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Digit Memory: An Indicator of Children's Language Ability

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ABSTRACT

Background: Language is a complex aspect of language development with numerous determinants. One such determinant is working memory capacity. Forward and backward digit memory activity is one indicator for predicting children's language abilities. This study was conducted to determine normative data on preschool-age digit memory and explore the relationship between digit memory and language abilities.

Method: The study used a cross-sectional approach. Respondents included 174 children aged 19–69 months (mean age, 46.71 months). The study was conducted in Surakarta, Central Java, from May to June 2024. Data were collected using forward and backward digit memory tests.

Result: A relationship exists between age and memory ability for forward and backward number recall. Digit memory is also related to other language abilities, namely vocabulary, average length of utterances, and the number of words in an utterance.

Conclusion: Age is one factor that influences forward and backward digit memory span. The more advanced a child's language skills, the greater their likelihood of developing digit memory activity. Digit memory activity is one aspect that can be considered in assessment and intervention processes.

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INTRODUCTION

Language ability is a complex skill. It plays a crucial role in individuals' ability to perform daily, social, and academic activities (Pratomo et al., 2016). Several aspects related to children's language abilities include cognitive (Jackson et al., 2020), motor (Loeb et al., 2020), perceptual (Maas et al., 2008), and social (Binns & Oram Cardy, 2019). As a predictor of language ability, cognitive function is a strong predictor of children's language development. Speech therapists are interested in assessing various potential predictors of children's language development. Predicting language ability using numerical memory is used to inform the formulation of assessment and intervention needs (Pratomo, 2022). Digit memory is a skill that measures short-term and working memory (Jackson et al., 2020). Digit memory is a simple activity with the main procedure of imitating a series of numbers spoken by the therapist. Digit memory is a complex interplay between verbal abilities, particularly phonology, memory storage, and executive function control processes. This activity is relevant to linguistic tasks, such as word retrieval, phrase and sentence production, and speech comprehension (Baddeley & Wilson, 1993; Gathercole et al., 1997; Jeffries & Everatt, 2004).

The relationship between language ability and digit memory is further strengthened by the working memory processing model. Forward digit memory is an activity that maximizes the phonological loop system for the temporary storage of verbal information. Forward digit memory plays a crucial role in vocabulary development and the process of learning new vocabulary in children (Gathercole et al., 2004; Swanson &

Ashbaker, 2000). Conversely, backward digit memory is a process that involves manipulating already stored information. This ability is linked to more complex language processing, including grammar and reading skills.

Although adequate use of digit memory can be a predictor of language ability, its use still requires considerable adjustment. The use of digit memory as a predictor of children's language abilities needs to be adapted to meet the ethnocultural needs of children (Pindzola et al., 2016). As we know, the pronunciation of numbers across languages varies according to linguistic and cultural variables. Research addressing digit memory in the context of speech therapy is urgently needed. Furthermore, the need for normative data on the development of digit memory and standardized assessments to assess children's language abilities still requires further exploration. This article has several objectives. The first is to determine normative data on digit memory in preschool-aged children. Second, this article explores the relationship between digit memory and language abilities.

Digit Memory Development

Digit memory development is influenced by several fundamental factors, including phonological development, processing speed, executive maturation, and the development of learning strategies. Phonological development ensures the ability to function effectively in phonological encoding when performing digit memory tasks. A child's ability to hear, understand, and pronounce sequences of sounds is a skill that must be developed. Maturation of executive control will foster attention and speech manipulation. Meanwhile, strategies for performing tasks effectively and efficiently are crucial for digit memory . Advanced digit memory ability can be reliably measured in children aged 2-3 years using an adapted procedure (Gathercole & Adams, 1993). At the age of 3, a child is generally able to remember 2-3 numbers in sequence. By age 5, most children can recall 3-4 numbers in sequence. At this stage, a strong relationship exists between advanced digit memory, vocabulary size, and speech rate (Gathercole et al., 1997).

As children enter early school, digit memory development accelerates. By age 6, children can repeat 4-5 digits forward. At the age of 7, they can recite 5 digits forward, and by the age of 8, they can recite 5-6 digits (Gathercole, 2006). Conversely, for backward digits, children can recite 2-3 digits at age 6. At the age of 7, they can recite three digits. At the age of 8, they can recite backward digits with a range of 3 to 4 digits. This stage has a strong influence on reading ability and academic skills (Swanson & Berninger, 1995). By the middle school years, especially when children are 9-12 years old, digit memory development reaches 6-7 digits. Backward digits, on the other hand, are slower, reaching 4-5 digits. This stage indicates the development of language and literacy skills for complex academic activities (Alloway & Alloway, 2010; Gathercole et al., 2004). Adolescents are capable of performing forward and backward digit memory tasks of 6-7 digits (Conklin et al., 2007; Luna et al., 2004). The development of digit memory across ages is described in Table 1 below.

Table 1. Digit Memory Development

Age	Forward Span	Backward Span	Developmental Features	Source
Preschool (3-5 years)	2-4	0-2	Phonological memory developing; vocabulary growth	Gathercole & Adams, 1993; Gathercole et al., 1997
Early Elementary Years (6-8 years)	4-6	2-4	Reading acquisition; backward span emerging	Gathercole, 2006; (Swanson & Berninger, 1995
Middle Childhood (9-12 years)	5-7	4-5	Approaching adult forward capacity; executive growth	Alloway & Alloway, 2010; Gathercole et al., 2004
Adolescent (13-16 years)	6-7	4-6	Adult-like forward span; continued backward growth	Conklin et al., 2007; Luna et al., 2004

METHOD

This study employed a correlational design, linking numerical memory variables with several language abilities. Based on the time of data collection, this study employed a cross-sectional approach for all variables.

Participants

The study included 174 children aged 19–69 months (mean age, 46.71 months). The children were typical, with no complaints of communication or swallowing problems. Data collection took place in Surakarta, Central Java, from May to June 2024. Details of the participants are presented in Table 2.

Instrument

The instrument used in this study was the Digit Memory Test. The test consists of two main sections: forward number sequences and backward number sequences. The forward number sequence consists of 22 items ranging from two to seven numbers. The backward number sequence consists of 22 items ranging from two to seven numbers.

The instructions for the forward number sequence are: "I'm going to say the numbers. Say them after me. If I say "1 – 4," you should say "1 – 4." Let's do this. Listen, I say "7 – 3." Now it's your turn ___________. Good, let's begin. (Repeat the example if the child still doesn't understand)." The instructions for the backward number sequence are: "I'm going to say the numbers. Say them after me. If I say "4 – 6," you should say "6 – 4." Let's do this. Listen, I say "1 – 4." Now it's your turn _____________. Good, let's begin." (Repeat the example if the child still doesn't understand).

Data Collection

Data collection was conducted by conducting direct tests on the children. Each child was measured twice, one week apart. Data collection was conducted by enumerators trained in eliciting responses. The data collection results were audio-recorded, with the test results attached.

RESULTS

Data processing used the SPSS for Windows 24 application. The total number of 174 children aged 19-69 months (mean 46.71, see table 2). The distribution of participant data is described in Table 1. The largest age group was the 61-66 months age group with 26 participants. The study involved 85 boys (48.9%) and 89 girls (51.1%). There were 36 children who were Indonesian speakers (21%), 19 children who were Javanese speakers (11%), and 117 children who were bilingual in Indonesian and Javanese (68%).

Table 2. Participant demographics

Age	Sex	N	Mean	SD	Minimum	Maximum
18 – 24	Boys	7	21.1	1.7	19	23
	Girls	9	21	1.9	18	23
25 – 30	Boys	9	27.1	1.7	25	29
	Girls	8	29	1.1	27	30
31 – 36	Boys	8	33.2	1.7	31	35
	Girls	9	33.6	1.7	31	36
37 – 42	Boys	11	39.8	1.5	37	42
	Girls	13	40.1	1.8	37	42
43 – 48	Boys	10	45.3	2.2	43	48
	Girls	10	45.7	1.8	43	48
49 – 54	Boys	10	51.1	1.7	49	54
	Girls	9	52.4	2	49	54
55 – 60	Boys	8	58	1.7	56	60
	Girls	7	57.7	2.1	55	60
61 – 66	Boys	10	63.1	2.1	61	66
	Girls	16	64.1	1.8	61	66
67 – 72	Boys	12	68.8	1.5	67	71
	Girls	8	67.6	0.7	67	69

Validity and Reliability

The validity value for forward digit memory ranges from 0.19 to 0.83. Forward sequence reliability was measured using two types of tests. The first measurement involved item analysis. The Cronbach's alpha test yielded a value of 0.867. The second measurement involved a test-retest. The test-retest analysis using a correlation test yielded an r-value of 0.914 with a significance level of $p \leq 0.01$. These results suggest that the forward digit memory test is a reliable measurement tool. The backward digit memory test ranged from 0.48 to 0.80. Forward sequence reliability was measured using two types of tests. The first measurement involved item analysis. The Cronbach's alpha test yielded a value of 0.814. The second measurement involved a test-retest. The Spearman correlation test yielded an r value of 0.887 with a significance level of $p \leq 0.01$. These results suggest that the backward digit memory test is a reliable measurement tool.

Age Group Average

The average length of digit memory was determined by looking at the mean for each age group. The correlation was determined based on the relationship between each digit memory component and the total digit memory score. An explanation of the digit memory span is provided in the table below.

Table 3. Digit memory Span

Age	N	Forward Digit Span			Backward Digit Span			r	Total Digit Span		
		Mean	SD	95% CI	Mean	SD	95% CI		Mean	SD	95% CI
18 – 24	16	1.63	1.89	0.62 – 2.63	0.19	0.75	-0.21 – 0.59	0.24	1.81	2.16	0.66 – 2.97
25 – 30	17	1.71	1.64	0.86 – 2.55	0.18	0.72	0.20 – 0.55	0.07	1.88	1.83	0.94 – 2.82
31 – 36	17	3.88	2.84	2.42 – 5.35	0.47	1.28	-0.19 – 1.13	0.28	4.35	3.53	2.54 – 6.17
37 – 42	24	4.21	3.84	3.01 – 5.41	0.96	3.05	-0.33 – 2.25	0.15	5.17	4.75	3.16 – 7.17
43 – 48	20	6.65	2.83	5.32 – 7.98	1.40	1.84	0.54 – 2.26	0.33	8.05	3.81	6.26 – 9.84
49 – 54	19	6.32	3.25	4.75 – 7.88	0.84	1.14	0.28 – 1.40	0.50*	7.16	4.00	5.23 – 9.09
55 – 60	15	6.93	2.65	5.46 – 8.41	1.00	1.77	0.02 – 1.98	0.72*	7.93	4.11	5.66 – 10.21
61 – 66	26	7.73	6.30	6.52 – 8.94	1.50	1.90	0.72 – 2.28	0.44*	9.23	4.17	7.54 – 10.92
67 – 72	20	7.50	2.78	6.20 – 8.80	2.00	1.97	1.08 – 2.92	0.43	9.50	3.92	7.66 – 11.34

r = the relationship between forward and backward digit memory .

The table shows that each age group has a varying length of memory. The length of digit memory is seen from the mean measurement. The difference in the length of forward and backward digit memory is evident in the mean variation. Backward digit memory has a lower mean than forward digit memory . The relationship between forward and backward digit memory varies. The correlation analysis employed Spearman's Rho test to determine the correlation coefficient between the two components. The lowest correlation value was in the 25-30 month age group. The highest correlation value was in the 55-60 month group. Thus, these findings strengthen the hypothesis that an analysis of assessment and intervention needs in cognitive and language areas is needed based on age.

Correlations between digit memory ability and other language indicators were analyzed. Correlations were conducted between forward digit memory , backward digit memory , total digit memory , vocabulary mastery, mean length of utterance (MLU), and average number of words per utterance (WPS). The correlation analysis used Spearman's Rho test to illustrate the relationship between variables. The relationship between digit memory and other abilities is described in the table below.

Table 4. Correlation of vocabulary mastery with other indicators

No	Variable		2	3	4	5	6
1	Vocabulary Size	r	0,414**	0,381**	0,544**	0,262*	0,535**
		p	≤0.001	0,001	≤0.001	0,023	≤0.001
2	Average Length of	r		0,967**	0,405**	0,167	0,398**
	Utterance	p		≤0.001	≤0.001	0,151	≤0.001
3	Number of Words per	r			362**	0,136	353**
	Utterance	p			0,001	0,244	0,002
4	Forward Digit memory	r				0,473**	0,961**
		p				≤0.001	≤0.001
5	Backward Digit	r					673**
	memory	p					≤0.001
6	Total Digit memory						

Table 4 shows that numerical memory ability is related to the variables of vocabulary size, length of utterance, and number of words in each utterance.

DISCUSSION

This research was conducted to describe aphasia management in Indonesia. The objective of The purpose of this article is to obtain normative data on digit memory in preschool children. Another objective is to explore the relationship between digit memory and language ability. The analysis shows variations in the length of forward and backward digit memory . The older the child, the higher the memory ability. It is clear that a child's age influences both forward and backward digit memory abilities. Furthermore, differences in the span of forward and backward digit memory were found. In conclusion, forward digit memory has a longer span than backward digit memory tasks. A potentially influential aspect of forward and backward digit memory abilities is the maturity of working memory function.

Cognition is a fundamental aspect that individuals require. This function influences all human activities, including daily tasks. Attention, memory, thinking, and executive functions are integrated components that work together to produce an activity. In language activities, working memory and executive functions play a central role in attention. Working memory has a strong relationship with language activities. This ability plays a crucial role in the mechanism of attention, the storage of vocabulary, phrases, and sentences, the recognition of linguistic symbols, and the flexible manipulation of language in every language activity. As a result, the digit memory task is one of the abilities that can predict working memory ability.

The data analysis of this study shows that children's forward digit span is greater than their backward digit span. This difference is influenced by the working memory mechanism. Forward digit memory is an activity that emphasizes the temporary storage of acquired verbal information. When children hear a sequence of words, they process the sequence based on the order presented. Conversely, in backward digit memory tasks, both storage and manipulation occur within the sequence of numbers. Children must listen carefully, remember the sequence, and then say the sequence in reverse. This activity requires simultaneous storage and manipulation mechanisms. This means that backward digit memory requires higher processing demands and a higher level of difficulty than forward digit memory tasks.

This finding further strengthens the belief that digit memory is a strong predictor of children's language development and processing. This finding is consistent with previous research. Age determines the length of a child's response time on digit memory tasks. Studies conducted by Gathercole (2006), Gathercole et al. (1997, 2004), Gathercole & Adams (1993), and Swanson & Ashbaker (2000) found that in preschoolers, the forward digit memory span ranges from 2 to 6 digits. Their findings are similar to the results of this study, which range from 1 to 7 digits. Furthermore, other studies on backward digit memory tasks also show lower digit span scores than those on forward digit memory tasks.

The variation in digit span differences in forward and backward digit memory tasks is influenced by cognitive function and language processing. As previously noted, working memory mechanisms have a strong influence on children's language processing. Higher working memory capacity enables children to develop better language skills. The language component is closely related to attention, phonological processing, and integration of all modalities. Therefore, working memory is one of the predictors influencing language ability. Therefore, it can be said that digit memory activity is related to language processing.

Children with neurodevelopmental disabilities tend to have lower numerical memory scores compared to typical children. Children with language impairments have a shorter numerical memory span than typical children. Research conducted by Jackson et al. (2020) indicates that children with language impairments experience difficulties with numerical memory tasks. Both forward and backward numerical memory tasks yield lower scores compared to typical children. Furthermore, backward numerical memory skills also yield lower scores compared to forward numerical memory tasks.

Another study of children with learning disabilities found similar results. Children with dyslexia and reading disorders have lower numerical memory skills (Swanson & Ashbaker, 2000). Backward numerical memory tasks yield lower performance than forward numerical memory tasks (Jeffries & Everatt, 2004). These findings confirm that phonological working memory plays a significant role in the reading process. Reading requires complex processing. Working memory functions in attention, letter or symbol recognition, and activity control.

Clinical Implications

The clinical implications of this research are reviewed from two perspectives. First, speech therapy interventions. Speech therapy interventions, including assessment and intervention, require adjustments. The assessment process involves collecting valid and reliable data on language and reading performance. Working memory, as an activity that can predict language and learning abilities, should be considered in a comprehensive examination procedure. Adapting working memory assessments will provide a more precise interpretation of working memory function, enabling more targeted recommendations. Furthermore, the need for a standardized numerical memory assessment is the gold standard that must be met in the management of language problem assessments. The use of numerical memory as an examination instrument is crucial.

Furthermore, regarding intervention implications, numerical memory has been shown to be related to the process of storing and manipulating information. This activity offers speech therapists insight into language problems from multiple perspectives. The first perspective is the attentional mechanism that determines whether a stimulus is perceived effectively or not. Second, working memory maturity is also a crucial component of intervention. The selection of activities related to working memory mechanisms should be considered for use in strengthening the process of storing and manipulating information. Third, from the perspective of language processing. Vocabulary, grammar, and sentence complexity are indicators that can be predicted based on the results of a numerical memory task (Kronenberger et al., 2013). In conclusion, numerical memory can be recommended as a beneficial activity for individuals who experience difficulties with language and literacy.

Research Implications

This study successfully uncovered age-related variations in forward and backward digit span memory. The analysis indicates that, in typical children, digit memory varies, warranting exploration. Various demographic determinants across cultures should be considered in relation to digit memory tasks. Furthermore, digit memory activity is associated with language and learning difficulties. Future studies are needed to explore memory abilities across disorders to obtain updated data. Furthermore, an exploration of the impact of digital memory activity on assessment and intervention processes is needed to provide evidence-based practice.

CONCLUSION

Research has found that age is a factor influencing both forward and backward digit span memory. This finding is consistent with previous research indicating that digit memory is a predictor of children's language abilities. These results further strengthen the relationship between digit memory activity and language processing. The higher a child's language ability, the greater the likelihood of engaging in digit memory activities. This relationship also holds true. Children with language and learning difficulties tend to have lower memory abilities compared to typical children. These findings have both practical and theoretical implications. Data on children's digit memory abilities is a crucial component in any assessment of children suspected of having language and learning difficulties. The selection of instruments and the analysis of assessment results are vital in therapeutic interventions. Furthermore, determining recommendations and interventions involving digit memory activities is crucial. Interventions should be tailored to the specific clinical situation or population. Future studies should explore the impact of digit memory assessments and interventions on language and learning outcomes in each clinical population.

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