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The Effect of Domain-Specific and Domain-General Precursors of Mathematical Training on Preschoolers' Number Sense and Estimation

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Abstract

The present study aimed to investigate the effect of domain-specific and domain-general precursors of mathematical training on preschoolers' number sense and estimation. This study adopted a quasi-experimental, pretest-posttest-follow-up design. The statistical population comprised all preschoolers in Kermanshah (Iran) in 2020. Using multi-stage cluster random sampling, a sample of 45 was selected and allocated to three groups (15 per group). The data were collected using the short form of the Wechsler Preschool and Primary Scale of Intelligence (WPPSI), the Number Sense Screener, and the PLUS test (number estimation). The data were analyzed using descriptive statistics and repeated-measures analysis of variance (ANOVA). The mean (SD) of IQ was 95.91 (4.21) in the working memory group and 97.78 (3.38) and 96.66 (4.03), respectively, in the number estimation and control groups. In the linear combination of number estimation variables in terms of group membership, the group x time interaction was significant on the pretest, posttest, and follow-up ($p<0.01$). The difference in the mean scores of the working memory, number estimation, and control groups was also significant on the variable of number sense ($p<0.01$). There was no significant difference in the effectiveness of the two training methods on the posttest and follow-up, and both interventions exerted the same effect on improving number sense and estimation.

Keywords: Domain-specific precursors, Number estimation, Number sense, Preschooler, Working memory

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Introduction

Preschool is a fundamental educational level laying the ground for children's general development. It is a highly sensitive period for personality development (Martínez-Bello & Estevan, 2021). About 75% of the brain is formed in the first six years of life, and about 90% of children's abilities are oriented during this period. Accordingly, many researchers and policy-makers highlight the content of preschool skills training, with a special emphasis on mathematics (Piasta, Pelatti, & Miller, 2014). According to contemporary theories of mathematical development, students adapt new information to their already acquired information, and their mathematical knowledge is mostly intuitive. Poor mathematical knowledge leads to an unfavorable socioeconomic status in adulthood and, in the long run, impacts psychological well-being (Naderi Dehsheykh, Hafezi, & Dashtbozorgi, 2021). Efforts to delve into individual differences in terms of basic mathematical knowledge suggest the significance of core mathematical skills (Razm, Hafezi, Marashian, Naderi, & Dashtbozorgi, 2021).

Based on most recent research and theoretical models, learning mathematics is a complex process demanding a full range of cognitive abilities that can be classified into domain-specific and domain-general categories (Chu, vanMarle, & Geary, 2016). Domain-general abilities involve cognitive abilities used to support and direct learning at the general level, regardless of the type of information acquired. The brain mechanisms necessary for these abilities exist in the human brain from birth and allow these domains to cooperate so that the benefits of skills developed from an acquired activity can be transferred to non-trained skills (Sharifi, Fathabadi, Karimi, & Sharifi, 2018).

The core executive functioning skills, including information monitoring and manipulation in the mind (working memory), resistance to disturbing information and unwanted responses (inhibition), and flexible thinking are the most important domain-general abilities (Cassidy, White, DeMaso, Newburger, & Bellinger, 2016; Cragg, Keeble, Richardson, Roome, & Gilmore, 2017). These cognitive abilities are required for learning any type of academic or non-academic information and skill and can potentially shape the development of several other processes (Esmailzadeh Roozbahani, Behroozi, Omidian, & Maktabi, 2021). In contrast, cognitive abilities used to support and direct learning at a particular level are known as domain-specific. According to domain-specific learning theories, people acquire different types of information differentially, each covered by a distinct brain region. These theories claim that these neural domains are independent of one another, and each brain region merely covers the acquisition of a particular skill and cannot directly contribute to learning other unrelated skills (Chu et al., 2016).

Studies on precursors of mathematics indicate that the Approximate Number System (ANS) is the most important domain-specific cognitive ability, and working memory is the most important domain-general cognitive ability essential for development and progress in learning mathematics (Bull, Marschark, Nordmann, Sapere, & Skene, 2018). The ANS is a cognitive system supporting the estimation of the values of sets without relying on language and symbols. This system is used for the non-symbolic representation of numbers greater than four; with the onset of infancy, the ANS allows human beings to detect differences in values between groups without relying on counting and symbols. The accuracy of this system improves during childhood and reaches the final level of 15% in adulthood. This means that an adult can distinguish 100 items from 115 items without counting (Darko Odic & Ariel Starr, 2018). The ANS plays a pivotal role in the development of other numeric abilities, e.g., the precise concept of numbers and simple arithmetic skills. The level of accuracy of the ANS in childhood has been shown to predict the progress of mathematics in school years (Cai, Zhang, Li, Wei, & Georgiou, 2018).

The ANS is the central component of a broader ability known as number sense (Bull et al., 2018). Although the precise definition of this construct is still challenging, it is an umbrella term for more than 30 mathematical constructs (Odic & Starr, 2018). Number sense is the ability to mentally represent and manipulate numbers and quantities, which enable the comparison and manipulation of numbers. This construct at an early age is the most important predictor of future mathematical performance, and its significance in the development of mathematics has been estimated to be even more than general intelligence (Szkudlarek & Brannon, 2017). Difficulty in primary number sense can cause persistent problems in mathematical performance throughout schooling. In recent decades, research on number sense has indicated the predictive role of the components of this construct on subsequent mathematical performance, the possibility of correcting defects in number sense, and delaying its development (Tosto et al., 2017).

The significance of mathematics in future social and professional life has recently motivated the design of a growing number of interventions to promote the development of mathematical abilities (Hoffman et al., 2021). Still, few studies have specifically designed, examined, and compared the role of training the domain-specific precursors of the ANS. The question remains whether the underlying cognitive mathematical abilities can be altered, and focusing on which underlying cognitive domains is more effective in promoting the key construct of number sense. According to this background, the present study aimed to investigate the effect of domain-specific and domain-general precursors of mathematical training on preschoolers' number sense and estimation in Kermanshah.

Methods

Design

This study adopted a quasi-experimental, pretest-posttest-follow-up design.

Participants

The statistical population comprised all preschoolers in Kermanshah (Iran) in 2020. One district (District 2) was selected from different Department of Education districts of Kermanshah via multi-stage cluster random sampling. Then, three centers were randomly selected out of 150 preschool centers in this district. In the next stage, 20 newly enrolled students were selected from each preschool center. Jordan's Number Sense Screener and the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) were then administered to the sample. Next, 51 children with average-to-high IQ who had scored the lowest on the number sense test were selected as the main sample and randomly assigned to two experimental and one control groups (15 per group). The participants were randomly homogenized by controlling their IQ and sex. In random homogenization, an attempt was made to match the participants in terms of the variable of desire. To this end, after the participants were matched as much as possible in terms of IQ and sex, a list of participant pairs was drawn up, and each participant was randomly assigned to the control and the other one to an experimental group. The inclusion criteria were the age range of 5-6 years, scoring low on the number sense test, average-to-high IQ (≥ 85) based on the WISC, and speaking Persian. The exclusion criteria were the presence of any neurodevelopmental disorder; motor, hearing, or visual disability; missing more than three sessions of the intervention; and simultaneously participating in other interventional programs.

Instrument

Wechsler Preschool and Primary Scale of Intelligence (WPPSI): This is one of three Wechsler scales developed in 1967 using the Wechsler Intelligence Scale for Children (WISC). This test is individually administered and targets the age group of 4-6.5 years. It contains 11 sub-tests with items arranged in ascending order of difficulty. Five sub-tests (Information, Vocabulary, Arithmetic, Similarities, and Comprehension) tap into verbal intelligence, and the sixth subtest (Sentences) is a supplemental verbal test. The other five subtests are Animal Pegs, Picture Completion, Mazes, Geometric Design, and Block Design to assess non-verbal intelligence. The sum of five verbal and five non-verbal subtests yields the full-scale IQ (Liu & Lynn, 2011). Karami, Karami, and Alipour, (2020) reported a Cronbach's alpha of 0.85 for the scale.

The Number Sense Screener: This test was developed by Jordan in 1010 and is based on the three basic components of counting, number recognition, and operations. It serves as a screening tool to assess children suspected of dyscalculia. The developers reported a Cronbach's alpha of 0.92 indicating the test's reliability (internal consistency) (Jordan, Glutting, Ramineni, & Watkins, 2010). Jadidi Feighan, Faramarzi, Abedi, Jamali, and Jadidi Feighan, (2017) reported the reliability of this scale equal to 0.83 based on Cronbach's alpha coefficient.

The PLUS program test: This test is based on the research by Van Herwegen in 2017 to evaluate the ANS. The test consists of two types of tasks (estimation and comparison) in the form of familiar games for preschoolers, using tactile, visual, and auditory sensory stimuli, each corresponding to a function of the ANS. In these tasks, children must distinguish/compare different numerals at different ratios (1:2, 2:3, 3:4, 4:5, and 5:6 with both small and large numbers). To evaluate estimation, the Guessing Game and to evaluate comparison, the In a Line task, each at 10 large and small ratios, were administered to the children. The children answered 20 questions and received a score for each correct answer. The overall score was obtained by summing the correct answers (Van Herwegen, Costa, & Passolunghi, 2017).

Procedure

The number estimation training group received four tasks per session (two tasks to strengthen the estimation and two to strengthen the comparison ability). This training was administered for 20 minutes per session, three days a week, for five weeks. The working memory group received three tasks per session focusing on three components of working memory (phonological loop, visuospatial plane, and central executive). This training was administered for 20 minutes per session, every other day, for 5 weeks. In total, each experimental group received 12 sessions of their respective program, while the control group received routine preschool education in this period.

Statistical Analyses

The data were analyzed via descriptive statistics and repeated-measures analysis of variance (ANOVA).

Findings

The working memory group comprised nine children aged five years and six children aged six years, while the estimation group comprised eight children aged five years and seven children aged six years. The control group consisted of 11 children aged five and four children aged six years. The mean and standard deviation (SD) of IQ was 95.91 (4.21) in the working memory group and 97.78 (3.38) and 96.66 (4.03), respectively, in the number estimation and control groups.

The descriptive statistics such as mean (SD) of the studied variables is presented in Table 1. The results of Mauchly's test (0.9, obtained via chi-square and based on the significance level) showed the validity of the sphericity assumption. The results of the variance homogeneity test indicated no significant difference between the experimental groups and the control group in the three stages of measurement, thereby showing the homogeneity of variances.

Table 1.
Mean (SD) of the Variables in Experimental and Control Groups in the Pre-test, Post-test, and Follow-up

Variables	Phases	Number estimation group	Working memory group	Control
		Mean (SD)	Mean (SD)	Mean (SD)
Number estimation	Pre-test	33.33 (9.29)	30.47 (5.87)	33.67 (7.38)
	Post-test	68.93 (6.55)	64.73 (5.27)	27.40 (6.30)
	Follow-up	71.33 (3.50)	69.13 (3.52)	29.27 (5.30)
Number sense	Pre-test	8.13 (1.55)	8.93 (1.49)	8.53 (1.25)
	Post-test	15.53 (1.85)	16.93 (1.49)	8.80 (1.57)
	Follow-up	15.13 (1.30)	17.20 (1.70)	10.13 (1.77)

The results of repeated-measures ANOVA showed a significant difference between the experimental and control groups in number estimation ($F= 225.99, p<0.01, \eta^2= 0.91$). The within-subject effect showed that the mean number estimation on the pre-test, post-test, and follow-up significantly increased ($F= 232.29, p<0.01, \eta^2= 0.85$). The interaction effects also revealed a group × time interaction, and the mean number estimation increased in at least one group compared to the other groups on the pre-test, post-test, and follow-up ($F= 84.84, p<0.01, \eta^2= 0.80$). Moreover, there was a significant difference between the experimental and control groups in number sense ($F= 120.78, p<0.01, \eta^2= 0.85$). The within-subject effect showed that the mean number sense on the pre-test, post-test, and follow-up significantly increased ($F= 191.42, p<0.01, \eta^2= 0.82$). The interaction effects also revealed a group × time interaction, and the mean number sense increased in at least one group compared to the other groups on the pre-test, post-test, and follow-up ($F= 34.38, p<0.01, \eta^2= 0.62$) (Table 2).

Table 2.
Repeated Measurement Results for the Effects of Time and Interaction of Time and Group

Variables	Source	Source	SS	df	MS	F	p	η2
Number estimation	Within groups	Time	15755.15	2	7878.67	232.29	0.01	0.85
		Time × group	11510.87	4	2877.72	84.84	0.01	0.80
		Error	2849.11	84	33.92			
	Between groups	Group	6868.15	2	3384.08	225.99	0.01	0.91
		Error	628.92	42	14.94			
Number sense	Within groups	Time	885.61	2	442.81	191.42	0.01	0.82
		Time × group	318.07	5	79.52	34.38	0.01	0.62
		Error	194.31	84	2.31			
	Between groups	Group	216.67	2	108.34	120.78	0.01	0.85
		Error	37.67	42	0.90			

Discussion

This present study aimed to investigate the effect of effect of domain-specific and domain-general precursors of mathematical training on preschoolers' number sense and estimation. Both interventions improved number estimation, and these effects persisted to the follow-up. Moreover, the effectiveness of the two training programs was significantly higher on the variable of ANS compared to the control group. In other words, the domain-specific number estimation precursor improvement and the domain-general working memory precursor improvement programs significantly promoted the participants' number estimation ability, and their effects persisted to the follow-up.

The children who received the number estimation training gained a significant improvement in their number estimation and comparison abilities compared to the control group. Thus, in line with previous studies, it is possible to improve the numerical skills of preschool children through numerical activities and games, even before they enter elementary school (Passolunghi, Cargnelutti, & Pastore, 2014). The improved ANS abilities, including number estimation and comparison in both groups (working memory and number estimation training) is another evidence that quantitative judgments and estimation based on the NAS can be developed by intensive adaptive training over a relatively short period. This confirms the results of previous research on the malleability of NAS skills in children (Obersteiner, Reiss, & Ufer, 2013).

Improving number sense by NAS training indicates that the activities performed in this study can enhance the relationship between the symbolic and non-symbolic numerical values, thus improving the acquisition of arithmetic skills. Increasing the accuracy of the NAS by promoting the development of number sense (or the relationship between symbolic and non-symbolic numerical representations) might lead to better mathematical achievements in life at the outset of formal elementary education. A major finding of the present study dealt with the working memory training group who also showed significant improvements in both working memory abilities, number estimation, and number sense. This promising result is consistent with previous studies on working memory training in preschool and elementary children (Xu, Deng, Nan, & Cai, 2021).

Process-based programs for working memory improvement are based on the theory of brain neuroplasticity. Based on this theory, although these fluid intelligence constructs are hard to change and have inherent capacity constraints in many aspects, because of brain neuroplasticity, they are malleable to training-induced changes; that is, brain functions can be altered and improved by training, and these changes can be generalized to similar contexts (near-transfer effect) and, possibly, other contexts (far-transfer effect) (Sánchez-Pérez et al., 2018). Furthermore, this neuroplasticity is greater at younger ages.

According to this fundamental idea, during cognitive training, the neural regions involved in the tasks are frequently activated and strengthened. Cognitive function is thus supported through a specific neural region, and consequently, the effects of training can be generalized and transferred to similar non-trained tasks due to the involvement of a similar brain region and a shared processing infrastructure (near-transfer effect). In this type of transfer, after training the visual working memory, one's performance in visual memory tasks is expected to improve with stimuli differing from those used in the training. Besides, according to this theory, after cognitive training, the acquired ability is expected to generalize beyond the trained domain, i.e., to dissimilar non-trained tasks, thanks to the involvement of similar neural regions and cognitive mechanisms (far-transfer effect) (Maraver, Bajo, & Gomez-Ariza, 2016). For example, based on this type of transfer, after training visual working memory, performance enhancements are expected to appear in more complex cognitive abilities such as reading and mathematics that require visual working memory. Consistent with theories of effect transfer, executive function and working memory training can potentially be transferred to educational settings, and significant improvements in these abilities can be reflected in behaviors and learning in and out of the classroom.

It is noteworthy to discuss the nature of the working memory program administered in this study. The process-based nature of this program can explain its success in transferring the effect to other skills. According to cognitive studies, among various educational programs, process-based training interventions that teach specific cognitive processes without specific strategic training have achieved promising results in transferring the effect of training to everyday and academic functions (Simplicio et al., 2020). In this intervention, the participants receive simple repetitive exercises on cognitive infrastructural processes (e.g., memory, precision, processing speed, etc.). Unlike strategy-based training methods, these protocols target the general rather than specific processing abilities of a task. They target abilities such as processing speed, working memory, or executive functions that are responsible for multiple cognitive operations and are involved in all cognitive and behavioral functions. Thanks to their focus on a specific process, they also have greater explanatory power than multi-domain training (Allen, Giofrè, Higgins, & Adams, 2020).

Conclusion

Domain-specific and domain-general precursors of mathematical training improved number estimation in preschoolers. Moreover, the effectiveness of the two training programs was higher on the variable of number sense compared to the control group. Overall, the domain-specific number estimation precursor improvement and the domain-general working memory precursor improvement programs promoted the preschoolers' number estimation ability. These results constitute a major step towards understanding the variable accuracy of the ANS and designing effective ANS training programs for children. Based on the findings, the ANS is malleable in the preschool years, and improving NAS skills can facilitate number sense. These results can have several practical applications for intervention programs. According to the positive outcomes of the training programs administered in this research, these programs can be used in designing preschool interventions. Similar training activities, including individual face-to-face programs, can help improve children's cognitive precursors for future academic learning and prevent preschool learning difficulties.

There were several methodological limitations in the present study. The statistical population was limited to preschool children in Kermanshah. There was no information on the continuation of improvement induced by education in elementary school. The groups could not be homogenized in terms of some effective components, e.g., practice hours at home and training by parents, due to limits on the sample size. Finally, the researcher was involved in the process of administering the interventions as well as assessments. With an adequate budget, this study can be replicated on larger and more diverse samples of students with dyscalculia in different cities and educational districts. In this way, researchers can overcome the limitations of the current study and obtain more valid, reliable, and generalizable results.

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Conflicts of Interest

The authors declare that they have no conflict of interests.

References

Allen, K., Giofrè, D., Higgins, S., & Adams, J. (2020). Working memory predictors of mathematics across the middle primary school years. *The British Journal of Educational Psychology, 90*(3), 848-869.

Bull, R., Marschark, M., Nordmann, E., Sapere, P., & Skene, W. A. (2018). The approximate number system and domain-general abilities as predictors of math ability in children with normal hearing and hearing loss. *British Journal of Developmental Psychology, 36*(2), 236-254.

Cai, D., Zhang, L., Li, Y., Wei, W., & Georgiou, G. K. (2018). The role of approximate number system in different mathematics skills across grades. *Frontiers in Psychology, 9*, 1733-1733.

Cassidy, A. R., White, M. T., DeMaso, D. R., Newburger, J. W., & Bellinger, D. C. (2016). Processing speed, executive function, and academic achievement in children with dextro-transposition of the great arteries: Testing a longitudinal developmental cascade model. *Neuropsychology, 30*(7), 874-885.

Chu, F. W., vanMarle, K., & Geary, D. C. (2016). Predicting children's reading and mathematics achievement from early quantitative knowledge and domain-general cognitive abilities. *Frontiers in Psychology, 7*.

Cragg, L., Keeble, S., Richardson, S., Roome, H. E., & Gilmore, C. (2017). Direct and indirect influences of executive functions on mathematics achievement. *Cognition, 162*, 12-26.

Esmailzadeh Roozbahani, A., Behroozi, N., omidian, m., & maktabi, g. (2021). The effect of computerized cognitive rehabilitation (CCR) on verbal skills of the students with mathematical learning disorder. *Iranian Journal of Learning & Memory, 4*(13), 38-46.

Hoffman, A. J., McGuire, L., Rutland, A., Hartstone-Rose, A., Irvin, M. J., Winterbottom, M., . . . Mulvey, K. L. (2021). The relations and role of social competencies and belonging with math and science interest and efficacy for adolescents in informal STEM programs. *Journal of Youth and Adolescence, 50*(2), 314-323.

Jadidi Feighan, M., Faramarzi, S., Abedi, A., Jamali, S., & Jadidi Feighan, M. (2017). Effectiveness of early educational interventions on sense of number in preschoolers. *Knowledge & Research in Applied Psychology, 15*(56), 78-85.

Jordan, N. C., Glutting, J., Ramineni, C., & Watkins, M. W. (2010). Validating a number sense screening tool for use in kindergarten and first grade: prediction of mathematics proficiency in third grade. *School Psychology Review, 39*(2), 181-195.

Karami, A., Karami, R., & Alipour, A. (2020). The investigation of psychometric properties of fifth version of Wechsler Children's Intelligence in Iran. *Quarterly of Educational Measurement, 11*(41), 97-125.

Liu, J., & Lynn, R. (2011). Factor structure and sex differences on the Wechsler Preschool and Primary Scale of Intelligence in China, Japan and United States. *Personality and Individual Differences, 50*(8), 1222-1226.

Maraver, M. J., Bajo, M. T., & Gomez-Ariza, C. J. (2016). Training on working memory and inhibitory control in young adults. *Frontiers in Human Neuroscience, 10*.

Martínez-Bello, V. E., & Estevan, I. (2021). Physical activity and motor competence in preschool children. *Children (Basel, Switzerland), 8*(4), 305.

Naderi Dehsheykh, M., Hafezi, F., & Dashtbozorgi, Z. (2021). Relationship of students' math anxiety with their optimism and perceived classroom structure, mediated by mathematics attitudes. *Iranian Journal of Learning & Memory, 4*(15), 69-76.

Obersteiner, A., Reiss, K., & Ufer, S. (2013). How training on exact or approximate mental representations of number can enhance first-grade students' basic number processing and arithmetic skills. *Learning and Instruction, 23*, 125-135.

Odic, D., & Starr, A. (2018). An introduction to the approximate number system. *Child Development Perspectives, 12(*4), 223-229.

Passolunghi, M. C., Cargnelutti, E., & Pastore, M. (2014). The contribution of general cognitive abilities and approximate number system to early mathematics. *British Journal of Educational Psychology, 84*(Pt 4), 631-649. d

Piasta, S. B., Pelatti, C. Y., & Miller, H. L. (2014). Mathematics and science learning opportunities in preschool classrooms. *Early Education and Development, 25*(4), 445-468.

Razm, F., Hafezi, F., Marashian, F. S., Naderi, F., & Dashtbozorgi, Z. (2021). Effectiveness of flipped teaching and problem-solving methods on problem-solving ability and sense of responsibility among female high school students. *Iranian Journal of Learning & Memory, 3*(12), 31-38.

Sánchez-Pérez, N., Castillo, A., López-López, J. A., Pina, V., Puga, J. L., Campoy, G., . . . Fuentes, L. J. (2018). Computer-based training in math and working memory improves cognitive skills and academic achievement in primary school children: behavioral results. *Frontiers in Psychology, 8*, 2327-2327.

Sharifi, M., Fathabadi, J., Karimi, A., & Sharifi, M. (2018). The effectiveness of teaching critical thinking skills on students' academic achievement in mathematics and science: a study in timss framework. *Iranian Journal of Learning & Memory, 1*(1), 21-30.

Simplicio, H., Gasteiger, H., Dorneles, B. V., Grimes, K. R., Haase, V. G., Ruiz, C., . . . Moeller, K. (2020). Cognitive research and mathematics education-how can basic research reach the classroom? *Frontiers in Psychology, 11*, 773-773.

Szkudlarek, E., & Brannon, E. M. (2017). Does the approximate number system serve as a foundation for symbolic mathematics? *Language Learning and Development: The Official Journal of the Society for Language Development, 13*(2), 171-190.

Tosto, M. G., Petrill, S. A., Malykh, S., Malki, K., Haworth, C. M. A., Mazzocco, M. M. M., . . . Kovas, Y. (2017). Number sense and mathematics: Which, when and how? *Developmental Psychology, 53*(10), 1924-1939.

Van Herwegen, J., Costa, H. M., & Passolunghi, M. C. (2017). Improving approximate number sense abilities in preschoolers: PLUS games. *School Psychology Quarterly, 32*(4), 497-508.

Xu, J., Deng, M., Nan, W., & Cai, D. (2021). The effects of working memory training in children revealed by behavioral responses and ERP. *Brain and Behavior, 11*(8), e2310-e2310.