Thematic Article

Development and Initial Evaluation of an Individualized Moderately Challenging Computer-tablet Mastery Motivation Measure for 3−8 year-olds

Krisztián Józsa [26] *, Karen Caplovitz Barrett* [27] *, Gabriella Józsa* [28] *, Noémi Kis* [29] *& George A. Morgan* [30]

Abstract

This paper describes information about the development of a new computer-based, individualized mastery motivation assessment and reports results from a study using the assessment with a sample of 274 children aged 3-8 years in Hungarian kindergartens and elementary schools. Mastery motivation as an important characteristic in early childhood, in part because it is a predictor of later cognitive and school performance. In the present study, each child was given four number search and four letter search tasks that varied in assumed difficulty for their age from easy to hard. Results suggest that the children enjoyed the tasks and varied meaningfully in persistence in matching target numbers or letters from an array. As the tasks increased in assumed difficulty, children spent more time searching, but were less successful and made more errors in matching the letters or numbers. Mastery motivation scores were calculated based on each child's computer-calculated persistence on the tasks that were actually moderately challenging for that child. This individualized persistence score was significantly correlated with teachers' and experimenters' ratings of persistence, providing support for the measure's criterion/construct validity. These results support the promise of the tasks as part of a school readiness assessment to predict children's school performance.

Keywords: motivation, child development, computer-assisted testing, mastery motivation, individualized tasks, moderately challenging, mastery tasks

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[26] University of Szeged, Szeged, Hungary, jozsa@edpsy.u-szeged.hu, ORCID 0000-0001-7174-5067

[27] Colorado State University, Fort Collins, CO, USA, karen.barrett@colostate.edu, ORCID 0000-0003-2724-6361

[28] KSZC Kandó Kálmán High School, Kecskemét, Hungary, jszgabi@gmail.com, ORCID 0000-0001-9134-1764

[29] University of Szeged, Szeged, Hungary, kisnoemimi@gmail.com, ORCID 0000-0003-3376-7390

[30] Colorado State University, Fort Collins, CO, USA, george.morgan@colostate.edu, ORCID 0000-0003-2978-3988

Introduction

Mastery Motivation

Morgan, Harmon, and Maslin-Cole (1990) proposed that mastery motivation is a multifaceted, initially intrinsic psychological force that stimulates an individual to attempt to master a skill or task that is at least moderately challenging for him or her. Morgan, MacTurk, and Hrncir (1995) identified three main instrumental aspects of mastery motivation: (1) cognitive persistence, a child's motivation to persist at and master cognitive and school-related tasks, (2) gross motor persistence, the motivation to master physical skills, and (3) social persistence, the motivation to master interpersonal relations with adults and with peers. In addition to these instrumental dimensions, Barrett and Morgan (1995) emphasized the importance of the affective or expressive aspects of mastery motivation; they highlighted the role of mastery pleasure in enhancing mastery motivation and the rate of frustration, sadness, or shame after failure in potentially undermining it. Mastery motivation inclines children to practice and acquire a new skill or ability even when it is challenging, and thus should fundamentally impact development (MacTurk & Morgan, 1995; Messer, 1993; Wang & Barrett, 2013).

The literature highlights the importance of research on and assessment of mastery motivation (Busch-Rossnagel & Morgan, 2013; Shonkoff & Philips, 2000; Wang & Barrett, 2013). Research has indicated that mastery motivation may be a better predictor of cognitive development than intelligence, hence playing a crucial role in school achievement (Gilmore, Cuskelly, & Purdie, 2003, Józsa & Molnár, 2013; Mercader, Presentación, Siegenthaler, Moliner, & Miranda, 2017). However, extant behavioral measurements of mastery motivation for 3 to 8 year-olds are time-consuming and require training to administer, making them impractical for teachers to administer in authentic school settings. Previous large-scale studies used adult-report questionnaire measures (i.e., the Dimensions of Mastery Questionnaire), which, although less challenging to administer, are subject to potential rater biases, such as confounding motivation and competence (e.g., Józsa & Molnár, 2013; Józsa & Morgan, 2014; Józsa, Wang, Barrett, & Morgan, 2014; Morgan, Wang, Liao, & Xu, 2013).

We distinguish the motive to master moderately challenging skills and problems from the somewhat related concept of intrinsic motivation. The two concepts are different in terms of focus and measurement. Although mastery motivation has usually been assumed to be initially intrinsic in infants, the focus of mastery motivation research has been on a child's persistent attempts to master challenging tasks, whether the reward comes from within or whether extrinsic rewards are offered (Józsa & Morgan, 2014; Józsa et al., 2014). In contrast, the intrinsic motivation literature places little emphasis on mastery, focusing instead on the source (internal or external) of the motivation.

Individualized Mastery Tasks

The approach taken in our computerized assessment is based on earlier work by Morgan, Busch-Rossnagel, Maslin-Cole, and Harmon (1992) to individualize the difficulty level of mastery tasks. Theoretically, mastery motivation involves persistence on tasks that are at least moderately challenging, but level of challenge of any particular task varies with the ability of the person working on the task. Morgan and his colleagues strove to separate motivation from ability by selecting tasks that are moderately challenging for each individual child. This strategy involved the use of sets of similar tasks/toys, such as puzzles, which had several levels of difficulty. The child's motivation was assessed with the level of each set of tasks that was found to be moderately difficult for that individual child. Specifically, a task was selected so that the child would successfully complete at least part of it, but would not finish all parts of the task too quickly. Thus, the level chosen for a given child was moderately challenging but not so hard that partial completion was not achieved. The child's persistence and pleasure at those moderately difficult tasks were used to measure mastery motivation.

McCall (1995) called this individualized approach, with its identification and use of moderately difficult tasks "one of the most important measurement advances" (p. 288), in part because it facilitates the separation of ability or competence from motivation. This individualized method has been used by a number of researchers and led to an increasing understanding of mastery motivation in young children developing typically and, especially, atypically (e.g., Gilmore & Cuskelly, 2011; Young & Hauser-Cram, 2006; Wang, Morgan, Hwang, & Liao, 2013; Wang et al., 2016). We used the Morgan et al. (1992) methods as the starting point for developing our new computer-based assessment described in this paper.

Purposes of this paper

The goals of this paper are to present findings from two studies used to develop and test the computer-based mastery motivation tasks and a new individualized, moderately challenging persistence measure. First, we summarize the method and results of the face-to-face pilot study used to develop and refine the new mastery motivation tasks. Then we describe the method and results of the initial study of the computer-based mastery motivation tasks. We present data about descriptive statistics, the development of the individualized persistence measure, and validity of this new measure.

Face-to-Face Pilot Study

Method

Participants

Kindergarten in Hungary includes three or more years from age 3 to 6–8. The first year of kindergarten (preschool) is the first stage of public education. Hungarian Law

guarantees free kindergarten for all children. There were 12 Hungarian kindergarten children aged 4 to 7 in the face-to-face pilot study. Half of them were boys. They were middle class children in a preschool in a middle size city in the central part of Hungary.

Measures

Test items were developed based on the Morgan et al. (1992) moderately challenging task procedure for young children. We used a letter search and a number search game. Both of them included 8 difficulty levels; all children were given the same 8 tasks. The tasks were in color printed on white A4 (ca. 8.3x11.7 inches) paper. Each difficulty level was printed on a separate sheet. The layout of the papers were designed to simulate future computer monitor/tablet screens; that is, children saw a monitor screen-like layout on the table in front of them. They were given paper discs to put on the letters and numbers they were instructed to find.

Procedure

The aim of the individual face-to-face pilot study was to see if children understood and liked these tasks, and to check if difficulty levels were defined appropriately. Data collection took place at a kindergarten in a room suitable for testing. The pilot study was carried out by the first and the third authors of this paper. The kindergarten teacher was present during the testing, to help children feel comfortable in the presence of the unknown testers.

At the start of the examination, a training task was given to the children. Our goal with this was to make sure participants understood the instructions. In the training task children had to find, among three numbers or letters, the one that was highlighted at the top of the page. Understanding was aided by verbal instructions. Only one child needed more detailed explanation during the training task. After the completion of the training task, all children understood the instructions.

One of the researchers interacted with the child, while the other was responsible for recording the time with a stop watch and for filling in the data recording form. Children were allowed 2 minutes on each of the eight levels or until they had finished (or in a few cases, at the hardest levels, until they gave up). Time spent on the tasks in seconds, number of "errors", and "missing" cards were recorded on this form. "Errors" occurred when discs were placed on pictures that did not match the target picture. An answer was "missing" when no disc was put on a picture that was identical with the target picture. Emotional reactions, signs of giving up, as well as off-task behaviors were also recorded. Every child was given each of the eight difficulty levels of the number search task and the eight levels of the letter search. Data collection started with the letter search task for half of the children and with the number search for the other half. A child's letter and number search tasks were administered on different days.

Results

The first two difficulty levels proved to be easy for every child; they found all the letters and numbers at these levels. Time spent on tasks increased as the level increased from level 1 to 8 (see Table 1). Although the sample in the pilot study was small, Table 1 also shows that the time needed to complete the game-like task was similar for the letter and the number search tasks on the corresponding levels. On the higher levels, more errors occurred and more correct pictures were "missing" (not found). A few children's persistence (time spent) was seemingly lower on the higher levels, in part because off-task behavior also was observed in some children. Two children did not even start the last two levels of the letter search, so their times were not included in Table 1.

Table 1. Average Time Spent in Seconds on the Different Difficulty Levels (L1-L8) of the Pilot study

Search Tasks	L1	L2	L3	L4	L5	L6	L7	L8
Letter	13	13	30	44	77	79	73	94
Number	10	13	25	20	39	65	66	97

Note. N = 12 for each task, except for 2 children who did not start levels 7 and 8 of the letter search.

Discussion: Changes Based on the Face-to-Face Pilot Test

The results supported the ordering of the tasks in difficulty level, and also suggested that the lowest levels may be appropriate for even younger age groups. Based on our desire to train children on how to do the task rather than to familiarize them with the numbers and letters that would be included in the task, numbers and letters were replaced by pictograms (banana, boat, house, ship) for the training level on the computer-based tasks. Using the pictograms also enabled children to learn how to do the search through more familiar symbols. In the computer-based version, a built-in function prevents children from moving on from the training level until they demonstrate an understanding of the task instructions. For this reason, more than one training level is given if it is needed. If a child does not seem to understand the instructions, the test will not start.

After the pilot study, some changes were made to the combinations of the letters. This seemed necessary to increase the difficulty of the higher levels. In the face-to-face pilot study, all eight levels of the letter and number tasks were included as part of the computer-based test. However, given time constants, we decided to give each child only four different levels for the computer assessment: one that was assumed to be easy for their age, two moderate, and one difficult. Thus, in the computer-based version children were given a total of four age-appropriate levels each of the number and letter search tasks instead of the original eight levels.

In this face-to-face study, we originally planned to have children report on their emotional state before, during, and after the tasks. Children were presented with four stylized drawings of faces depicting four different emotions (happy, neutral, sad, and angry) and were asked to point to the face that showed how they felt during that task.

However, children's answers did not seem to reliably reflect their task-related emotions. Most children chose the happy face, often saying they liked it the most. Some children spoke about emotions resulting from some other situation, such as playing in the courtyard that morning, rather than the task. This method did not seem to validly measure the young children's emotional responses to challenge, mastery, and/or failure; therefore, it was not included in the computer-based test. Instead, the examiner was asked to rate the child's emotions as they did the tasks.

Children in the pilot sample showed pleasure in participating in the study. They regarded it as a game and enjoyed finding the letters and numbers. After the pilot study and the modifications made, we found the tasks to be appropriate to start the development of the computer-based test.

Initial Testing of the Computer-Based Mastery Tasks

Method

Participants

Participants in the initial testing of the computer tasks were kindergarten and elementary school children in Hungary. Using a cross-sectional design, we collected data from children from 3 to 7 or more years old (Table 2). The total sample size was 274; 49.3% of the children were boys. The data collection was done in a mid-size city in Southern Hungary. The children were recruited from 8 kindergartens and 3 elementary schools. We made an effort to sample schools that would include children from all categories of parental educational levels. The average number of years of parental education was approximately 10.5 years for fathers (SD = 1.78) and 10.9 for mothers (SD = 2.03). Approximately 16% of the fathers and 15% of the mothers had a BA degree or higher; 32% of the fathers and 22% of the mothers had less than a high school degree.

Table 2. Distribution of the Sample by Age

Sample	3-4 yrs.	4-5 yrs.	5-6 yrs.	6-7 yrs.	7 or more yrs.
N	62	79	76	23	34
Age [in months]	40(6)	54(4)	65(3)	75(3)	94(15)

Note. Age shows the mean age in months; SD is in parentheses.

Computer-based Mastery Motivation Tasks

Based on both our theoretical approach (Morgan et al., 1992) and our experiences from the face-to-face pilot study, computer-based, game-like tasks were developed to measure (a) mastery motivation, (b) pre-academic skills, and (c) executive functions. Barrett, Józsa, and Morgan (2017) provide a more detailed description of all the tasks. Based on the literature we assumed that these three components together should be a good measure of school readiness (Józsa & Barrett, 2017; Zelazo, Blair, & Willoughby, 2016). The present paper focuses just on the mastery motivation tasks.

These computer tasks were designed to measure an important aspect of the child's mastery motivation: persistence while trying to solve a moderately challenging task. The tasks assess the child's persistent attempts to find all matching numbers and letters from an array. Both letter and number searching tasks varied in difficulty from those assumed to be easy for 3-year-olds to ones assumed to be difficult for 8-year-olds, based on findings of the face-to-face pilot.

The assessment does not require children to read; the examiner selects a language, either English or Hungarian, and the computer narrator, Little Bear, guides children through the tasks in that language. The tasks were developed to be appropriate for both Hungarian and American cultures. Children were readily able to do the easy level of both of the tasks, regardless of language spoken.

In the *number search* tasks, the computer introduces the task by saying "This is the Number Search game. In this game, you will find the numbers. Over here, you will see a number (number flashes) that is in a red box. The other numbers are in blue boxes. You will need to touch all of the blue numbers that are exactly the same as the red number. During these games we will not tell you if you have found them all." As the level of difficulty increased, the number of blue boxes to be matched increased. The *letter search* tasks were similar except that at the more difficult levels (6 to 8), the child was told to "ignore the order of the letters and find them in any order" (Barrett et al., 2017). The blue "boxes" that had letters or numbers in them are called "cards" in the rest of the paper.

The letter and number search tasks were designed primarily to obtain measures of time spent on moderately challenging tasks (i.e., mastery motivation). The computers also yielded measures of accuracy on the tasks (matching cards found and non-matching cards touched; i.e., errors). Based on those variables, a competence score was computed. A computer-based, individualized persistence score on moderately challenging tasks was computed based on the child's competence score and time spent on the task. These and other computer-based scores are described in more detail in the next section.

As Table 3 shows, each child was given one level assumed to be easy, two assumed to be moderately difficult, and one assumed to be hard, based on their age, for up to two minutes each. A level was terminated when the child touched the "Little Bear" signaling that he or she was done with the level.

Table 3. Assumed Difficulty Levels of the Search Tasks Used at Different Ages

Age group in years	Easy	Moderately challenging 1	Moderately challenging 2	Hard
3–4	1	2	3	5
4–5	1	3	4	6
5–6	2	4	5	7
6–7	3	5	6	8
7 or more	4	6	7	8

Computer-based Scores

The computer saved all of the children's computer responses into a database. From that database, several types of scores were produced for each child in each of the four assumed difficulty levels of the number search tasks and the four letter search tasks. Remember that the easy, two moderate, and hard levels of the task were difficulty levels assumed to be that level of difficulty for the average child of that age. The computer-based scores were:

1. Computer-calculated time spent persisting (TSP) in trying to match target cards. This was the time, in seconds, during each of the four levels x 2 types of tasks given to each child. Time spent is a rough measure of the child's persistence trying to match the target card (i.e., mastery motivation) because it included both accurate matches and errors, i.e., touching non-matching cards. However, time spent could, but usually did not, include off-task behaviors such as looking around the room because the computer program was not able to detect such behaviors. The examiner ratings, described below, provided an estimate of actual time on tasks. A summary TSP score, based on the four tasks that were assumed to be moderately challenging, was used to assess reliability in Table 8.
2. Percentage of matching cards found (PMC). For each child in each task, a percentage score was computed consisting of the correct cards that the child touched (i.e., the cards that matched the target card) out of correct cards possible. A PMC on the four tasks assumed to be moderate was used in Table 8 for reliability.
3. Percentage of non-matching cards touched (PNM). Similarly, a score was computed of the percentage of the incorrect or non-matching cards the child touched or "found." The PNM on the four tasks assumed to be moderate was used in Table 8 for reliability.
4. Percentage of completely successful trials. A child's performance on a specific level (e.g., assumed easy) was completely successful if he/she touched or "found" all (100%) of the matching cards and none (0%) of the non-matching cards.
5. Computer search competence score (CST). For each of the four difficulty levels of both types of search task. We computed the mean of two variables for each child: the percentage of matching cards found and 100% minus the percentage of non-matching cards touched (i.e., the errors). Some examples of competence scale values are:
   − 100 if the child touched all (100%) of the matching cards and none (0%) of the non-matching cards,
   − 90 if, for example, the child touched 90% of the matching cards and 10% of the non-matching cards. That is, (90 + 100 -10) / 2,
   − 50 if, for example, 50% of the correct cards are found and 50% of the wrong cards were touched,
   − 0 if the child touched none of the matching cards and all of the non-matching cards.

The CST on the four tasks assumed to be moderate was used to calculate reliability in Table 8.

Empirically-based Actual Levels of Difficulty

As indicated previously, the computer presented task levels that were assumed to be easy, moderately challenging, and hard based on children's age. However, it was evident from descriptive statistics using the above scores that some of the tasks *assumed* to be moderately challenging were very easy for many of the children. Similar to criteria used by Morgan et al. (1992) and Wang, Liao, and Morgan (2017), we empirically defined levels for each child that were considered to be *actually* easy, actually moderate and actually hard. We used the following criteria to define a moderately challenging level for an individual child: (a) the child's search competence score was between 50% and 90%, or (b) the competence score was higher than 90% and the time spent on the task was longer than the mean time plus one standard deviation for a child of his/her age on that level of the task. A task was defined as hard if the competence score was less than 50. An easy task was one in which the child had a competence score of more than 90 and took less time to complete the task than was required for it to be considered moderate.

Examiner Ratings

In addition to the computer produced data and scores, the children were rated on persistence and emotion by the examiner at the end each of level of the computer tasks. Thus, these were ratings of what the child was doing while working on the computer tasks. A rating sheet, developed for this purpose, included the following dimensions for each task level presented to the child:

1. The most intense emotion: positive, neutral or negative during each task level.
2. The intensity of emotions at each task level.
   a) If the most intense emotion was neutral, the intensity of emotion was noted as 0.
   b) Positive emotion: 1 = low positive (e.g. closed mouth smile), 2 = moderate positive (e.g. open mouthed smile), 3 = high positive (e.g. smile and positive vocalization or clapping, excited body);
   c) Negative emotion: 1 = low negative (e.g. slight frown), 2 = moderately negative (e.g. clearly angry or sad face), 3 = high negative (e.g. angry or sad face and negative vocalization or crying).
3. Persistence was rated as the percentage of the time the child was focused on trying to do the task. 1 = 0–19%, 2 = 20–39%, 3 = 40–59%, 4 = 60–79%, 5 = 80–100%.

Dimensions of Mastery Questionnaire (DMQ 17)

The Hungarian version of Dimensions of Mastery Questionnaire (Józsa & Molnár, 2013) was used to measure mastery motivation. This instrument was developed by Morgan, Busch-Rossnagel, Barrett, and Wang (2009); see also Morgan et al. (2013). The questionnaire consists of 5-point Likert items. The instrument has seven scales: cognitive persistence, gross motor persistence, social persistence with adults, social persistence with children, mastery pleasure, negative reaction to failure, and competence. The questionnaires were completed by each child's teacher. The cognitive persistence, mastery pleasure, and negative reaction scales were used in the present

study. The reliabilities of the Hungarian questionnaires were high (Hwang et al., 2017; Józsa & Molnár, 2013; Józsa et al., 2014).

Procedure

The computer-based tasks were administered in preschool and school settings. Trained education graduate students were the examiners. They tested the children individually in quiet rooms. After a warm-up period, the examiners introduced the computer-tablet assessment to the child. All of the children used touch screen tablets in this study. The testing situation, including training on each task, lasted 10–20 minutes. The examiners rated the children's persistence and emotion reactions during the computer tasks on the rating sheet described above. The teacher filled out the DMQs before the computer based assessment.

Results

Computer-produced Time Spent Trying to Match the Target Card

The computer recorded the time each child spent on each task. Table 4 shows the time in seconds that children spent working on search tasks by age group. With increased difficulty level of the tasks, the time also increased. The children spent a similar amount of time on the letter and the number search tasks. Repeated-measures ANOVA for the total sample showed a significant linear (straight line) increasing trend in time both on the number search ($F = 223.40$ $p < .001$, partial $\eta^2 = .464$), and letter search ($F = 234.71$ $p < .001$, partial $\eta^2 = .499$).

Table 4. Average Time in Seconds Spent on the Different Assumed Difficulty Levels

Age	Number search				Letter search			
	E	M1	M2	H	E	M1	M2	H
Less than 4	20 (13)	32 (21)	42 (22)	52 (28)	18 (14)	26 (11)	36 (19)	59 (35)
4–5	19 (12)	39 (19)	56 (29)	55 (33)	16 (16)	41 (20)	55 (31)	42 (29)
5–6	23 (13)	54 (24)	50 (23)	61 (37)	14 (11)	49 (24)	62 (35)	47 (27)
6–7	32 (13)	41 (17)	50 (23)	57 (25)	25 (12)	53 (20)	42 (16)	62 (31)
7 or more	35 (18)	37 (18)	46 (22)	49 (21)	20 (07)	29 (10)	39 (16)	46 (26)
Total	23 (15)	42 (22)	50 (25)	56 (31)	17 (14)	40 (21)	50 (30)	49 (30)

Note. Assumed difficulty levels. E = Easy, M1 = Moderately challenging 1, M2 = Moderately challenging 2, H = Hard; SDs are in parentheses.

Percentage of Matching Cards Found

The computer recorded whether or not a child touched every card that was the same as the target card. From that, we computed the percentage of matching cards found score. Children found about 95% of the matching cards on the assumed easy number and letter search tasks. On average, they found significantly fewer matching cards at the 1st moderately challenging levels (number search 76%, letter search 79%), and less still at the 2nd moderately challenging levels (number search 66%, letter search 68%). On the assumed hard tasks, they found 53% of the matching numbers, and 56% of the matching letters; thus, on the hard task children found about half of the cards whereas on the easy

task they found almost all of them. Repeated-measures ANOVA shows a significant decreasing linear trend in the numbers of matching cards found, both in the number search (F = 298.41 p < .001, partial η^2 = .532), and the letter search (F = 384.38 p < .001, partial η^2 = .618). These large eta squares indicate steep linear declines for both tasks in the number of matching cards found as the assumed difficulty increased.

Percentage of Non-matching Cards Touched

The computer also recorded when the children touched cards that did not match the target. When children touched non-matching cards, we considered that an error. Note that mastery motivation includes both successful attempts to solve a problem and those that are not successful; i.e., non-matching touches or errors. The percentage of non-matching cards touched on the assumed easy task, 1st and 2nd moderately challenging tasks, and the hard number search tasks were: 4%, 5%, 11%, and 16%, respectively; and for the letter search were: 4%, 4%, 9%, and 13%. Repeated-measures ANOVA shows a significant linear increase in the non-matching cards touched both in the number search (F = 55.61 p < .001, partial η^2 = .175), and the letter search (F = 32.69 p < .001, partial η^2 = .121). These eta squares for errors are smaller than the ones for cards found correctly, which indicates that expected difficulty level is less strongly predictive of the change in error rate than is the change in successful matching.

Percentage of Completely Successful Trials

As described in the Method section, children who were 100% successful not only correctly touched all matching cards, but also refrained from touching any (0%) of the non-matching cards. Table 5 displays the percentage of children with scores of "yes" on the dichotomous variable "completely successful".

Table 5. Percentage of Children Who Touched All of the Matching Cards and None of the Non-Matching Cards

Age group	Number search tasks				Letter search tasks			
	E	M1	M2	H	E	M1	M2	H
Less than 4	76(43)	59(50)	15(36)	3(18)	73(45)	88(33)	27(45)	0
4–5	88(32)	44(50)	4(19)	1(11)	88(33)	63(49)	14 (35)	3(17)
5–6	97(16)	30(47)	27(45)	7(25)	89(31)	43(50)	4(20)	8(27)
6–7	80(41)	40(50)	35(49)	30(47)	86(36)	19(40)	32(48)	12(33)
7 or more	74(45)	44(50)	38(49)	21(41)	82(39)	56(50)	35(49)	18(39)
Total	85(35)	43(49)	19(40)	8(27)	85(36)	52(50)	18(38)	6(24)

Note. E = Easy, M1 = Moderately challenging 1, M2 = Moderately challenging 2, H = Hard; SDs are in parentheses.

A non-parametric Friedman test of differences among levels was conducted for the number and also for the letter search tasks. There were significant differences among the levels in both cases (number search $\chi^2(3)$ = 386.86, p < .001; letter search $\chi^2(3)$ = 352.11, p < .001). The mean ranks for the number search task were 3.39, 2.71, 2.08, 1.82, and were for the letter search task 3.43, 2.58, 2.11, 1.88, respectively. All of the possible pair differences were significant at p < .001 for in both tasks (Wilcoxon test z scores for number search task were 7.86, 8.26, 4.73, letter search task 9.82, 6.33, 4.73, respectively.).

Computer Search Competence Scores

As described in the Method section, we derived a search competence score from the computer produced data for each child in each assumed difficulty level for both types of tasks. Table 6 shows the means and standard deviations for the search competence score by child's age and task difficulty level.

Table 6. Means of the Search Competence at the Search Tasks

Age	Number search				Letter search			
	E	M1	M2	H	E	M1	M2	H
Less than 4	92 (19)	86 (21)	74 (20)	64 (17)	89 (19)	86 (20)	80 (20)	60 (12)
4–5	96 (13)	86 (18)	72 (16)	66 (17)	95 (15)	89 (18)	76 (19)	71 (16)
5–6	99 (06)	84 (18)	80 (19)	66 (17)	97 (08)	87 (18)	69 (17)	72 (16)
6–7	98 (06)	85 (19)	89 (13)	77 (22)	97 (11)	84 (17)	88 (15)	72 (20)
7 or more	97 (09)	89 (17)	85 (18)	85 (19)	98 (06)	93 (12)	83 (20)	76 (22)
Total	96 (13)	86 (18)	78 (19)	69 (19)	95 (13)	88 (18)	77 (19)	70 (17)

Note. E = Easy, M1 = Moderately challenging 1, M2 = Moderately challenging 2, H = Hard; SDs are in parentheses.

Repeated-measures ANOVA for the total sample showed a steep, significant decreasing linear trend; the within-subjects statistics for the total sample for the number search task were: $F(1, 262) = 497.92$, $p < .001$, partial $\eta^2 = .655$, and for the letter search were: $F(1, 238) = 481.83$, $p < .001$, partial $\eta^2 = .669$. This means that for both tasks the competence scores were lower as the tasks increased in assumed difficulty.

Computer-based Persistence Score at Tasks That Were Actually Moderately Challenging

Table 7 presents the empirically defined levels of actual difficulty for each child, as described in the Method section. The table shows that, based on our definitions, most of the children found the assumed easy and moderate 1 levels to be actually easy. Most of the children found the assumed moderate 2 and the hard tasks to be actually moderately challenging. Few children found any of the tasks to be actually hard, according to the above definition.

Table 7. The Percentage of Tasks of the Four Levels of Assumed Difficulty that Turned Out to be Actually Easy, Moderate, or Hard

Actual difficulty	Number search tasks				Letter search tasks			
	E	M1	M2	H	E	M1	M2	H
Easy	80	55	30	16	77	55	28	15
Moderate	18	43	67	74	23	45	66	79
Hard	2	2	3	10	0	0	6	6

Note. Assumed difficulty levels: E = Easy, M1 = Moderately challenging 1, M2 = Moderately challenging 2, H = Hard.

A child could have 0 to 8 empirically defined actually moderately challenging levels. The percentages of children who had 0 to 8 actually moderately challenging levels were the following: 7%, 8%, 12%, 18%, 18%, 17%, 19%, 7%, and 1%, respectively. Thus, 7% had no moderate tasks, and only 1% of the children found all 8 to be moderate; 72% had between 3 and 6 moderate tasks.

Examiner Ratings of Persistence and Emotion

As described in the Method section, the examiner rated the children's task-directed persistence on a 1–5 scale at each level while the child was working on the computer (Figure 1). Based on these ratings, children's persistence was very similar for the letter and the number search tasks; there were no significant differences between them at any of the levels. However, there were steep significant decreases in persistence as the levels got harder. Repeated-measures ANOVA shows significant decreasing linear trends; the within-subjects statistics for the number search task were: $F(1, 100) = 73.71$, $p < .001$, partial $\eta^2 = .424$, and in case of the letter search task: $F(1, 100) = 64.48$ $p < .001$, partial $\eta^2 = .404$, which indicates that as the tasks get harder, children were rated by the experimenter as spending a lower percentage of their time focused on trying to match the cards correctly. The cubic (two bend) trend was also significant for the number search task ($F(1, 100) = 5.66$ $p = .019$, partial $\eta^2 = .054$). Both the quadratic (one bend) trend ($F(1, 100) = 13.37$ $p < .001$, partial $\eta^2 = .123$), and the cubic trend ($F(1, 100) = 5.07$ $p = .027$, partial $\eta^2 = .050$) were significant for the letter search task ($F(1, 100) = 5.66$ $p = .019$, partial $\eta^2 = .054$). The non-linear trends have much smaller effect sizes (η^2) than the linear trend.

Figure 1. Mean examiner ratings for a 1 to 5 Likert-type scale of persistence at the search tasks assumed to be easy, moderate, and hard. E = assumed easy, M = assumed moderate, H = assumed hard

The examiners also rated the intensity of children's positive and negative emotions on 1–3 scales during each of the four levels (Figure 2). The children did not show very intense emotions. Typically, they showed moderate positive emotions (mastery pleasure), and few children showed any negative emotions.
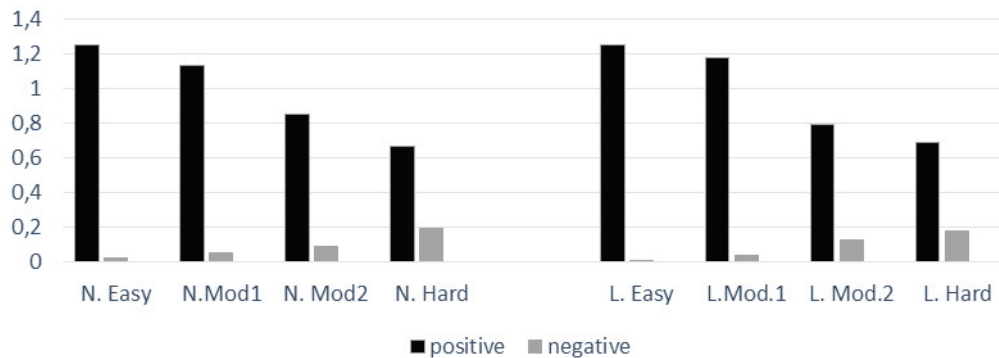
Figure 2. Mean examiner ratings of positive and negative emotion from 1 to 3 on the search tasks assumed to be easy, moderately challenging, and hard. N = number search task, L = letter search task, Mod 1 = 1st task assumed to be moderately challenging, Mod 2 = 2nd, somewhat hard task assumed to be moderately challenging

Repeated-measures ANOVA showed a significant decreasing linear trend in positive emotions. The within-subjects statistics for the number search were: $F(1, 100) = 55.64$, $p < .001$, partial $\eta2 = .260$, and for the letter search were: $F(1, 100) = 69.03$, $p < .001$, partial $\eta2 = .311$, which indicates that as the assumed level of the task got harder, the children were rated as showing less pleasure while working on it. Repeated-measures ANOVA also showed a significant increasing linear trend in negative emotions. The within-subjects statistics for the number search were: $F(1, 100) = 12.89$, $p < .001$, partial $\eta2 = .075$, and for the letter search were: $F(1, 100) = 14.88$, $p < .001$, partial $\eta2 = .089$, which indicated that children showed somewhat more negative reactions as the task got more difficult.

Reliability

Cronbach's alpha reliabilities were computed for the three types of measures used in the study: computer-based scores, examiner ratings of the child's behavior as they worked on the computer tasks, and teacher ratings of the child's mastery behavior in the everyday school environment using the DMQ. These reliabilities, shown in Table 8, were calculated using the four task levels assumed to be moderately challenging at each age. All of the values are at least marginally acceptable (above .6, see Gliner, Morgan, & Leech, 2017). Reliabilities of the examiner ratings of persistence and positive emotion and of computer measures of percentage of matching cards and competence on the search tasks were good to excellent; those for negative emotional reaction rated by the examiner and those for computer-based persistence and non-matching cards touched were lower but adequate. Cronbach's alphas for the DMQ scales were generally high (all over .7).

Table 8. Internal Consistency and Correlations between Number and Letter Search Tasks Assumed to be Moderately Challenging

Reliability	Computer measure				Examiner ratings			DMQ		
	TSP	PMC	PNC	CST	EP	EPE	ENE	TCP	TMP	TNR
Cronbach's α	.689	.870	.634	.737	.892	.893	.613	.880	.872	.741
NL correlation	.478	.496	.353	.540	.800	.807	.742	-	-	-

Note. N = 255; NL correlations of the two assumed number search with the two letter search tasks, TSP = Time spent, persistence on the four tasks assumed to be moderately challenging, PMC = Percentage of matching cards found, PNC= Percentage of non-matching cards touched, CST = Competence on the search tasks, EP = Examiner rating of persistence, EPE = Examiner ratings of positive emotion, ENE = Examiner ratings of negative emotion, TCP = DMQ teachers' ratings of cognitive persistence, TMP = DMQ teachers' ratings of mastery pleasure, TNR = DMQ teachers' ratings of negative reaction to failure.

The number and letter search each included two tasks assumed to be moderately challenging. We computed an average number search and an average letter search score for the computer measures and for the examiner ratings. Thus, we had seven number search and seven letter search variables. Table 8 shows correlations between the number and letter search variables. The correlations were higher for experimenters' ratings (.74 – .81) than for the computer-based data (.35 – .54), but in all cases were significant and at least moderate in size (Cohen, 1988; Leech, Barrett, & Morgan, 2015). These correlations confirm that there was moderate consistency in individual differences in persistence and competence across the letter and number search tasks.

Validity

Next, we standardized the time spent on each task (M = 0, SD = 1) separately for each level and each age. The computer persistence score displayed in Table 9 was the mean of the standardized times spent on all empirically-defined, actually moderately challenging levels for that individual child. This individualized moderately challenging computer (IMCC) persistence score was used to examine the validity of the computer-based mastery tasks.

In this study, mastery motivation was measured with three different measures. First, the computer tablets recorded time spent on all of each child's *actually* moderately challenging number and letter search tasks. As described earlier, these times were standardized and used to compute the individualized, moderately challenging, computer (IMCC) persistence score. Second, the examiners rated on-task persistence and emotional reactions during the four tasks assumed to be moderately challenging. Third, before the child did the computer-based assessment, teachers rated the child's mastery motivation using the DMQ. Correlations among these variables are given in Table 9.

Table 9. Correlations among the Different Measures of Task Persistence and Mastery Emotions

	Variables	1	2	3	4	5	6
1	IMCC persistence						
2	DMQ persistence	.25**					
3	Ex. rating persistence	.33**	.35**				
4	DMQ mastery pleasure	.19	.53**	.21*			
5	Ex. rating pos. emotion	.40**	.29*	.30**	.29**		
6	DMQ negative reaction	-.13	-.28**	-.07	-.11	.18	
7	Ex. rating neg. emotion	-.47**	-.18	-.42**	-.38**	-.35**	.23*

*Note. IMCC persistence = the average time spent on all the computer tasks found to be individually moderately challenging for each child. DMQ = Dimensions of Mastery Questionnaire, Ex. = Examiner. Examiner ratings are based on the four tasks assumed to be moderately challenging; * p < .05, ** p < .01.*

Persistence on the individualized moderately challenging computer-based tasks was correlated significantly with examiners' persistence ratings and teachers' ratings of DMQ cognitive persistence, *r* = .33 and .25, respectively. These correlations provide evidence for the validity of the newly developed computer-based measure. The computer persistence score also was positively correlated (.40) with the child's positive emotions during the tasks rated by the experimenter, and was negatively correlated with the negative emotions rating (-.47). This suggests that children who show more positive and fewer negative emotions on moderately challenging tasks also persist more on moderately challenging tasks, again providing convergent validity for the computer-based measure of mastery motivation.

Teachers' DMQ cognitive persistence ratings were significantly correlated with examiners' rating of persistence on the tasks (.35), supporting the validity of both DMQ and examiner ratings. The significant correlations shown in Table 9 have small to medium effect sizes (Cohen, 1988; Leech et al., 2015).

Discussion

Summary of the Results

The results of a face-to-face pilot study of 12 children 4-7 years old and a large study using the computer-tablet tasks with 274 Hungarian children from 3 to 8 years-old support the reliability and validity of our new computer-based measure of mastery motivation (persistence on tasks that are moderately challenging for the individual child), as well as the examiner ratings of children's behavior during the tasks. In the pilot study, the children were assessed for the time spent (persistence) trying to match a target number or letter to an array on a printed page. As the tasks increased in difficulty, the children's time spent trying increased and success rate decreased. These pilot tests indicated that children understood, liked, and persisted at trying to match the letters or numbers, but children also made some errors and younger children were more likely to give up on or not want to try the harder tasks. The pilot study also led to changes and improvements in the method as the computer-based tasks were developed.

The computer-based mastery task study produced interesting results related to the computer's measures of the child's search for matching cards and the experimenter's

ratings of the child's persistence at the tasks and positive and negative emotions during the tasks. Each child was given eight tasks, four number search and four letter search. For each type, the child was presented with one task assumed to be easy, two assumed to be moderately challenging, and one assumed to be hard for a child that age. As the task difficulty increased, the time children spent trying to find all the matching letters or numbers increased in a significant linear way. Similarly, there was a decreasing linear trend in the percentage of cards found for both types of tasks as the assumed level of difficulty increased, and there was an increasing linear trend in errors (i.e., touching a wrong card). Likewise, a measure of the child's competence had a decreasing linear trend for both types of tasks as the difficulty increased.

However, it became evident that for many children, tasks assumed to be moderately difficult were actually easy, and few tasks were actually hard for any of the children. Based on the child's competence score and the time spent trying to find matches, we made an empirical/behavioral definition of tasks we considered to be actually moderately challenging. Then each child was given a persistence score for moderately challenging tasks based on all the letter and number tasks that were found to be actually moderately challenging for that child personally. This was the individualized moderately challenging computer-based persistence score used to assess the validity of the tasks.

It is interesting to note that there was no evidence that older children spent more time searching for matches than did younger children on tasks that were assumed to be hard for each age (see Table 4). However, a higher percentage of older than younger children touched all the matching and none of the non-matching cards (Table 5), suggesting older children may have had more systematic and effective search strategies and/or better inhibitory control. We also collected data on Executive Functions (EF) for the same children; it will be interesting to see if EF is higher for older children and whether age predicts fewer errors and omissions. Similarly, the older children had somewhat higher competence scores (Table 6).

Evidence for Validity of Individualized Moderately Challenging Mastery Measure

In the current study, there was evidence to support the validity of the individualized computer measure of persistence based on significant correlations with experimenter ratings of persistence of the tasks and ratings of cognitive persistence on the DMQ by teachers. Ratings of positive affect by experimenters were also significantly related to the computer-based persistence measure.

Several other studies have used a somewhat similar individualized approach to measuring mastery motivation using mastery-oriented toys such as puzzles rather than computer tasks. Wang et al. (2016, 2017) also provided support for the validity of individualized moderately challenging tasks based on significant correlations with parent DMQ ratings of object/cognitive persistence and correlations with cognitive and fine motor ability in young children with developmental delays. Wang (2016) also found

that the individualized task persistence scores predicted cognitive and fine motor ability 6 months later, and they mediated the relation between the quality of maternal teaching and later ability.

Gilmore and Cuskelly (2009, 2017) followed 25 4 to 7 year-old children with Down syndrome into adolescence and then young adulthood. At the youngest age (T1), they were assessed with the Morgan et al. (1992) individualized mastery tasks and the DMQ. Evidence for validity was provided by strong contemporaneous correlations of persistence on the tasks with DMQ persistence. More importantly, the T1 individualized mastery tasks predicted T2 reading performance as well as persistence on tasks and DMQ persistence. The 2017 paper reported evidence for the long-term predictive validity of adult adaptive behavior and self-determination from the T1 individualized mastery tasks.

Another study that provided evidence of long-term predictive validity for the individualized moderately challenging mastery tasks is Hauser-Cram, Woodman, and Heyman (2014). They used the Morgan et al. (1992) tasks to assess mastery motivation in 3-year-old children with developmental disabilities. They found that the 3-year-olds who had higher persistence on the individualized mastery motivation tasks performed better on an executive function task as young adults.

Because the current study was cross-sectional, the results did not provide evidence about how these mastery task measures would relate to later school performance. However, other studies using similar individualized, moderately challenging tasks have predicted later behavioral outcomes. This suggests that our computerized tests may predict school performance, which is an ultimate goal for these mastery motivational tasks.

Evidence for Reliability of Scores on Tasks Assumed to be Moderately Challenging

In the current study, adequate internal consistency reliability was found for the computer measures and for the experimenter ratings of children's behaviors on the tasks. None of the other studies using individualized moderately challenging tasks reported Cronbach alphas, no doubt because they had only 1 or a few such tasks. They did usually report that the different types of task (e.g., puzzles and shape sorters) were significantly correlated, as is true for the current computer-produced data. In the current study, there were four tasks assumed to be moderately challenging so we computed alphas, but four tasks is minimal for computing alphas, which are highly influenced by the number of items. Furthermore, many of those four tasks turned out to actually be easy. Other studies (e.g., Morgan et al. 1992; Wang et al. 2016) have found evidence of good test-retest and interrater reliability from their individualized tasks.

Limitations

A problem with our computer-based persistence scores is that we do not have a direct, computer-based assessment of the time spent actually focusing on and trying to do the task. We do know how much time the child spent before finding all the matching letters and numbers or giving up, which ended the trial. However, is possible that some time was spent looking around the room or other non-task behaviors. The examiner ratings of on-task behavior somewhat compensated for this problem. We also had only examiner ratings for task-related emotions. In future versions of the computerized assessment, we hope to video-record gaze and facial expressions to better address these issues.

Conclusion

This study used computer tablet number and letter search tasks to assess 3–8 year-old Hungarian children's mastery motivation. A measure of each child's persistence at tasks that were moderately challenging for them, personally, was demonstrated to have construct validity. Future plans include doing longitudinal studies to examine the potential as a school readiness assessment of the whole battery of these tablet tasks, which include measures executive functions and of number and letter recognition.

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