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The Impact of Early Intervention on Cognitive Performances of Children with Typical Development and with Hearing Loss: Working Memory and Short Term Memory

Abstract

One of the problematic issues in childhood temporary memory research seems to be the elusiveness of the factors affecting working memory (WM) and short-term memory (STM) capacities. The purpose of this research was (a) to determine the impact of one year preschool education -a form of early intervention- on WM and STM capacities of children either with typical development or with hearing loss, and (b) to determine the impact of early parent guidance on WM and STM capacities of children with hearing loss. The sample (N = 223) consisted of children with typical development (n = 103) and children with hearing loss (n = 120) from three different educational settings in Eskişehir, Turkey. Measures were Sentence-Digit Span, Task Paper-Folding, and Digit Span-Backward tasks for WM, and Digit Span task for STM capacity. Among children with typical development, one-way MANCOVAs indicated no significant differences between children who had preschool education and those who had not on mean WM and STM tasks scores when age and IQ were controlled. On the side of children with hearing loss, both preschool education and early parent quidence resulted in better WM/STM task performances. Finding of the study clearly indicated that early intervention is a must for cognitive development, at least for WM/STM capacities of children with hearing loss.

Key Words: Children with hearing loss, cognitive processes, early intervention, early parent guidence, preschool education, working memory.

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Structured Abstract

Working memory (WM) and short term memory (STM) are one of the most influential constructs for the last 35 years in cognitive psychology. Contemporary memory research has focused more on WM than STM (Dehn, 2008). Up to date, there are more than 10 theoretical approaches to WM (Miyake and Shah, 1999). Because the studies about temporary memory in childhood mostly depend on, a central place was given to the multi-component model of WM which was first proposed by Alan Baddeley and Graham Hitch in 1974, and later improved by Baddeley (1986). According to the model, "the theoretical concept of WM assumes that a limited capacity system, which temporarily maintains and stores information, supports human thought processes by providing an interface between perception, long-term memory and action" (Baddeley, 2003a, p.829). More transparently, it is the cognitive ability of an individual to hold (store, maintain) and manipulate (process) information in the mind over limited periods (Gathercole and Alloway, 2008).

For Baddeley's model, WM consists of four inter-linked components: central executive, and three sub-systems (visuo-spatial sketchpad, phonological loop, and episodic buffer which has been recently added to the model and not included in current study). The *central executive* is responsible for controlling attention and coordination of the flow of information through WM and is involved in higher-level mental processes. Central executive controls the functions of other components by supporting either processing or storage, and supplemented by visuo-spatial sketchpad and phonological loop. *Visuo-spatial sketchpad* processes and stores information that can be presented in terms of visual and spatial structures, such as images, pictures, and locations. *Phonological loop* provides temporary storage for linguistic material and storing a linguistic input is possible via subvocal rehearsal which is an active processing entity (Baddeley, 2003a, 2007).

Although there are many cognitive functions that have close relations to WM, two of them are especially important: intelligence and STM. (1) It is speculated that as close cognitive constructs, intelligence is relatively more stable than WM. It is better to consider intelligence as a control variable in WM studies (Gathercole, Pickering, Ambridge and Wearing, 2004a; Gathercole and Alloway, 2008). (2) While STM is unitary in structure and is a passive storage system, WM has multi-components and is a dynamic system including both processing and storage demands (Sayar and Turan, 2012).

WM capacity tends to increase from early childhood to adolescence. A typical four-year-old child has two-item (i.e. 8-4) capacity for digit span-backward, while a fifteen-year-old adolescent approximately has 5 item capacity. Children start to use rehearsal process, which is necessary for phonological loop, at about seven years of age. At about fifteen years of age, WM capacity reaches to adult levels. The level of interactions between the sub-components of WM vary by chronological age. In round figure, all the

subcomponents of WM are separable by 7 years of age. Despite individual differences, it seems that the controlling function of the central executive on slave systems is getting stricter as the child grows (Gathercole et al., 2004).

WM/STM's relation to reasoning/fluid intelligence, executive functions, complex thought, problem-solving, language acquisition, language comprehension, vocabulary development, verbal fluency, translation skills, reading decoding, reading-comprehension, spelling, written expression, following instructions, note taking, mathematical skills, and science is well documented (Baddeley, 2003b; Daneman and Hannon, 2007; Dehn, 2008). These skills are crucial for academic learning and education both for children with typical development and children with disabilities (e.g. Alloway and Gathercole, 2006; Swanson, Zheng and Jerman, 2009). Failure in aforementioned skills leads to difficulties in learning, therefore it can be concluded that limitations in WM capacity is related to learning difficulties which creates a group of children in need of special education (Dehn, 2008). However the relationship between WM and special education is not limited to learning difficulties. During the last decade several researchers attempted to explore the role of WM limitations in cognitive functioning of children with a range of neuro-developmental disorders such as attention/deficit hyperactivity disorder (Roodenrys, 2006), autism, Asperger syndrome, borderline and mild intellectual disabilities (Ozonoff and Jensen, 1999; Williams, Goldstein, Carpenter and Misnshew, 2005; van der Molen, van Hulit, van der Molen, Klugkist and Jongmans, 2010), Williams syndrome, developmental coordination disorder (Alloway, Rajendran and Archibald, 2009), and Down syndrome (Ozonoff and Jensen, 1999)**.**

By the side of the group of children with special needs, research about the cognitive processes of children with hearing loss had mostly focused on intelligence, but relatively not much enough studies were held on dynamic processes such as WM and STM. The existing few studies had concerned on the relationships of WM capacity and a series of academic, linguistic, and cognitive abilities, such as *reading* (Swanson et al., 2009), *writing* (Briscoe, Bishop and Nurbury, 2001), *mathematics* (Bull, 2008) speech perception (Ibetson et al., 2009), *speech production* (Geers, 2006), *vocabulary* (Cleary, Pisoni and Kirk, 2002), *word knowledge*, *novel word learning* (Hansson et al., 2004), *grammar development*, *speech intelligibility* (Wilstedt-Svenson et al., 2004), *intelligence* (Remine et al., 2007), *comprehension*, *reasoning* (Marschark and Hauser, 2008), *metacognition* (Tsui et al., 1991), *visual* and *auditory discrimination* (Lunner, Rudner and Rönnberg, 2009) ve *phonological awareness* (Koo et al., 2008). In general literatüre, few studies had drawn attention on the relationships of audiological and educational characteristics and temporary memory processes (WM and STM) of children with hearing loss.

To conclude, probably the most considerable question is "Why WM is important for children's cognitive functioning?" Because, it (a) is in the center of- and central to information flow, (b) is related to higher-level/complex cognitive activities such as reading, comprehension, language, arithmetic, reasoning, intelligence, everyday cognitive functioning, etc., and (c) has a strong predictive power for learning, which also facilitates a more dynamic and practical way of understanding any sort of difficulties in learning both for children with typical development and for children with hearing loss.

One of the problematic issues in childhood WM research seems to be the factors affecting WM capacity. Genetic factors, age, and related cognitive factors are known to affect WM capacity in children with typical development. In the face of children with hearing loss, some additional factors, such as educational and audiological factors are thought to be predictive of WM capacity. Unfortunately, these speculations do not depend on empirical studies even in children with typical development (Pickering, 2006), indicating a clear need to conduct research about the factors related to WM/STM capacities of children either with typical development or with hearing loss.

In the light of the literature, we focused on an educational factor, early intervention (preschool education and early parent guidance), which is considered to have a potential impact on the development of WM/STM capacities of two groups: children with typical development and children with hearing loss. Therefore, the purpose of this research is to determine the role of early intervention (preschool education and early parent guidance) on WM and STM capacities of children either with typical development or with hearing loss. The research questions were as follows:

1. Among children with typical development, is there any significant performance differences between subgroups (those who had preschool education and those who had not) on WM and STM task measures when age and IQ were controlled?

2. Among children with hearing loss, is there any significant performance differences between subgroups (those who had preschool education and those who had not) on WM and STM task measures when age and IQ were controlled?

3. Among children with hearing loss, is there any significant performance differences between subgroups (those who had early parent guidance and those who had not) on WM and STM task measures when age and IQ were controlled?

Method

Design

Factorial design when criterion is the number of independent variables (IVs), and also comparative design when criterion is the trial conditions (Büyüköztürk, 2010). IVs are preschool education for 1st and 2nd research questions, early parent guidance for the 3rd one. Dependent variables (DVs) are the measures of WM components and STM performance.

Participants

The total sample [N = 223] consisted of children with typical development [n = 103] from various elementary schools, and children with hearing loss [n = 120] from three different educational settings in Eskişehir, Turkey: Children from (1) Education and Research Centre for Hearing Impaired Children, namely İÇEM [*n* = 62], (2) Mainstream settings [*n* = 27], (3) School for the Deaf [*n* = 32]. (1) and (2) use oral language, but (3) use combination of oral language and a sort of sign system as the mode of communication. Age range of the children was 7 to 15 years. Groups and subgroups were matched by age, mean IQ score, grade level and family income. Also no known psychiatric/neurological problems reported for any group.

Measures and Procedure

Measures of the study were two-fold. First group of measures aimed to determine the participant characteristics, such as *Pure Tone Audiometry* for hearing level, *Participant Information Form-Parents (PIF)* for socio-demographic variables, *Teacher Information Form (TIF)* for academic progress of the students, and Turkish version of *WISC-R Performance Subscales* for Performance IQ (Savaşır and Şahin, 1995). The second group of measures, which were developed by the researcher, aimed to determine WM and STM capacities of children: (1) *Sentence-Digit Span Task* (SDS) for phonological loop component of WM, (3) *Paper-Folding Task* (PF) for visuo-spatial sketchpad component of WM, (3) *Digit Span-Backward Task* (DS-B) for central executive and (4) *Digit Span Task* (DS) for STM capacity (for the details of development process each task, see Doğan, 2011). Risk of ceiling effect was prevented by administering all the tasks to a group of talented children (*n* = 8) during the pilot study. Interrater reliability found to be satisfactory with coefficients between 96% to 100% for all the tasks of WM and STM.

Following informed consent, PIF and TIF were sent to parents and teachers in an enclosed envelope and they were requested to send back after filling the forms. All the tasks were administered by the researcher in a quite testing room as individual sessions. All the administration sessions were audio recorded.

Results

In order determine the effect of early intervention on WM and STM capacities of participants, group data on the WM (SDS, PF and DS-B) and STM (DS) tasks were analyzed using a combination of one-way Multiple Analysis of Covariance (MANCOVAs) and one-way Analysis of Variance (ANOVAs) via a statistical package for social sciences. Age and IQ were covariates in all analysis. Before analyzing the main data, preliminary assumption testing was conducted for checking univariate and multi-variate normality, linearity, multi-collinearity and homogeneity that resulted in no violation. Hotelling's T^2 was selected as the multivariate test. For separate analysis on the dependent variables (DVs), Bonferroni Corrections were applied to reduce the chance of Type 1 error, so that the only probability values less than .013 (.05/4) were accepted statistically significant.

To answer the 1st and 2nd research questions the group mean WM and STM task scores were presented in Table 1 for both groups (children with typical development and children with hearing loss).

Table 1.

Group mean and corrected means WM and STM tasks scores of children with typical development and with hearing loss

Children with Typical Development						
	DVs				Covariates	
Pres. edu.	SDS	PF	DS-B	DS	WISC-R	Age
Had (n = 55)						
M (SD)	4.96 (1.17)	7.81 (1.79)	7.29 (1.44)	10.36 (2.04)	129.44 (27.88)	122.87 (24.60)
Cor.M(S_e)[a]	5.09 (.14)	8.04 (.16)	7.40 (.18)	10.53 (.24)		
Had not (n = 48)						
M (SD)	5.75 (1.22)	8.27 (1.46)	7.87 (1.67)	10.91 (2.07)	138.06 (26.45)	135.90 (24.97)
Cor.M(S_e)[a]	5.60 (.15)	8.01 (.18)	7.74 (.20)	10.72 (.26)		
Children with Hearing Loss						
Pres. edu.	SDS	PF	DS-B	DS	WISC-R	Age
Had (n = 84)						
M (SD)	4.52 (1.23)	7.66 (1.98)	6.40 (1.48)	8.90 (1.39)	127.34 (28.90)	126.66 (24.79)
Cor.M(S_e)[a]	4.64 (.11)	7.99 (.15)	6.49 (.14)	8.96 (.15)		
Had not (n = 30)						
M (SD)	4.00 (1.05)	7.18 (1.79)	5.73 (1.17)	7.70 (1.84)	139.27 (23.38)	149.36 (18.76)
Cor.M(S_e)[a]	3.65 (.19)	6.77 (.27)	5.47 (.25)	7.53 (.27)		

Note. SDS = Sentence-Digit Span Task; PF = Paper Folding Task; DS-B = Digit Span-Backward Task; DS = Digit Span Task; DVs = Dependent Variables/Measures; [a] Corrected means and standard errors after IQ and age were covariated.

Results Related to Research Question 1

According to Hotelling's T^2 criterion, interaction between combination of covariates and combination of DVs was statistically significant [$F(4, 97) = 27.61$, $p < .01$, partial η^2 = .53]. But one-way between-groups MANCOVAs indicated that group main effect on DVs was not statistically significant [$F(4, 97) = 1.15$, $p > .013$, partial $\eta^2 = .06$]. In other words, among children with typical development, no significant differences observed between children who had preschool education and those who had not on mean WM and STM tasks scores when age and IQ were controlled (See Table 1).

Results Related to Research Question 2

Accoding to Hotelling's T^2 criterion, interaction between combination of covariates and combination of DVs was statistically significant [$F(4, 108) = 25.56$, $p < .01$, partial $\eta^2 = .48$]. One-way between-groups MANCOVAs indicated that group main effect on DVs was statistically significant [$F(4, 108) = 7.64$, $p < .01$, partial $\eta^2 = .22$]. In other words, among children with hearing loss, significant differences were observed between children who had preschool education and those who had not on mean WM and STM tasks scores when age and IQ were controlled. A series of one-way ANOVAs followed by Bonferroni test for multiple comparisons indicated that children who had preschool education performed better than those who had not preschool education on all WM and STM tasks [$F_{SDS}(1, 110) = 17.40$, $p < .01$, partial $\eta^2 = .14$; $F_{PF}(1, 110) = 13.93$, $p < .01$, partial $\eta^2 = .11$; $F_{DS\text{-}B}(1, 110) = 11.34$, $p < .01$, partial $\eta^2 = .10$; $F_{DS}(1, 110) = 18.57$, $p < .01$, partial $\eta^2 = .14$]. (See Table 1 for comparisons.)

Results Related to Research Question 3

To answer the 3rd research question the group mean WM and STM task scores were presented in Table 2.

Table 2.

Group means and corrected means WM and STM tasks scores of children with hearing loss

	DVs				Covariates	
Parent guidence	SDS	PF	DS-B	DS	WISC-R	Age
Had (n = 76)						
M (SD)	4.68 (1.21)	7.86 (2.03)	6.51 (1.48)	9.07 (1.32)	128.68 (29.72)	127.38 (25.44)
Cor. M. (S_e) [a]	4.80 (.11)	8.11 (.16)	6.59 (.14)	9.12 (.15)		
Had not (n = 38)						
M (SD)	3.78 (.96)	6.95 (1.61)	5.65 (1.14)	7.60 (1.68)	134.12 (24.30)	142.79 (22.20)
Cor. M. (S_e) [a]	3.56 (.15)	6.80 (.23)	5.51 (.21)	7.51 (.23)		

Note. SDS = Sentence-Digit Span Task; PF = Paper Folding Task; DS-B = Digit Span-Backward Task; DS = Digit Span Task; DVs = Dependent Variables/Measures; *a* Corrected means and standard errors after IQ and age were covariated.

Accoding to Hotelling's T^2 criterion, interaction between combination of covariates and combination of DVs was statistically significant [$F(4, 108) = 28.43$, $p < .01$, partial $\eta^2 = .51$]. One-way between-groups MANCOVAs indicated that group main effect on DVs was statistically significant [$F(4, 108) = 14.56$, $p < .01$, partial $\eta^2 = .35$]. Precisely, among children with hearing loss, significant differences were observed between children who had early parent guidance and those who had not on mean WM and STM tasks scores when age and IQ were controlled. A series of one-way ANOVAs followed by Bonferroni test for multiple comparisons indicated that children who had early parent guidance exhibited better performance than those who had not parent guidance on all WM and STM tasks [$F_{SDS}(1, 110) = 38.50$, $p < .01$, partial $\eta^2 = .26$; $F_{PF}(1, 110) = 20.56$, $p < .01$, partial $\eta^2 = .16$; $F_{DS\text{-}B}(1, 110) = 16.45$, $p < .01$, partial $\eta^2 = .13$; $F_{DS}(1, 110) = 31.20$, $p < .01$, partial $\eta^2 = .22$]. (See table 2 for comparisons.)

Discussion

In this research, we tried to determine the impact of early intervention (preschool education and early parent guidance) experience on WM/STM tasks performances of two groups of children: children with typical development and children with hearing loss. In order to test our idea, the purpose of the research was constructed as (a) to determine the role of preschool education on WM and STM capacities of children either with typical development or with hearing loss, and (b) to determine the role of early parent guidance on WM and STM capacities of children with hearing loss by between-groups comparison. The first finding indicated that among children with typical development, when age and IQ were statistically controlled, no significant differences on WM and STM tasks scores observed between children who had preschool education and those who had not. As opposed to this, on the side of children with hearing loss, the second finding revealed a difference on WM and STM tasks scores indicating that children who had preschool education performed better than those who had not. By combining these two findings, it can be concluded that regardless of age and IQ, one year preschool education had significant impact on enhancing WM and STM capacities of children with hearing loss, but not of those children with typical development. The finding that WM and STM performances of children with typical development were not affected by preschool education is understandable for two reasons. First, speculations of some authors (e.g. Gathercole and Alloway, 2008), that early intervention may enhance WM/STM capacities of children is based on the data from those who have limited WM capacities. It could be concluded that children whose WM capacity is not limited may acquire WM/STM capacity in a more spontaneous/natural way. Second, in this research preschool education is only one year before primary school. So the finding might have been different if not only the preschool status but also the levels of caregiver-child interaction in very early years (e.g. 0 to 3 years of age) were taken into account.

When children with hearing loss is considered, it was very obvious that both preschool education and early parent guidence played a role on enhancing WM/STM capacities either measured by verbal tasks or by visuo-spatial task. Research considering language development of children with hearing loss repeatedly emphasized the importance of early identification and early intervention. Younger age of identification and quality early intervention services provided resulted in better language prognosis (Turan, 2012; Yoshinaga-Itano, 2003). It seems clear that early intervention is a must not only for language development but also for cognitive development, at least for WM/STM capacities of children with hearing loss.

We used multiple measures (SDS and DS-B tasks) for verbal WM, but not for visuo-spatial WM (PF task) and STM (DS task). Further research on the issue is recommended to conduct at least two tasks/measures for each component of WM for methodological robustness. Our second suggestion for future research is to focus on longitudinal methodology rather than cross-sectional one in order to understand the developmental nature of WM/STM capacities of children as detailed as possible, both for children with typical development and with hearing loss.