# Age and Schooling-Related Effects on Executive Functions in Young Children: A Natural Experiment

<table>
<thead>
<tr>
<th>Journal:</th>
<th><em>Child Neuropsychology</em></th>
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</thead>
<tbody>
<tr>
<td>Manuscript ID:</td>
<td>NCNY-2007-0024.R1</td>
</tr>
<tr>
<td>Manuscript Type:</td>
<td>Original Article</td>
</tr>
<tr>
<td>Date Submitted by the Author:</td>
<td>06-Aug-2007</td>
</tr>
</tbody>
</table>
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| Keywords: | executive functions, early schooling, cognitive development, response inhibition, working memory, preschool, kindergarten |
Running Head: EXECUTIVE FUNCTIONS IN YOUNG CHILDREN

Age and Schooling-Related Effects on Executive Functions in Young Children: A Natural Experiment

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Abstract

We employed a cutoff design in order to examine age and schooling-related effects on executive functions. Specifically, we looked at development of working memory and response inhibition over the period of one school year in pre-kindergarten and kindergarten students born within four months of each other. All children improved on executive function and word-decoding tasks from the beginning to the end of the year. Additionally, we found pre-kindergarten and kindergarten schooling effects for the working memory and word decoding tasks (p < .05), and a trend-level pre-kindergarten schooling effect for the response inhibition task (p < .10).
Age and Schooling-Related Effects on Executive Functions in Young Children: A Natural Experiment

Executive functions are cognitive mechanisms that collectively regulate thought processing. They account for the ability to actively maintain and manipulate task-relevant information, to resist impulsive behavior, to sustain attentional focus on specific tasks and ignore distracting information and to flexibly switch attention as task demands change. These skills (working memory, response inhibition, sustained attention, resistance to distractors and task-switching) are, in large part, functions of the frontal lobes (Awh & Jonides, 2001).

As recently as a decade ago, our understanding of executive functions was remarkably limited. Recent behavioral, neuroscientific and modeling research suggests there are several distinct core executive functions or mechanisms, with different although overlapping neuroanatomical bases (Awh & Jonides, 2001). For example, Miyake, Friedman and Emerson (2000) conducted a latent-variable analysis based on a data from 137 adult participants who performed three types of executive function tasks: maintenance and updating of working memory, task-shifting and inhibition. They found that a three-component model of executive control provided a better fit to the data than a unitary or a two-component model. In addition, neuroimaging data from adult subjects also provide converging evidence to support the claim that there are multiple, independent executive control skills. Although less clear, the developmental behavioral and neuroimaging data also suggest systematic links between certain areas of brain activity and cognitive and behavioral responses, which fall under the umbrella of executive processes (see next section).
In this study, we examine the unique effects of age-related development and schooling-related influence on 4- and 5-year-olds’ acquisition of two key executive function components identified as important for early school success (Shallice, Marzocchi, Coser, Del Savio, Meuter, & Rumiati, 2002): working memory and response inhibition. Working memory is defined as the ability to maintain task-relevant information in the context of competing demands. As shown in Table 1, working memory tasks are associated with activity in the prefrontal cortex, particularly its dorsolateral portion (Cohen, Perstein, & Braver, 1997; Jonides, Reuter-Lorenz & Smith, 1996). Response inhibition, the ability to inhibit contextually inappropriate information or responses is associated with activation in the prefrontal cortex, and, more specifically, the anterior cingulate portion of the prefrontal cortex (Casey et al., 1997).

**Development of Executive Function**

Multiple factors contribute to individual and developmental differences in executive function in early childhood (Cameron, McClelland, Jewkes, Connor, Farris, & Morrison, 2006; Shonkoff & Phillips, 2000; Zelazo, Müller, & Goswami, 2002). Davidson, Amso, Anderson and Diamond (2006) found that, while young children (ages 4-6) could exercise inhibition in a steady state, it exacted a performance cost not seen in adults. With each year of increase in age, inhibitory abilities improved. Additionally, accuracy on working memory tasks improved from ages 4-6. Contrary to their original predictions of independence between working memory and inhibition, reaction times for memory and inhibition tasks were highly correlated in participants ages 4-13 (with correlations as high as 0.8), although accuracy correlations were not nearly as strong (less than 0.4).

Our understanding the development of executive function and overall cognitive competence has been illuminated by neuropsychological data as well. Developmental research
collectively shows that young children recruit larger, more diffuse prefrontal regions when performing cognitive control tasks than do adults (Casey, Galvan, & Hare, 2005). Tsujimoto, Yamamoto, Kawaguchi, Koizumi, & Sawaguchi (2004) demonstrated that the lateral prefrontal cortex (LPFC) of preschoolers is active during working memory tasks. Casey et al. (1997) demonstrated that children as young as 7 years old exhibit activity in orbital frontal and anterior cingulate cortices while performing a go/no go task. However, studies have also shown that that young children show more widespread activation in the prefrontal cortex when performing both working memory and inhibition tasks and that this activation becomes more localized as children mature (Casey et al., 1997; Tsujimoto et al., 2004; Tsujimoto, Kuwajima, & Sawaguchi, 2006). This research, together with the behavioral research described above, demonstrates that the extent to which executive functions such as working memory and response inhibition are separable in young children is still an open question.

**Experiential Effects on Executive Function**

Recent theories of cognitive development emphasize how experience and practice with problem-solving in real-world situations enable children to continually refine schemas for their actions and operate according to increasingly complex rule systems (DeBaryshe & Fryxell, 1998; Diamond, Kirkham, & Amso, 2002; Morrison & Ornstein, 1996; Shields, Dickstein, Seifer, Magee, & Spritz, 2001; Zelazo, Müller, Frye, & Marcovitch, 2003). Empirical research corroborates this position by revealing that executive function can be improved through intensive laboratory-based training in adults and children (Dowssett & Livesey, 2000; Klingberg, Fernell, & Olesen, 2005; Moutier, 2000b; Olesen, Westerberg, & Klingberg, 2004; Rueda, Rothbart, Saccamanno, & Posner, 2005). For example, Klingberg et al. (2005) trained normal adults and children with ADHD on a battery of working memory tasks. Compared to controls, training
groups improved significantly on visuo-spatial and verbal working memory tasks, an inhibition task (the Stroop Task), and Raven’s progressive matrices, used as a measure of general intelligence.

Using fMRI, Olesen et al. (2004) trained participants on working memory tasks and found increased prefrontal and parietal neurological activity following training. Curtis & D’Esposito found decreased levels of neural recruitment in these same areas associated with an increase in performance on working memory tasks. Despite contradictory finding as to whether improved performance on working memory tasks is associated with increased or decreased brain activity, the active prefrontal and parietal regions have been well established, and are only confirmed by training research such as the Olsen et al. (2004) study.

A few studies demonstrate similar amenability of executive function to interventions with younger populations. In three training sessions, Dowsett and Livesey (2000) gave one group of preschoolers a task involving a series of complex rules, and found that the training group showed improved inhibitory control (as measured by a go/no-go task), compared with participants who did not undergo training. In addition, older children performed better than younger children, but this was attributed to developmental differences rather than training effects.

Research has shown that there are significant cultural differences in executive function processes, even from a young age (Sabbagh, Xu, & Carlson, 2006). Sabbagh and colleagues found differences in performance on measures of executive function when comparing Chinese and United States preschoolers (Sabbagh et al., 2006). The Chinese preschoolers performed significantly better than U.S. preschoolers on response inhibition, working memory and general executive function tasks. It is possible that sociocultural factors such as differential emphasis on the importance of school in general, or of self-regulation specifically, in Chinese and U.S.
classrooms may contribute to these differences (Blair & Razza, 2007; Stevenson & Stigler, 1992). Additionally, research in the United States has shown that young children of low socioeconomic status perform below middle class children on a wide range of cognitive and achievement tasks. Further, psychosocial factors such as presence of both parents in the home and parental stress and depression may also affect the development of cognitive and executive skills (Noble, Norman, & Farah, 2005).

Despite evidence that executive function (a) undergoes dramatic age-related development during the preschool period, and (b) can be influenced by early experiences, unique contributions of schooling and non-schooling/developmental experiences to different executive functions in young children are not well understood. In this study, we used a natural experiment, the school cutoff technique, to disentangle these two important influences in pre-kindergarten and kindergarten children.

The School Cutoff Technique

The cutoff technique creates a natural experiment, allowing researchers to separate schooling effects from those related to non-schooling experiences (e.g., development, Morrison, Smith, & Dow-Ehrensberger, 1995). The design takes advantage of arbitrary school cutoff dates that determine when children of virtually the same age will begin formal schooling. For example, if the state cutoff date for kindergarten is December 1, all children reaching a certain age before December 1 will begin kindergarten, whereas those born after the date will enroll the following year and will, instead, attend pre-kindergarten. In a cutoff study, participants born close to the cutoff date thus have different schooling experiences, but are similar in chronological age (e.g., within four months, with birthdays either the two months before or the two months after the arbitrary cutoff date). Skills are assessed as close as possible to the beginning and end of the
school year. This allows the effects of one year of schooling (which one group of children experience) to be separated from those of age-related development (which all children experience).

The following example illustrates the way that both fall and spring group differences are interpreted in a cutoff study. If a group of kindergarteners performs better on a reading test than their same-aged pre-kindergarten counterparts in the fall, one concludes that this difference is, at least in part, due to the previous pre-kindergarten year experienced only by the kindergarteners. This interpretation holds if the kindergarteners have gone to pre-kindergarten the year before and are matched on important factors such as maternal education level, IQ, or social maturity. Proportionate differences between the two groups (pre-kindergarten and kindergarten) in the spring are attributed to the year of schooling experienced by both groups. In other words, if chronological age is the only factor affecting the development of tested skills, one expects the groups to perform similarly in both the fall and spring.

Because students are not randomly assigned to groups, it is important to take into account other factors that might affect their task performance during fall and spring sessions. One assumption of the cutoff technique that has proven robust to empirical scrutiny is that the main factor affecting children’s enrollment in school (i.e., date of birth), is not systematically related to the variables under investigation (Morrison et al., 1995). For example, studies have considered potential confounding factors such as IQ and amount of preschool experience and found no group differences for students within the same school systems (Bisanz, Morrison, & Dunn, 1995; Christian, Morrison, Frazier, & Massetti, 2000; Ferreira & Morrison, 1994; Varnhagen, Morrison, & Everall, 1994). In this study, we found no group differences on years of maternal education.
Previous cutoff studies have examined age and schooling-related effects on early literacy and numeracy skills, as well as short-term memory (Bisanz et al., 1995; Christian et al., 2000; Ferreira & Morrison, 1994; Varnhagen et al., 1994). Bisanz et al. (1995) found that 6-year-olds who made the cutoff for first grade entry exhibited enhanced performance on short-term memory tasks, compared with same-aged kindergarteners who missed the cutoff. Both age-related and schooling effects were found for phonological word segmentation (decoding). Throughout the early elementary years, schooling experiences have a robust effect on word decoding skills (Christian, Bachman, & Morrison, 2001).

To our knowledge, one prior cutoff study conducted with early elementary-aged children explicitly focused on executive function (McCrea, Mueller, & Parrila, 1999). Using the 4-month window for the cutoff described above, McCrea et al. (1999) found a small to moderate effect of schooling experiences on executive function in 7- to 9-year-olds, with the performance of children of similar ages enhanced by school attendance. General executive function measures were used, including the Wisconsin Card Sort task (Heaton, Chelune, Talley, Kay, & Curtiss, 1993), the Thurstone Word Fluency task and a mazes task (Wechsler, 1991). McCrea et al.’s study provides evidence for separable influences of age and formal schooling on the development of executive function in early elementary school children; however, no studies have examined schooling effects on executive function in children at the formal school transition. Further, measures of multiple executive function components are needed to assess whether schooling may influence one skill but not another (i.e., working memory but not inhibitory control). Event Related Potential (ERP) data reveal how changing are the brain areas recruited during executive tasks, and how variable are the skills and strategies among children of similar ages (Segalowitz & Davies, 2004). It would add considerably to our understanding of early
executive development to know whether experiences like school extend beyond individual
differences in skills to help explain variance in children’s working memory and response
inhibition skills. The current inquiry attempts to replicate and expand upon McCrea et al.’s
results with pre-kindergarten and kindergarten participants, using assessments that measure two
distinct yet interrelated aspects of executive function.

**Rationale & Hypotheses**

In this study, we extend the work of McCrea et al. (1999) to a younger age group,
investigating age-related and schooling effects on executive functions using the cutoff method
over the transition to kindergarten. Research has shown that the early school years are crucial for
the development of executive function (Espy, 1997). In addition, pre-kindergarten helps children
acquire many important school readiness skills, including emergent literacy and numeracy, as
well as social skills. It is likely that pre-kindergarten and kindergarten experience improves
executive function – perhaps differentially – but little is currently known about this issue.

We examined two related, but separable executive function skills identified as important
for school-based performance: working memory and response inhibition (Shallice et al., 2002).
Our first research question was: How do age-related development and schooling experiences
influence growth of working memory and inhibitory control in young children? More
specifically, are there executive function skills in which children attending kindergarten make
gains relative to children of the same age who attend pre-kindergarten? Second, we asked
whether we would find different patterns of effects for working memory and inhibitory control.

Given that previous studies have found schooling effects on short-term memory, which is
closely related to working memory (Colom, Shih, & Flores-Mendoza, 2006), we hypothesized
that schooling effects would emerge on working memory. Evidence suggests that inhibitory
control develops significantly during the school transition, but a lack of prior research precluded strong hypotheses about patterns of schooling and age-related effects for this skill component.

Method

Participants

Participants were 45 children (18 “old” pre-kindergarteners; 27 “young” kindergarteners) whose dates of birth fell within the two months before (October 1 – November 30) or the two months after (December 1 – January 31) an arbitrary cut-off date of December 1st. This date was set for kindergarten entry by their state. The district is located in an urban fringe area in the Midwest. Mothers in both groups had a mean of 16 years of education. Eight-three percent of the pre-kindergarteners and 82% of the kindergarteners were Caucasian; the other students were African-American (2%), Asian-American (4%), Hispanic (2%) and Bi-racial (8%). Pre-kindergarteners had attended preschool or daycare for an average of 26 months, while kindergarteners had attended preschool or daycare for an average of 30 months prior to the school year in which they were tested. In order to have a sufficient sample size, two cohorts of data were collected; one during the 2004-2005 school year and one during the 2005-2006 school year. Children’s mean ages at the time of testing were 57 months for the old pre-kindergarteners and 60 months for the young kindergarteners. In the pre-kindergarten group, there were 8 males and 10 females; in the kindergarten group there were 12 males and 15 females.

Procedure

This study was approved by the Behavioral Science Institutional Review Board at the host university. Parental written consent was obtained via letters distributed and collected by classroom teachers. Child oral assent was obtained in the school on the day of testing. Once in the fall (September and October) and once in the spring (April and May), researchers assessed
participants individually on a battery of tasks, including two executive function tasks, and a letter word identification task. To prevent order effects, the tasks were administered in two different sequences; children were randomly assigned to one sequence. Testing took place in a quiet area at participants’ schools. Children were given stickers as they went through the battery, which took 20 – 30 minutes. Following testing, questionnaires were sent out to parents requesting background information about parental occupations, and children’s prior preschool experiences.

**Measures**

Executive function tasks included one working memory measure, the Auditory Working Memory test from the Woodcock-Johnson III Tests of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001b), and one inhibitory control measure, called Head-Toes-Knees-Shoulders (HTKS). Letter-Word Identification (a word-decoding task) from the Woodcock Johnson III Tests of Achievement (Woodcock, McGrew, & Mather, 2001a) was also used as a control measure, since researchers have consistently shown the skill is affected by schooling (Christian et al., 2001). Therefore, it acts as a useful comparison task to assess whether the cutoff technique functioned as expected in this sample of young children. For the two Woodcock-Johnson tasks, W scores were used, which area conversion of raw scores, with equal-interval measurement characteristics.

**Auditory Working Memory**

In the Auditory Working Memory subtest, children are given multiple elements to remember and cognitively manipulate. The experimenter states a list of nouns (called “things”) and numbers (e.g., dog, 7, shirt). Children are instructed to listen and then respond by reordering the list elements, saying the nouns first, and then the numbers, in the same order that they were initially presented (e.g., dog, shirt, 7). The lists of nouns and numbers increase in length, and
therefore, difficulty, as the task progresses. Testing stops after the child responds incorrectly 6
consecutive times. Like similar tasks that tap working memory such as the Corsi blocks test and
digit span tasks, we would expect working memory-related neuroanatomical correlates of this
task to be in the frontal lobe (particularly the dorsolateral prefrontal region), although we did not
assess neurological activation in this study (Tsujimoto et al., 2004; Lezak, 1995).

Head-Toes-Knees-Shoulders (HTKS)

Head-Toes-Knees Shoulders (HTKS) is a direct measure of behavioral regulation,
drawing primarily on inhibitory control to require children to respond non-intuitively to four
behavioral commands. Like similar tasks that tap response inhibition such as the go/no-go and
Stroop tasks, we would expect inhibition-related neuroanatomical correlates of this task to be in
the frontal lobe (particularly the anterior cingulate cortex) (Casey et al., 1997; Lezak, 1995). The
task extends the Head-to-Toes Task (HTT), which has demonstrated reliability, as well as
internal and predictive validity in early childhood (Cameron et al., in press; McClelland et al., in
press); the HTKS itself has been used to predict achievement in elementary-aged children
(Cameron, McClelland, Matthews, & Morrison, 2007; Connor, Huddleston, Glassney, Phillips,
Underwood, Cameron, 2007). The task is comprised of four parts. First, children are trained to
simply touch their heads or toes, depending on what the experimenter says to do. In the second
part of the task, they are then told to “do the opposite” of what the experimenter says. Therefore,
if the experimenter says to touch her head, the child should instead touch her toes. After four
opportunities to practice with feedback (i.e., a re-explanation of the task, up to three times), the
child is given 10 test trials with these two rules (head, toes). For the third part of the task,
commands to touch shoulders and knees are added; children are directed to touch their shoulders
when told to touch their knees and vice versa and given four opportunities to practice. In the
fourth and final part, participants are told to do the opposite of each command (pairing head commands with toes responses, and knees with shoulders, etc.). The experimenter then gives 10 final trials of head, shoulders, knees and toes commands, presented in random order.

Correct responses on all items receive a score of 2, self-corrects (discernible motion to incorrect, with final response given correct) receive a score of 1, and incorrect responses receive 0 points. The two sets of 10 test items are summed to a total of 20 items with a possible high score of 40.

*Letter-Word Identification*

In this task, the experimenter shows children pages with letters and words that increase in difficulty. Children begin by pointing to the correct letter or word and are then asked to read the letter/word out aloud. Testing stops after 6 consecutive incorrect responses. In the current study, this task was used as a check on the cutoff manipulation, based on research demonstrating a robust schooling effect in kindergarten on letter-word decoding (Christian et al., 2001)

**Results**

Data for all participants were included in analyses for both the Letter-Word ID task and the Auditory WM task. Five participants (3 pre-kindergarteners and 2 kindergarteners) showed a floor effect (zero score) on HTKS. It is likely that these participants did not understand the task instructions and were not performing the task correctly; therefore, we did not include their data in the analyses for this task.

Table 2 presents descriptive statistics for both pre-kindergarteners and kindergarteners (Group) on all three tasks for both fall and spring testing sessions (Testphase). To assess the effects of development and schooling we conducted a 2 (Testphase) x 2 (Group) repeated measures ANOVA on the three tasks. Significant results are reported below.
Repeated Measures Effects of Development (Testphase)

There was a main effect of Testphase for all tasks: Letter-Word ID, $F(1, 43) = 111.19, p < .001, \eta^2 = .708$; Auditory WM $F(1, 43) = 16.86, p < .001, \eta^2 = .280$; HTKS $F(1, 38) = 7.57, p < .01, \eta^2 = .155$; with both groups improving significantly on all of the tasks from fall to spring.

Between Group Effects of Schooling (Group)

There was a main effect of Group for the Letter-Word ID task, $F(1, 43) = 6.38, p < .05, \eta^2 = .129$, with kindergarteners performing better compared with pre-kindergarteners in the fall and spring (see figure 1). The Auditory Working Memory task showed a similar group effect, $F(1, 43) = 7.14, p < .05, \eta^2 = .142$, with kindergarteners outperforming pre-kindergarteners in both the fall and spring (see figure 2).

Development X Schooling Interaction Effects

In addition, there was a marginally significant Testphase X Group interaction effect for the HTKS task (see Figure 3), $F(1, 38) = 3.34, p = .08, \eta^2 = .068$, with kindergarteners performing better than pre-kindergarteners in the fall. There were no group differences in the spring. Interaction effects for the Letter-Word ID task, $F(1, 43) = 2.80, p > .05, \eta^2 = .0008$, and the Auditory Working Memory task $F(1, 43) = .435, p > .05, \eta^2 = .007$, were not significant.

Discussion

Replicating the findings of previous studies, our results showed significant group effects on word decoding (Christian et al., 2001) Kindergarteners outperformed pre-kindergarteners of the same age on word reading in both fall and spring. Notably, a similar pattern of effects was found for the working memory task. Kindergarteners both began and ended the school year performing at higher levels on this task compared with their age peers in pre-kindergarten. A
marginally significant Group X Testphase interaction showed that kindergarteners outperformed pre-kindergartners on our inhibitory control task in the fall; by the spring, this was not the case.

Since there were both fall and spring group differences in word decoding skills and auditory working memory, this suggests that these skills improve as a result of both pre-kindergarten and kindergarten-related experiences. That is, even though they were the same age as the pre-kindergartners, kindergarten participants entered school in the fall with better word decoding and auditory working memory skills. Given the participants were matched on a maternal education measure, we interpret this as an effect of the kindergartener’s previous pre-kindergarten experience (experience not shared by the pre-kindergartners). Differences in spring scores are interpreted as an effect of the year of differential (pre-kindergarten vs. kindergarten) schooling experiences directly measured by the study. It is possible, however, that both prior schooling-related experience and home practices may account for these differences. For instance, research suggests that many parents increase literacy and other practices in the anticipation of their children entering kindergarten (Son & Morrison, 2005, April). Similar schooling/developmental patterns for word reading and working memory are also consistent with research demonstrating early associations between literacy skills and working memory (Adams & Snowling, 2001; Gathercole et al., 2000).

In contrast, inhibitory control, as measured by HTKS, appeared to be somewhat affected by attending pre-kindergarten, but not kindergarten. In other words, children who went through pre-kindergarten in the study exhibited fall-spring growth in HTKS, whereas kindergarteners did not. This effect did not reach significance and should be interpreted cautiously. Nonetheless, for the sake of exploring a relatively new area, it is intriguing to consider how pre-kindergarten and
kindergarten experiences may differentially promote the executive function skills involved in a
task like HTKS.

An intriguing, but very preliminary result was the different patterns of schooling effects
on the two executive function tasks. This supports the notion that executive functions are distinct
processes in children as young as four and five (Hongwanishkul et al., 2005; Miyake, Friedman,
Emerson, Witzki, & Howarter, 2000). However, the limited number of tasks prevents definitive
claims about distinct schooling effects on working memory versus inhibitory control.

This study contributes to growing evidence that the development of at least some
executive function processes is influenced by school-related experiences. The finding that
kindergarteners performed better on a working memory task at the fall and spring testing
sessions is also similar to what Morrison et al. (1995) found: in their study, first graders
performed better on short-term memory tasks than their kindergarten counterparts in both the
beginning and end of the school year. Taken together, these two findings suggest that there may
be schooling effects on short-term and working memory throughout the early school years.

The current study is limited because only one measure was used for each executive
function component. Thus it is difficult to know whether the tasks drew primarily from the
intended component (working memory versus inhibitory control), without heavily accessing
other skills (e.g., attention). Certainly, attention was required in both tasks, and the working
memory task required inhibitory control, and vice versa. Future work should use multiple
measures of these skills, and ideally, collect data on children’s contexts including their homes
and classrooms.

Additionally, as with all natural experiments, participants were not randomly assigned to
groups by the experimenters. Therefore, they may differ on variables that may contribute to
Executive Functions

... differential performance on executive function tasks. While the current study did not find differences between pre-kindergarteners and kindergartners on a maternal education measure, the authors did not collect data on IQ, social skills or other potential relevant factors. However, similar studies using the cutoff technique have not found differences in these and other variables, supporting the notion that the cutoff technique separates children naturally into similar experimental groups (Bisanz et al., 1995; Christian et al., 2000; Ferreira & Morrison, 1994; Varnhagen et al., 1994).

Cutoff studies pose challenges in recruitment, data collection, and statistical power, but this tool helps disentangle significant and often confounded influences on skill acquisition (age-related and schooling). Because of the strength of this methodology to illuminate the murky waters of development, we encourage and anticipate future cutoff investigations in the earliest years of school, especially those that utilize neuroscientific methods such as ERP and fMRI. Additionally, this technique and others can be used in the future to better understand cross-cultural differences in executive function by examining the effects of early schooling on the development of EF in Chinese as well as U.S. classrooms (Sabbagh et al., 2006). Finally, future research can begin to identify specific types of schooling experiences that promote development of executive function, which underlies a successful transition to formal schooling and paves the way for academic trajectories throughout children’s lives (Blair, 2002; Shonkoff & Phillips, 2000).

In conclusion, this study provides new evidence that the development of executive function is affected by both maturational and early schooling experiences in 4- and 5-year-olds. As increasing numbers of children are enrolled in early education and care programs before entering kindergarten, scientific investigations to understand the effects of these programs on...
skills necessary for school success are critical (Boocock, Larner, Barnett, & Boocock, 1998; Gilliam, 2005).
Author Note

The authors would like to thank members of the University of Michigan Pathways to Literacy project as well as the parents, children and school district personnel, without whom this study would not have been possible. This research was supported by grant #(get this info from Fred or someone in the lab who knows).

Claire Cameron Ponitz is now at the University of Virginia, Center for the Advanced Study of Teaching and Learning.
References


Table 1

*Executive function processes examined in the current study*

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<tr>
<th>Executive function process</th>
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<th>Neuroanatomical basis</th>
<th>Developmental status in early childhood</th>
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<td>Working Memory</td>
<td>Auditory Working Memory</td>
<td>Prefrontal cortex (dorsolateral portion)</td>
<td>Performance improves from ages 4-6 LPFC activation in preschoolers (also diffuse prefrontal activation)</td>
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<td>Response inhibition</td>
<td>Head-Toes-Knees-Shoulders</td>
<td>Prefrontal cortex, (anterior cingulate portion)</td>
<td>Performance cost as compared to adults Activation in orbitofrontal and anterior cingulated (age 7) (also diffuse prefrontal activation)</td>
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Table 2

*Descriptive Statistics by Group and Testphase*

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<td>Mean</td>
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<td>Letter Word ID</td>
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<td>(W-Scores)</td>
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<td>(Raw Score)</td>
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<td>30.28</td>
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Figure Captions

Figure 1: Mean W-scores for Letter-Word ID task for pre-kindergarteners and kindergarteners in fall and spring.

Figure 2: Mean W-scores for Auditory WM task for pre-kindergarteners and kindergarteners in fall and spring.

Figure 3: Mean scores for HTKS for pre-kindergarteners and kindergarteners in fall and spring.