EXPLORING THE POSSIBILITIES OF ONLINE ASSESSMENT OF EARLY NUMERACY IN KINDERGARTEN

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EXPLORING THE POSSIBILITIES OF ONLINE ASSESSMENT OF EARLY NUMERACY IN KINDERGARTEN

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The aims of the study are to develop an easy-to-use online test for early numeracy, to empirically validate the instrument and to examine the effects of ICT familiarity on early numeracy achievements. The research design comprised of online and face-to-face measures with 30 children from age five to six. The newly developed early numeracy and ICT familiarity tests were administered online. Face-to-face measures included basic counting and numeracy, and relational reasoning. Results revealed that the online early numeracy test was reliable and it was strongly correlated with the face-to-face measures. There was ceiling effect on the ICT familiarity test although it also correlates with early numeracy results. Findings of our study indicated that our online test can become a useful, easy-to-use educational tool to assess early numeracy and provide valuable information for teachers to design their teaching process.

INTRODUCTION

Mathematics achievement highly depends on the successful acquisition of early numerical skills therefore assessment of these skills in kindergarten is inevitable to diagnose difficulties in time and prevent children falling behind. However, carrying out testing on a regular basis in kindergarten is cost and time consuming since it has to be done by traditional face-to-face assessment methods. Technology-based assessment could be the solution to overcome these difficulties by providing the possibility of developing easy-to-use assessment instruments for kindergarten teachers (Csapó, Molnár, & Nagy, 2014).

EARLY NUMERACY

The construct of early numeracy comprises several basic skills and concepts (Jordan, Kaplan, Locuniak, & Ramineni, 2007). Number word sequence skills are an important basis of other early mathematical skills. The knowledge of the correct order (forward or backward) of number words is essential to the development of enumeration skills, and it has significant role in solving basic additions and subtractions (Aunio & Rasanen, 2015). Enumeration is also an important component of the early numerical skills. It is related to the cardinal meaning of numbers when children identify the last number of the sequence with the number of the element they counted (Aunio & Niemivirta, 2010; Aunio & Rasanen, 2015). Basic counting skills develop swiftly after children are aware of number word sequences and understand the cardinal number

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concept. They are able to solve additions, subtractions and later they understand the part-part-whole concept as well (Fritz, Ehlert, & Balzer, 2013; Resnick, 1992). Another essential component of early numerical skills is the knowledge of number symbols. Numeral recognition and number identification are the two segments of this factor. At the beginning children learn Arabic numerals then they will be able to identify and read numbers. Establishing connections between Arabic symbols and quantities are also important basic skills of numeracy. Studies have shown the numeral knowledge as a strong predictor of later formal mathematical achievement (Purpura & Napoli, 2015). There are several standardised mathematical test batteries to measure the numerical skills of children from age four to eight (e.g., the Utrecht Test of Early Numeracy – ENT; Early Numeracy Test – WENT) (Aunio & Rasanen, 2015). In Hungary a diagnostic test battery called DIFER (Diagnostic System for Assessing Development for four- to eight-year-old children) is widely used to assess key skills for school readiness (Nagy, Józsa, Vidákovich, & Fazekasné Fenyvesi, 2004). These instruments share the same characteristics: they require resource and time consuming face-to-face test administration and the educators' proper qualification is also necessary otherwise the objectivity of the measurement can be compromised.

TECHNOLOGY-BASED ASSESSMENT IN EARLY CHILDHOOD

Technology-based assessment is an umbrella term and it refers to use any technological solutions during the testing process. Online assessment is a narrower term where test administration and data processing is carried out on computers through internet (Jurecka & Hartig, 2007). Over the past decades there have been a growing interest for technology-based assessment in educational context due to its advantages over traditional assessment formats such as the opportunity to present more stimulating innovative items (e.g. using sounds, pictures and videos, interactivity), to apply automatic feedback and to manage data processes more effectively (Csapó, Ainley, Bennett, Latour, & Law, 2012). All of these features contribute to the implementation of testing young students and carrying out large scale assessments as well (Csapó, Molnár, & Nagy, 2014; Molnár & Pásztor, 2015). For instance, we can apply pre-recorded instructions and design items with the possibility of manipulation which is essential in the development of skills in young ages. In contrast with traditional face-to-face methods technology opens the way for testing more children at the same time. To conclude if the infrastructure is available (e.g. tablets and internet connection) we can provide easy-to-use assessment instruments for kindergarten teachers to identify children difficulties and to improve the quality of their teaching (e.g. fitting their teaching methods for the actual level of students' knowledge and skills). However, there are many concerns as well regarding the validity and reliability of these technology-based instruments in early childhood. For example the relationship has to be explored between the results from using face-to-face assessment tools and online tests to ensure the validity of the online instruments (Csapó, Molnár, & Nagy, 2014). In addition, the level of children ICT familiarity may influence the achievement scores in the targeted construct. Therefore we have to ensure that children have the necessary ICT skills to provide the answers for the tasks (Molnár & Pásztor, 2015).

AIMS OF THE STUDY

The aims of the study are (1) to develop an easy-to-use online test for early numeracy and to analyse the psychometric properties of the test; (2) to empirically validate the instrument and (3) to examine the effects of ICT familiarity on early numeracy achievements.

METHOD

Participants

Our assessment took place in two kindergartens with the participation of 30 children. The sample consisted of 15 boys and 15 girls between the age of five and six (M age=5.7 years SD=.22). Informed consent form about the research was given to the parents.

Instruments

In our newly developed online test children could solve the tasks through manipulation: they had to drag and drop objects or select the right solution by tapping on it. Items were designed with respect of range of interest of the targeted age cohort (see figure 1). Children listened to instructions through headphones, which were reviewed by experienced Kindergarten teachers. There were no letters to read on the task pages. Children could listen to the instructions as many times as they wanted by tapping on the speaker icon. The test comprised of 40 items and included five subtests; Basic counting, Number word sequence, Numeral recognition, Magnitudes and numerals and Relations. The *Basic counting* subtest contains manipulative tasks, addition, and subtraction of magnitudes, and tasks related to the part-part-whole concept. Within these tasks children need to add, take away or sort the right amount of magnitudes. The *Number word sequence* subtest measures whether children can recognize a correct forward or backward number word sequence. They hear a sequence of three numbers, then they can listen to three possible conclusions and they need to decide which is the correct one (Figure 1). In the *Numeral recognition* subtest children need to recognize Arabic numbers with one, two and three digits. They select the right card out of four that shows the number what they hear. In the *Magnitudes and numerals* subtest children manipulate magnitudes based on the number they hear or see. Tasks with smaller amounts are solved by drag and drop technique (Figure 1) but tasks with larger amounts can be solved by the selection of the right picture of three different magnitudes. Tasks of the *Relations* subtest measured whether children can compare number sets and find the larger, largest or smaller, smallest quantities.
In order to provide possibilities for practising the tapping and drag and drop operations and to familiarize children with the test environment they also completed an ICT familiarity test before the early numeracy assessment. The instrument consisted of 16

items (Figure 1). To maximize the training effects children had a second chance to solve these items in case of failure.

Figure 1: Sample items for the ICT familiarity and the early numeracy test (from the left to the right). ICT familiarity, instruction: '*Drag the matchboxes to the shelf and the balls to the carpet*.' Number word sequence, instruction: '*Help Pete decide which animal continues the counting correctly. Pete starts the counting every time. If you click on the speakers next to the animals you can hear how they continue the counting. Click on the animal which continues the counting correctly. Click on the speaker next to Pete and he starts the counting'*. Magnitudes and numerals, instruction: '*You can see a number on the card. Drag as many ducks into the lake as the card shows!*'

To validate our online assessment we used two tests (counting and basic numeracy, relational reasoning) of the Hungarian DIFER test battery. The counting and basic numeracy skills test included 38 items. 14 items were intended to assess the knowledge of the number word sequence forward and backward (e.g., count up to 21), 11 items were related to manipulative counting skills (e.g., 'Here are six sticks. Make it ten.'), 9 items aimed to assess counting number sets (e.g., 'Show me the card with five drawings.'), 4 items assessed the ability to read one, two and three digit numerals (e.g., 3, 22, 118) (Nagy et al., 2004). The test was reliable (Cronbach's alpha = .80).

The relational reasoning test assessed the understanding of words which stand for relations between different objects, attributes or processes. It has four equivalent test versions; each of them contains 24 items of 24 relation words. We used the first variant of the test which had eight words connected to spatial relations (e.g., inside, in front of), four items determining quantity (e.g., few, many), four words indicating actions (e.g., step in, step on), four items related to time (e.g., night, afternoon) and four relational expressions (e.g., the longest, the same length) (Nagy et al., 2004). Verifying the reliability of the test two items were excluded from further analyses. For the remaining 22 items Cronbach's alpha = .62.

Procedure

Data collection by the online early numeracy test and ICT familiarity test were administered through Internet via eDia (Electronic Diagnostic Assessment) online assessment platform (Csapó, Lőrincz & Molnár, 2012) on tablet computers. The tests were carried out in the kindergartens in groups of four or five children supervised by kindergarten teacher candidates. Their assistance was expected only in case of technical difficulties. Face-to-face assessments of the DIFER test were also organized in separated rooms in the kindergartens. The DIFER test is usually administered by kindergarten and primary school teachers but in our research we trained kindergarten teacher candidates to carry out the assessments. 15 children completed the online tests first, the other half of the sample started with the face-to-face measurements in order to precede effects of which test they complete first. Assessments were carried out during the first two weeks of December 2016. Beside the quantitative measures we used video observation as well, the analysis of the data is still in progress.

RESULTS

Reliability and the average performance on the online early numeracy test and its subtests are listed in *Table 1*. Due to the low reliability value (Cronbach's alpha < .3) of the Relations subtest we excluded its 6 items from further analyses. The test with the remaining 34 items proved to be reliable (Cronbach's alpha=.88). The reliability of the subtests was still acceptable apart from the value of Numeral recognition. The average achievements on the online early numeracy subtests were over 50% except the Number word sequence where the mean score was the lowest (31.82 %p; SD=24.32; *Table 1*). Large standard deviations indicate that the test had good differential power and they also refer to large individual differences (*Table 1*).

Subtests	Number of items	Reliability (Cronbach's alpha)	%p (SD)
Basic counting	11	.75	74.85 (20.21)
Number word sequence	11	.75	31.82 (24.32)
Numeral recognition	6	.66	60.00 (27.19)
Magnitudes and numerals	6	.77	77.22 (28.19)
Early Numeracy Total	34	.88	58.73 (19.21)

Table 1: Reliability and the average performance on the early numeracy test and its subtests

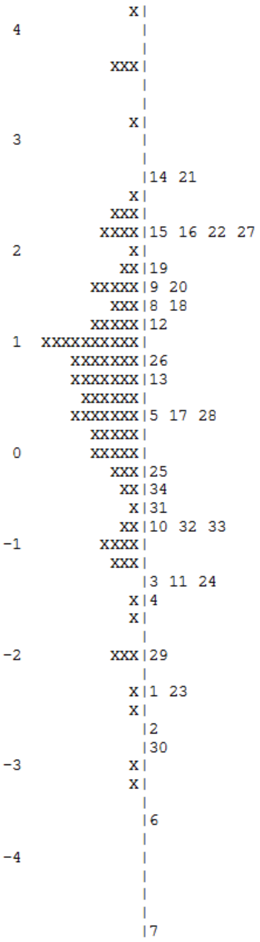

Figure 2: Person item map for the early numeracy test. Each 'X' represents .3 cases.

One-parameter RASCH analyses was also carried out in order to gain a more detailed picture about the behaviour of the items. The EAP/PV reliability was good: .91. *Figure 1* shows that in general the items were covering the different skill levels. However, the pattern is not balanced. In case of some skill levels further item analysis would be necessary.

We found significant correlations between the achievements on the subtests which provide some empirical evidence for construct validity (*Table 2*). Further support for validity is the strong correlation between the face-to-face Counting and basic numeracy test and the online early numeracy test (r=.84). In addition, the online subtests are also connected to the face-to-face test results.

The reliability of the ICT literacy test was low (Cronbach's alpha= .40). Possible reasons for this might be the training (i.e. the second chance for solving the items in case of failure) or the ceiling effects (M=91.5% SD=7.6%; the lowest score was 75% and the highest was 100% in case of 9 items out of 16). The high achievements indicate that children had no difficulties in handling the tablets and providing answers for the tasks. However, there are positive correlations between the early numeracy test results and the ICT familiarity scores. But this result has to be interpreted in the light of the finding that ICT familiarity also correlated with face-to-face test results.

Measure	1	2	2a	2b	2c	2d	3
1 ICT familiarity	-						
2 Early Numeracy	$.47^{**}$	-					
2a Basic counting	$.48^{**}$	$.82^{**}$	-				
2b Number word sequence	.32	$.79^{**}$	$.46^{*}$	-			
2c Numeral recognition	$.51^{**}$	$.80^{**}$	$.65^{**}$	$.45^{*}$	-		
2d Magnitudes and numerals	.18	$.75^{**}$	$.49^{**}$	$.45^{*}$	$.57^{**}$	-	
3 D. Counting and basic numeracy	.34	$.84^{**}$	$.63^{**}$	$.49^{**}$	$.81^{**}$	$.84^{**}$	-
4 D. Relational reasoning	$.48^{**}$	$.60^{**}$	$.45^{*}$	$.51^{**}$	$.39^{*}$	$.51^{**}$	$.46^{*}$

Table 2: Correlations between the measured constructs. *Note*. ** = *p<.01;* * = *p<.05; D.= DIFER*

DISCUSSION

The current study is part of a longer test development process. Our intention is to create an easy-to-use online test environment which grabs and maintains young childrens' attention while provides reliable and valid information about the current state of the early numerical skills. The present version of our online early numeracy test proved to be reliable, even the subscales had acceptable reliability. However, items of important subscales such as Relations and Numeral recognition need to be revised. IRT analyses also showed the potential for further item development.

The correlations between the subscales and also the relation of our online test results to the face-to-face test performances provided empirical evidence for validity. The strong correlation between the face-to-face counting and basic numeracy test and the online early numeracy test indicates that we succeeded to measure a nearly equivalent construct of early numeracy compared to the one in the face-to-face assessment. However, further item analyses and item to item comparisons between face-to-face and online measures are necessary to strengthen these claims.

In addition, we have some concerns related to ICT familiarity which raise some questions regarding validity. In spite of the ceiling effect on the ICT familiarity test we still found positive correlations between early numeracy and ICT familiarity test achievements. This finding can lead to a conclusion that we have validity problems. However, the ICT familiarity test scores were also positively correlated with the face-to-face test results. This relation pattern could be interpreted in a way that ICT familiarity test measures not only ICT familiarity but something else as well. It might be related to social background or also attention or motivation of the students. Further research should focus on investigating these assumptions. In addition, the examination of the role of ICT literacy could be integrated with qualitative measures such as the analyses of the data from video observation. Nevertheless, our findings clearly represented the necessity of a prior ICT familiarity testing in early childhood in case of any online assessment.

To conclude, by further improvements our online early numeracy test can become a useful, easy-to-use educational tool to assess early numeracy and to provide valuable information for teachers to design their teaching process. Even our current version is suitable for everyday use if the infrastructural background is given (e.g. tablets and internet connection). Our findings indicate that online assessment even in early childhood has many advantages. However we need to be very careful when carrying out the measurements and interpreting the results.

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