Spring 2019

Self-Regulation: A Cross-Sectional Study of Preschool-Age Children

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SELF-REGULATION: A CROSS-SECTIONAL STUDY

OF PRESCHOOL-AGE CHILDREN

A Capstone Project Presented in Partial Fulfillment

of the Requirements for the Degree Bachelor of Science

with Honors College Graduate Distinction at

Western Kentucky University

By

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April 2019

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I dedicate this thesis to my parents, Jamie and Terri Fugate, who have supported me and provided me with the opportunity to pursue a college education.

ACKNOWLEDGEMENTS

This project would not have been possible without the support from my family, friends, and most importantly, my faculty advisor, Dr. Lemerise. I would like to thank Dr. Lemerise for the time she has dedicated to not only my thesis, but to my overall academic success. Dr. Lemerise has been my faculty mentor for over two years, and without her support in the classroom, in the research lab, and with my post-graduation plans, I would not have been given near the same amount of opportunity for success. I would also like to thank my second reader, Dr. Lickenbrock, who has also provided me with the necessary support to complete this project. Additionally, my sincerest gratitude is extended to the other students who contributed to the success of this project through their assistance in the research lab and with the data collection.

Lastly, I would like to thank the Mahurin Honors College for the encouragement they have provided me, both in and out of the classroom, during my four years here at WKU. The opportunities presented from the Honors College have had a profound effect on my college career.

ABSTRACT

Self-regulation predicts school readiness and consists of "cool" and "hot" self-regulation. "Cool" self-regulation is characterized by inhibition of a dominant response, working memory, and set shifting. "Hot" self-regulation involves inhibition, shifting attention, and regulation of emotion in arousing situations. In this study, self-regulation was measured in 80 preschool-age children (3-5 years). Two "cool" tasks (Pencil Tap and Day/Night) were coded for percent correct, and the other two "cool" tasks (Dimensional Change Card Sort and Head-Toes-Knees-Shoulders) were coded for total score. The "hot" task (Snack Delay) was coded for compliance to task demands (no touching of snack/materials until timer beeped while keeping hands flat). As seen for all tasks, the 4-year-old participants demonstrated better scores than the 3-year-old participants. For Snack Delay, 4-year-olds demonstrated a slightly longer wait with their hands flat than 3-year-old participants, in general. Also, for snack delay, both age groups demonstrated very poor success rates for all 10 trials. Pencil Tap and Head-Toes-Knees-Shoulders showed significant age effects, demonstrating that 4-year-old children showed significantly better performance than 3-year-old children. Dimensional Change Card Sort, Day/Night, and Snack Delay yielded no significant age effects. No effects of gender were found.

Keywords*:* Self-Regulation, Executive Function, Effortful Control

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Self-regulation is the ability to control one's own thoughts, behaviors, and/or emotions. It is often utilized to achieve some latent goal through problem solving or mental planning (Blair & Ursache, 2011). Self-regulation also is used to act in a socially acceptable manner, specifically when internal emotions do not mirror desirable behavior (Leyland, Rowse, & Emerson, 2019). Additionally, self-regulation is linked to various other factors, such as academic ability (Lonigan, Allan, & Phillips, 2017), socioeconomic status (Malanchini, Engelhardt, Grotzinger, Harden, & Tucker-Drob, 2018), and age (Carlson, 2005). To provide a full understanding of self-regulation, it can be broken into two subsets: "cool" self-regulation and "hot" self-regulation.

"Cool" self-regulation is rooted in the concept of executive function (EF), which refers to the collection of cognitive processes that are required for proper regulation of emotion or behavior (Carlson, 2005). Executive function is a very broad concept at young ages, but as children develop, executive function differentiates into distinctive subsections (Carlson, 2005). Executive function often includes the response inhibition, working memory, and set shifting (McClelland et al., 2014). Response inhibition requires an individual to suppress desires and employ favorable reactions instead. Working memory is used to understand immediate information and to perform a desired outcome (McClelland et al., 2014). Set shifting requires the ability to quickly alternate between rules/demands for different tasks (Lonigan et al., 2017). Executive function, as a subset of self-regulation, also shares relations with other factors, such academic ability and socioeconomic status.

Executive function is often a predictor of school readiness for young children (Blair, 2002). Although intellect is often considered when deciding on a child's readiness to enter into kindergarten, executive function can provide a profound understanding as to how that child will perform in school (Malanchini et al., 2018). Correlational studies of working memory and set shifting with mathematical achievements longitudinally indicate positive associations. These associations are shown to be better predictors of success in math than reading ability or IQ scores (Blair & Raver, 2015; Bull & Scerif, 2001). Further, as reported from a survey of kindergarten teachers (performed by the National Center for Education Statistics), the most important characteristic for children entering kindergarten is their regulation abilities (Blair, 2002). Although only 7-10% of teachers indicated the importance of academic milestones, such as the ability to count to 20 or recite the alphabet, 84% of teachers specified the significance of children being able to communicate their needs/desires effectively (Blair, 2002). Further, 60% of teachers emphasized the importance of children's abilities to follow directions, avoid distractions, and be cognizant of others' emotions (Blair, 2002).

In addition to the relationship between executive function and academic achievement, executive function also demonstrates a relationship with environmental factors, such as socioeconomic status (SES) (Blair & Raver, 2015). In one study, using the Trail Making Test that is designed to measure attention, mental flexibility, and set shifting, participants from lower SES backgrounds performed worse compared to individuals of higher SES (Shaked et al., 2018). In addition, across five different tests designed to measure unique facets of cognitive function, children of lower SES (measured by education levels and income of household) underperformed compared to those of higher SES (Turrell et al., 2002). Overall, children whose parents have obtained higher levels of education, which is associated with SES, also tend to exhibit better self-regulation (McClelland et al., 2007).

"Hot" self-regulation is characterized by effortful control, which deals heavily with the suppression of dominant responses (Kochanska, Murray, & Harlan, 2000). Effortful control consists of inhibition, attention shifting, and regulation of emotions. Inhibition traditionally refers to behaviors, such as inhibiting the desire to use physical acts to express anger. Attention shifting, which has been linked to higher self-control in later ages, requires individuals to alter their focus despite desires. Regulation of emotions can include both excitatory, such as the employment of positive emotions, and inhibitory responses, such as masking anger. Effortful control surfaces as early as six months of age, but it is highly developed during preschool (Rothbart, 1998).

Effortful control has both biological and environmental aspects (Kochanska et al., 2000). First, the underlying biological basis of effortful control is temperament, as shown by the level of arousal typically associated with measures of effortful control. Temperament is defined as the natural, innate differences in reactivity, arousability, and self-regulation exhibited by individuals (Rothbart & Derryberry, 1981). Temperament is associated with regulation abilities, including emotion regulation, and social skills (Brophy-Herb et al., 2019). Thus, arousing tasks, such as those involving the presence of forbidden snacks or toys, are often used as measures of effortful control.

Similar to executive function, environmental factors, such as SES, also play a role in developing effortful control. For example, individuals subject to poorer/ lower quality home environments show decreased effortful control (Lengua, Honorado, & Bush, 2007). Predictors of low SES, such as parental education and home environment quality, yield significant negative correlations with academic success at ages 2-4 (Merz et al., 2014). Moreover, performance on both delay of gratification and inhibition tasks has been shown to be poorer in children from lower SES, single-parent homes, or unsafe environments (Li-Grining, 2007). In addition, other extrinsic factors, such as parenting styles, also have been shown to affect the development of effortful control in children. For example, the authoritarian style of parenting, characterized by strict rules, little nurturing, and low levels of openness, leads to lower levels of effortful control (Lengua et al., 2007).

Effortful control has a significant association with academic abilities (Allan & Lonigan, 2014). Effortful control is related to more than cognitive abilities, however. It is interrelated with other behaviors and skills, such as the ability to focus attention, that aid in academic success. The relationship between effortful control and academic success is speculated to be causal due to the role effortful control plays in children's educational motivation in the classroom (Garon, Bryson, & Smith, 2008). Specifically, effortful control can act as a predictor of both learning behaviors and social competence, both of which assist in educational settings (Denham, Warren-Khot, Bassett, Wyatt, & Perna, 2012). When children are able to suppress overwhelming responses, they are able to attend to new information, and thus, are enhancing their attainment of knowledge (Merz et al., 2014). This provides an explanation for why effortful control at young ages is an important predictor of academic success later in life; the foundation of an individual's education paves the path for their attainment of knowledge in subsequent years.

Many factors play a role in the development of executive function and effortful control, but one common factor is their association with child age (Allan & Lonigan, 2014; Blair, 2002; Blair & Raver, 2015; Bull & Scerif, 2001; Garon et al., 2008; Malanchini et al., 2018; Merz et al., 2014). As a child gets older, both executive function and effortful control have been shown to increase also (Blair, 2002; Carlson, 2005). In normal development for children, the improvement of cognitive processes that are indicative of high executive functioning also occurs (Blair, 2002; Lonigan et al., 2017). In addition, another longitudinal study of children measured children at two time points, in first grade and in second grade. They found a positive correlation between child advanced working memory and academic performance (Willoughby, 2019). This result was moderated by child age due to the understanding that working memory develops as an individual matures. For example, the children in this study exhibited higher levels of reading comprehension as their executive function developed. This was reasoned to be a result of an improvement of their working memory, which allowed the children to interpret the information more accurately at the second-grade stage.

In another study that focused on 602 preschool children, 65% of the participants showed significant age effects, demonstrating their accuracy on executive function tasks increased with age (Carlson, 2005). Additionally, after controlling for executive function and verbal ability, the 3-5-year-old participants' collective scores also increased on the tasks administered. Carlson (2005) understood this change to be both biological and contextual. In a contextual setting, social experiences constantly enhance an individual's executive function skills. In regard to biology, the brain provides a basis for this development. Specifically, the dorsolateral prefrontal cortex (DLPFC), which is the brain's decision-making area, plays a noteworthy role (Shaked et al., 2018) in executive function development. With a prior understanding that executive function, on average, is more advanced in individuals of higher socioeconomic status, the DLPFC is shown to act as a mediator (Shaked et al., 2018). Shown through a battery of cognitive tasks, the DLPFC plays a role in executive function of individuals of all ages, not just children.

Effortful control is also correlated with age (Bull, Espy, Wiebe, Sheffield, & Nelson, 2011**;** Kochanska, 2000), surfacing around 6 months old and developing dramatically around preschool age (Bull et al., 2011; Rothbart, 1998). Traditionally, as effortful control develops in children, the inhibitory control aspect, specifically, illustrates the strongest transition at age 4 (Blair & Razza, 2007). As effortful control increases, however, it becomes a very stable construct exhibited by individuals (Blair, 2002). One such piece of evidence for this suggestion is that children show a significant positive correlation between age and behavioral control, as demonstrated by observational measures of behavior (Hinde, Stevenson-Hinde, & Tamplin, 1985) and teacher-reports (Valiente, Swanson, Lemery-Chalfant, & Berger, 2014). Further, in another study, children's age showed significant correlations with 7 different tasks that were designed to measure individual facets of effortful control (Allan & Lonigan, 2011). This study also illustrated that effortful control is related to both the externalizing and internalizing behavior, as well as behavioral problems overall. Moreover, additional studies have supported the idea that effortful control has a strong relationship with age. For instance, age was shown to correlate with latent effortful control (Bull et al., 2011). Both Bull et al. (2011) and Bernier et al. (2010) have shown that although effortful control is correlated with age starting around preschool, there is large variability exhibited among these preschool-age children.

Through all the previous research that has been conducted on the executive function and effortful control of preschool-age children (3-4-years-old), I aimed to combine these constructs of both "cool" and "hot" self-regulation to determine their relations with age and each other. I aimed to use the data collected to elaborate on the developmental gap that children show between 3 and 4 years of age, specifically in their self-regulation abilities. This study had two research aims. First, I wanted to measure the presence of age differences between 3- and 4-year-olds on self-regulation tasks. It was expected that 4-year-old children would generally outperform the 3-year-old age group. Second, as an exploratory research question, I wanted to look between tasks to determine general performance, such as the least difficult and most difficult tasks for both age groups.

Method

Participants

This study included 80 preschool-age children: 34 three-year-old children (18 boys and 16 girls) and 46 four- and five-year-old children (28 boys and 18 girls). Specifically, there were 41 four-year-old children and 5 five-year-old children; however, the four- and five-year-old children were classified under one group (the "four-year-old age group") because the five year old children had very recently turned five. All of the children were recruited from local Head Start preschool programs, 50 students from the WKU Child Care Center, a blended Head Start/child care program, and 20 students from the Warren County Head Start. Parental consent was acquired for every child, and the children's assent was also obtained prior to testing.

Measures

Children were given a battery of tasks that measure the different facets of both executive function and effortful control. Each child was randomly assigned one of two batteries (Battery A or Battery B). All four cool tasks were included in both batteries, but the hot tasks were divided between the two. The cool tasks included Pencil Tap (Blair & Razza, 2007), Dimensional Change Card Sort (Frye, Zelazo, & Palfai, 1995), Day/Night (Gerstadt, Hong, & Diamond, 1994), and Head-Toes-Knees-Shoulders (McClelland et al., 2014). For the hot tasks, Battery A included Impossibly Perfect Circles **(**Kahle, Miller, Lopez, & Hastings, 2016), Snack Delay (Kochanska et al., 2000), No Stickers Left (Goldsmith, Reilly, Lemery, Longley, & Prescott, 1993), and Gift Delay (Kochanska et al., 2000; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996), and Battery B included Transparent Lock Box (Gagne, Van Hulle, Askan, Essex, & Goldsmith, 2011), Snack Delay, and Disappointing Gift (Saarni, 1984). Only those tasks present in both batteries were analyzed for this study, the four cool tasks and Snack Delay.

In order to ensure interrater reliability, two experimenters were live-coding at the time of testing. Before data collection occurred, all experimenters practiced both task administration and coding reliability through mock trials with each other. Additionally, all sessions were video and audio recorded in order to allow further review of the data. One experimenter administered the tasks; the other operated the video camera.

Cool Tasks. In this study, the cool tasks were selected based on their measures of the individual components of executive function. Dimensional Change Card Sort measures set-shifting. Pencil Tap, Day/Night, and Head-Toes-Knees-Shoulders all focus on working memory. However, Pencil Tap and Head-Toes-Knees-Shoulders also measure inhibition of a dominant response.

Dimensional Change Card Sort (Frye et al., 1995). The child was introduced to two boxes with openings carved on the top. The first box contained a picture of a red bunny, and the second box contained an illustration of a blue boat. The child was taught that in the “color” game, all blue cards were placed in the box with the blue boat, and all red cards were placed in the box with the red bunny (sorting cards based on color). After correctly repeating the rule, the child was introduced to six cards in a pseudorandom order. Before presentation of each card, the experimenter restated the rule, and the child was responsible for sorting each card. If the child correctly sorted five of the cards, he/she proceeded to the “shape” game. The same procedure was used. However, the child was instructed that in the “shape” game, all cards depicting a boat were placed in the box with the blue boat, and all cards depicting a bunny were placed in the box with the red bunny (sorting based on shape, not color). If the child correctly sorted five of the six cards again, he/she proceeded to the advanced card sort. The same procedure was used again. In this phase, the child was instructed that upon presence of a card possessing a black border, he/she was to sort the card according to the rules of the “color” game. The child was reminded of the rules for the “color” game. When a card with no black border was presented, the child was instructed to play the “shape” game and was reminded of these rules. The advanced cart sort included twelve trials (6 cards with a border and 6 cards without), and the child was scored for accuracy (number of cards sorted correctly). For both the Color and Shape games, there was a maximum of 6 cards that could be sorted correctly, and for the Advanced portion, there was a maximum of 12 cards that could be sorted correctly. Overall, the highest score a participant could receive was 24 cards correctly sorted.

Pencil Tap (Blair & Razza, 2007). The child was given an unsharpened pencil. The experimenter instructed the child to tap the pencil two times when he/she tapped his/her pencil one time and to tap one time when he/she tapped two times. After correctly answering three of the six teaching trials, the experimenter administered 16 uninterrupted scored trials in a pseudorandom order. Accuracy was scored as the number of correct trials. Trials were marked as correct when the child tapped twice after the experimenter tapped once or the child tapped once when the experimenter tapped twice. The maximum score possible for this task was 16/16 (100% correct).

Day/ Night (Gerstadt et al., 1994). The experimenter started by declaring this was a “silly game.” The experimenter proceeded to show the child a black card with a moon and stars present (a depiction of nighttime) and told him/her to say “day” upon presentation of this card. The experimenter then showed the child a white card containing an image of a sun (depicting daytime) and instructed him/her to say “night” when this card was presented. After answering correctly for both cards in practice trials, the experimenter administered 16 scored trials in a pseudorandom order. Accuracy was scored as the number of correct trials. Trials were marked as correct when the child said “Day” upon presentation of a card depicting night or when the child said “Night” upon presentation of a card depicting day. The maximum score possible for this task was 16/16 (100% correct).

Head-Toes-Knees-Shoulders (McClelland et al., 2014). In Part I, the child was instructed to stand and mimic the experimenter as he/she alternated touching his/her head and toes. The child was then coached to do the opposite action from what the experimenter announced (e.g. when told to touch his/her head, the child was supposed to touch his/her toes instead). After brief training and practice trials, the child was given ten trials to continue performing the opposite action. Accuracy was scored from 0-2 (0- incorrect; 1-self-correct; 2-correct) for each trial. If five or more trials were performed correctly, the procedure was repeated using shoulders and knees (Part II). First, the child was told to touch the body part that the experimenter announced but was then told to touch the opposite body part again. Training and practice trials were presented but were not followed by scored trials using only shoulders/knees. The child was then told to combine all the body parts, continuing to perform the opposite action. The experimenter reiterated the previous four rules and then proceeded with ten more scored trials in a pseudorandom order. Accuracy was scored using the same code as in Part I. The maximum score for this task was 52 points (32 points in Part I and 20 points in Part 2).

Hot Task: Snack Delay (Kochanska et al., 2000). The child was presented with goldfish and M&Ms and asked which snack was preferred. The chosen snack was used for the duration of the task. The child was instructed that while the snack was hidden under a [transparent] cup, he/she was to keep his/her hands flat on the table until the timer beeped. The experimenter explained that after the timer beeped, the snack could be removed from under the cup and placed into an adjacent [transparent] cup to be saved for later. After a 10-second practice trial, 10 scored trials were conducted with variable time intervals. The time intervals were as follows: 20-, 40-, 10-, 60-, 20-, 90-, 10-, 120-, 15-, 180-seconds. The first four trials were always conducted regardless of whether the child passed or failed. If the child ate the snack early in one of the first four trials or any of the subsequent trials, the task was terminated. Scores were determined using the following coding system: 4- waits for the timer to beep (does not touch cup or timer), 3-touches cup/timer, 2- touches snack, 1- eats snack. In addition, ability to keep hands flat for the entirety of each trial was recorded using the following code: 0- did not keep hands flat, 1- kept hands flat.

Results

Analysis Strategy

There were two goals of the analyses. The first goal was to determine if age effects were present for each of the tasks. Second, I wanted to determine if there were overall task effects. In order to determine this, a repeated measures ANOVA was performed with age group and gender as between-subjects variables and task as the repeated within-subjects variable. There were no significant effects found with gender, so the repeated measures ANOVA was repeated with just age and task. This analysis revealed a significant task effect, F (4,304) = 20.93, p = .000, partial eta^2 = .269. No significant effects of age were found. This analysis was followed up with five age group ANOVAs, one on each task.

Cool Task Results

Table 1 demonstrates the average percent of trials correctly answered for both Pencil Tap (PT) and Day/Night (DN). These two tasks included 16 trials that were either marked as correct or incorrect, yielding an easy comparison by age group through average accuracy. For Pencil Tap, there was a significant effect of age, F (1,77) = 6.50, p = .013. Three-year-old children averaged 34.74% of trials (5 of the 16 trials) correctly performed, and 4-yr-olds demonstrated accuracy on 52.45% of the trials (8 of the 16 trials). For Day/Night, there were no significant effects of age. Three-year-old children averaged 53.49% trials (8 of the 16 trials) correctly performed, and 4-yr-olds demonstrated success on 64.54% of the trials (10 of the 16 trials). Three- and 4-year-old age groups each demonstrated a range of 0-100% correct for both Pencil Tap and Day/Night.

Table 1

Pencil Tap and Day/Night Percentage of Correct Responses

	3-yr-olds (n=34)		**4-yr-olds (n=46)**		**Age Effect**
	Mean	**SD**	**Mean**	**SD**	
Pencil Tap	34.74%	26.88%	52.45%	33.22%	*p=.009*
Day/Night	53.49%	38.28%	64.54%	32.69%	*ns (p = .156)*

Table 2 illustrates the average total of trials correctly answered for both Dimensional Change Card Sort (DCCS) and Head-Toes-Knees-Shoulders (HTKS). Both of these tasks have multiple conditions. DCCS involved three different conditions (Color Game, Shape Game, and Advanced Card Sort). In order to pass into the next trial, 83% accuracy was required (5 of the 6 cards sorted correctly). As a result, the participants experienced variability in the number of conditions they were administered. An agegroup ANOVA on the number of correctly sorted cards yielded a nonsignificant age trend, F (1,77) = 3.22, p = .077. Overall for this task, the 3-year-old and 4-year-old age groups demonstrated an average of 9.38 (range= 1-20) and 11.69

(range= 0-20) correctly sorted cards, respectively. I also performed age ANOVAs for the Color Game and Shape Game. For the Color Game there were no significant effects of age. The 3-year-olds averaged 5.86 correct responses. 4-year-old participants demonstrated an average of 5.88 correct responses. For the Shape Game there was a significant effect of age, F (1,77) = 4.33, p = .041**.** Three-year-olds correctly sorted 1.82 cards and 4-year-olds correctly sorted 3.17 cards, on average. For the Advanced Cart Sort, there were no significant effects of age. The average for 3- and 4-year-olds for the advanced portion of this task was 1.694 and 2.74 cards correctly sorted, respectively.

In HTKS, the participants were required to demonstrate 50% accuracy (5 of the 10 trials correct) on Part 1 (Head/Toes) in order to move into Part 2 (Knees/Shoulders). The ANOVA on the total number of points yielded a significant effect of age, F (1,77) = 8.53, p = .005. For the task overall, the 3-year-old age group averaged 8.82 points with a range of 0-32 points, and the 4-year-old age group obtained, on average, 15.63 points with a range of 0-33 points. Specifically, for Part I, there was a significant effect of age, F (1,77) = 6.84, p = .011. In part I, which had a maximum of 32 points possible, the 3-year-old participants averaged 3.60 points, and the 4-year-old age group demonstrated an average of 7.62 points. Part II yielded no significant effect of age. In Part II, which had a maximum of 20 points possible, the 3-year-old participants averaged 1.13 points, and the 4-year-old age group demonstrated an average of 2.77 points.

Table 2

Dimensional Change Card Sort and Head-Toes-Knees-Shoulders Average Correct

	3-yr-olds (n=34)		4-yr-olds (n=46)		Age Effect
	Mean	**SD**	**Mean**	**SD**	
Dimensional Change Card Sort	9.38	5.59	11.69	5.85	*ns (p = .061)*
Head-Toes-Knees-Shoulders	8.82	8.97	15.63	11.49	*p=.004*

Hot Task Results

There were no significant effects of age on the longest wait for snack delay (hands flat *and* received a score code of 4, indicating they did not eat the snack early or touch any test materials). For 3-year-old participants, there was an average wait of 24.72 seconds with flat hands; 4-year-old participants demonstrated an average wait of 26.15 seconds. I also examined the number of trials in which children were able to keep their hands flat and not touch any test materials in a gender by age ANOVA. There were no significant effects of age. Three-year-olds, on average, passed 1.95 trials, and 4-year-olds passed 1.51 trials, on average.

Table 3

Snack Delay Average Longest Trial with Hands Flat

Snack Delay Task	**3-yr-olds (n=34)**		**4-yr-olds (n=46)**		**Age Effect**
	Mean	**SD**	**Mean**	**SD**	
Longest Wait with Hands Flat	24.72 s	40.95 s	26.15 s	34.40 s	*ns (p = .863)*
Average Trials Passed	1.95 trials	0.40 trials	1.51 trials	0.35 trials	*ns (p = .409)*

Discussion

Cool Tasks

Although 4-year-olds performed more accurately than 3-year-olds on all cool tasks, these differences were only significant for Pencil Tap and Head-Toes-Knees-Shoulders. Both Pencil Tap and Day/Night are rooted in working memory, but Pencil Tap also focuses on measuring the inhibition of a dominant response. Thus, the difference in results between these tasks are understood as this difference in what the tasks require from the children. Pencil Tap's additional aspect of inhibition of a dominant response requires both a cognitive aspect and behavioral aspect (the physical tapping of the pencil). Both tasks begin with up to 6 practice trials. The participants are able to move to the testing phase after 3 successful trials for Pencil Tap and 2 successful trials for Day/Night. Thus, there is a similarity in the training for the participants for these tasks. Consequently, the inhibition of a dominant response, the main difference between these tasks, is suggested as the underlying cause of the significant age difference for Pencil Tap and not for Day/Night.

The results found in both Pencil Tap and Day/Night are consistent with previous research. In Carlson's (2005) measure of executive function in preschool-age children, Day/Night also was found to have no significant age effect. Her study employed 17 different tasks, and only 5 of them were not significant, including Day/Night. In addition, as seen in Blair and Razza's (2007) study, Pencil Tap (referred to as Peg-tapping) was a significant predictor of executive function in 3-5-year-old children.

DCCS yielded a range of 1-20 correctly sorted cards for 3-year-old children and 0-20 correctly sorted cards for the 4-year-old participants. 20 is the maximum number of cards presented for this task, indicating that both age groups had participants who received perfect scores. Additionally, the range for both age groups is very similar, but 4-year-old children had at least one participant who was unable to sort any of the cards correctly. There is no suggested explanation for this slightly larger range for 3-year-old children compared to the 4-year-old group. Furthermore, this task did not demonstrate a significant age effect for the average performance; however, when the conditions were analyzed individually, one of the three conditions (Shape Game) yielded a significant age effect. For the task overall, the 3-year-old age group, on average, sorted 9.38 cards correctly, and the 4-year-old participants sorted 11.69 of the 20 cards correctly. This difference yielded no significant age effect. The first condition of DCCS, the Color Game, also demonstrated no age effect due to the similarity in performance between age groups. However, the second condition, the Shape Game, had a significant age effect due to the variability exhibited between age groups. The Shape Game's results were likely significant due to 4-year-old children's enhanced abilities to alternate rules between tasks or employ their abilities to shift between sets. The Color Game alone does not require any form of set shifting. However, when the Shape Game is introduced, the children must be able to switch between sets in order to accurately complete the test. This would account for the 4-year-old age group's ability to perform better on the Shape Game compared to the 3-year-old age group. Performance on the third condition, Advanced Card Sort, was very poor for both age groups, indicating that although 4-year-olds were able to switch rules between tasks, they were unable to adequately switch rules between trials within a task (alternating between the Color and Shape Game during the Advanced Cart Sort portion).

Carlson's (2005) study demonstrated a significant age difference for DCCS. In comparison, Carlson's number of participants for this task was half (40 participants) of the size of the cohort for this current study (80 participants); however, the participants in her study were slightly older (4-5-year-old children) than the current study. DCCS also was seen in a study performed by Zelazo, Müller, Frye, and Marcovitch (2003) In this study, the age cohort consisted of 3- and 4-year old children, similar to the current study. The results of Zelazo et al.'s (2003) experiment also yielded no significant age effect. DCCS is designed to measure set-shifting, the ability to alternate between rules for a task (e.g. switching between sorting cards based on color to sorting based on shape). Based on recent research from Ahmed, Tang, Waters, and Davis-Kean (2019), attentional shifting (i.e. set shifting) begins to develop fully between the ages of 4- and 5-years-old. This information provides a plausible understanding for the difference in results between the current study and Carlson's (2005) study. Further, this information can be used to explain why 4-year-olds were able to switch rules between task but not within a task. At 4 years of age this ability (set-shifting) is just beginning to develop. Thus, it is expected that if this study was adapted to include 5- to 6-year-olds, there would be additional variability. As a result, it is suggested that Dimensional Change Card Sort is a prominent determination of executive function for children nearing the end of their preschool career/ beginning kindergarten.

Head-Toes-Knees-Shoulders also demonstrated a significant age difference in total score for 3- and 4-year-old children. The results for this task align with prior research conducted by McClelland et al. (2014), which illustrated a significant age effect between early and late preschool-age children (3- and 4-years-old) for HTKS. This task is designed to measure both inhibition of a dominant response and working memory, similar to Pencil Tap. Thus, the current study suggests that as age increases from 3-years to 4-years of age, there is an increase of ability to inhibit a dominant response and working memory. Specifically, because HTKS demonstrates a physical inhibition alongside the cognitive inhibition, these results can be expanded to include the importance of being able to inhibit physical responses.

Hot Task

Successful performance on Snack Delay was determined by the longest wait in which participants were able to refrain from touching any test materials (including the snack, cup, or timer) *and* keep their hands flat on the table. Although there was a general difference in performance for the 3- and 4-year-old participants, no significant age effect was shown. On average, 3-year-old participants were successful in keeping their hands flat and not touching the materials for 24.72 seconds, whereas 4-year-olds were able to meet these requirements for 26.15 seconds. Furthermore, the 3-year-old age group demonstrated a range of 0-150 seconds, and the 4-year old age groups demonstrated a smaller range of 0-120 seconds. The second part of this task looked at the number of trials successfully completed, which is measured the same as above (being able to refrain from touching any test materials *and* keep their hands flat on the table). On average, 1.95 trials were completed successfully by 3-year-olds and 1.51 trials by 4-year-olds.

There is no reasonable explanation that accounts for the slightly better performance shown by 3-year-old children. Overall, performance on this task was very poor for both age groups. One reasonable suggestion to account for this performance is that low income families, such as those enrolled in Head Start programs, do not typically have an abundance of resources, such as food. Therefore, when presented with the snacks, it is hard for the children to resist the temptation.

Overall Comparison

Overall, 4-year-old children performed better than 3-year-olds on each of the five tasks. However, only two of these tasks, Pencil Tap and Head-Toes-Knees-Shoulders, showed significant age differences. As discussed previously, this is suggested to be a result of the differences in abilities that are required to complete these tasks accurately. Pencil Tap, Day/Night, and Head-Toes-Knees-Shoulders all focus on the use of working memory. However, Pencil Tap and Head-Toes-Knees-Shoulders also require inhibition of a dominant response, both mentally and physically. These tasks are, in general, more difficult due to the multiple facets present.

Furthermore, one notable congruency for the 3- and 4-year-old age groups is the pattern similarity of worst and best performance. Both age groups yielded the best (most successful) results for Day/Night; in contrast, both age groups performed worst (least successfully) on Head-Toes-Knees-Shoulders. These results were determined by comparing the mean score to the maximum score possible for each task. Thus, the pattern similarity suggests that although general performance increases across age, the comparative level of difficulty between tasks stays the same.

Limitations

There are several limitations throughout this study. First, there were time constraints in many different parts of the study. The children in this study were tested over the course of two months. Live-coding was performed at all data collections, but due to a lack of time, the sessions were not recoded using the video recordings. This would have provided more valid results. In addition, the time allotted into constructing the written portion of this project provided limitations. Due to the decreased time, the interrater reliability was not able to be calculated. The data presented in this project is part of a larger research project, involving five additional hot tasks. These additional tasks were tested at the same time as the five tasks presented in this paper. However, the additional tasks were not able to be used due to the need to code variables from videotape. This coding is time and labor intensive, so these results are not yet available. More time would have allowed for further modification and analysis of these results.

Another limitation of this study is the lack of demographic variables obtained for the participants, such as race and socioeconomic status. One of the preschools in which testing was performed, the WKU Child Care Center, is a blended Head Start/child care program, and the other school, Warren County Head Start, is strictly a Head Start program. Due to this blend of participants, socioeconomic status should be obtained and used in analysis to determine its effect on the results. The addition of demographic variables, including socioeconomic status and race, would allow for a better understanding of the representativeness of this sample to the general public.

Future Implications

The results of this study were designed to provide the preliminary step to understanding when children are prepared to enter into kindergarten. The information presented in this study is part of a larger, ongoing project that includes more variables, such as five additional hot tasks, child assessment reports on behavior, child assessment reports on temperament, and teacher reports on child's socio-emotional readiness for school. This additional information will allow for a better understanding of how children's executive function and effortful control ratings relate to factors, such as academic ability. As seen in previous research, increased levels of executive function and effortful control are correlated with increased academic success (Allan & Lonigan, 2014; Blair, 2002; Blair & Raver, 2015; Bull & Scerif, 2001; Garon, et al., 2008; Malanchini et al., 2018; Merz et al., 2014). Thus, the overall goal for the study is to use measures of executive function and effortful control tasks for 3- and 4-year-old children as a basis to predict academic success beyond preschool. In addition, both executive function and effortful control are trainable skills. Thus, early determination of delayed development in these two skills would allow for early intervention to help resolve these developmental differences.

Conclusion

The results from this study do not allow for overarching conclusions to be made in regard to the general public. However, as suggested by the results in this project, Dimensional Change Card Sort, Pencil Tap, and Head-Toes-Knees-Shoulders provide a better understanding as to which aspects of executive control develop first and thus, are predicted to play a role in early kindergarten performance. Due to the lack of differences displayed between age groups on Snack Delay, there is more research required before being able to make any specific claims about how measures of effortful control can be applied to other factors, such as academic success.

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