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Development of Executive Functions in Pre-schoolers[1]

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Abstract

The aim of this study was to investigate the development and developmental trajectories of the three most frequently postulated executive function (EF) components. In addition, we explored the developmental relation between early expressive and receptive language skills and EF longitudinally. Expressive and receptive language tasks and age-appropriate working memory, inhibition, and shifting tasks were conducted with 70 pre-schoolers (36 girls and 34 boys) aged between 36 and 65 months. Measures were taken two times at 6 month intervals within a longitudinal design. The findings of the present study revealed that different aspects of language had predictive relations with shifting and working memory components of EF 6 months later. The findings also showed how components of EF develop during the preschool years both cross-sectionally and longitudinally.

Keywords: Executive functions; Language; Working memory; Inhibition; Longitudinal; Pre-schooler.

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Okul Öncesi Dönemde Yönetici İşlevler Gelişimi

Öz

Bu çalışmanın amacı, yönetici işlevlerin üç bileşeninin gelişimini ve gelişim örüntülerini ve bu bileşenlerin dil becerisinin alıcı ve ifade edici yönleri ile olan ilişkisini boylamasına araştırmaktır. Alıcı ve ifade edici dil görevleri ve yaşa uygun çalışma belleği, ketleme ve kurulumu değiştirme (shifting) görevleri 36-65 ay arasında değişen 70 okul öncesi çocuğa (36 kız ve 34 erkek) uygulanmıştır. Boylamsal bir desende 6 aylık aralıklarla iki kez ölçüm alınmıştır. Bu çalışmanın bulguları, dilin farklı yönlerinin 6 ay sonraki kaydırma ve çalışma belleği bileşenleriyle yordayıcı ilişkilere sahip olduğunu ortaya koymuştur. Ayrıca bulgular yönetici işlevlerin farklı bileşenlerinin okul öncesi yıllarda hem kesitsel hem de boylamsal olarak nasıl geliştiğini göstermiştir.

Anahtar Kelimeler: Yönetici işlevler; Dil; Çalışma belleği; Ketleme; Boylamsal; Okul öncesi dönem.

Introduction

Executive functions (EF) is a broad term used for processes foundational for goal-directed behaviour and thoughts and encompass sub-functions, such as cognitive flexibility, selective attention, inhibition and working memory (Zelazo, Craik and Booth, 2004). Examining EF's development trajectories in young children is important, both because of this being the time of the beginning and development of the core components of EF (Best, Miller and Jones, 2009; Carlson, 2005) and because of its role in normative social and cognitive functioning. For instance, EF has been found to be linked with abilities ranging from theory of mind (Moses and Tahiroğlu, 2010), to mathematical skills (Bull and Scerif, 2001; Clarck, Pritchard and Woodward, 2010), to academic achievement (Best, Miller and Naglieri, 2011), to reading ability (Blair and Razza, 2007), and to social and emotional self-regulation (Best et al., 2009; Hofmann, Schmeichel and Baddeley, 2012).

One question in literature is whether executive functions refer to a unitary process or multiple, diverse processes. In the theoretical unity/diversity framework suggested by Miyake et al. (2000), executive functions are considered to comprise three components: inhibition, updating, and shifting. Inhibition refers to the suppression of a proponent stimulus or response, updating refers to monitoring and updating representations held in working memory, while shifting refers to shifting between mental sets or tasks. Although these components are diverse in reflecting unique abilities, they are also correlated with each other, which signals some shared underlying processes or unity (Miyake and Friedman, 2012). In a review article, Garon, Bryson and Smith (2008) come to the conclusion that what is common to the different theories proposed for the development of EF in early childhood years (such as Diamond, 2006; Miyake et al., 2000; Munakata, 2001; Zelazo and Frye, 1998) is the suggestion that attention is the underlying factor for various EF abilities. Thus, focusing attention on a task and ignoring irrelevant information has been proposed to be pivotal to EF development. Moreover, executive functions are such a broad term that while tests used to measure the same component, it may measure different aspects of the same component. For instance; Karakaş and Karakaş (2000) found that two different tests (i.e., Wisconsin Card Sorting Test (WCST) and Stroop Test) that are used for measuring inhibition component of executive function, measure two different aspects of inhibition and activate different parts of prefrontal cortex.

During the pre-school years, significant changes happen in terms of the development of all EF components. For instance, children become better able to deal with conflicting information (Doebel and Zelazo, 2015), to self-regulate (Montroy, Bowles, Skibbe, McClellandand and Morrison, 2017) to inhibit for a longer time (Best et al., 2009), in addition to holding more representations in the mind (Gathercole, 1998). When the development of EF tasks was examined, it was found that children experience significant improvements in the majority of tasks during the preschool period (Carlson, 2005). Even after controlling for the relation between EF and language, EF scores improve significantly from 3 to 5 years, which seem to reflect maturational changes at both the biological and contextual levels. When the nature and direction of the relation between executive functions, theory of mind, working memory and language were compared in 3-year old and 5-year old Turkish speaking children, different relations were found (Karakelle and Ertuğrul, 2012). This may reflect that relations among these components may change accordingly.

Aside from age, which factors might be important in EF development or individual differences in this development? Studying the relation between language and EF is likely to be useful when addressing this question. Language is considered significant in the development of EF in most of the theoretical explanations of EF (Doebel and Zelazo, 2013) although in different ways and to varying degrees. For example, according to Cognitive Complexity Theory (Zelazo and Frye, 1998), language is needed for the formulation and maintenance of higher order rules. Language triggers attention to aspects of the task and reflection on representations (Doebel and Zelazo, 2013), thus making EF tasks less demanding on EF. As a result, when the conflict between rule changes is emphasized, and the children instead of the experimenter label the test cards, task performance and the rates of successful switching are facilitated (Doebel and Zelazo, 2015). In addition to this explanation of how language and EF are causally related, another explanation focuses on the role of self-directed speech (Vygotsky, 1962) in self-regulation. From this view, language provides children with the necessary mental tools to be used in self-regulative behaviours and thoughts. This relation between language and EF is corroborated by many experiments (Bohlman, Maier and Palacios, 2015; Kuhn, Willoughby, Vernon-Feagans and Blair, 2016; Montray et al., 2017) on English speaking children. Similarly previous studies on Turkish children showed that both receptive and expressive language are correlated with cognitive flexibility or set-shifting component of EF (Gültekin-Ahçı, 2016; Karakelle and Ertuğrul, 2012). Additionally, Ekerim and Selçuk (2018) demonstrated that inhibitory control predicted both concurrent and 1 year later vocabulary knowledge.

There is a well-established relationship between EF and language in previous studies; however, most of them focused on concurrent relations but not longitudinal or developmental ones. Reliance on only one aspect of language or on cross-sectional designs is found to be problematic to illuminate the relationship between language and EF since it seems that relations are complex and change at different time points during development (Kuhn et al., 2016). For instance, Kuhn et al. (2016) found that child expressive vocabulary provides a foundation for EF development; however, expressive vocabulary skills at 36 and 60 months were either negatively associated or not significantly associated with EF. Although Kuhn et al. (2016) focused on different indicators of the language they did not differentiate components of executive functions. Thus, it seems necessary to investigate the relationship between language and different EF abilities separately. In this paper, we included components of EF that Miyake et al. (2000) suggested and receptive vocabulary was measured in addition to expressive vocabulary.

Within this scope, the first objective of this study was to investigate the development and developmental trajectories of different components of EF in a longitudinal design. To include the three most frequently postulated EF components, we examined working memory, inhibition, and shifting in relation to performance on the Mr. Peanut, Delay of Gratification and Dimensional Change Card Sorting (DCCS) tasks respectively, which are well developed for these EF components. DCCS was classified as a task of the attention shifting component of EF since it involves a change in the rule for selecting between aspects of stimuli that have been labelled (Garon et al., 2008). Delay of Gratification was classified as a task of the simple response inhibition component of EF (Garon et al., 2008) since it involves withholding or restraint of motor response and measures the ability to postpone an immediate reward to gain a delayed but bigger reward. Mr. Peanut task is used for the measurement of working memory, which requires holding information in mind over a delay. This task made it possible to clarify how the inhibition, shifting, and working memory components of EF emerge and develop in a 6-month period in different age groups and to identify how they interact with each other.

Secondly, we addressed the question of how early language skills might be related to later EF. Our objective was to clarify how language skills and different aspects of executive function relate to each other longitudinally. Moreover, the issue of whether different aspects of language ability show different relations with components of EF or not was examined.

The research questions of this study were:

1. Are there any age-related differences in inhibition, shifting and working memory components of EF?
2. Are there any gender related differences in inhibition, shifting and working memory components of EF?
3. Is there a significant time effect between first and second time of the testing phase which involves a six-month interval?
4. Is there a correlation between EF and language tasks at different time of testing?
5. Do earlier receptive and expressive language scores predict later executive functions scores?

Method

Participants

The children were recruited from the three public pre-schools in Erzurum. Before the children were enrolled in this study, the teachers filled in the

Personal Information Form for Children and Ankara Development Screening Inventory (AGTE). Those children who did not have either a developmental delay (obtained a standard t-score above 35 from development screening inventory) or a permanent health problem were determined as the participants of this study.

Since measures were taken two times at 6 month intervals within a longitudinal design, this study started with 85 children, but this number decreased to 70 children at the second time of testing phase because of children leaving the school or moving to another city. A total of 70 children (36 girls and 34 boys) completed both measures were included in this study.

The final sample of present study consisted of 5 age groups: 14 young 3-year-olds (M=38.36, SD=1.73, age range 36-41 months, 11 girls and 3 boys), 14 old 3-year-olds (M=44.71, SD=1.77, age range 42-47 months, 7 girls and 7 boys), 15 young 4-year-olds (M=50.43, SD=1.7, age range 48-53 months, 9 girls, 6 boys), 15 old 4-year-olds (M=56.59, SD=1.85, age range 54-59 months, 4 girls and 11 boys) and 12 young 5-year-olds (M=62.93, SD=1.81, age range 60-65 months, 5 girls and 7 boys).

22% of mothers and 21% of fathers had completed high school, 74% of mothers and 77% of fathers held a university degree and 4% of mothers and 2% of fathers had a postgraduate university degree. 77% of mothers and all fathers had a job. Only one parent was separated and the most of the children, about 73% had at least one sibling.

Measures

EF Measures

Dimensional change card sorting task (DCCS).

The DCCS (Frye, Zelazo and Palfai, 1995) was used to measure cognitive flexibility or set-shifting (Doebel and Zelazo, 2015).

Two sorting trays were put on a table side by side and behind each of them, a target card (blue rabbit, red boat) was attached to display panels. First, the children were instructed to sort bivalent test cards (red rabbit, blue boat) according to the colour dimension. Before each trial, the children were reminded of the rule, and the card was labelled by the experimenter. To pass the pre-switch phase, the children had to sort all six cards successfully. If a child passed this phase, on the post-switch phase, the child was instructed to sort the cards according to the shape dimension. If the children could switch flexibly and sort at least five out of the six cards correctly, they proceeded to the border version. On the border version, border test cards were introduced, and the child was instructed to play the colour game if there was a border and to play the shape game if there was no border. To pass this phase, the child had to sort correctly at least 9 cards out of 12. Children gained one point for each phase that they passed and hence the maximum score for this task was 3.

***Delay of gratification*.**

The delay of gratification task (Mischel, Schoda and Rodriguez, 1989) was used to measure the ability to postpone an immediate reward to gain a delayed but bigger reward.

The experimenter explained to the child that she (the experimenter) had to go out of the room for a while. The experimenter instructed the child that if s/he could wait for her return, then s/he could have the larger reward (one pocket of jelly tots), but if s/he did not want to wait for the experimenter, then s/he could call her and have the smaller reward (one jelly tot). The experimenter then left the room and using a hidden camera, filmed the child and watched the child via a cell phone. If the child called the experimenter or ate the reward, s/he got a score of zero. If s/he did not eat the reward or call the experimenter, the child got a score of 1 and one pockets of jelly tots.

***Mr. Peanut task*.**

The Mr. Peanut task was developed by Case (1985) and adapted by de Ribaupierre and Billeux (1994) for the measurement of working memory. It requires holding information in mind over a delay.

In this task, a clown figure, which had a number of red dots on his body parts (1 to 8 levels) was presented to the child for 5 seconds and then removed. Then the child was given a blank outline of the clown figure and was asked to place stickers on the body parts that previously had a dot on them. If the child placed the stickers incorrectly for all three figures that belonged to the same level, the task was over. The highest achievable score of this task was 8.

Language Ability

Turkish expressive and receptive language test (Tifaldi).

The Tifaldi test (Berument and Güven, 2010) was used to assess the children's language development in terms of expressive and receptive vocabulary skills.

Expressive Language Sub Scale, this scale had high reliability (test re-test=.97, Cronbach's Alpha=.98, Spearman-Brown=.99) and validity (related to WISC-R and Ankara Developmental Screening Inventory (ADSI)).

In this sub-scale, the children were instructed to state the name of an object in the target picture. The number of correct answers represented the child's raw score. The highest achievable score of this sub-scale was 80.

Receptive Language Sub Scale, this scale also had high reliability (test-retest validity=.97, Cronbach Alpha=.99, Spearman-Brown=.99) and validity (related with WISC and ADSI).

In this sub-scale, the children were instructed to select out of four pictures the picture of the target word that was articulated by the tester. The number of correct answers represented the child's raw score. The highest achievable score of this subscale was 104.

Procedure

Children were tested individually in a quiet room at their preschool. The measurements in the first and second time of the testing phase were held in two sessions in order to maintain the children's attention. The tasks were administered in a fixed order. In the first session, the receptive and expressive language tests, and in the second session the DCCS, Mr. Peanut and delay of gratification tasks were administered respectively. The language tests took approximately 20-35 minutes whereas the DCCS task took 10-15 minutes, the Mr. Peanut task took 5-10 minutes, and the delay of gratification task took 5 minutes. There was a 6-month interval between the first and second time of the testing phase.

Results

Table 1 shows the means and standard scores of language and executive function tasks both at the first and second phase of testing.

Age Related Differences in Executive Functions

Since the DCCS (0, 1, 2 or 3) and DoG (0 or 1) scores are categorical, a chi square test was conducted between these tasks and the child's age group. The analysis demonstrated a significant effect of age across the DCCS scores, $X^2(12)=28.366$, $p=.005$. Further analysis showed that the young 3-year-olds had lower DCCS scores than the old 4-[$X^2(2)=7.76$, $p=.02$] and young 5-year-olds [$X^2(2)=14.62$, $p=.001$]. Moreover, the old 3-year-olds had lower DCCS scores than the old 4-year-olds [$X^2(3)=5.99$, $p=.05$] at a conventional significant level and then the young 5-year-olds [$X^2(3)=10.07$, $p=.008$] at a significant level.

The relation between age groups and DoG was found to be significant at the conventional level, $X^2(4)=9.313$, $p=.054$. Further analysis showed that only the young 3-year-olds had lower scores than the young 4- [$X^2(1)=5.10$, $p=.02$], old 4- [$X^2(1)=4.66$, $p=.03$] and young 5-year-olds [$X^2(1)=5.10$, $p=.02$]. Other differences between the age-groups were nonsignificant, ($p>.05$).

Before identifying the working memory differences across age groups, normality tests were conducted. Normality tests indicated that our working memory scores do not follow a normal distribution, with skewness of .309 and kurtosis of -.255. So a Kruskal-Wallis test was conducted and it showed that there was a statistically significant difference in Mr. Peanut scores between different age groups, $X^2(4)=21.480$, $p=0.000$.

Gender Related Differences in Executive Functions

Since there were unequal numbers of girls and boys in each age group, a chi square analysis was conducted between DCCS and gender by holding age as a control variable. It was found that there was a significant relation between gender and DCCS scores, $X^2(3)=9.24$, $p=.026$. When investigated at the age level, gender was found to be nonsignificant for the 4-year-olds ($p=.27$) and 5-year-olds ($p=.68$) whereas it was found to be nonsignificant for the 3-year-olds ($p=.054$) at the conventional level. In our study, boys get higher DCCS scores than girls at age 3.

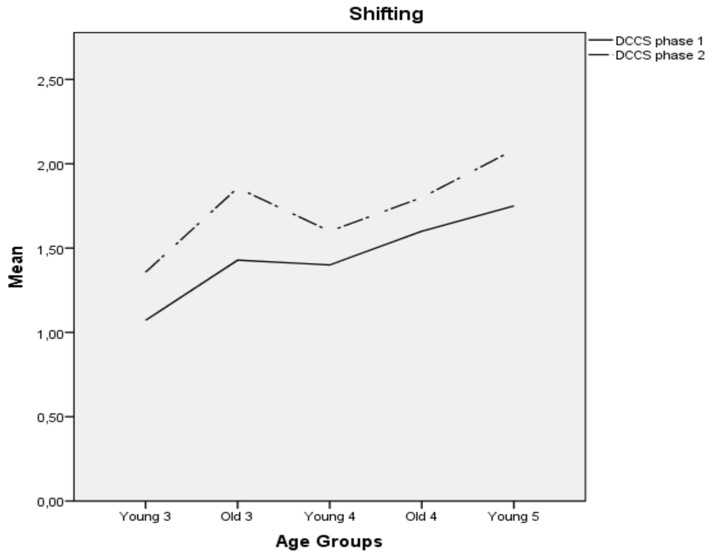
Thus, it was concluded that differences in the DCCS scores across gender stems from the 3-year-old boys performing better than the 3-year-old girls. Moreover, the significant relation between DCCS scores and gender disappeared in the second phase of testing, $X^2(3)=2.81$, $p=.42$. Besides, no significant difference was found for receptive [t (31)=.62, $p=.54$] or expressive language [t (31)=.26, $p=.79$] across gender at age 3. When controlled for age, it was found that gender had no significant effect on DoG [X^2 (1)=1.015, $p=.31$].

Table 1. Descriptive Statistics of Measurements of Executive Functions and Language at the First and Second Phase of Testing on the Basis of Age Groups

	Young 3		**Old 3**		**Young 4**		**Old 4**		**Young 5**		**3 years olds**		**4 years olds**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
DCCS (Phase 1)	1.07	.47	1.43	.94	1.40	.63	1.60	.51	1.75	.45	1.25	.75	1.50	.57
DoG (Phase 1)	.57	.51	.71	.47	.87	.35	.87	.35	.92	.29	.64	.49	.87	.35
Receptive Lang. (Phase 1)	29.86	12.98	43.14	17.08	51.93	14.74	63.53	14.27	67.33	10.26	36.50	16.35	57.73	15.43
Expressive Lang (Phase 1)	28.57	11.35	35.86	9.00	41.73	7.80	48.07	14.40	53.33	8.50	32.21	10.71	44.90	11.82
Mr. Peanut (Phase 1)	.78	.36	.50	.70	1.22	.52	1.73	.44	1.66	.70	1.14	.66	1.48	.54
DCCS (Phase 2)	1.36	.63	1.86	.53	1.60	.51	1.80	.56	2.08	.51	1.61	.63	1.70	.53
DoG (Phase 2)	.57	.51	.64	.50	.80	.41	.87	.35	.83	.39	.61	.50	.83	.38
Receptive Lang. (Phase 2)	42.29	15.37	57.86	13.99	61.07	13.12	73.93	11.50	79.50	9.20	50.07	16.46	67.50	13.78
Expressive Lang (Phase 2)	38.21	7.40	44.14	7.61	48.13	7.16	54.00	11.77	58.50	6.70	41.18	7.96	51.07	10.02
Mr. Peanut (Phase 2)	1.36	0.55	1.78	.53	1.78	.72	2.20	.64	2.05	.62	1.57	.57	1.99	.70

Developmental Patterns

The Wilcoxon signed rank *t* Test was performed to determine if there was a significant time effect in the DCCS and DoG scores. It was found that the children elicited a statistically significant change in the DCCS scores (*Z*=-3.332, *p=0.001*), and in Mr. Peanut scores (*Z*=-5.009, *p=0.000*) across the two time points. However, the change in the DoG scores for 6 months was found to be nonsignificant, (*Z*=-1.000, *p=.317*). In sum, the children in our study showed a significant performance change only in the DCCS and Mr. Peanut tasks.



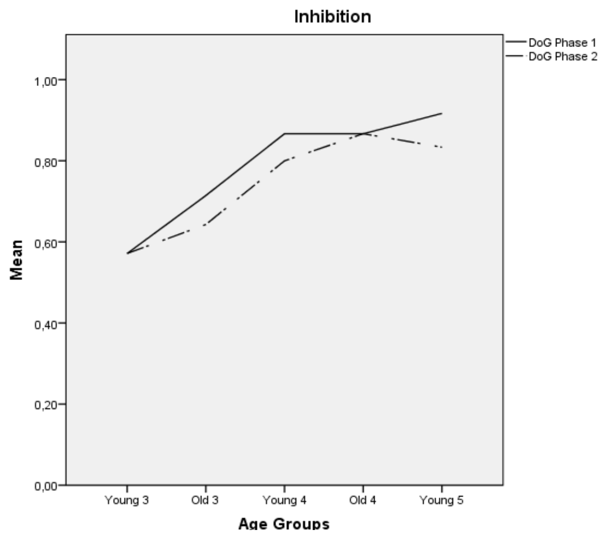


Figure 1. Developmental Patterns of Measures of EF on the Basis of Age Groups.

Further, developmental patterns of measures of EF on the basis of age groups can be seen in Figure 1. It appears that the DCCS and Mr. Peanut tasks followed somewhat similar developmental patterns. Moreover, it seems that all age groups showed a parallel increase in terms of DCCS and Mr. Peanut performance during a 6-month period.

Since this study involved a time period of 6 months, in the last phase of testing, all children's age groups shifted to the successive age group. For instance, if a child was in the young 3-year-old group in the first phase of testing, then s/he was in the old 3-year-old group in the last phase of testing. This made it possible to compare individual children's EF development. Table 2 shows the means of the first phase and the last phase of components of the EF scores of the same children based on their changing age groups.

It appears that except for the DoG task, the other two tasks showed an improvement in all age groups. However, the old 3-year-olds and young 3-year-olds, in particular, seems to show the most improvement in terms of shifting and working memory respectively.

Table 2. Means of the First and Second Phase of Components of EF Scores of the Same Children Based on Their Changing Age Groups

	Young 3	Old 3	Young 4	Old 4	Young 5	Old 5
DCCS	1.07	1.43	1.40	1.60	1.75	
		1.36	1.86	1.60	1.80	2.08
DoG	.57	.71	.87	.87	.92	
		.57	.64	.80	.87	.83
Mr. Peanut	.78	1.50	1.22	1.73	1.66	
		1.36	1.78	1.78	2.20	2.05

Relations among Executive Functions and Language.

Table 3 demonstrates the full (in parentheses) and partial correlations between EF tasks and language tasks at each time of testing.

Two points are noteworthy. First as expected DCCS and Mr. Peanut components of EF show some correlations among each other. Even when age was partialed out, relations between both testing phases of DCCS and Mr. Peanut remained significant (r=.27-.44). However only first testing phase of DoG was correlated with both testing phases of DCCS and the second testing phase of Mr. Peanut. Secondly, all EF measures were correlated with all language measures at both testing phases (r=.24-.51). The partial correlations indicated that DCCS and Mr. Peanut scores were related to language measures independently of age level.

Table 3. Simple and Partial Correlations between Measures of Executive Functions and Language at Both Phases of Testing

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Phase 1										
2. DCCS	1	.19 (.25*)	.44** (.49**)	.28* (.38**)	.35** (.43**)	.39** (.43**)	.09 (.15)	.39** (.44**)	.40** (.47**)	.36** (.44**)
3. DoG		1	.09 (.16)	.09 (.24*)	.18 (.29*)	.24* (.29*)	.63** (.65**)	.19 (.25*)	.26* (.36**)	.23 (.33**)
4. Mr. Peanut			1	.31** (.43**)	.20 (.34**)	.21 (.27*)	.10 (.16)	.52** (.57**)	.36** (.46**)	.22 (.35**)
5. Receptive Lang.				1	.63** (77**)	.24* (34**)	.18 (27*)	.44** (52**)	.75** (84**)	.57** (73**)
6. Expressive Lang.					1	.34** (42**)	.18 (27*)	.39** (48**)	.68** (80**)	.85** (90**)
7. Phase 2										
8. DCCS						1	.12 (.17)	.28* (.34**)	.43** (.49**)	.41** (.47**)
9. DoG							1	.14 (.20)	.27* (.34**)	.14 (.24*)
10. Mr. Peanut								1	.43** (.51**)	.42** (.50**)
11. Receptive Lang									1	.72** (82**)
12. Expressive Lang.										1

Predictive Relations among Early Language and Later Executive Functions.

In order to find out how much of the variance of EF can be explained by earlier language skills, a regression analysis was conducted between the first testing phase of language and the second testing phase of DCCS and working memory. Since when age was partialed out, the relation between language and DoG turned out to be nonsignificant, regression analysis was not held for DoG. The results of the regression analyses are presented in Tables 4 and 5.

Table 4. Regression Analysis: Predicted Influence of Earlier Receptive and Expressive Language on the Shifting Component of Executive Function

	B	Standard Error	Beta	T	sig.
Receptive Language (Phase 1)	.001	.005	.04	.276	.78
Expressive Language (Phase 1)	.017	.008	.38	2.20	.03

The results of the regression analyses showed that earlier receptive and expressive language significantly explained 17% of the variance in later DCCS performance, $F(1.69)=7.14$, $p=.002$. It was found that expressive language significantly contributed to the model ($t=2.20$, $p=.03$, $R^2=.17$). Thus, those children who had more advanced expressive language showed a more progressed DCCS performance 6 months later.

Table 5. Regression Analysis: Predicted Influence of Earlier Receptive and Expressive Language on the Working Memory Component of Executive Function

	B	Standard Error	Beta	T	sig.
Receptive Language (Phase 1)	.013	.006	.36	2.25	.02
Expressive Language (Phase 1)	.010	.008	.20	1.21	.22

The results of the regression analyses showed that earlier receptive and expressive language significantly explained 26% of the variance in the 6-months later working memory performance, $F(1.69)=13.18$, $p=.000$. It was found that receptive language significantly contributed to the model ($t=2.20$, $p=.02$, $R^2=.26$). In other words, those children who had more progressed receptive language showed more progressed working memory performance 6 months later.

Discussion and Conclusions

The goal of this study was to investigate the development and developmental trajectories of the multiple dimensions of EF and to explore how early language skills might be related to EF-development longitudinally. Development of the inhibition, shifting, and working memory components of EF were selected because of their theoretical representability. Overall, our findings showed how EF develops during the preschool years on the group and individual basis and how early language contributes to this development.

First of all, our data showed parallel results with Miyake and Friedman's (2012) general conclusion about EF development. Different components of EF both showed some correlations among each other which were far from perfect and showed different relations with language measures. Thus, the EF measures used in this study showed both unity and diversity as suggested by Miyake and Friedman (2012).

In terms of the working memory and inhibition components of EF, girls and boys showed similar performances. The only gender difference stems from the finding that the 3-year-old boys performed better than the 3-year-old girls on the DCCS task, but this difference disappeared 6 months later. However, this result is contradictory with the results of other studies, which have found later developmental trajectories for boys (Montroy, Skibbe, McClelland and Morrison, 2016) or no gender differences (Wiebe et al., 2011). When we analyzed other possible differences between 3-year-old boys and girls, we did not find any difference in terms of receptive or expressive language. Although only children whose parents were at least high school graduates were included as participants, there may be other social variables that we did not control for and that may be critical for the difference between 3-year-old girls and boys. For example, Hughes, Ensor, Wilson and Graham (2010) found no effect of age, but a rather sociodemographic risk, which is measured by family income, was found to have a relation with latent EF. More work controlling for socioeconomic variables is necessary to explain these inconsistent EF gender relationship findings in the literature.

In line with the studies that show EF develops rapidly during the preschool years (Carlson, 2005; Garon et al., 2008), the children showed age-related improvements in the DCCS and Mr. Peanut performances. Although age effect across the DoG scores was found to be non-significant at the borderline level, the young 3-year-olds in particular, performed worse than the 4-

and 5-year-olds in all three tasks. When interpreting these results, it is important to be cautious regarding whether these developmental differences between measures of EF might be reflecting individual differences rather than age differences, as suggested by Carlson (2005). So we further investigated how individual children showed developments in EF during a 6-month period. In line with age differences, on the individual base, only the DCCS and working memory scores showed important improvements following the 6-month period. The change in the DoG scores across the two testing phases separated by 6 months was found to be nonsignificant. This might mean that children between 3 and 5 years old experience only quantitative changes, which build upon simpler EF abilities (Garon et al., 2008), and if a complex inhibition task were used, it might be possible to see the improvement in inhibition which we failed to find because of the simplicity of the DoG task. Or another reason failing to find an age improvement for inhibition might be the sensitivity of DoG task which is categorical and does not give much range for children.

It appears the DCCS and Mr. Peanut tasks followed similar developmental patterns. Moreover, it seems that all age groups showed a parallel increase in terms of performance in the DCCS and Mr. Peanut tasks during a 6-month period. Beside age differences, the old 3-year-olds showed a rapid increase in terms of DCCS and working memory scores but a linear development in terms of DoG performance, which is a sign of individual differences among the development of EF measures. The same pattern continued to be valid for the old 3-year-olds 6 months later; however, the young 3-year-olds did not show the same rapid increase when 6 months later, they reached the age of the old 3-year-olds.

In line with the earlier findings (Doebel and Zelazo, 2015; Kuhn et al., 2016) and theoretical explanations about the role of language as a mental tool in self-regulation (Vygotsky, 1962), our results showed that early language ability is related with later EF development. We further found that different aspects of language have predictive relations with different components of EF. When the longitudinal relation between language and components of EF was investigated, it was found that all variables contribute to the model of DCCS, but the only significant contribution comes from the variability in expressive language. Additionally, 26% of the variance in later working memory was explained by receptive and expressive language with all variables contributing to the model, but with the only significant contribution coming from the receptive language. Thus, different aspects of language were found to be significant in the developmental rate of different EF measures, which is in accordance with the findings of Kuhn et al. (2016), that is, that EF and language relations are complex and change at different time points.

One explanation is that early language or self-directed speech may facilitate reflection on the representation of the rules, and this, in turn, helps children to formulate higher order rules (Zelazo and Frye, 1998). Thus, children who have earlier more progressed language abilities may better organize information and represent the contradictory rules and may better pay attention to aspects of the task (Doebel and Zelazo, 2013) and this ability may predict their later EF development. The finding of the critical role played by expressive language in DCCS is also in line with the study of Doebel and Zelazo (2015) in which they found an improvement in task performance when the children instead of the experimenter labelled the test cards. The relation between the working memory component of EF and receptive language may be explained by the role of the phonological loop in the vocabulary gain. The phonological loop participates in the storage of words for a short period of time and in the learning of the phonological system of language (Gathercole, Service, Hitch, Adams and Martin, 1999). Thus, with this reciprocal relation, children that have a better vocabulary might show a better rate of development in working memory.

The current study also has several important limitations. One of the limitations is using only one task for the measurement of each component of EF and not measuring aspects of a language other than expressive and receptive vocabulary. Ideally, to obtain a better picture of development, each component would be assessed based on different tasks, which have different degrees of difficulty. Secondly, some of the tasks used in this study are categorical in nature, which might have caused us not to assess the target EF component sensitively. Another possible limitation is that we did not control for some important sociodemographic factors such as income or ethnicity. Thus, the results of this study should be considered within the scope of the tasks used. Lastly, although language precedes executive functions, our data is correlational and far from inferring causality. There may be other variables that mediate this relationship. In sum, this study is important for being one of the few studies that investigate different dimensions of EF both cross-sectionally and longitudinally; and examines the association of language measures with different EF components. Further comprehensive longitudinal works are necessary to determine the underlying mechanisms and possible predictors other than language.

References

Berument, S. K. and Güven, A. G. (2010). *Turkish Expressive and Receptive Language Test: Receptive Vocabulary Sub-Scale (TIFALDI-RT)*. Ankara: Turkish Psychological Society.

Best, J. R., Miller, P. H. and Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review*, *29*, 180-200. Doi: 10.1016/j.dr.2009.05.002.

Best, J. R., Miller, P. H. and Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learn Individual Differences*, *21*, 327-336. Doi:10.1016/j.lindif.2011.01.007.

Blair, C. and Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*, *78*(2), 647-63. Doi:10.1111/j.1467-8624.2007.01019.x

Bohlmann, N.L., Maier, M.F., and Palacios, N. (2015). Bidirectionality in self-regultion and expressive vocabulary: Comparisons between monolingual and dual language learners in preschool. *Child Development,* 86, 1094-1111.

Bull, R. and Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology*, *19*, 273-293. Doi: 10.1207/S15326942DN1903_3.

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology*, *28*(2), 595-616. Doi:10.1207/s15326942dn2802_3.

Case, R. (1985). *Intellectual development: Birth to adulthood*. New York: Academic Press. Doi:10.1111/j.2044-8279.1986.tb02666.x

Clark, C. A., Pritchard, V. E. and Woodward, L. J. (2010). Preschool executive functioning abilities predict early mathematics achievement. *Developmental Psychology, 46,* 1176-1191. Doi: 10.1037/a0019672.

De Ribaupierre, A. and Bailleux, C. (1994). Developmental change in a spatial task of attentional capacity: An essay toward an integration of two working memory models. *International Journal of Behavioral Development*, *17,* 5-35. Doi: 10.1177/016502549401700102.

Diamond, A. (2006). The early development of executive functions. In E. Bialystock & F. I. M. Craik, (Eds.), *The early development of executive functions. Lifespan cognition: Mechanisms of change* (pp. 70-95). Oxford, England: Oxford University Press.

Doebel, S. and Zelazo, P. D. (2013). Bottom-up and top-down dynamics in young children's executive function: Labels aid 3-year-olds' performance on the Dimensional Change Card Sort. *Cognitive Development, 28,* 222-232. Doi:10.1016/j.cogdev.2012.12.001.

Doebel, S. and Zelazo, P. D. (2015). A meta-analysis of the Dimensional Change Card Sort: Implications for developmental theories and the measurement of executive function in children. *Developmental Review*, *38*, 1-28. Doi:10.1016/j.dr.2015.09.001.

Ekerim, M. and Selçuk, B. (2018). Longitudinal predictors of vocabulary knowledge in Turkish children: The role of maternal warmth, inductive reasoning, and children's inhibitory control. *Early Education and Development*, *29*(3), 324-341. Doi:10.1080/10409289.2017.1407607.

Frye, D., Zelazo, P. D. Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development*, *10*, 483-527. Doi: 10.1016/0885-2014(95)90024-1.

Garon, N., Bryson, S. E. and Smith, I. M. (2008). Executive function in pre-schoolers: A review using an integrative framework. *Psychological Bulletin*, *134*, 31-60. Doi: 10.1037/0033-2909.134.1.31.

Gathercole, S. (1998). The development of memory. *Journal of Child Psychology and Psychiatry*, *39*, 3-27.

Gathercole, S. E., Service, E., Hitch, G., J., Adams, A. M. and Martin, A. J. (1999). Phonological short-term memory and vocabulary development: Further evidence on the nature of the relationship. *Applied Cognitive Psychology*, *13*, 65-77.

Gültekin-Ahçı, Z. (2016). 3-5 yaş çocuklarının yürütücü işlev performansları ve dil becerileri ile ilişkisi. *Cumhuriyet International Journal of Education, 5*(2), 84-99.

Hofmann W., Schmeichel, B. J. and Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Science*, *16*, 174-180. Doi:10.1016/j.tics.2012.01.006.

Hughes, C., Ensor, R., Wilson, A. and Graham, A. (2010). Tracking executive function across the transition to school: A latent variable approach. *Developmental Neuropsychology, 35*, 20-36. Doi:10.1080/87565640903325691.

Karakaş, S. and Karakaş, H. M. (2000). Yönetici işlevlerin ayrıştırılmasında multidisipliner yaklaşım: bilişsel psikolojiden nöroradyolojiye. *Klinik Psikiyatri, 3*, 215-227.

Karakelle Ş. S. and Ertuğrul, Z. (2012). Zihin kuramı ile çalışma belleği, dil becerisi ve yönetici işlevler arasındaki bağlantılar küçük (36-48 ay) ve büyük (53-72 ay) çocuklarda farklılık gösterebilir mi? *Türk Psikoloji Dergisi, 27*, 1-25.

Kuhn, L. J., Willoughby, M. T., Vernon-Feagans, L. and Blair, C. B. (2016). The contribution of children's time-specific and longitudinal expressive language skills on developmental trajectories of executive function. *Journal of Experimental Child Psychology, 148*, 20-34. Doi:10.1016/j.jecp.2016.03.008.

Mischel, W., Shoda, Y. and Rodriguez, M. L. (1989). Delay of gratification in children. *Science*, *244*, 933-938.

Doi:10.1126/science.2658056.

Miyake, A. and Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: four general conclusions. *Current Directions in Psychological Science*, *21*(1), 8-14. Doi:10.1177/0963721411429458.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A. and Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49-100. Doi:10.1006/cogp.1999.0734.

Montroy, J. J., Bowles, R. P., Skibbe, L. E., McClelland, M. M. and Morrison, F. J. (2017). The development of self-regulation across early childhood. *Developmental Psychology*, *52,* 1744-1762. Doi: 10.1037/dev0000159.

Moses, L. J. and Tahiroğlu, D. (2010). Clarifying the relation between executive function and children's theories of mind. In J. Carpendale, G. Iarocci, U. Müller, B. Sokol & A. Young, (Eds.), *Self- and social-regulation: exploring the relations between social interaction, social cognition, and the development of executive functions* (pp. 218-233). Oxford University Press. Doi: 10.1093/acprof:oso/9780195327694.003.0009.

Munakata, Y. (2001). Graded representations in behavioral dissociations. *Trends in Cognitive Sciences, 5,* 309-315. Doi:10.1016/S1364-6613(00)01682-X.

Vygotsky, L. S. (1962). *Thought and language.* Cambridge MA: MIT Press.

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A.C., Chevalier, N. and Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of Experimental Child Psychology*, *108*, 436-452. Doi:10.1016/j.jecp.2010.08.008

Zelazo, P. D., Craik, F. I. M. and Booth, L. (2004). Executive function across the life span. *Acta Psychologica*, *115*, 167-183. Doi:10.1016/j.actpsy.2003.12.005.

Zelazo, P. D. and Frye, D. (1998). Cognitive complexity and control: The development of executive function. *Current Directions in Psychological Science, 7,* 121-126. Doi:/pdf/10.1111/1467-8721.ep10774761.