wordt het kind gevraagd om in een tekenboekje verschillende papier- en pentaken (volgen van sporen, kleuren, maken van voorbereidende schrijffiguren, schrijven van de eigen naam en het kopiëren van letters en nummers) uit te voeren, terwijl de therapeut of leerkracht die de test afneemt de uitvoering (pengreep, uitgangshouding en het resultaat van de papier- en pentaken) observeert. Het subdomein 'Taakuitvoering' is het toekomstig normgerefeerde subdomein van de WRITIC. De andere subdomeinen geven criteriumgerefeerde informatie, te gebruiken voor advies en interventie.

Er is een factoranalyse van het domein 'Papier- en pentaken' uitgevoerd. Twee factoren zijn gevonden: 'Taakuitvoering' met een Cronbach's Alpha van 0.82 en 'Intensiteit van uitvoering' met een Cronbach's Alpha van 0.69. Deze factoren definiëren de subdomeinen van het domein 'Papier- en pentaken'. Het subdomein 'Taakuitvoering' bestaat uit zeven items over het resultaat van de papier- en pentaken en uit zes items over de kwaliteit van de uitvoering van de papier- en pentaken (pengreep en uitgangshouding). Het subdomein 'Intensiteit van uitvoering' bestaat uit vier items betreffende een ontspannen versus krampachtige pengreep en uitgangshouding.

Discriminatieve validiteit is vastgesteld bij onderzoek naar twee contrasterende groepen met kinderen met goede ($n = 142$) en zwakke ($n = 109$) uitvoering van de papier- en pentaken, ingedeeld op basis van het oordeel van de leerkracht. Deze groepen verschilden significant op twee subdomeinen van de WRITIC: 'Volgehouden aandacht' (domein 'Kind') en 'Taakuitvoering' (domein 'Papier- en pentaken'). Omdat de kinderen uit de twee groepen uit dezelfde klasgroepen afkomstig waren, verwachtten we geen verschillen te vinden op de subdomeinen 'Fysieke omgeving' en 'Sociale omgeving'. Dit werd in dit onderzoek bevestigd. Er was ook geen significant verschil op het subdomein 'Interesse' (domein 'Kind') en op het subdomein 'Intensiteit van de uitvoering' (domein 'Papier- en pentaken').

De bruikbaarheid van de WRITIC is vastgesteld op basis van de tijd die het kost om de WRITIC af te nemen en de mening van de kinderen over het uitvoeren van de WRITIC. De gemiddelde tijd om de WRITIC af te nemen was 20 minuten (variërend van 12 tot 28 minuten). Daarbij zijn na het afnemen van de WRITIC nog vijf minuten nodig om het scoreformulier verder in te vullen. Het percentage kinderen dat het leuk vond om de WRITIC te doen was 83%, 10% van de kinderen vonden het een beetje leuk en 7% van de

kinderen vond het niet leuk. Alhoewel de WRITIC in de klas afgenomen wordt, hebben de leerkrachten dit niet als een verstoring van de normale klasgroep-routine ervaren. De conclusie is dat de WRITIC bruikbaar is, ook om af te nemen in de context van de klas.

In **hoofdstuk 5** zijn drie cohortstudies beschreven. Twee daarvan zijn uitgevoerd om de test–hertest– en interbeoordelaarsbetrouwbaarheid te bepalen, en de derde om de convergente validiteit van de WRITIC met de Developmental test for Visual Motor Intergration (BeeryTMVMI) en de Nine–Hole Peg Test (9–HPT) vast te stellen. Dit hoofdstuk gaat in op het totale assessment van *handwriting readiness*. Een handelingsgericht assessment begint op het niveau van het dagelijks handelen om te evalueren hoe kinderen hun activiteiten uitvoeren in de context. Daarna worden de activiteiten, taken en de voorwaarden geëvalueerd. In het assessment betreffende *handwriting readiness* is de eerste stap het afnemen van de WRITIC (handelen, activiteiten en taken) en in een tweede stap kunnen de voorwaarden onderzocht worden met de BeeryTMVMI en de 9–HPT.

Het is belangrijk dat een test reproduceerbaar is en dat herhaalde metingen dezelfde uitkomst geven. Daarom is de test–hertestbetrouwbaarheid van de WRITIC bepaald met 59 kinderen en is de interbeoordelaarsbetrouwbaarheid van de WRITIC bepaald met 72 kinderen. Er bleek een zeer goede test–hertest– en interbeoordelaarsbetrouwbaarheid van het toekomstig normgerefeerde subdomein 'Taakuitvoering' met intra–class correlation coefficients (ICC's) die variëren van 0.92 tot 0.95 ($p < 0.001$). Op de andere criteriumgerefeerde subdomeinen is er een matige tot goede betrouwbaarheid gevonden met ICC's die variëren van 0.70 tot 1.0 ($p < 0.001$) en gewogen Kappa's die variëren van 0.30 ($p = 0.005$) tot 0.89 ($p < 0.001$). Op basis van deze resultaten is de conclusie dat de WRITIC stabiel is in de tijd en tussen personen die de test afnemen.

Convergente validiteit is bepaald met 119 kinderen met de BeeryTMVMI en de 9–HPT. De gevonden correlaties waren matig met een r_s die varieert van 0.34 tot 0.40 ($p < 0.001$). Deze correlaties zijn vergelijkbaar met andere studies waarbij de correlaties tussen meetinstrumenten betreffende deze voorwaarden en het schrijven zijn onderzocht. Dit ondersteunt het construct van *handwriting readiness* van de WRITIC.

Hoofdstuk 6 beschrijft een prospectieve longitudinale cohortstudie van de WRITIC, de BeeryTMVMI en de 9–HPT naar de voorspellende waarde van deze meetinstrumenten op de schrijfvaardigheid in groep 3, zoals geëvalueerd met de Systematische Opsporing Schrijfproblemen (SOS). Bij een groep van 119 kinderen (60 jongens, gemiddelde leeftijd 70 maanden) zijn in groep 2 het subdomein 'Taakuitvoering' van de WRITIC, de BeeryTMVMI en de 9–HPT afgenomen. Een jaar later, in groep 3, is bij 109 kinderen van dit zelfde cohort (55 jongens, gemiddelde leeftijd 85 maanden) de SOS afgenomen. Een multivariabel lineair mixed model is gebruikt om die variabelen vast te stellen die onafhankelijk voorspellend zijn op de SOS in groep 3. Onafhankelijke variabelen waren de uitkomsten van subdomein 'Taakuitvoering' van de WRITIC, de BeeryTMVMI, de 9–HPT, 'volgehouden aandacht', 'geslacht', 'leeftijd', en 'interventie in de tussenliggende periode'. De resultaten

laten zien dat al deze variabelen, met uitzondering van leeftijd, voorspellers zijn van de uitkomst van het schrijven, gemeten met de SOS. Daarbij was het subdomein ‘Taakuitvoering’ van de WRITIC de belangrijkste voorspeller van de uitkomst op het onderdeel kwaliteit van de SOS. De BeeryTMVMI en 9-HPT waren de belangrijkste voorspellers op het onderdeel snelheid van de SOS. De conclusie van dit onderzoek is dat dit assessment voor oudste kleuters, dat bestaat uit het subdomein ‘Taakuitvoering’ van de WRITIC, de BeeryTMVMI en de 9-HPT, bijdraagt aan het opsporen van kinderen met risico op het ontwikkelen van schrijfproblemen.

Hoofdstuk 7 bediscussieert alle bevindingen in relatie tot de state of the art van de literatuur. Het plaatst het proces van de ontwikkeling van de WRITIC in de context van de huidige inzichten. In overeenstemming met het steeds belangrijk wordende perspectief van een handelingsgericht assessment, is de WRITIC een taakgericht meetinstrument dat afgenomen wordt in een relevante context, waarbij de interesse van het kind in de papier- en pentaken geëvalueerd wordt.

Het afnemen van de WRITIC in groep 2 is een goed tijdstip om *handwriting readiness* te evalueren. Als kinderen op basis van de WRITIC niet klaar blijken te zijn voor het schrijf- onderwijs in groep 3, kan voor een verdere evaluatie van de voorwaarden in een tweede stap van het assessment de BeeryTMVMI en 9-HPT afgenomen worden. Op basis van de uitkomst van dit assessment van *handwriting readiness*, kan een tijdige interventie gestart worden om de voorbereidende schrijfvaardigheden te verbeteren. Zo kunnen extra moeite en belasting van kinderen en eventuele schrijfproblemen worden voorkomen. De literatuur maakt duidelijk dat de eerste jaren van de basisschool het meest (kosten)effectief zijn voor een interventie.

De klinimetrische eigenschappen van de WRITIC zijn geëvalueerd op basis van de kwaliteitscriteria voor meetinstrumenten die ontwikkeld zijn door Terwee et al. (2007). Het resultaat is dat de meeste klinimetrische eigenschappen van de WRITIC positief beoor- deeld zijn, behalve de responsiviteit, die nog niet onderzocht is (zie tabel 1).

Tabel 1. samenvatting van de klinimetrische eigenschappen van de WRITIC volgens de criteria van Terwee et al. (2007) in normaal ontwikkelende kleuters van vijf en zes jaar.

	Inhouds- validiteit	Interne consistentie	Construct- validiteit	Betrouw- baarheid	Criterium- validiteit	Respon- siviteit
WRITIC	+	+	+	+	+	0

+ = positief; 0 = geen informatie over

De volgende stap in de ontwikkeling van de WRITIC is het verzamelen van leeftijdsnormen van het toekomstige normgerefereerde subdomein 'Taakuitvoering' van de WRITIC. Als deze verzameld zijn kunnen de afkappunten vastgesteld worden. Dan kan de WRITIC gebruikt worden als een test om te beslissen of er wel of geen interventie nodig is zodat een kind in groep 3 goed voorbereid kan starten met het schrijfonderwijs.

De inhoud van de criteriumgerefereerde informatie uit de andere subdomeinen van de WRITIC worden in dit hoofdstuk bediscussieerd. Het subdomein 'Volgehouden aandacht' is belangrijk omdat dit subdomein ook discrimineert tussen kinderen met een goede en met een zwakke uitvoering van de papier- en pentaken, en omdat dit subdomein een voorspeller is voor het schrijven in groep 3. Dit wordt bevestigd door recente literatuur die aangeeft dat 'volgehouden aandacht' een belangrijke voorwaarde is voor het schrijven.

De voorspellende waarde van de WRITIC is in lijn met andere studies betreffende school readiness. Omdat geslacht en volgehouden aandacht ook predictieve waarde hebben is het van belang dat leerkrachten meer alert zijn ten aanzien van jongens en kinderen met aandachtsproblemen.

Met de introductie van de Wet passend onderwijs in augustus 2014 is er een toegenomen focus op vroege identificatie van kinderen die problemen kunnen krijgen en daarnaast op het uitbreiden van de expertise van leerkrachten hoe om te gaan met kinderen met problemen. Een meetinstrument zoals de WRITIC past goed in deze ontwikkeling, te meer als speciale leerkrachten de WRITIC kunnen afnemen bij kinderen waar zij zich zorgen over maken.

Conclusies en aanbevelingen

In dit promotietraject is de WRITIC ontwikkeld, een nieuw gestandaardiseerd, betrouwbaar, valide en voorspellend meetinstrument dat *handwriting readiness* evalueert bij oudste kleuters van vijf en zes jaar oud. Het kan afgenomen worden in de fase van het voorbereidend schrijven, bij kinderen waarbij leerkrachten zich zorgen maken over de *handwriting readiness*. Het toekomstige normgerefereerde subdomein 'Taakuitvoering' evalueert of kinderen startklaar zijn voor het schrijfonderwijs in groep 3. De andere criteriumgerefereerde subdomeinen geven waardevolle informatie aan kindertherapeuten en gespecialiseerde leerkrachten over de inhoud van advies en interventie. Als kinderen volgens de WRITIC niet startklaar blijken te zijn voor het schrijfonderwijs in groep 3, kunnen de BeeryTMVMI en 9-HPT worden afgenomen voor aanvullende informatie.

Aanbevelingen voor toekomstig onderzoek zijn:

- Voer klinimetrische studies uit om:
 - a. normwaarden te verzamelen en afkappunten te bepalen ten aanzien van kinderen die risico lopen om schrijfproblemen te ontwikkelen;

- b. de betrouwbaarheid en validiteit van de WRITIC vast te stellen bij kinderen met een diagnose waardoor zij problemen hebben met de papier- en pentaken;
 - c. de responsiviteit van de WRITIC te bepalen bij kinderen die op basis van de WRITIC een interventie hebben gehad.
- Door het toenemend gebruik van tablets in de basisschool kan het een volgende stap zijn de WRITIC aan te passen voor stylus- en tablettaken en kan er een betrouwbare en valide digitale versie van de WRITIC ontwikkeld worden.

Dankwoord



Handwriting readiness, en in het Nederlands: 'klaar zijn om te gaan schrijven', is het onderwerp van dit proefschrift. Daarbij staan oudste kleuters in het basisonderwijs centraal. Voor mij ging het dit laatste jaar echter vooral over 'klaar zijn met het schrijven'. De vraag: "Wanneer ben je klaar met het schrijven van je proefschrift?", is veel aan mij gesteld de afgelopen periode en die kan ik nu eindelijk met een oprecht "Nu!" beantwoorden. Het boekje dat jullie nu in handen hebben is daar de ultieme 'evidence' van.

Dit proefschrift zou niet tot stand gekomen zijn zonder alle mensen om mij heen die daarbij een belangrijke rol hebben gespeeld. Daarom dit dankwoord voor allen die hier op een of andere manier bij betrokken zijn geweest. Zonder jullie was het niet gelukt. Heel erg veel dank!

Als eerste dank aan de 331 kinderen die mee hebben gedaan aan het onderzoek, en aan de ouders en de betrokken leerkrachten van groep 2 en 3. Zonder jullie waren er geen data en dus ook geen valide, betrouwbaar en voorspellende WRITIC. Ontzettend bedankt!

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Curriculum Vitae





Curriculum Vitae

Margo van Hartingsveldt is op 30 mei 1960 geboren te Gorinchem. In 1978 behaalde zij het VWO-diploma. Van 1979 tot 1983 volgde zij de opleiding Ergotherapie te Weesp, een voorloper van de huidige opleiding ergotherapie van de Hogeschool van Amsterdam (HvA). In 2003 studeerde ze cum laude af aan de Master of Science Paramedische Zorg van het Radboudumc, de Hogeschool van Arnhem en Nijmegen (HAN) en het Nederlands Paramedisch Instituut (NPI).

Na haar opleiding heeft zij meer dan 25 jaar op verschillende plekken gewerkt, in het begin als ergotherapeut en na vijf jaar als kinderergotherapeut: in een verpleeghuis, verschillende revalidatiecentra, het academisch ziekenhuis, het regulier onderwijs en in een particuliere praktijk. In die periode heeft ze een jaar in Suriname en twee jaar op Curaçao gewerkt. Van 2003 tot 2011 was zij hoofd Ergotherapie, kinderergotherapeut en onderzoeker van de afdeling Revalidatie van het Radboudumc te Nijmegen. Zij gaf in die periode regelmatig gastcolleges en workshops op de opleiding Ergotherapie van de HAN. Sinds 1 april 2011 is zij werkzaam als opleidingsmanager van de opleiding Ergotherapie en beoogd lector Ergotherapie van het kenniscentrum ACHIEVE, domein Gezondheid van de HvA.

Sinds 2005 geeft zij binnen en buiten Nederland studiedagen over kinderergotherapie en het gebruik van verschillende meetinstrumenten. Zij geeft regelmatig lezingen, op congressen, in binnen- en buitenland en is auteur van zo'n 40 nationale en internationale publicaties op het gebied van de ergotherapie.

Zij is betrokken bij ontwikkelingen binnen de beroepsvereniging Ergotherapie Nederland: als voorzitter in van de adviesgroep Kind & Jeugd en als lid van de programmacommissie van het jaarcongres in de periode van 2010–2013. Verder is zij lid van de landelijke werkgroep Schrijven.nl van paramedische en onderwijsprofessionals met expertise op het gebied van schrijven.

Margo is getrouwd met Philippe van Hartingsveldt en samen hebben ze twee dochters, Anniek (1992) en Tessa (1995).

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