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Self-regulation in ethnic minority children : associations with academic performance and the transition to formal schooling

Yeniad Malkamak, N.

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Author: Yeniad Malkamak, Nihal

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Cognitive flexibility in children across the transition to school: A longitudinal study

Nihal Yeniad, Maike Malda, Judi Mesman, Marinus H van IJzendoorn, Rosanneke A. G. Emmen & Mariëlle J.L. Prevoe. Manuscript submitted for publication.

ABSTRACT

Longitudinal research exploring the development of cognitive flexibility is lacking. In this study we investigated the speed-accuracy pattern in cognitive flexibility performance measured in the mixed block of a task switching paradigm in eighty-seven 5- to 6-year-old children before and after the transition to formal education. For the total group, longitudinal change was observed in accuracy but not in speed of responding. Children with low accuracy scores in kindergarten were faster than those with high accuracy scores, but the low-accuracy group showed a significant performance gain in accuracy over time, whereas high-accurate kindergartners only gained in speed. These results suggest an important role of formal schooling in cognitive control in narrowing the performance gap between less able children and their more able peers. The findings also show that diverse developmental paths in flexible thinking can be identified.

Keywords: flexibility, shifting, executive function, task switching, cognitive development, children

INTRODUCTION

Flexible thinking in the face of ever-changing situations is crucial for human cognition. This ability, known as the shifting or cognitive flexibility component of executive function (EF), refers to switching between multiple and conflicting representations, strategies or responses as task demands change (Miyake et al., 2000). This is a decision-making process in which a compromise is made between making quick and correct choices (Bogacz, Wagenmakers, Forstmann, & Nieuwenhuis, 2010). Some individuals tend to make fast decisions by taking the risk of making errors; others tend to use additional time to ensure that they make the right choice (Ivanoff, Branning, & Marois, 2008). Although accuracy and speed are interrelated (Pachella, 1974), it is unclear whether they capture the same processes (Cragg & Chevalier, 2012) or whether they always go in the opposite direction across conditions and across people (Salthouse, 2010). Previous research has shown that the speed-accuracy tradeoff in task switching develops over time (Davidson, Amso, Anderson, & Diamond, 2006). Young children are too impulsive to trade speed for making correct decisions in contrast to adults. The major gains in shifting ability occur in the preschool years although it shows a protracted development until adulthood (Cragg & Chevalier, 2012). The first year of formal education, during which children need to adjust to a set of standards that are likely to be substantially different from those in kindergarten and at home, provides children with several opportunities to use and practice EF skills (Diamond, Barnett, Thomas, & Munro, 2007). The main aim of this study is to explore children's speed-accuracy pattern in cognitive flexibility performance before and after the transition to the first year of formal education, which is an important milestone in children's cognitive development.

Cognitive flexibility

Cognitive flexibility enables us to see the world from a new and different perspective, which is vital for adaptation and creativity (Davidson et al., 2006). We build particular representations to different circumstances and switch between the competing responses by activating and modifying the representations in a dynamic way when circumstances change unpredictably (Deak & Narasimham, 2003). This is a complex cognitive mechanism involving multiple subprocesses. Diamond (2006) proposed that flexibility incorporates two other well-known EF components: working memory for keeping task goals actively in mind and inhibition for overriding the previous task set. On the other hand, there is some evidence showing that working memory, rather than inhibition, mainly accounts for cognitive flexibility in young children (Blackwell, Cepeda, & Munakata, 2009; Cepeda & Munakata, 2007). Accordingly, having stronger working memory representations of the current task enhances successful switching, which cannot be explained by inhibitory abilities, motivation or general cognitive

ability. Nevertheless, the nature of cognitive flexibility is not yet fully understood. It involves other EF components to some extent, there seems to be a consensus that cognitive flexibility cannot be reduced to one single component or cannot be explained by the combination of inhibition and working memory per se (Cragg & Chevalier, 2012).

Task switching

In recent years, cognitive flexibility has been frequently assessed by the task-switching paradigm in school-age children (Crone, Bunge, van der Molen, & Ridderinkhof, 2006; Davidson et al., 2006; Huizinga, Burack, & Van der Molen, 2010; Karbach & Kray, 2007). In the task-switching paradigm, participants are asked to perform the same task across all trials in simple blocks whereas they must alternate between two tasks from trial to trial in mixed blocks. They switch their response when the rule changes from trial to trial (i.e., switch trials) and they repeat their response when the rule does not change (i.e., nonswitch trials). Comparing performance between single and mixed blocks (global switching) or performance between switch trials and nonswitch trials within mixed blocks (local switching) taps into the different processes specific to shifting ability (Cragg & Nation, 2010). The difference scores, namely costs in accuracy (or errors) and reaction time between different blocks (i.e., single versus mixed) or types of trials (i.e., switch versus nonswitch), are commonly used as indicators of shifting performance. It has been argued that age-related changes are more noticeable while comparing performance between the single and mixed blocks than comparing performance on different types of trials within the mixed block (Dibbets & Jolles, 2006; Karbach & Kray, 2007; Kray, Eber, & Lindenberger, 2004). There are however some concerns regarding the reliability of the difference scores due to the restricted range and variability of the scores which makes it difficult to detect individual differences (Eide, Kemp, Silberstein, Nathan, & Stough, 2002; Lee, Ng, & Ng, 2009; Strauss, Allen, Jorgensen, & Cramer, 2005).

The task score that is used as an indicator of cognitive flexibility (i.e., accuracy, reaction time or efficiency) mostly varies with the age of the participant. Whereas accuracy is typically used in preschoolers, reaction time is reported in older children and adults. It has been suggested to measure both to make valid comparisons between different age groups (Cragg & Chevalier, 2012). Studies comparing performance of distinct age groups have shown that slowing down responses for accurate shifting is an age-related improvement (Crone et al., 2006; Davidson et al., 2006). With increasing age, people are more likely to know that slowing down is sometimes necessary for accurate performance and to detect the situations where slowing down is more advantageous than maintaining speed. Longitudinal studies might be useful to obtain a more nuanced understanding regarding which aspects of performance on a shifting task change with age (Best & Miller, 2010). Although the early

elementary school years represent a critical period in the development of cognitive flexibility (Roebbers, Rothlisberger, Cimeli, Michel, & Neuenschwander, 2011), there seems to be no study examining speed-accuracy pattern on this ability longitudinally in these years.

Factors related to cognitive flexibility

There are a number of variables that might be related to the development of shifting ability. A strong association between language and cognitive flexibility has been reported although the mechanisms explaining the nature of the association are not exactly known (Jacques & Zelazo, 2005). Inner speech is considered to help one to form representations of the rules that are used to retrieve and activate the relevant goals of the task (Cragg & Nation, 2010). In a longitudinal study, the rates of change in a latent EF factor reflecting planning, inhibitory control, and working memory performance across the transition to school were predicted by children's verbal mental age (assessed by a vocabulary scale), indicating that school experience functioned as "an equalizing force" by helping verbally less able children to make the greatest gains and to catch up with their peers (Hughes, Ensor, Wilson, & Graham, 2010). The findings point to the importance of language for the development of executive control, but it is not clear whether this holds for cognitive flexibility.

In addition, previous research has shown that family socio-economic status (SES) is associated with children's cognitive outcomes as it affects the quality of stimulating resources and experiences in the home (Bradley & Corwyn, 2002). Research focusing on the potential relation between SES and shifting ability is scarce. There is some cross-sectional evidence showing that poverty affects performance on several EF measures including those requiring shifting ability in kindergarteners and school-age children (Noble, Norman, & Farah, 2005; Sarsour et al., 2011). Some findings also demonstrated that cognitive flexibility is affected by SES in infancy (Lipina, Martelli, Vuelta, & Colombo, 2005) and delays are stable over time (Clearfield & Niman, 2012). Hughes and colleagues (2010) reported that family income did not predict developmental changes in EF from the age of four to six years, indicating that children from poorer families continued to stay behind those from wealthier families following the transition. Thus, previous findings suggest that SES may have irreversible consequences in EF development, and hence needs to be taken into account in investigating the early development of cognitive flexibility.

Child characteristics such as gender may also lead to individual differences in performance on cognitive flexibility tasks, although the findings are ambiguous. Some studies showed that girls outperform boys on EF measures in the early years of life (Hughes & Ensor, 2005; Wiebe, Espy, & Charak, 2008), others reported no gender difference in preschoolers (Vitiello, Greenfield, Munis, & George, 2011) and school-aged years (Ardila, Rosselli, Matute, & Guajardo, 2005). It is likely that the gender effect on EF performance

varies with children's age, tasks used to measure EF components of interest, or the score type of the task.

The current study

There is some evidence showing that flexibility is related to school readiness (Vitiello et al., 2011) and academic achievement (Yeniad, Malda, Mesman, Van IJzendoorn, & Pieper, 2013). In this regard, examining the development of this ability in diverse samples especially those who may have difficulties at school is crucial. Some studies demonstrated that ethnic minority children might be at risk in academic achievement due to several reasons such as coming from socioeconomically disadvantaged families (Suárez-Orozco & Suárez-Orozco, 2001), attending elementary schools with deprived resources and low academic focus (Crosnoe, 2005), having a low level of host language proficiency (Bhattacharya, 2000), and being less likely to be enrolled in center-based child care or preschool before formal education (Magnuson, Lahaie, & Waldfogel, 2006). The transition to formal schooling is an assessment point for educators to identify potential risk and protective factors that may influence children's long-term academic trajectories. Tracking the early development of cognitive flexibility in this population may provide some insight regarding potential assessment and prevention programs for academic difficulties.

In this study, we explore the development of cognitive flexibility performance in speed and accuracy in 5- to 6-year-old ethnic minority children across the transition to formal reading and writing education, taking into account the potential associations with vocabulary, working memory and SES. The contributions of this study are threefold. First of all, most of the previous research regarding cognitive flexibility has been conducted either in preschoolers (Chevalier & Blaye, 2008; Diamond, Carlson, & Beck, 2005; Yerys & Munakata, 2006) or school-age children (e.g., Cepeda, Kramer, & Gonzalez de Sather, 2001; Crone et al., 2006; Kray, Eber, Linderberger, 2004). Studies investigating the ability both in preschool and school-age years are scarce (e.g., Davidson et al., 2006; Karbach & Kray, 2007). Longitudinal research examining the development of flexible thinking during the transition to formal schooling is lacking. Our study is an attempt to obtain a nuanced understanding of which aspects of cognitive flexibility performance change in this period. Second, given some concerns regarding the question whether different types of scores tap into the same processes of executive control (Cragg & Chevalier, 2012) or whether they develop in the same pattern (Davidson, et al., 2006; Salthouse, 2010), we investigate developmental changes of task switching both in accuracy and reaction time. Third, our sample involves children with a Turkish ethnic minority background in the Netherlands. Given a body of research showing that ethnic minority children might have difficulties at school (Bhattacharya, 2000; Magnuson, et al., 2006), research on the development of cognitive flexibility that contributes

to school readiness (Vitiello, et al., 2011) and achievement (Yeniad et al., 2013) could especially benefit this particular group.

METHOD

Participants and Procedure

Turkish immigrant mothers, who had 5- or 6-year old children in the 2nd year of Dutch primary school—which corresponds to kindergarten in the U.S.—were recruited from the municipal records of several cities in the Netherlands. The sample consisted of 87 Turkish immigrant mothers and their children. To ensure the homogeneity of the sample, mothers who were born in the Netherlands (with at least one of their parents born in Turkey) or moved to the Netherlands before the age of 11, were selected. Furthermore, if the child's father's background was not Turkish, the family was excluded. Eligible families were informed about the research project through an introduction letter and a brochure. All correspondence was in Turkish and Dutch. In total, 639 families were reached of whom 113 (18%) agreed to participate. A subgroup of mothers who did not want to participate (N = 151) provided some general information about their families by filling out a form. These families did not differ significantly from the participating families in age of father, mother and child, child gender, country of birth of mother and father, mother's marital status, family situation, and the number of siblings (*ps* .12 to .89).

Participating families filled out questionnaires and they were visited at home at two different time points: when children were in the second semester of kindergarten (T1) and one year later, in the second semester of the first year of formal education (T2). Two trained research assistants conducted mother and child interviews, child testing and video observation during the 2-hour home visit. The tasks of interest for the current study were administered to the child in a quiet room in the following order: the Expressive One Word Picture Vocabulary Test, Digit Span Backward and Hearts and Flowers.

In kindergarten, the data for nine children were missing due to the technical problems. Of the 104 children participating in the study in kindergarten, 87 provided valid data for the variables of interest in the first grade of formal education. Children who dropped out after kindergarten did not differ in age, gender, number of siblings, birth rank, country of birth of parents, mother's marital status, family SES, working memory capacity, vocabulary performance and speed on the task switching paradigm (*ps* .12 to .87) from those who continued to participate in our study in the first grade. However, children who dropped out performed significantly worse on the task switching paradigm in the first wave of assessments,

evidenced by fewer accurate responses in the mixed block ($p < .05$) compared to children who stayed in the study.

At the first time point of data collection (kindergarten), the children had a mean age of 6.07 years ($SD = .30$). Forty-one percent of the sample consisted of boys. The mothers had a mean age of 32.73 years ($SD = 4.12$). Most children lived in two-parent families with both their biological parents (94%). The majority of the children had one sibling (60.9%), 11.5% had no siblings and 27.5% had two or more siblings. Sixty percent of the children were the first-born child in their family.

Measures

Vocabulary. The Expressive One Word Picture Vocabulary Test (EOWPVT, Brownell, 2000) was translated into Dutch to measure Dutch expressive vocabulary. In this test, a picture is shown to the child on a computer screen and he or she is asked to name the picture in one word. The child's answers were recorded on a score sheet. In addition, the administration was audio-recorded to be able to decide on the scoring afterwards in case of ambiguous answers. Based on pilot assessments of the Dutch translation of this test, the map of the United States was replaced with a map of the Netherlands and the items 118 (reel), 146 (prescription) and 160 (monocular) were deleted since there were no appropriate Dutch translations. Item-response analyses (Furr & Bacharach, 2008) revealed that the increase in difficulty level of the items is similar to the increase in difficulty level of the items in the original English version. The raw scores that were computed according to the test manual were used. The split-half (odd/even) sample reliability was .97.

Working Memory. The Digit Span Backward (Wechsler, 2003) was used as a verbal working memory test, in which the child hears a series of digits that were audio-recorded at a rate of 1 digit per second and is asked to repeat the digits in the opposite order. The digit clusters range from 2 to 9 digits, and there are eight trials. Each trial contains two items with similar numbers of digits. The task is terminated when the child fails to repeat both items of a trial correctly. The total number of correct responses was used. The split-half (odd/even) sample reliability was .85.

Cognitive Flexibility (task switching). The Hearts and Flowers task (Diamond et al., 2007) was used to measure task switching. The task was presented on a Dell laptop computer using E-prime 2 (Schneider, Eschman, & Zuccolotto, 2007) to present the stimuli and record responses for each trial. There were two types of stimuli; a red heart and a red flower appearing either on the right or the left side of the screen. Each stimulus was presented for 1500 msec. The response button for the left side was the "z" key on the computer keyboard, and the response button for the right side was the "m" key. The response buttons were indicated with a colored sticker. The task consisted of three blocks; congruent-only, incongruent-only and

mixed. For each block, instructions were presented on the computer screen and read aloud by the researcher to ensure that the child understood the requirements. Each of the first two blocks started with a block of four practice trials. Prior to the third block, no practice trials were applied.

The first block (congruent-only) involved 12 trials in which the stimulus (a heart) appeared randomly on the right or left side of the screen. Participants were instructed to press the key that matched the side of the screen at which the heart appeared. The second block (incongruent-only) consisted of 12 trials, in which the stimulus was a flower. In this block, the participants were asked to press the key on the side opposite of the flower. The third and last block (mixed) included 16 congruent and 16 incongruent trials, which were semi-randomly mixed. The congruent-only block requires remembering a rule (press on the same side as the heart) whereas the incongruent-only block requires inhibiting the previously learned rule in addition to keeping a new rule in mind (press on the opposite side of the flower). Participants perform the same task across trials in single blocks (i.e., only hearts or only flowers are shown), whereas the mixed block requires switching between the two tasks (the same side and the opposite side), which taps into cognitive flexibility (Diamond, et al., 2007). Two consecutive trials can be either nonswitch trials (i.e., both show a heart and both show a flower) or switch trials (i.e., one shows a heart and the other one a flower). The number of switch trials varied between and within individuals as a result of the semi-randomized design of the task.

In the statistical analyses, median reaction time for all items and mean accuracy scores were used. Reaction time of only correct items and reaction time of all items were highly correlated ($r = .93, p < .001$ in single, $r = .95, p < .001$ in mixed block at T1 and $r = .98, p < .001$ in single, $r = .97, p < .001$ in mixed block at T2). Responses faster than 200 ms were excluded from the analyses as they indicate a failure to wait for the upcoming stimulus or to release the button following the previous trial (Davidson et al., 2006). Accuracy and reaction time of the practice items and the first trial in each block, which was considered as a warm-up, were excluded from the analyses. Trials following an error were not excluded from the analyses due to the limited number of trials in the blocks. The mean accuracy and median reaction time scores of the congruent-only and incongruent-only blocks were averaged to compare performance between the single-task condition and the mixed condition. In addition to the absolute scores (aggregated accuracy and reaction time per block), we computed global (or general) switch costs as the difference between the single blocks versus all trials in the mixed block as previous research suggested that age-related changes are more profound in global comparison than local comparison (e.g., Korbach & Kray, 2007).

Socioeconomic status (SES). Family SES was based on the family's annual gross income and the highest completed educational level of both parents. The annual gross income was measured on a 7-point scale (1 = no income to 7 = more than €50,000). Parents'

highest completed education was also measured on a 7-point scale (1 = no qualification to 7 = university level degree). Parental education level was recoded according to the international standard classification of education (ISCED; UNESCO, 2011). Because the factor analysis showed that maternal and paternal educational levels and annual family gross income loaded on a single factor (loadings of .81, .83, and .78 respectively), SES was computed as the mean of the standardized values of the income and education variables. For the children of single mothers ($n = 5$), SES was based on mother's education level and income. There were no missing values for mother's education. The missing values for father education ($n = 3$) and family income ($n = 7$) were imputed through regression in which the available values in the SES variables were used as predictors.

Analyses

Statistical analyses were performed using SPSS 19 software. Longitudinal changes in accuracy and speed of cognitive flexibility performance from kindergarten (T1) to the first grade of formal education (T2) were explored in repeated measures ANOVAs. The first group of analyses was conducted with 'task blocks across time' as the within-subjects factor (T1Single, T1Mixed, T2Single, T2Mixed) and the absolute scores of the task blocks (mean accuracy and median reaction time aggregated per block) as separate dependent variables. The second group of analyses was performed with time (T1, T2) as the within-subjects factor and global switch costs in accuracy and reaction time as separate dependent variables to examine whether developmental changes were observed in the cost scores. Greenhouse-Geisser corrections were performed when necessary.

Covariates

To investigate whether the longitudinal changes in working memory or vocabulary performance explain the improvement of cognitive flexibility performance from kindergarten to the first grade, differences between T1 and T2 working memory and vocabulary scores were computed. These difference scores were used as covariates in addition to gender and SES in a second set of GLM analyses.

Accuracy groups

To understand the relation between accuracy and reaction time longitudinally, children were grouped by a median split based on the absolute accuracy scores in the mixed block at T1 (*median* = 0.60). The high-accuracy group ($M = 990.70$, $SD = 202.70$) were significantly slower than the low-accuracy group ($M = 740.24$, $SD = 213.97$) in the mixed block at T1 ($t(85) = -5.60$, $p < .001$). High accuracy children performed better (evident by more accurate

responses) than low accuracy children both on the switch ($t(84) = -11.37, p < .001$) and nonswitch trials ($t(84) = -11.65, p < .001$) of the mixed block. Seventy percent of T1 high accuracy children scored higher than the median accuracy score of the mixed block at T2 ($median = .70$), $\chi^2(1) = 15.75, p < .001, \phi = .42$. The mean number of switch trials was not significantly different between the groups, $t(85) = 0.88, p = .38$ at T1, and $t(85) = 0.13, p = .89$ at T2. In a third set of analyses, the “T1 accuracy groups” variable was included as additional between-subjects factor.

RESULTS

Descriptives

Descriptive statistics of the main variables at T1 and T2 are reported in Table 1. Bivariate correlations between the child’s age, SES, working memory, vocabulary, and task switching scores were computed (Table 2). In line with the speed-accuracy tradeoff phenomenon, reaction time showed a positive correlation with accuracy in the mixed block of the task switching paradigm at both time points. Working memory was positively associated with absolute reaction time in the mixed block at T1. In addition, SES and vocabulary performance measured at T1 were positively correlated with absolute accuracy in the mixed block measured at T2. Gender differences were examined on the variables of interest. Boys were significantly faster than girls in the mixed block at T1, $t(85) = -2.06, p < .05$, and in the single block at T2, $t(85) = -2.40, p < .05$. No gender differences were found for global switch costs in accuracy or reaction time.

Table 1
Descriptive Statistics for Child's Age and Test Scores Before and After Transition to Formal Education

	Kindergarten (T1)				First grade (T2)				
	Total sample (N = 87)	T1 high-accuracy (N = 44)	T1 low-accuracy (N = 43)	Total sample (N = 87)	T1 high-accuracy (N = 44)	T1 low-accuracy (N = 43)	Total sample (N = 87)	T1 high-accuracy (N = 44)	T1 low-accuracy (N = 43)
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
Child age (months)	72.44 (3.65)	72.11 (3.99)	72.77 (3.27)	82.96 (3.33)	83.10 (3.53)	82.84 (3.15)	82.96 (3.33)	83.10 (3.53)	82.84 (3.15)
Working memory	3.59 (1.99)	4.20 (1.66)	3.30 (1.99)	4.64 (1.61)	4.86 (1.15)	4.41 (1.96)	4.64 (1.61)	4.86 (1.15)	4.41 (1.96)
Vocabulary	46.72 (12.11)	50.75 (14.32)	43.41 (9.35)	57.09 (11.96)	58.86 (12.27)	55.28 (11.51)	57.09 (11.96)	58.86 (12.27)	55.28 (11.51)
SES (standardized)	0.00 (0.80)	0.12 (0.78)	-0.12 (0.81)	-	-	-	-	-	-
TS Single Acc	0.91 (0.11)	0.93 (0.86)	0.88 (0.12)	0.91 (0.11)	0.93 (0.86)	0.89 (0.13)	0.91 (0.11)	0.93 (0.86)	0.89 (0.13)
TS Mixed Acc	0.65 (0.18)	0.80 (0.11)	0.49 (0.07)	0.70 (0.19)	0.78 (0.18)	0.61 (0.17)	0.70 (0.19)	0.78 (0.18)	0.61 (0.17)
TS Single RT	642.82 (202.52)	616.80 (187.88)	669.43 (215.43)	523.63 (145.48)	517.04 (136.65)	530.38 (155.34)	523.63 (145.48)	517.04 (136.65)	530.38 (155.34)
TS Mixed RT	866.91 (242.48)	990.70 (202.85)	740.24 (213.97)	788.95 (223.60)	803.50 (211.78)	774.08 (236.65)	788.95 (223.60)	803.50 (211.78)	774.08 (236.65)
Switch costs Acc	0.26 (0.18)	0.12 (0.10)	0.39 (0.14)	0.21 (0.19)	0.15 (0.18)	0.28 (0.19)	0.21 (0.19)	0.15 (0.18)	0.28 (0.19)
Switch costs RT	224.97 (118.16)	373.90 (205.30)	68.95 (250.26)	265.32 (188.16)	286.45 (173.95)	243.69 (201.43)	265.32 (188.16)	286.45 (173.95)	243.69 (201.43)

Note. TS = Task switching; Acc = Accuracy (mean); RT = Reaction time (median) in msec.

Longitudinal changes in the absolute scores and global switch costs

The first group of repeated-measures ANOVAs revealed a significant main effect of ‘task blocks across time’ factor (T1Single, T1Mixed, T2Single, T2Mixed) on mean accuracy $F(2.77, 238.94) = 93.52, p < .001, \eta^2_p = .52$ and median reaction time $F(2.48, 213.61) = 71.01, p < .001, \eta^2_p = .45$. Contrasts demonstrated that children performed worse in the mixed block than the single block, as shown by less accurate responses, $F(1, 82) = 64.51, p < .001, \eta^2_p = .66$ at T1, $F(1, 82) = 37.35, p < .001, \eta^2_p = .54$ at T2, and longer reaction times, $F(1, 82) = 20.00, p < .001, \eta^2_p = .40$ at T1, $F(1, 82) = 82.96, p < .001, \eta^2_p = .69$ at T2. From kindergarten to the first grade, children showed a significant increase in accuracy in the mixed block $F(1, 86) = 5.80, p < .05, \eta^2_p = .06$, but not in the single block. In addition, they showed a significant decrease in reaction time in the single $F(1, 86) = 38.07, p < .001, \eta^2_p = 0.31$, but not in the mixed block (Figure 1). The gain in the mixed block performance, which requires flexible responding to conflicting demands, was in accuracy, but not in reaction time. Controlling for the potential influences of gender, SES, the longitudinal differences in working memory and vocabulary in the repeated measures ANCOVA with ‘task blocks across time’ as within-subjects factor and absolute accuracy or reaction time as the dependent variables did not change the results. There were no significant interactions between time and any of the covariates. The second group of repeated-measures ANOVAs with time (T1, T2) as the within-subjects factor and global switch costs as separate dependent variables did not show significant changes for accuracy ($p = .10$) or reaction time ($p = .21$).

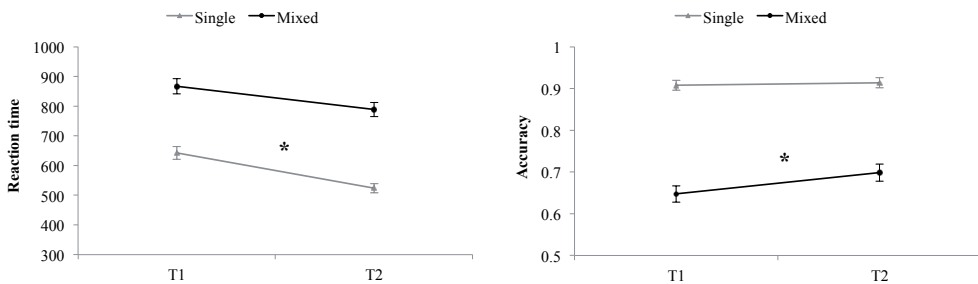


Figure 1. Longitudinal change in the single and mixed blocks of the task switching paradigm ($\pm SE$). Asterisk (*) indicates significant difference.

Longitudinal patterns of the accuracy groups in absolute scores

The repeated measures ANCOVA with ‘task blocks across time’ as within-subjects factor, T1 accuracy groups (low versus high accuracy) as between-subjects factor, gender, SES, the longitudinal differences in working memory and vocabulary as the covariates on absolute

accuracy and reaction time as the dependent variables revealed a significant interaction between ‘task blocks across time’ and ‘T1 accuracy groups’ factors on accuracy, $F(2.54, 208.30) = 25.02, p < .001, \eta^2_p = 0.23$ and reaction time, $F(2.51, 206.32) = 13.58, p < .001, \eta^2_p = 0.14$. Within-subjects contrasts revealed that in kindergarten the T1 high-accuracy group showed a significant increase in reaction time from the single to the mixed block at T1, $F(1,39) = 52.21, p < .001, \eta^2_p = 0.57$ in contrast to the T1 low-accuracy group who did not change their speed from the single to the mixed block ($p = .41$). In the first grade however, both groups were able to slow down from the single to the mixed block (T1 high-accuracy group: $F(1,39) = 45.76, p < .001, \eta^2_p = 0.54$, T1 low-accuracy group: $F(1,38) = 31.12, p < .001, \eta^2_p = 0.45$). A glance on the longitudinal performance of the groups in the mixed block (Figure 2) demonstrated that the T1 high-accuracy group increased their speed, $F(1,39) = 11.66, p < .01, \eta^2_p = 0.23$ without any significant gain (or loss) in accuracy ($p = .73$). The T1 low-accuracy group, on the other hand increased their accuracy in the mixed block, $F(1,38) = 10.35, p < .01, \eta^2_p = 0.21$, without any significant change in speed ($p = .58$). Despite the accuracy gain of the T1 low-accuracy children over time, they were still significantly less accurate ($M = 0.61, SD = 0.17$) than T1 high-accuracy children ($M = 0.78, SD = 0.18$) in the mixed block at T2, $t(85) = -4.48, p < .001$.

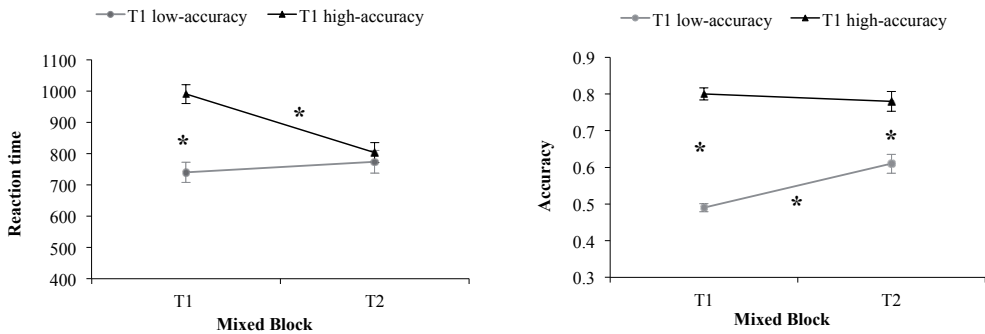


Figure 2. Longitudinal change of the T1 accuracy groups in the mixed block of the task switching paradigm (\pm SE). Asterisk (*) indicates significant difference.

DISCUSSION

The findings of our study showed that 5- to 6-year-old ethnic minority children showed increases in absolute accuracy scores on a cognitive flexibility task from kindergarten to first grade when they had to switch back and forth between two conflicting tasks that appeared randomly (i.e., the mixed block). In addition, children who showed high switching accuracy in kindergarten maintained their initial performance level from kindergarten to the first

grade, whereas those in the low-accuracy group improved their performance substantially. The reaction time patterns revealed that children in the high-accuracy group became faster whereas reaction time in the low-accuracy group did not change. Additional analyses demonstrated no developmental changes in the decrease in performance between the single and mixed blocks (i.e., global switch costs) from kindergarten to first grade.

Taking a close look at absolute speed and accuracy scores of the mixed block in a cognitive flexibility task provided some insight in how children handle an ambiguous situation with continuously changing, conflicting and time-limited demands. Our findings based on the performance of the whole sample suggested that the developmental change in flexible thinking was observed only in accuracy but not in speed of responding from kindergarten to the first year of formal schooling after taking into account the potential effect of the covariates (the longitudinal differences in working memory, vocabulary in addition to SES and the child's gender). This result seems to be in line with previous findings that accuracy of responding is more sensitive to age-related differences in performance than reaction time, due to high variability of speed in the task-switching paradigm during early and middle childhood (Diamond & Kirkham, 2005; Hommel, Kray, & Lindenberger, 2011). In the literature, the scoring methods of flexibility measures vary. Different tasks provide different scores such as reaction time, accuracy, and efficiency. In addition, some tasks provide difference or cost scores (e.g., reaction time difference between Parts A and B of Trail Making Task), whereas others give absolute scores (e.g., total reaction time to complete the task). The current results support the idea that different score types could show different results and hence could lead to different conclusions (Davidson et al., 2006).

To obtain a deeper understanding of how accuracy and speed of flexible responding unfold longitudinally, we distinguished between children showing high and low accuracy in the mixed block in kindergarten (T1). As expected, T1 high-accuracy children were significantly slower than T1 low-accuracy children in the mixed block. However, the speed difference between the groups disappeared in the first grade because the T1 high-accuracy group increased speed whereas the T1 low-accuracy group did not change speed. In contrast, the accuracy gap between the groups remained significant in the first grade despite the significant gain in accuracy of T1 low-accuracy group. The T1 high-accuracy group showed no significant change in accuracy from the first to the second wave of assessment. It is likely that progress of more competent children (the high-accuracy group) may be more limited due to a ceiling effect. On the other hand, the T1 low-accuracy group was still less accurate than the T1 high-accuracy group in the first grade despite their gains in accuracy. These findings indicate that children in the two accuracy groups showed longitudinally different response patterns to ambiguity and conflict resulting from task switching. The transition to formal education is characterized by changes in context and content of learning as well as expectations regarding children's performance. Individuals differ in the level of adjustment

to such changes. We suggest that children may have benefited from the transition period differentially in their development of flexible thinking, in line with previous research revealing that low performing children show greater gains in executive function during the transition to school (Hughes, Ensor, Wilson, & Graham, 2010).

The children's minority status might have specific implications for the interpretation of our results. Our study sample consisted of ethnic minority children who were all born in the Netherlands and most of whom have at least one parent who was born in the Netherlands as well. On average, ethnic minority children (even of the third generation) perform less well in some areas of learning (Kao & Tienda, 1995; Leventhal, Xue, & Brooks-Gunn, 2006), are more likely to drop out of school without a diploma (Rumberger, 1995), and tend to be from lower socioeconomic backgrounds than ethnic majority children (Suárez-Orozco & Suárez-Orozco, 2001). From this perspective, our findings are encouraging in that the school transition seems to have a positive effect on those who did not perform very well on task switching at kindergarten age. This finding can be seen as supportive of policies regarding early school entry for low-SES and ethnic minority children in the Netherlands comparable to the U.S. Head Start programs (Dominguez, Vitiello, Fuccillo, Greenfield, & Bulotsky-Shearer, 2011; Raver et al., 2011; Welsh, Nix, Blair, Bierman, & Nelson, 2010). Nevertheless, the *no-group difference hypothesis* states that although there may be mean-level differences in certain skills and behaviors between ethnic groups, developmental processes are not altered by culture-specific experiences (Rowe, Vazsonyi, & Flannery, 1994). Given that some of our main findings are consistent with general theoretical frameworks and findings from previous empirical work in ethnic majority families, the general developmental patterns found in this study are likely to reflect more than just group-specific patterns.

Our additional analyses showed no significant changes in global switch costs of accuracy and reaction time (comparing performance between the mixed and the single blocks) from kindergarten to the first grade. Previous research showed age-related differences in switch costs although the findings were mixed. Some found that global costs in reaction time increased whereas global costs in accuracy decreased from the age of six to young adulthood indicating that as children get older, they adjust their speed to preserve accuracy when they encounter an unpredictably changing situation (Davidson et al., 2006; Karbach & Kray, 2007). Others showed no change in the size of global costs with increasing age either in speed or accuracy (Crone et al., 2006) or only in accuracy (errors) but not in speed (Dibbets & Jolles, 2006). It is important to note that the switch costs in our study reflect the performance difference between single and mixed blocks in line with Karbach and Kray (2007), which differ from the switch costs in some studies that reflect the difference between nonswitch trials within the mixed block only (i.e., task repetitions) and all trials of the single blocks (e.g., Crone et al., 2006; Davidson et al., 2006). In addition, all the findings mentioned above are based on cross-sectional research and very few of them included children at kindergarten

age (e.g., Dibbets & Jolles, 2006). To the best of our knowledge, there is no study exploring the longitudinal, within-subjects changes in switch costs across school-age childhood. In our study, no developmental changes were observed in the global switch costs in children during the school transition. It remains to be seen whether these findings are confirmed in future longitudinal research with multiple time points.

Implications

Our study has several implications. The different longitudinal patterns of accuracy and reaction time indicate that they may not capture the same processes of flexibility. The findings suggest that in the early elementary school years accuracy of responding is a more sensitive measure for age-related differences in flexibility in an ambiguous situation with changing and time-limited demands (i.e., the mixed block) than speed, supporting the idea that accuracy is a more reliable measure of performance in young children (Davidson et al., 2006; Diamond et al., 2007; Hommel et al., 2011). Second, formal education after the transition to school that provides a cognitively stimulating (i.e., lessons requiring abstract thinking) and structured (i.e., rules) learning context may have helped children who performed less well in kindergarten to move their cognitive flexibility performance to a more optimal level. We suggest that transition to school is an important assessment point for children's strengths and skills for improvement as our findings indicate that executive control might be malleable to changing environmental conditions during this period. Given the evidence that this ability is related to school readiness (Vitiello et al., 2011), academic learning (Yeniad et al., 2013), and behavioral outcomes (Riggs, Blair & Greenberg, 2003), it is worthwhile to explore whether the performance gap between the two groups can be narrowed further by some deliberate effort such as daily EF practices at school (e.g., simple games that aid "thinking out of the box", Diamond et al., 2007).

Limitations

It is important to note some limitations of this study. First, the response rate was low, although we used brochures both in Dutch and Turkish with culturally adapted pictures and we personally visited each family who did not respond to initial attempts via letters. However, our low response rate was not an exception, given that nonresponse among ethnic minorities in the Netherlands, especially families with low SES has been reported previously (Feskens, 2007). Second, if we had a mixed sample of ethnic majority and minority children, we would be able to examine how ethnic minority children perform in flexibility relative to majority children during the school transition. It should be noted however that it is a methodological challenge to recruit ethnic majority children who are comparable to minority children in terms of family backgrounds, due to the disparity in the socioeconomic status

between minority and majority families (Suárez-Orozco & Suárez-Orozco, 2001). Third, our results regarding the development of flexibility are based on only one measure, the Hearts and Flowers task. Flexibility tasks, like other EF measures, differ in terms of complexity as a result of different amount of loadings on nonexecutive processes (e.g., intelligence), which leads to the well-known task impurity problem. Although the task switching paradigm is considered not to suffer from this risk with its minimum load on problem solving skills as opposed to complex shifting measures such as the Wisconsin Card Sorting Test (Huizinga & Van der Molen, 2011), future studies should include a battery of shifting measures for more robust findings.

Conclusion

In sum, our findings reveal that the ability to accurately adapt to constantly changing and conflicting demands improved from kindergarten to the first year of elementary school and children showed differential accuracy gains in this ability following the transition. The formal schooling context may have helped less able children to gain more in flexibility performance. The findings point to the malleability of cognitive control through environmental changes.

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