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Assessment of Working Memory Capacity in Preschool Children Using the Missing Scan Task

Adrienne S. Roman[a,*], **David B. Pisoni**[a], and **William G. Kronenberger**[b]

[a]Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN, USA

[b]Riley Child and Adolescent Psychiatry Clinic, Department of Psychiatry, Indiana University School of Medicine, Indianapolis, IN, USA

Abstract

The purpose of this study was to investigate the feasibility and validity of a modified version of Buschke's missing scan methodology, the Missing Scan Task (MST), to assess working memory capacity (WMC) and cognitive control processes in preschool children 3–6 years in age. Forty typically developing monolingual English-speaking children between 36 and 84 months in age participated in the study. The children were tested on measures of WMC (MST), verbal and nonverbal memory (NEPSY Narrative Memory and Memory for Designs subtests), and language skills (Peabody Picture Vocabulary Test, fourth edition). Children showed increased working memory capacity scores with age, as measured by the MST, with significant differences between 3- and 5-year-olds and 3- and 6-year-olds. Significant correlations were also found between the MST and language and verbal and nonverbal memory scores. MSTscores still remained significantly correlated with the other measures of memory even after age and global language were accounted for in a regression analysis, demonstrating that the MST captures unique variance related specifically to WMC and cognitive control processes used to retrieve and scan information in short-term memory (STM). The results of this study demonstrate that the MST is a feasible and valid methodology for assessing WMC in preschool children as young 3 years of age.

Keywords

missing scan; memory scanning; working memory capacity

Working memory (WM) is a construct that refers to the ability to retain and manipulate information during a short period of time (Klingberg, Forssberg, & Westerberg, 2002). WM has a foundational role in many critical components of cognitive development, including controlled attention, reasoning, organization, and speech and language functioning (Baddeley, Gathercole, & Papagno, 1998; Baddeley & Hitch, 1974; Cowan, 2005; Engle, 2002). More specifically, WM is important to such components that rely heavily on cognitive control including the following: (1) acquisition of language (Adams & Gathercole, 2000; Baddeley, 2003); (2) language comprehension (Daneman & Merikle, 1996); (3)

*Correspondence to: Adrienne Roman, Department of Psychological and Brain Sciences, Indiana University, Bloomington, IN 47405, USA. asroman@indiana.edu.

reading ability (Daneman & Carpenter, 1980; Savage, Cornish, Manly, & Hollis, 2006); (4) mathematics (Bull, Espy, & Wiebe, 2008); and (5) reasoning (Baddeley & Hitch, 1974). Numerous recent studies have reported that children with high WM scores show greater social skills (Sabol & Pianta, 2012), more successful goal-directed behaviours (Marcovitch, Boseovski, Knapp, & Kane, 2010), higher receptive vocabularies, more engagement in classroom activities, and greater achievements in mathematics and reading (Fitzpatrick & Pagani, 2012). Problems associated with poor WM skills in children include low levels of achievement in reading and mathematics (Alloway, Gathercole, Kirkwood, & Elliot, 2009; D'Amico & Guarnera, 2005), poor general academic progress (Gathercole, Brown, & Pickering, 2003), difficulty in complex problem solving and disturbances in sustaining and switching attention (Gathercole et al., 2008). WM is often thought of as a 'mental workbench' or 'workspace' because of its central role in language processing, thought, and action. Because of its importance to cognitive functioning, it has received a great deal of attention over the years by cognitive and developmental psychologists.

Little is currently known about WM in very young children because of the significant challenges that come with assessing these processes in this age range. Preschool children have a more limited knowledge base, are less verbally proficient, less literate, and more impulsive, and have more difficulty attending to stimuli in conventional behavioural tasks in the laboratory. Nevertheless, assessment of WM is possible in this age range, and a growing literature supports the validity and importance of measuring these processes in preschoolers. Espy, Kaufmann, Glisky, and McDiarmid (2001) demonstrated that several aspects of cognition could be assessed in children as young as 26 months including: executive control, working memory, inhibition, problem solving, and intelligence (Espy, Bull, Martin, & Stroup, 2006). Carlson (2005) analysed data from over 600 children, ranging from 22 to 83 months in age, based on nine studies using a battery of different executive function measures. She found that most of the children successfully completed the majority of executive function tasks and displayed significant age-related improvements in performance.

Because WM is viewed as a limited-capacity information-processing system, only a finite amount of information can be actively maintained in WM at any one point in time. This is often referred to as working memory capacity (WMC). WMC varies between individuals and can be reliably assessed in children over time (Cowan, 2005). Memory span tasks, for example, are the most common measures of WMC. Most span tasks require ordered serial recall of a sequence of stimuli either immediately after presentation and without any additional/competing processing (simple span) or following completion of an intervening competing mental task (complex span) (see Engle, Tuholski, Laughlin, & Conway, 1999, for an extensive review and interpretation of complex and simple spans). The length of the sequence (span) correctly recalled is often taken as an index of WMC. Examples of complex span tasks include reading span, counting span, operational span, listening span, and backwards digit span (La Pointe & Engle, 1990; Unsworth & Engle, 2007). Control processes, specifically the ability to allocate controlled attention, are also important components of WM, especially when completing complex span tasks. Previous research has shown that individuals who can successfully allocate attention in these types of dual tasks perform better on memory span tasks because of faster and more robust encoding of the stimuli and less susceptibility to distractors and interference reflecting control of inhibition (Kane, Bleckly, Conway, & Engle, 2001).

Although span tasks are commonly employed to assess WMC in older children, adolescents, and adults, they are problematic for a preschool population for several reasons. First, all memory span tasks create output interference at the time of recall, in which the process of recall of the test items interferes with the individual's retention of items later in the sequence. Younger children are more susceptible to these interference effects because of limitations in their controlled attention and ability to manage cognitive load. Second, all conventional span tasks involve an inherent sequential processing component because of the requirement that the test items must be recalled in serial order. This places extra demands beyond memory on the subject, increasing the overall cognitive load and adding additional cognitive demands (sequential processing and encoding order and item information) that may not be a core component of WMC processes. Third, because of the processing load imposed by the sequential recall demands in memory span tests, preschool children may not be able to complete conventional span tasks (floor effect) or may provide only very limited range of scores. Finally, because of limited language comprehension and cognitive skills, preschool children may not fully understand the directions for complex span tasks or may be unable to complete the intervening secondary cognitive task (e.g. some complex span tasks use math calculation problems for the intervening cognitive task, and preschool children may be unable to do these calculations as well as the primary span task).

Because of these limitations in using conventional span-based WMC measures with preschool children, it is not surprising that span tasks are infrequently used with children younger than 5 years of age. In fact, the memory span subtests (auditory, visual, and spatial) of the Wechsler Intelligence Scale for Children—Fourth Edition—Integrated (WISC-IV-I; Wechsler et al., 2004), for example, are given only to children aged 6 years and older. Similarly, simple and complex memory span subtests on the Children's Memory Scale (Cohen, 1997), Automated Working Memory Assessment (Alloway, 2007), Wide Range Assessment of Learning and Memory (Sheslow & Adams, 2003), and Working Memory Test Battery for Children (Pickering & Gathercole, 2001) are all normed only to age 4–5 years and often suffer from floor effects at those ages.

Normative data for 5-year-old children show significant floor effects for simple span tests, and normative data for children up to 9 years old frequently show a significant floor effect for complex span tests (Cohen, 1997; Pickering & Gathercole, 2001; Sheslow & Adams, 2003). For example, 29–46% of 5-year-olds have a span of three or less for digits recalled in a forward order; 48–59% of 5-year-olds have a span of two or less for words recalled in a forward order; 58–72% of 5-year-olds have a span of three or less for spatial locations recalled in a forward order; and over 85% of children under the age of 9 years had a span of two or less on a measure of complex listening span (Pickering & Gathercole, 2001). Although some digit span forward tests have been used with children as young as 2.5 years of age, the mean longest digit span forward length for 5-year-olds is only approximately four items, and most of the variability in digit span scores at preschool ages is obtained by administering several items at the same (short) span length (e.g. Elliott, 2007), which emphasizes consistency in performance over variability in span length.

An alternative to conventional span measures of WMC is the ‘missing scan’ methodology, originally developed by Buschke (1963a) to measure immediate memory capacity in adults. Buschke’s task consists of presenting the subject with a set of digits and then reproducing the same set of digits again in a randomized order with one of the original digits missing. The subject is then asked to report the missing digit. To carry out this task, the subject must scan the contents of actively maintained items in immediate memory and report which item was not included in the test set. The missing scan (MS) method is unique because it does not require that all items be retrieved and serially recalled from memory in order to assess the contents of information stored in immediate memory. Instead, the MS task requires the subject to ‘scan’ and retrieve the contents of immediate memory and therefore avoids effects related to output interference in recall and sequential processing.

Results of several studies with adults by Buschke in the 1960s showed that more information can be retained in immediate memory using the MS method than conventional memory span tasks like digit span (Buschke, 1963b). While Buschke used the MS methodology to test adults with dementia, his methodology is applicable for any population that faces problems or limitations in retrieving sequences of ordered items from memory using span tasks. The MS test is particularly advantageous for preschool-age children because of the simplicity of instructions, reduced demand on sustained-sequential processing, and expected lower floor effect, consistent with Bushke’s (1963b) finding of larger memory capacity measured using MS tasks as opposed to conventional span tasks.

The purpose of this study was to investigate the feasibility and validity of a modified version of Buschke’s missing scan methodology, the Missing Scan Task (MST), to assess WMC and cognitive control processes in preschool children 3–6 years in age. Feasibility of the MST methodology with preschool children was assessed by measuring the ability of children to complete the MST using highly familiar toy animals. Validity of the MST was evaluated in three ways: First, because WM improves with age throughout childhood (Gathercole, Pickering, Ambridge, & Wearing, 2004), we evaluated the relationship between the MST performance and chronological age in a preschool sample. Second, relations were calculated between scores on the MST and a measure of global language ability. Third, relations were also assessed between the MSTand two independent performance measures of verbal and nonverbal memory. We predicted that the MST could be easily completed by children as young as 3 years old and that scores on the MSTwould be correlated with age, global language skills, and other measures of memory, consistent with the relations observed between WM and global intelligence and other types of memory in older children and adults (Sheslow & Adams, 2003; Wechsler et al., 2004). We also predicted that the relations between the MST and the other measures of memory would remain robust even when age and language skills were statistically controlled, demonstrating that the MST has a component of unique variance related to WMC that is independent of other contributing variables.

METHODS

Participants

Forty typically developing monolingual English-speaking children between 36 and 84 months in age (*M* = 59.3 months, *SD* = 12.8; five boys and five girls for each age year in the 3- to 5-year range and four boys and six girls at age 6). The majority of the sample was Caucasian (*n* = 33), with the remaining identified as either Hispanic (*n* = 3) or more than one race (*n* = 4). By parent report, all children were monolingual native English speakers, had normal hearing and vision, and had no diagnosed cognitive/developmental delays. All children were recruited through an IRB-approved departmental database. Although no quantitative measure of socioeconomic status (SES) was obtained, the demographics of the population from which volunteers for this database are drawn (e.g. university setting) suggest that the majority of children likely were from educated families of middle to upper-middle SES.

Performance Measures

Working memory assessment

The Missing Scan Task (MST): Buschke's original MST was modified to obtain a new measure of WMC for 3- to 6-year-old preschool children. Instead of numbers, 65 Beanie Babies™ (small animal-shaped bean-filled bags) were used as test stimuli. Examples of animals in the test set include turtle, pig, cow, and duck. Each Beanie Baby was referred to by the name the child provided for each animal in order to prevent the need to learn new vocabulary, provided that the child used this label consistently and did not refer to another animal in the same set by the same name. To assess existing knowledge of the animal names in the stimulus set, children were asked to name pictures of each Beanie Baby animal prior to carrying out the MST. If the child did not recognize the animal, the animal was not included in the test set.

For the MST, the child sat across from the experimenter where a small cardboard house was placed on the table facing the child. Out of the child's line of sight, a backpack was placed under the table that contained the 65 animal-shaped Beanie Babies. The experimenter explained to the child that they were going to play a memory game. The experimenter brought out two randomly selected Beanie Babies and placed them on the table in front of the child. The two animals represented a memory set size of two and were used as the training and practice set for each child. The child was then asked to name the two animals out loud and to remember the animals because they were going inside the house where the child would not be able to see them anymore, and when they came back out of the house, one of the animals would be missing. Each child was given approximately 10 seconds to look at the animals in the memory set and name them out loud before the experimenter placed them inside the house. Two-to-three seconds later, one Beanie Baby was brought back out (chosen at random), and the child was asked, 'Which one is missing?' The child had to display understanding of the instructions before proceeding with the MST. If the child was unable to demonstrate an understanding, he/she would not continue with the MST. All children tested successfully completed the practice set and proceeded to the test sets.

For younger children (3- to 4-year-olds), the memory set size began with three animals and increased in length by one animal each time the child correctly reported the missing item. For older children (5- and 6-year-olds), the set size began with four animals and increased in length by one animal each time the missing animal was identified. The reasons for the different starting points were to keep the assessment brief and interesting to the child to maintain attention. A correct trial required the child to scan the contents of WM and verbally report to the experimenter the correct name of the animal that was missing from the memory set. After one correct trial at a given set size was completed, the memory set size was increased by one item. If the child incorrectly named the missing animal, the same memory set size was tested again with a new set of test items. In both training and test trials, the child was shown the missing animal after each trial regardless of correctness of answer. The MST concluded when the child failed to correctly name the missing animal on two trials of the same memory set size or correctly completed a set size of 10. The animals in each memory set were always novel and were randomized for each set size without replacement. The presentation order was also randomized for each child. WMC was defined as the longest set size (LSS) that the child could correctly scan with no errors.

Receptive vocabulary

Peabody Picture Vocabulary Test (fourth edition, form A): The PPVT-4 (Dunn & Dunn, 2007) was used to obtain a measure of the child's receptive vocabulary, which we used as an estimate of global language ability in this study. During the PPVT-4, the child was instructed to point to one of four pictures matching a word that was said out loud by the examiner. Raw and standard scores were obtained for each child. The PPVT has been used as a measure of verbal intelligence in studies of executive functioning in preschoolers (e.g. Espy et al., 2001) and is strongly correlated with other language measures (Dunn & Dunn, 2007).

Additional memory assessments

NEPSY-II (memory for designs and narrative memory subtests): The NEPSY is a widely used test battery for assessing neuropsychological development in preschool and school-aged children (Korkman, Kirk, & Kemp, 2007). We used two subtests from the memory and learning domains of the NEPSY to obtain normed measures (raw and scaled scores) of nonverbal (memory for designs subtest) and verbal (narrative memory subtest) memory for each child. Norm-based scaled scores obtained from both of these subtests have a mean of 10 and standard deviation of 3. The memory for designs (NEPSY MD) subtest assessed a child's ability to remember spatial locations (placement of cardboard rectangular cut-outs on a grid) and visual details (designs on the cardboard cut-outs) of designs presented from a test booklet. The narrative memory (NEPSY NM) subtest assessed a child's ability to recall verbal material from short stories read out loud by the examiner, using free recall, cued recall, and recognition.

As described earlier, traditional span length and operation span tests have limited range and validity for the assessment of WM in preschool populations; therefore, traditional span tests were not ideal for validating the MST in the age range of this study. The NEPSY MD and NM subtests were chosen as validating measures for the MST because they have several advantages in the assessment of memory in children as young as age 3: (1) well-established, standardized instructions for administration to children as young as age 3; (2) normative data from a nationally representative sample of children in the age range of the study, which was important for demonstrating the range of the NEPSY memory tests (and, specifically, the absence of floor and ceiling effects) even at the youngest ages in this study; (3) published results demonstrating validity across the full age range for this study; and (4) subtests evaluating different memory modalities (verbal and nonverbal) (Korkman et al., 2007). Furthermore, the NEPSY MD and NM evaluate a significant component of WM, because they require storage and manipulation (in the case of MD, simultaneous management of memory for location and content; in the case of NM, simultaneous management of phonological–lexical memory and comprehension–organization of thematic content) of memory information at a level that can be managed by preschoolers.

Procedures

The study was completed in one test session lasting between 1 and 1.5 hours. Parental consent was completed prior to testing as per the guidelines of the institutional review board. The order of test administration was consistent throughout testing: first, PPVT; second, NEPSY memory for designs; third, NEPSY narrative memory; and lastly, the Missing Scan Task. Parents were also asked to complete a demographic information form. At the conclusion of the experiment, all participants received monetary compensation and two books along with numerous stickers that were distributed throughout the testing session.

RESULTS

Descriptive Statistics by Age Group

Table 1 provides a summary by age group of the *Mean* and *SD* for each of the measures. Figure 1 shows the mean LSS scores for the four age groups along with data points for each score obtained by at least one child in the age group. As expected, raw scores on all measures, including the MST, increased with age. The four age groups differed significantly on mean LSS scores [$F(3, 36) = 3.87$, $p = .02$, $\eta^2 = .24$]. Independent-samples *t*-tests revealed that LSS scores for the 3-year-olds ($M = 4.1$, $SD = 1.60$) were significantly lower than scores for 5-year-olds ($M = 6.20$, $SD = 1.93$; $t(18) = -2.65$, $p = .016$, Cohen’s d effect size = 1.25) and 6-year-olds ($M = 6.8$, $SD = 2.35$; $t(18) = -3.01$, $p = .008$, $d = 1.11$). Although significant differences were not observed, the LSS score comparisons between the additional pairs of age groups were in the predicted direction.

Relationships Between LSS Scores, Age, Language Skills, and Memory

Table 2 provides a summary of the correlations between the measures. Correlations of LSS scores and the PPVT-4, a measure of receptive vocabulary used to index global language skills, were significant for both the PPVT-4 raw ($r = .71$, $p < .01$) and PPVT-4 standard ($r = .40$, $p < .05$) scores. Significant correlations between LSS scores and age and memory included LSS and age ($r = .49$, $p < .01$), NEPSY MD raw ($r = .59$, $p < .01$) and scaled scores ($r = .35$, $p < .05$), and NEPSY NM raw ($r = .65$, $p < .01$) and scaled ($r = .34$, $p < .05$) scores.

To investigate the independent contributions of age, language skills, and memory to LSS scores, we conducted a forced-entry hierarchical regression analysis (a regression in which all variables are entered in blocks of related measures) using LSS scores as the dependent variable. Age was entered in the first block because of its fundamental influence on development of WMC. The second block consisted of PPVT-4 standard scores in order to evaluate the role of language skills in WMC above and beyond the developmental influences of age. The third block consisted of the two memory measures (NEPSY MD and NEPSY NM scaled scores), in order to assess the relations between LSS scores and memory after accounting for age and global language ability. This final block tested the hypothesis that LSS scores share a unique variance with other validated independent memory tests even after developmental and verbal ability influences are accounted for; such a test is essential for demonstrating that the MST provides a unique measure of WMC and is not simply a proxy for global development or verbal ability. Norm-based (i.e. standard and scaled) scores for the PPVT-4 and NEPSY subtests were used as measures of global language and memory independent of age influences.

Results of the regression analysis are summarized in Table 3. The total model accounted for a substantial amount of the variance (57%) in the LSS scores. Age explained 24% of the variance in LSS scores (p <.001), whereas language skills (PPVT-4) explained an additional 19% of the variance (p <.001), demonstrating the contribution of developmental and global language abilities on WMC as assessed by the MST. Measures of verbal (NEPSY NM) and nonverbal (NEPSY MD) visuospatial memory explained an additional 14% of the variance after accounting for age and verbal ability (p <.007). The measure of verbal memory (NEPSY NM) contributed significantly (p <.004), and the measure of nonverbal visuospatial memory (NEPSY MD) approached significance (p <.10).

DISCUSSION

Progress in basic research of early development of WM in preschool children has been hindered by the limitations of existing behavioural measures of WMC. In this study, we assessed the feasibility and validity of a new measure of WMC in 3- to 6-year-old children, the MST. Our original predictions were confirmed: First, the MST demonstrated feasibility in this age range because all children were able to complete the task and they provided a wide range of scores. Second, LSS scores increased with age and were significantly correlated with a measure of global language skills as well as independent measures of verbal and nonverbal memory. Finally, LSS scores remained significantly correlated with the other measures of memory even after age and global language were accounted for in a regression analysis, demonstrating that the MST captures unique variance related specifically to WMC and cognitive control processes used to retrieve and scan information in short-term memory (STM).

In addition to age, LSS scores were correlated with measures of language skills, verbal memory, and nonverbal memory, and these relations (with the exception of a nonsignificant trend for visual memory) remained significant even after age was controlled for in the regression analysis. Furthermore, LSS scores were related to verbal memory even after controlling for age, visual memory, and verbal ability in the regression. The present findings demonstrate robust and independent contributions of developmental factors (age), language ability (verbal ability), and memory skills (verbal and, to a lesser extent, visual memory) to MST performance, consistent with what would be expected for the construct of WM (Baddeley, 2003; Baddeley et al., 1998).

Interestingly, LSS scores correlated with both verbal and visual memory scores from the NEPSY. This is not surprising owing to the dual nature of the MST. Although the MST is not primarily a language-driven task, the naming component requires encoding and active verbal mediation. The MST also contains a visual/nonverbal component because the children can keep a visual image of each animal in STM to facilitate memory search. While the MST and NEPSY memory tests assess the shared construct of memory, the NEPSY subtests differ in important ways from measures specifically targeting WMC. WM is involved in both the NEPSY MD and NM tasks, but neither task directly measures WMC.

One of the most important findings from this study is that the MST provides developmental scientists with a novel methodology that can be used to measure WMC without the use of a sequential span procedure, which is particularly advantageous for a population of young children who may have difficulty rapidly encoding and rehearsing both item and order information in STM. The MSTalso minimizes the effects of output interference because there is minimal build-up of proactive interference by using different items on each trial. Furthermore, because of the greater range and higher mean for LSS scores compared with conventional memory span tasks, use of a memory-scanning measure such as the MST methodology reduces floor effects by the youngest children, which results in more variability in scores and provides more information on WMC differences. Hence, memory-scanning tasks may be more appropriate for children in this age range because they do not require retrieval of both items and order information in STM.

While this study has contributed new information about a neglected and understudied area of research in preschool children, the present results must be interpreted in light of the characteristics and limitations of this behavioural methodology. First, the children who participated in this study scored over 1 *SD* above the mean on the PPVT-4, indicating that this sample is not representative of the wider population in verbal ability. We suspect the above-average performance on the PPVT-4 and other measures was a result of the higher SES (and resulting enriched environment) of the families recruited. We believe that the effect was particularly pronounced for the older children because they had the benefit of longer exposure to enrichment and because they were able to complete a larger set of items. Additionally, the limited number of subjects per age group may have affected the power of some statistical analyses, particularly in the regression. As a result, the nonsignificant trend for visual memory predicting LSS scores should be interpreted with caution. Because the primary purpose of this study was to test the feasibility of the MST methodology and to provide preliminary information on the validity of the MSTas a measure of WMC, the number of other (validating) tests was limited to key measures of core constructs related to WM development such as global verbal ability, visual–spatial memory, and verbal memory. Future research on WMC and memory scanning should explore the relations of the MST and additional measures of memory (including span measures when possible), executive functioning, and other related constructs. Finally, additional psychometric properties of the

MST, such as test–retest reliability, predictive validity (for later assessment of WM skills), and differential validity for assessment of syndromes associated with WM deficits in clinical populations should be evaluated in future research (e.g. Roman & Pisoni, 2012).

In summary, the results of this study demonstrate that the MST is a feasible and valid methodology for assessing WMC in preschool children. Performance on the MST increased with age, as observed in both correlation and regression analyses. Positive correlations were also found between the LSS and measures of global language skills (PPVT-4) and two measures of memory (NEPSY MD and NM). Thus, the MST is a promising new assessment instrument that can be used to evaluate WMC in typically developing preschool-aged children as well as children with developmental delays and/or co-morbid conditions that might reflect selective deficits in cognitive control processes used to encode, store, and retrieve information from STM. We are currently using this methodology to assess working memory capacity in young children with hearing loss who are known to be at risk for delays in verbal short-term and working memory (Roman & Pisoni, 2011).

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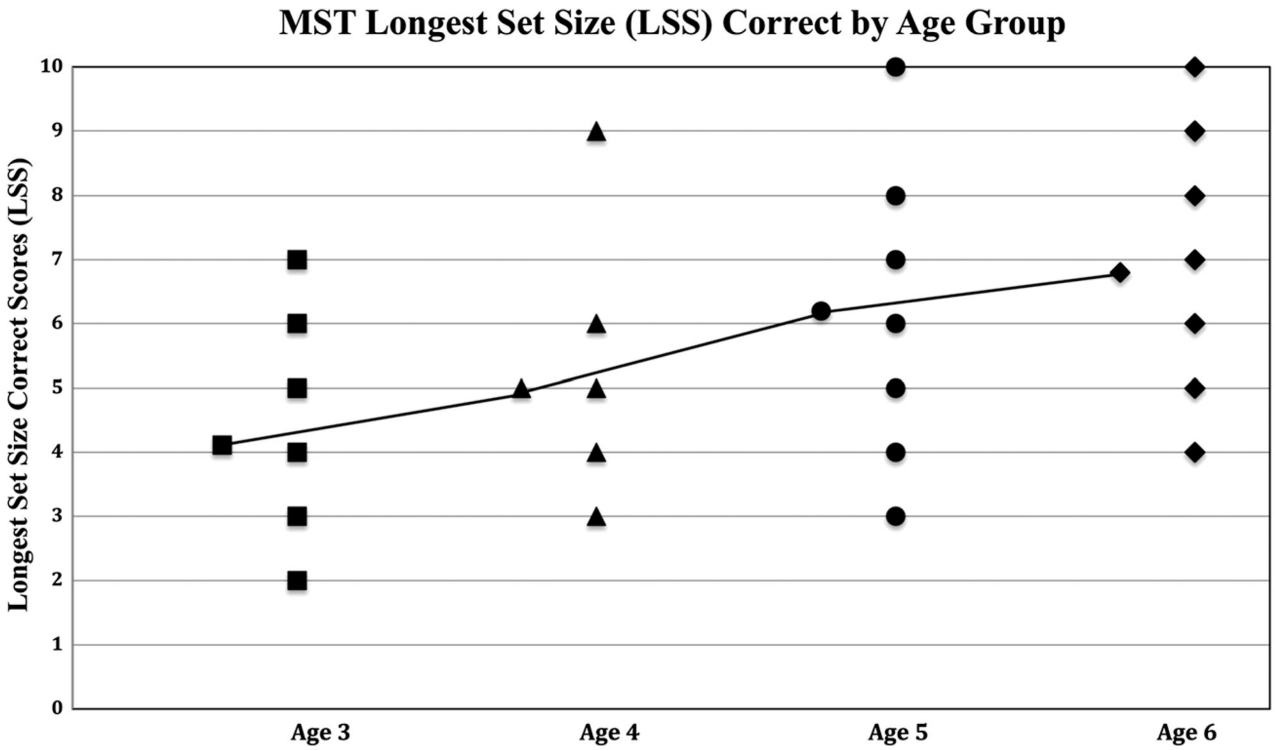

Figure 1.

Longest set size correct scores (LSS) on MST as a function of age. Different shaped markers (squares for the 3-year-olds, triangles for the 4-year-olds, circles for the 5-year-olds, and diamonds for the 6-year-olds) represent each age group's mean score (marked on left) and LSS obtained by at least one child (line of markers to the right of the mean).

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Table 1

Mean and *SD* for measures of language and memory skills across age groups

	Age 3		Age 4		Age 5		Age 6	
Measures	***Mean***	***SD***	***Mean***	***SD***	***Mean***	***SD***	***Mean***	***SD***
MST LSS	4.10	1.59	5.00	1.83	6.20	1.93	6.80	2.35
PPVT R	84.10	14.48	101.80	15.09	114.90	13.72	132.40	20.03
PPVT S	124.50	12.86	122.40	12.38	120.00	10.50	123.10	13.85
NEPSY MD R	42.10	11.90	70.40	20.55	80.60	26.98	89.50	22.67
NEPSY MD S	10.70	2.41	13.60	3.95	13.50	4.79	12.30	2.71
NEPSY NM R	5.30	4.55	6.00	2.94	14.10	7.75	19.10	7.06
NEPSY NM S	9.70	3.43	7.20	1.99	8.90	3.25	9.50	2.95

Note. MST LSS = Missing Scan Task longest set size correct scores; PPVT R = Peabody Picture Vocabulary Test raw scores; PPVT S = Peabody Picture Vocabulary Test standard scores; NEPSY MD R = NEPSY memory for designs total raw scores; NEPSY MD S = NEPSY memory for designs total scaled scores; NEPSY NM R = NEPSY narrative memory raw scores; NEPSY NM S = NEPSY narrative memory scaled scores.

Table 2

Intercorrelations of performance measures

Measure	1	2	3	4	5	6	7	8
1. Age	—							
2. MST LSS	0.49**	—						
3. PPVT R	0.76**	0.71**	—					
4. PPVT S	−0.06	0.40*	0.56**	—				
5. NEPSY MD R	0.63**	0.59**	0.74**	0.24	—			
6. NEPSY MD S	0.15	0.35*	0.39*	0.32*	0.83**	—		
7. NEPSY NM R	0.69**	0.65**	0.61**	0.05	0.43**	0.05	—	
8. NEPSY NM S	0.06	0.34*	0.08	0.04	−0.01	−0.03	0.70**	—

Note. MST LSS = Missing Scan Task longest set size correct scores; PPVT R = Peabody Picture Vocabulary Test raw scores; PPVT S = Peabody Picture Vocabulary Test standard scores; NEPSY MD R = NEPSY memory for designs total raw scores; NEPSY MD S = NEPSY memory for designs total scaled scores; NEPSY NM R = NEPSY narrative memory raw scores; NEPSY NM S = NEPSY narrative memory scaled scores. $df = 38$.

* $p < .05$,

** $p < .01$.

Table 3

Summary of hierarchical regression analysis for variables predicting MST scores

Variable	β	R^2	R^2 increase	p
Block 1		0.24	0.24	0.001**
Age	0.49			0.001**
Block 2		0.43	0.19	0.001**
PPVT standard score	0.43			0.001**
Block 3		0.57	0.14	0.007**
NEPSY MD total scaled score	0.21			0.096
NEPSY NM scaled score	0.35			0.004**

Note. Analysis was a forced-entry hierarchical regression (a regression in which all variables are entered in blocks of related measures) using LSS scores as the dependent variable. Variables were entered in blocks as follows: Block 1, developmental stage (age); Block 2, language (PPVT-4 standard score); and Block 3, memory (NEPSY memory for designs and narrative memory scaled scores).

* $p < .05$,

** $p < .01$.