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Investigating the Link Between Executive Function and Creativity in School Aged Children

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INVESTIGATING THE LINK BETWEEN CREATIVITY AND EXECUTIVE FUNCTION IN SCHOOL-AGED CHILDREN

By

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Dedication Page

I would like to dedicate this thesis to Pinecrest Conference and Recreation Center. More specifically, I give my gratitude to the counselors who have served on staff with me and all the children who spend their summers in the pines. It is through Pinecrest that I have gained invaluable skills and confidence to succeed not only academically but also in life. This project would have been more complicated and difficult without their willingness for me to conduct my experiments during the summer.

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ABSTRACT

KATHERINE C. CRENSHAW: Investigating the Link Between Executive Function and Creativity in School Aged Children (Under direction of Stepahnie Miller)

The primary purpose of this research was to examine links between executive function (i.e., EF or conscious control) and creativity in school aged children. To accomplish this, participants completed measurements of creativity (i.e., Alternative Uses) and EF (i.e., the Backwards Digit Span to test working memory, the Delay of Gratification task to test inhibition). I also examined whether a creative manipulation (i.e., free coloring or coloring task-relevant materials) would impact EF performance in the Dimensional Card Change Sort (DCCS) focused on cognitive flexibility. While I did not find evidence for a relationship between my measures of EF and creativity, I found that those who were low in certain creative components (i.e., the ability to switch between categories called flexibility, the ability to generate a number of unique ideas called atypical fluency, and originality) performed better on the DCCS when allowed to freely color before the DCCS, while those who performed higher in creative measures generally did not benefit from a creative manipulation before the task. This suggests that those who are low in creativity may experience EF benefits from adding unstructured creative activities before a task.

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Executive function (EF) is an element of higher-order cognitive skills used in problem solving (Miyake & Friedman, 2012; Carlson, 2005). EF has been shown to be important in communication, academics, and emotional regulation skills (Blair & Razza, 2007; Diamond, Barnett, Thomas, & Munro, 2007; Pennington & Ozonoff, 1996). Though there has been research suggesting EF and creativity are related, results are equivocal, especially in school aged children (Suddendorf & Fletcher-Finn, 1999). There are also no studies that examine how short-term creative manipulations may influence EF and how the impact of creative manipulations may vary based on individual differences in creativity. In this study, I expand the research examining the link between EF and creativity in early childhood by examining whether 1) measures of creativity and EF correlated, 2) creative manipulations affected performance on an EF task, and 3) individual differences in creativity interacted with the effects of the creative manipulation on EF performance.

Executive Function

Frameworks of EF

EF is an important component of cognition that involves many higher-order cognitive processes such as *working memory* (i.e., manipulation of information in one's mind), *inhibition* (i.e., suppressing or controlling a prepotent response), and *cognitive flexibility* (i.e., switching flexibility between tasks or mental sets, see Miyake & Friedman, 2012; Carlson, 2005). Although understanding the components involved in EF are important, some researchers have argued that EF may be best understood and studied as a macro-construct of problem-solving. This perspective is unique from other EF models because it suggests that the function of EF is to solve a problem, and failing to solve a problem indicates a failure in EF. Take the Dimensional Change Card Sort for example (DCCS, Frye, Zelazo, & Palfai, 1995). In this task participants are asked to sort bidimensional cards (e.g., blue bunny or red boat) to conflicting target cards (e.g., red bunny, blue boat) repeatedly by one dimension (e.g., if sorting by color, the blue bunny goes with the blue boat, and the red boat goes with the red bunny). On the critical EF trials, the sorting rule is changed and children need to switch and hold a new sorting rule in mind while inhibiting the old sorting rule (e.g., if switching to sort by shape children must inhibit sorting by color and now sort the blue bunny with the red bunny and the red boat with the blue boat). Next, the task can be made more difficult for older children by using a hierarchical rule structure that switches (e.g., if the card has a border sort by color, if the card has no border sort by shape). From a problem solving framework, if children fail to switch to the new sorting rule (i.e., they perseverate on sorting by color when asked to sort by shape) that would be considered a failure in EF.

The problem solving framework further categorizes the stages of a complex problem solution and allows researchers to distinguish inflexibility at four functionally distinct steps (Zelazo, Carter, Reznick, & Frye, 1997). The first phase in solving a problem is known as problem representation. For a person to solve a problem, one must have an accurate understanding of the problem. In the DCCS task, this would be a person’s ability to understand and represent the rules of the task and relevant stimuli (e.g., sort the bunny by shape). The next phase considers the information-processing approach of planning. Though there are multiple ways to think of this; searching for the problem space for a promising plan and sequencing temporal actions are primary. In the DCCS task, this would be visualizing sorting the correct cards based on the rule to the target cards. The third phase is known as execution. In order to properly execute the plan, one must possess intending and rule use. Intending is the ability to remember a plan long enough to complete it while rule use is actually translating the plan into a behavioral action. For example, the participant must remember which dimension to sort by (i.e. intending) and then physically put the card in the correct box (i.e. rule use). These are important subphases of execution because it is possible to experience inflexibility to each of these processes. In the final phase of the problem solving framework, one evaluates if the actions have solved the problem. Evaluation involves both error detection and error correction which involves possible revision of a previous stage of the framework. In the DCCS task, this would be the participant realizing they sorted by the wrong dimension then correctly sorting the card on the next trial (Zelazo et al. 1997).

Benefits of this organized framework is that it provides an intuitive and functional way to assess EF-- namely EF is executed if one solves the problem correctly, and an EF failure occurs when there is an error in problem solving, which can occur at one one of the phases described above. Further, this framework provides the ability to locate EF mistakes in a sequence of problem solving phases. Before, errors in EF could be due to a variety of reasons. By keeping the problem solving framework in mind, it is possible to pinpoint disruptions in the problem solving process. This macro-construct also showcases the variety of psychological processes working together (e.g., inhibition, working memory, flexibility) to solve both simple and complex problems (Zelazo et al., 1997). This point (i.e., the reliance on multiple cognitive processes) is similar to other frameworks, such as the unity/diversity framework proposed by Miyake and Friedman (2012).

Like the problem solving framework, the unity/diversity framework suggests multiple components contribute to EF but they take a different approach to EF. Instead of suggesting that multiple components contribute to an overarching macro-construct of EF, this framework focuses on modeling what is common and what is distinct across the problem solving of a number of EF tasks. The "diversity" in this model focuses on the differences or unique contributions of component processes in working memory and flexibility to problem solving. However, they also acknowledge that there is "unity" in EF related to the extracted inhibition component which they term "common EF". Common EF is related to performance in all EF tasks and may be best described as the ability to actively maintain task goals and goal-related information and then using this information for lower level processing. This framework is important to consider because it involves the idea of EF having similar underlying processes, but task performance may rely on additional EF abilities based on the task at hand (e.g., an inhibition EF task may rely primarily on common EF whereas a flexibility EF task may rely on both common EF and an additional flexibility component related to abilities in transitioning to new task representations, Miyake & Friedman, 2012). This differs from Zelazo et al. (1997) framework because it suggests the components of EF can exist independently but still be connected which might account for differences in children's EF. This framework is particularly important when understanding EF of children older than five where inhibition, working memory, and cognitive flexibility appear diverse in development (Best & Miller, 2010).

Development of EF

There are multiple perspectives of how EF develops as well. For example, Representational frameworks (e.g., Zelazo, 2004; Marcovitch & Zelazo, 2009) focus on children's ability to represent their environment internally. These frameworks suggest that as children develop in their ability to represent and reflect on their representations of the world, they are better able to control behavior consciously and execute EF. For example, newborns are hypothesized to be incapable of reflecting and thus do not exercise EF or control, and instead are motivated primarily based on pain and pleasure (e.g., putting a rattle on their mouth to suck because it is pleasurable). When children begin labeling and representing the world through language and pointing (usually around 1 year), they gain an ability to attach experience to long term memory or working memory. Thus, they would be able to better control their behavior by reflecting on their representations (e.g., the word rattle linked to a memory of a toy that can be shaken). Instead of executing an immediate action like sucking the toy they may control behavior and shake the rattle. Thus, representation and reflection adds depth to experiences and allows for more details to be remembered. More than that, a higher level of consciousness is credited with representing more complex knowledge structures which can help children control behavior (i.e., controlled shaking versus reflexive sucking of the rattle). These abilities of representation and higher consciousness increase with age (Zelazo, 2004) as children develop in their ability to represent complex rule structures like embedded if-then statements (e.g., in the DCCS it is not until about 4 years of age that children can shift rules and appreciate that if they are playing the color game a card will be sorted one way, but if they are playing the shape game a card will be sorted a different way; Zelazo et al., 1999).

Other important EF frameworks are neurological in nature, suggesting that EF depends on neural circuitry within the prefrontal cortex (PFC, Luria, 1996; Shimamura, 2000). Although early childhood is a period of tremendous growth in the PFC, it is also important to consider the idea of neuroplasticity-- the idea that brain development is responsive to experience and can be trained to strengthen certain synapses. Therefore by strengthening the PFC, it might be possible to strengthen EF (Arnsten, Raskind, Taylor, & Connor, 2015). In fact, Olson and Luciana (2008) found evidence that supports the idea that different regions of the PFC activate with different EF components, but there are common regions that still are activated throughout all EF skills. The PFC also develops later than other neurological functions (e.g., speech and language, motor and sensory processing), and this section of the brain does not fully mature until early adulthood (Best, Miller, & Jones, 2009). This prolonged development is thought to be the main reason that children seem to benefit from EF improvement programs more than adults, most likely because the synapses are still being created and strengthened within the PFC. This brain development theory also supports the reason why EF development is so prolonged compared to motor and speech development (Best, 2010).

Malleability of EF

Given that we know that EF is developing across preschool and into school age, research has focused on what types of manipulations and interventions may improve EF abilities during childhood. Studies have shown EF to be malleable across this period, in children as young as four (Diamond, Barnett, Thomas, & Munro, 2007) and into older school age children as well (Benzing et. al, 2018). Interventions have been shown to have both short term and long term effects on EF.

In the short term, there are many manipulations within the course of an experiment that have been shown to improve EF performance. The use of language seems to benefit EF. Labeling different aspects of the task, such as the name of the hiding place of items in an EF search task has benefited EF performance (Miller & Marcovitch, 2011), and reflection seems to promote self regulation in adolescents, a component of EF (Doebel & Zelazo, 2015). Movement and exercise seem to have intervention effects as well. Adults seem to perform better in EF tasks after 5 minutes of walking (Jaffery, Edwards, & Loprinzi, 2018), while children also seem to experience some EF benefits from acute exercise prior to EF tasks (Jager, Schmidt, Conzelmann, & Roebers, 2014). To the best of my knowledge, no short term EF interventions involving mindfulness or creative arts have been published, but short term music training may enhance EF (Moreno et. al, 2011).

In the long term, Diamond and Lee (2011) have reviewed a number of studies examining the long term effects of physical activity on EF. In particular, traditional tae-kwon-do training, which focuses on self-control and discipline (inhibitory controls), has been shown to produce greater EF gains in children as well as improved mental math (which requires working memory). Some studies also suggest yoga, which focuses on physical training, relaxation, and sensory awareness, may produce better improvement of EF than just physical training (Diamond & Lee, 2011). A systematic review by Silveira and colleagues (2019) found that exercise stimulates the PFC, specifically with higher left PFC activation and positive psychological responses (i.e. higher affect, energetic arousal, lower anxiety, more calmness). Mindfulness programs have also been shown to enhance cognitive skills, including EF, in school aged children (Schonert-Reichl et. al, 2015). Further, an arts education program that focused on creative movements and music increased EF and also changed brain chemistry in school aged children (Park et. al., 2015).

Curriculums have also been developed to improve EF. By utilizing Tools of the Mind (Tools), Diamond et al. (2007) was able to successfully increase EF in preschool aged children compared to their baseline and closely matched peers. Tools uses a type of mature and dramatic play based on Vtgotsky's insights of EF's development. By supporting and challenging EF throughout the school day, the children's EF and academic performance increased, and more positive behavior was noted by teachers' observations (Diamond et al., 2007). PATHS (Promoting Alternative Thinking Strategies) is another curricula that trains teachers in prioritizing children's competencies in self-control, behavior regulation, and interpersonal problem-solving. By training children to verbalize their feelings and practice conscious self-control strategies, the children's inhibitory control and cognitive flexibility improved after a single year of PATHS. For the children who score highest on the posttest for inhibitory control, the effect was retained a year later (Diamond & Lee, 2011).

In general, children who initially exhibit the lowest EF scores benefit the most from EF development approaches. Lower-income and children with Attention Deficit Hyperactivity Disorder (ADHD), particularly boys, typically show the most EF improvement across EF development programs. Implementing and finding new EF development programs is therefore important for reducing the achievement gap between more- and less- advantaged children in the United States. It is also important to note that EF programs only see improvements when the program is designed to become more challenging. Stagnant programs that do not increase in EF difficulty do not show EF gains. Most importantly, it is seen that teachers who are given training and support, can easily implement EF curricula into the classroom and the children benefit without the need for extravagant expenses. Diamond and Ling (2020) found through a comprehensive systematic review that the best EF interventions contained physical movement and mindfulness, such as tae-kwon-do and yoga. In addition, Diamond and Lee (2011) suggest that EF benefits also depend on a child's willingness to devote time to the activity. The review suggests that the best approaches to improving EFs will be those that not only engage the child's passionate interests, but also activities that bring them joy, pride, ability to address stress, incorporate aerobic exercise, and give them a sense of belonging (Diamond & Lee, 2011).

Creativity

Most researched manipulations have focused on short term improvements due to language or movement and long term improvements due to exercise, curriculum, and the arts. However, no one to date has focused on creative processes (most similar to work examining the arts) as a means for improving EF. There are several reasons why creative manipulations may lead to a boost in EF. First, like EF, creativity is associated with the PFC and this link may even be stronger in younger samples as compared to adults, as Kleibeuker and colleagues (2013) found that adolescents activate more of the PFC than adult's during creative problem solving. Related to this point, there is also a large body of work suggesting that better creativity is related to better EF (Edl et. al, 2014). Second, researchers have found that greater creativity was correlated with earlier acquisition of representational theory of mind (Suddendorf & Fletcher-Finn, 1999)-- an ability that has strong ties to EF in childhood (e.g., Carlson et al., 2004; Miller & Marcovitch, 2012). Third, creativity has strong ties to mindfulness (Langer, 1989), which was shown to be the most effective long-term intervention for EF improvement (Takacs & Kassai, 2019; Diamond & Ling, 2020). Fourth, creative manipulations could have a theoretical basis in the EF literature, as encouraging children to more fully represent and reflect on the task through art may encourage more accurate performance in children (e.g., Zelazo, 2004). Finally, creativity through visual art has the ability to be motivating for the child as well as bring joy and pride, a way to address stress, and give them a sense of belonging- also important factors in an EF intervention's effectiveness (Barfield & Driessnack, 2018).

Defining Creativity

The current understanding of creativity is the ability to balance the processes of idea generation (i.e., producing many ideas) and evaluation (i.e., rejecting unfit ideas). For example, in the alternate uses task (Guilford, 1967) children are told to list as many uses as they could for a common object (i.e., brick), with an emphasis on uses that were unique. In idea generation, one thinks of multiple ways a brick might be used (i.e., building, shoe, firewood, paperweight). Evaluation is narrowing down these ideas into answers that are unique and appropriate (i.e. shoe, paperweight) and rejecting unfitting answers (i.e. building because it is not unique, firewood because it is not useful or feasible). This allows for a person to think creatively but still arrive at appropriate answers.

Creativity's Link to EF

Creativity is likely linked to EF tasks of inhibition through rejecting unfit answers and cognitive flexibility through blurring categorical boundaries of objects (Edl et al., 2014; Pirson et al. 2012). For example, in the AUT, it is useful to reject unfit answers quickly to think of more relevant answers while blurring categorical boundaries of objects allows a person to generate more unique ideas for an object's use. Bai and Yao (2018) also have linked highly creative people to a stronger cognitive inhibitory ability than less creative people. Sharma and Babu (2017) found older adults who possessed above average creativity also performed significantly better in EF tasks. Furthermore, mindfulness has been highly correlated to creativity. The Western mindfulness definition involves many EF skills in order to reach a place of mindfulness. Western mindfulness is understanding that the world is constantly and subtly changing with the ability to adapt to that change. Furthermore, it is the ability to flexibly shift between multiple angles of a problem (i.e. creative problem solving, Langer, 1989). Although this work generally takes a unidirectional approach (i.e., better EF is needed for or predicts better creativity) studies are primarily correlational and thus the directional nature of the relation cannot be specified.

However, there is evidence that suggests creativity and EF are bidirectionally connected. Suddendorf and Fletcher-Finn (1999) suggest that creativity and some EF skills (i.e., the false beliefs task) develop in tandem because once children can successfully pass the false beliefs task (i.e., understanding people's different mental capacities), their creativity increases. Suddendorf and Fletcher-Finn (1999) attribute this correlation to an unknown common underlying skill that enhances both tasks. Mindfulness, which is strongly connected to creativity, has also been shown to stimulate the PFC and EF when paired with aerobic exercise such as yoga or tae-kwon-do (Diamond & Lee, 2011). Because EF and creativity seem to influence each other through a possible common underlying skill, it stands to reason that creativity and EF may be bidirectionally linked.

Applied to EF manipulations, it is thus reasonable to predict that creative manipulations may impact performance on EF. Creativity stimulates the PFC similar to how physical exercise does (Gonen-Yaacovi et. al, 2013; Silveira et. al, 2019). Therefore, creativity might also strengthen the PFC and increase EF performance like physical exercise is thought to do (Diamond & Lee, 2011; Kleibeuker et al., 2013; Best, 2010).

Representational theory suggests the better a person's ability to represent task-relevant stimuli internally, the better problem solving ability that person would have. Thus, creative manipulations directly related to the task may have the ability to help provide a different and potentially stronger representation for task-relevant stimuli (Zelazo, 2004), especially if the representation was self-generated (e.g., Miller & Marocovitch, 2011). Further, Diamond and Ling (2020) found that the best EF interventions involve mindfulness and gross motor movement such as taekwondo and t'ai chi. Work in art therapy that involves visual arts, creativity, and mindfulness improves social, mental, and emotional functioning and increases feelings of well-being, (Malchiodi, 2011) may align with work by Diamond & Ling (2020). This physical creation of art may combine with mindfulness to produce greater EF gains. Furthermore, art therapy may have the potential to provide different representations of the problem as well as a way to increase creativity in a person. Therefore, art therapy may serve as a new potential EF intervention.

Finally, it is important to note that there are individual differences in creativity, and some children may benefit more than others from a creative manipulation. For EF, those who initially exhibit lower EF skills are the children who benefit the most from interventions (Diamond & Lee, 2011). Because EF and creativity are thought to be similar to each other, this might also be true for a creative intervention.

The Present Study

Research examining the EF-creativity relationship is conflicting and primarily focuses on correlational studies not able to examine directionality. The purpose of this study is to investigate the connection between EF and creativity in school aged children aged 6-12, and to examine support for short-term creativity and art-based intervention on EF. I proposed that 1) creativity and EF will be positively correlated, 2) a creative manipulation will improve EF scores, and 3) creativity level will influence how useful creative manipulations are. To examine my first hypothesis I had 2 measures of EF (i.e., an inhibition task and a working memory task) and 1 measure of creativity (i.e., the AUT). To examine my second and third hypothesis I had a possible 3 creative manipulations employed before an EF switching task : 1) *Color Cards Condition*, which included a structured coloring activity where participants used a stencil to color stimuli that would be used in the DCCS task to determine whether a specific relevant creative art-based manipulation may encourage children to reflect on task and improve EF), 2) *Free Color Condition,* which included an unstructured coloring activity where participants could draw whatever they wanted to determine whether a general creative art-based manipulation before a task influenced EF and 3) *Book Condition,* which included a similar delay and interaction with an experimenter who read them a short book before the task, to provide a non creative or art-based control. I hypothesized that children in the *Color Cards* and *Free Color* condition would perform better than the non-creative or art-based control, given that art therapy has positive psychological effects. However, I also hypothesized that the *Color Cards* condition may perform the best because it encouraged children to represent task relevant stimuli through art (e.g., Zelazo, 2004) and using structured art therapy typically is more effective than an unstructured session (Kaimal & Ray, 2016; Kaimal et al., 2017).

Methods

Participants

All participants were campers at Pinecrest Camp and Recreation. In all, 49 participants were tested during an eight week period. Participants were 61% female with an average age of 9 years, 3 months. The ethnicity was 92% Caucasian with the remaining 8% reporting multiple races including Hispanic, Arabic, and Native American. Of the reported income brackets, 65% made over $120,000 while 23% made between $60,000 and $119,999, and the remaining 22% made less than $59,999. Parents were informed of the study when their children registered for camp, and had the option to talk to the primary investigator when dropping their child(ren) off at Pinecrest. The children were primarily within three hours of Memphis, Tennessee.

Criteria for involvement included children aged 6-12 who were typically developing. Children were required to be native English speakers, and have no problems that compromised hearing. Those who did not meet the required age or typical development requirement were excluded from the study.

Procedure

Every parent received a packet of informed consent upon registering their child for any week of camp, and could then sign their child(ren) up for the study if desired. Parents also were asked to fill out a demographic sheet for the child. During camp, the participants would be asked individually if they wanted to come complete the study during swim, snack, or cabin quiet time. The tasks were administered by a trained researcher. Once in the testing space (a quiet corner of the main building in full view of the kitchen staff), verbal consent was gained from participants. The participants first completed the AUT, followed by the Backwards Digit Span, the Delay of Gratification task, and finally the DCCS task with one of the three conditions. If the parent's consented, each session was video recorded by the researcher. At the end of the session, children were allowed to take a prize from the treasure box as well as a set of crayons.

AUT (Guilford, 1967). This task was chosen to examine each participant's creativity through a divergent thinking assessment. Participants were given two minutes to generate "all the different ways" to use a common object (i.e., brick, chair, shoe). All responses were handwritten by the researcher.

For scoring, a primary coder first evaluated each response as typical (e.g., intended use, like sit for chair) or atypical (e.g., unique use, like paperweight for brick) while excluding nonsense answers (e.g., nonsensical use, like doll hair for brick). Several aspects of creativity were scored for each participant. Total fluency was scored as the number of responses generated across all three items, and was further divided into typical fluency (i.e., the total number of typical responses) and atypical fluency (i.e., the total number of atypical responses- more in line with the instructions of the task asking for different ways to use a common object). Scores from each item were added together to achieve one score for both typical and atypical fluency. Total flexibility was also scored by the primary coder assigning each response in a category (e.g., building or pretend play for brick) then counting each participant's total number of categories across all three items. Finally, originality was scored using a subjective scoring method (Plucker, Qian, &

Wang, 2011). Each response was scored from 1 (not creative at all) to 5 (highly creative) by 3 raters. Responses were judged as being highly creative if they followed these three criteria: *uncommon* (occur infrequently in the sample), *remote* (remotely linked to the everyday object), and *clever* (strike people as insightful, fitting, or smart). The first rater's (the primary scorer) was aware of the number of responses per participant and what responses came from which participants, but the two second raters scored independently in a private Excel sheet with no participant ID number attached to each response. Second raters just rated individual responses and were therefore unaware of a participant's number of responses, which response came from which participant, or other identifying information about the participants when they scored each response. Participants received a total of 9 originality scores by averaging the originality for their answer set for each rater (i.e., rater1_brick, rater 2_brick, rater3_brick, rater1_shoe, rater 2_shoe, rater3_shoe, rater 1_chair, rater2_chair, rater3_chair). To further reduce scores, reliability was assessed across raters using intraclass correlations, demonstrating moderate reliability for average ratings of shoe, chair and brick across raters with ICCs > .63. Given the moderate reliability, I created an originality score for each participant on each item by averaging the score for each rater together. Finally, the calculated originality scores for brick, shoe, and chair were significantly correlated, rs(47)>.41, ps<.004, so I created an overall originality score by averaging scores together across the three items (i.e., chair, brick, and shoe).

Backwards Digit Span (WAIS –III; Wechsler, 1997)**.** This task assessed working memory. Participants were read a list of numbers aloud, and were asked to orally repeat the numbers backwards. For example, if read 2, 5, the correct response was 5, 2. Participants were presented with up to six sets with three trials each (i.e., a total of 18 possible trials). More specifically, Set 1 had three trials with two numbers each, Set 2 had three trials with three numbers each, continuing until Set 6 of three trials with seven numbers each. After a short training trial in which all participants demonstrated they were able to successfully repeat a set of two numbers backward with feedback, participants completed as many trials as possible until they missed three in a row. This task was scored according to how many trials the participants recalled correctly backward.

Delay of Gratification (Mischel, 1974). This task assessed inhibition. In this task, participants were presented with a card depicting a decision where they were asked if they would like a smaller reward now (i.e. pennies, stickers, or erasers) or a larger reward later. The experimenter completed two practice trials for the participant to demonstrate the rules (i.e., the experimenter chose 1 eraser now instead of 1 later with the eraser was placed in front of the experimenter, and the experimenter chose 8 erasers later instead of 1 now with the erasers placed out of reach in an envelope). The rewards were kept in clear tupperware containers in front of the participant, and the participant was presented with 9 trials with decisions of 1 now vs. 2 later, 1 now vs. 4 later, and 1 now vs 6 later for each reward. This task was scored by the number of times the participant chose to wait for a larger reward.

DCCS (Frye, Zelazo, & Palfai, 1995). This task was chosen to examine whether a creative manipulation influenced participants' cognitive flexibility. The structure of the task was similar for all children, who sorted 4x6 inch cards into 8x5x4 inch boxes that were closed with a sorting slot cut in the top so that cards were not visible once sorted. In this task, the sorting cards consisted of blue squares and red circles that were sorted to target cards (i.e., a blue circle and red square). Each target card was affixed to the front of the sorting box so that children were able to see the targets during the sorting procedure. Although some children completed a creative manipulation before the DCCS, the presentation of the DCCS remained essentially the same across the groups and consisted of three phases.

In the postswitch phase, children were asked to switch to sorting six sorting cards by another dimension (e.g. if they sorted by color in the preswitch they switched to sorting by shape and the blue square sorting card was now sorted to the red square target card). All but one participant performed perfectly in the postswitch phase, and so moved on to the more difficult borders phase (the child who failed to sort correctly on the postswich phase did not progress to the borders). In the border phase, children were presented with a set of twelve cards where they had to switch between sorting rules based on whether the card had a border (n=6, sort by color) or did not have a border (n=6, sort by shape) presented in a pseudorandom order fixed across participants. Performance on the DCCS was scored by measuring accuracy of the card sorting in the borders task.

Before the DCCS, each participant was randomly assigned to one of the three conditions meant to assess whether a creative art-based manipulation would influence DCCS performance in the borders phase of the task. The *Book Condition* served as a control where participants did not engage in a creative art-based task but did have interaction with an experimenter as they listened to a 5 minute story (Dr. Seuss's *Oh the*

Places You'll Go!) read aloud by the researcher before they completed the DCCS task. In the *Free Color Condition* participants engaged in an unstructured creative art-based task where the experimenter gave participants two crayons (i.e., a red and blue crayon) and a piece of 4x6 inch paper with the instructions to draw whatever they wanted for five minutes on both the front and back of the card for the entire 5 minute span, even if they said they were done. In the third condition, *Color Card Condition,* participants were engaged in a structured creative art-based task that was task-related in which the participants made were also presented with crayons (i.e., a red and blue crayon) and two pieces of 4x6 inch paper to create their own target cards for the DCCS by using a 3x3 inch stencil so that the size of the shapes on the target cards (i.e., square and circle) would match the other groups who did not create their own target cards. Participants were shown both stencils and instructed to pick a shape (i.e., circle or square). Then they were presented with both crayons and prompted to pick a color (i.e., red or blue). After this, they were instructed to color the stenciled shape carefully (e.g. blue square). Next they made the other target card with the remaining shapes and colors (e.g. red circle). Finally, the researcher attached velcro on the back of the cards to be used as target cards in the DCCS task.

Results

Descriptive Statistics

Descriptive statistics for variables of interest are presented in table 1. There was no missing data, except for one child who did not have data on the DCCS because they failed to pass the preswitch trials (i.e., at least 5 out of 6 correct). Missing data was handled in a pairwise deletion fashion. Performance on the two EF tasks, the backward digit span and delay of gratification, were not correlated, $r = -.03$, $p = .86$, so these components of EF were considered separately in analyses.

Table 1

Descriptive Statistics

	Mean (SE)		Range		N
EF					
Number of correct trials on BDS	7.06	(.32)	3	-13	49
Number of trails they chose later	7.67	(.21)	5	-9	49
DCCS	10.83	(.24)	0	-12	48
Book Condition	10.81	(.42)	0	-12	16
Free Color Condition	11.31	(.35)	0	-12	13
Color Card Condition	10.53	(.42)	0	-12	19
Creativity					
Total Fluency	23.20	(1.81)	3	-81	49
Total Typical Fluency	8.94	(.73)	3	-24	49
Total Atypical Fluency	14.08	(1.73)	0	-78	49
Total Flexibility	13.53	(.91)	3	-42	49
Total Originality	2.00	(.06)	1	-2.9	49

Note. BDS=Backward Digit Span (Working Memory).
DCCS=Dimension Change Card Sort Task (Cognitive Flexibility).

Are creativity and EF related?

To examine the first research question inquiring whether creativity was related to EF assessments, bivariate correlations were conducted between creativity (i.e. total fluency, total typical fluency, total atypical fluency, total flexibility, total originality) and EF (i.e. BDS and delay of gratification). I found no significant correlations between creativity and EF, *rs* > 0.25, *p* > .1, indicating that creativity was not related to EF measures in working memory and inhibition administered in my study.

Does EF performance differ by creative condition?

To examine my second research question examining whether EF performance differed by creative condition, I conducted a general linear model on DCCS borders performance (number correct out of 12) with condition (3 levels: book, color card, free color) and age (continuous) as predictors. Results demonstrated no significant effect of age $F(1,42) = .70$, $p = .41$, condition $F(2,42) = .19$, $p = .83$, or an age by condition interaction $F(2,42) = .14$, $p = .87$ with regard to number correct on the borders task, indicating that age and creative condition did not impact DCCS performance.

Does the effect of condition vary by children's creativity abilities in typical fluency?

Although creative condition did not appear to influence DCCS performance, my third set of analyses addressed whether the effect of condition interacted with individual differences in children's creative ability. Given that I found no effect of age in my first analysis, I did not consider age further. To examine this question, I conducted a general linear model on DCCS borders performance with condition (categorical: 3 levels), total fluency (continuous: total number of responses generated) and a condition by total fluency interaction as predictors in the model. Fluency was a significant predictor of DCCS performance $F(2,42)=6.82$, $p=.01$, which was qualified by an interaction between condition and total typical fluency $F(2,42) = 3.48$, $p = .04$. To further examine the interaction, I did a simple slopes analysis looking at the impact of condition for children one SD below the mean on total typical fluency (M=3.184) and one SD above the mean on typical fluency (M=14.068). Those who were one SD below the mean on typical fluency did not have significant differences between conditions, all pairwise comparisons, *p*>.11. Those who were one SD above the mean on typical fluency did have significant differences between conditions, where children who were in the color cards condition performed worse than children in the book condition, *p*=.03, and worse than children in the free color condition, *p*=.05, see Figure 1.

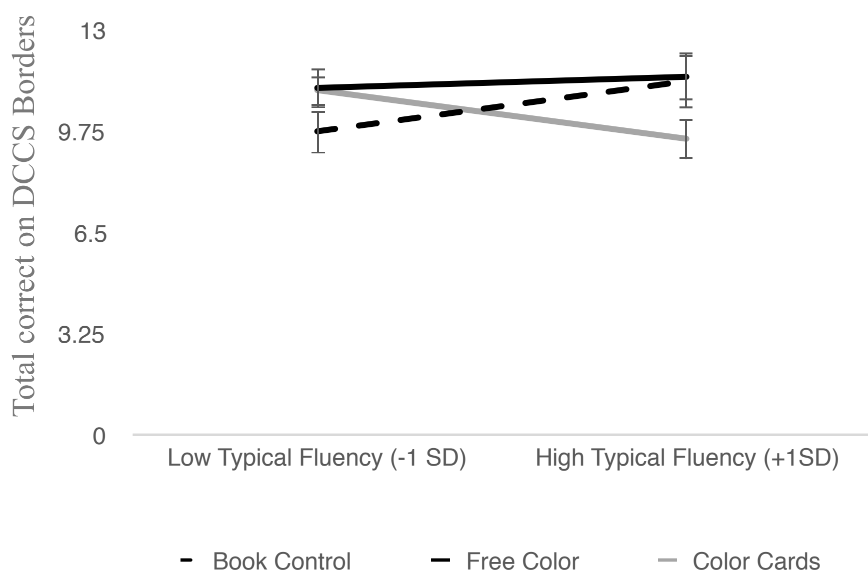

Figure 1. Individuals high in typical fluency performed worse in the color cards condition compared to the free color and book control.

Does the effect of condition vary by children's creativity abilities in atypical fluency?

Next, I performed a general linear model on DCCS borders performance with condition (categorical: 3 levels), atypical fluency (continuous: total number of atypical responses generated), and a condition by atypical fluency interaction as predictors. Results indicated that all of our predictors were significant: total atypical fluency $F(1,42) = 8.77$, $p = .01$, condition $F(2,42) = 3.58$, $p = .037$, the atypical fluency by condition interaction, $F(2,42) = 3.3$, $p = .05$. To further examine this interaction, I did a simple slopes analysis looking at the impact of condition for children who were one SD below the mean on atypical fluency (M=1.997) and one SD above the mean on atypical fluency (M=26.163). Those who were one SD below the mean on atypical fluency performed better on the DCCS task when in the free color condition compared to color card $p=.03$ and book $p=.04$, see figure 2. Those who were one SD above the mean on atypical fluency did not have significant differences between conditions, all pairwise comparisons, $p>.17$.

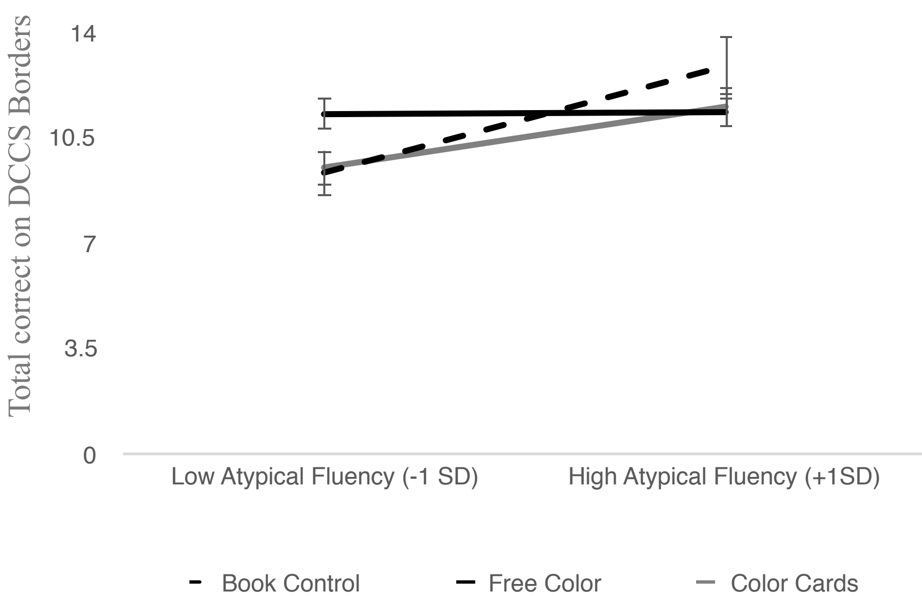

Figure 2. Individuals low in atypical fluency performed best in the free color condition compared to the color cards and book control.

Does the effect of condition vary by children's creativity abilities in total flexibility?

Next, I performed a general linear model on DCCS borders performance with condition (categorical: 3 levels) and total flexibility (continuous: total number of categories generated). I found an interaction between condition and total flexibility $F(2,42) = 3.37$, $p = .04$. A simple slopes analysis was conducted looking at the impact of condition for children who were one SD below the mean on total flexibility (M=7.166) and one SD above the mean on total flexibility (M=19.894). Those who were one SD below the mean on total flexibility performed worse on the DCCS task when in the color card condition compared to free color p=.03 and book p=.08. Those who were one SD above the mean on total flexibility had one marginally significant difference between conditions, with better performance on DCCS in color card condition compared to book, p=.07, see Figure 3.

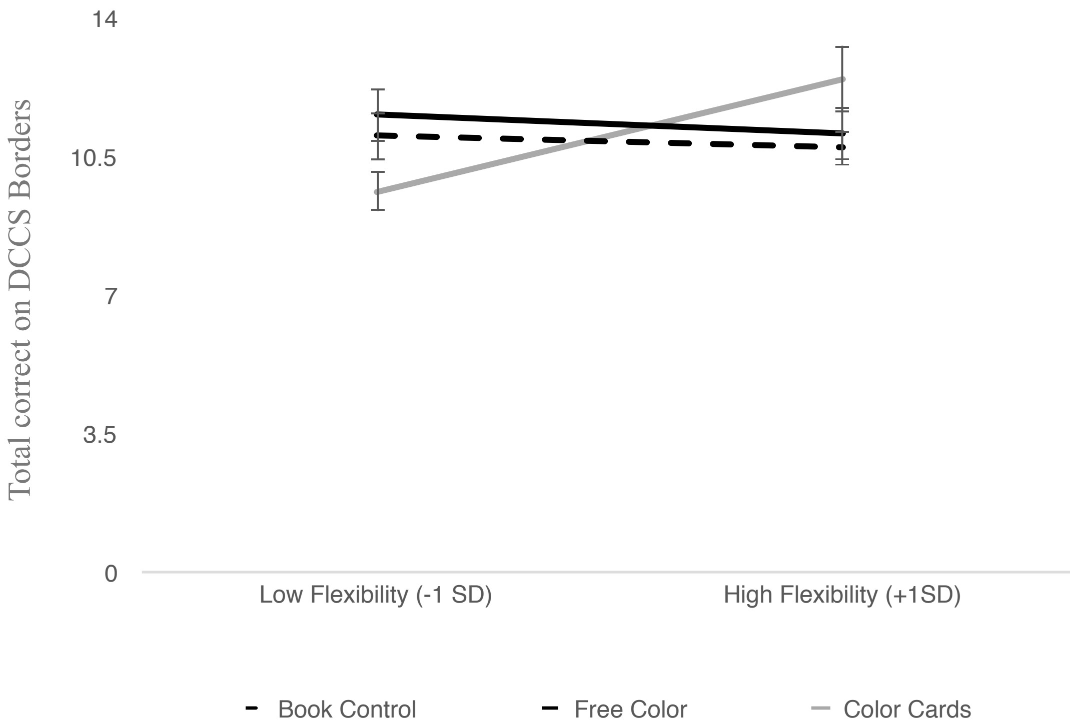

Figure 3. Individuals low in flexibility performed best in the free color and marginally better in book condition compared to color cards. Individuals high in flexibility performed marginally better in the color cards condition compared to book control.

Does the effect of condition vary by children's creativity abilities in total originality?

Finally, I examined whether the influence of condition might differ by children's originality. A general linear model on DCCS borders performance was conducted with condition (categorical: 3 levels) and total originality (continuous) as predictors. Overall, the model was not significant $F(5,42)=1.58$, $p=.19$. Although condition was significant, $F(2,42)=3.4$, $p=.04$, there were no differences when probed further. There was a moderately significant interaction between condition and total originality $F(2,42)=3.0$, $p=.06$.The simple slopes analysis examined the effect of condition for children who were one SD below the mean on total originality (M=1.598) and one SD above the mean on total originality (M=2.394). Those who were one SD below the mean had significantly higher DCCS performance in the free color condition compared to the color card condition, *p*=.01. Those who were one SD above the mean on total originality did not have significant differences between conditions, all pairwise comparisons *p*> .44.

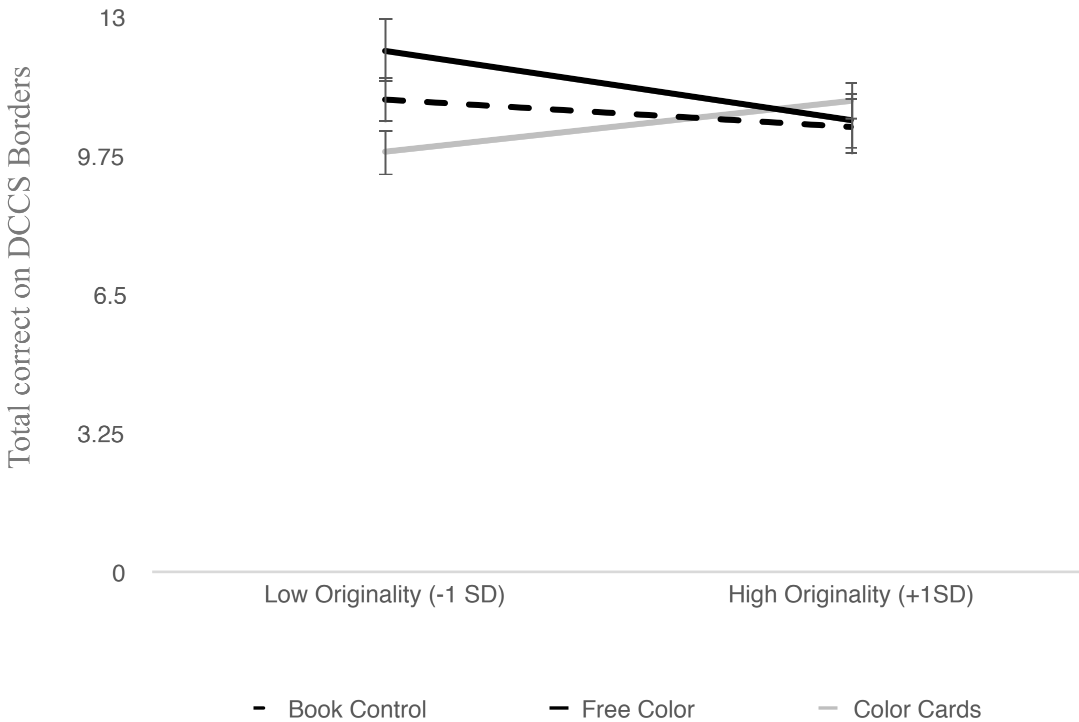

Figure 4. Individuals low in originality performed best in the free color compared to color cards.

Discussion

The present study aimed to examine the relationship between EF and creativity in school aged children. Furthermore, it was designed to examine the effect of creative manipulations on EF outcomes as well as the effectiveness of creative manipulations compared to the child's innate creative ability. I found little evidence that creativity measures on the AUT related to EF. However, I did find evidence that creative conditions influenced EF as measured through the DCCS and most importantly the impact of creative condition varied by creative ability. Those who are low in creativity (i.e. high in typical fluency and low in atypical fluency, flexibility, and originality) seemed to benefit from the creative manipulation of free color, but for those who were high in creativity (i.e. low in typical fluency and high in atypical fluency, flexibility, and originality) the condition typically did not matter.

There are numerous studies examining the relationship between creativity and EF. The results are mixed, with a few studies claiming a connection (e.g. Bendek et al., 2012; Edl et al., 2014), while others suggest otherwise (e.g. Carson et al., 2003; Healey & Rucklidge, 2006; Sharma & Babu, 2017). The present study seemed to support the latter. These results were not expected as we hypothesized that since creativity and EF seem to have similar processes, that they would positively impact each other. These different results may be the result of using different EF measures (i.e. DCCS instead of Stroop) and different creative measures (i.e. AUT instead of Torrance Tests of Creative Thinking) used in the other studies. It may be that EF and creativity have a common factor so that while there may not be a direct link between EF and creativity, there is an indirect link of a common factor(s) in both EF and creativity. More research is needed in order to better understand this connection.

Although I found no main effect for the creative manipulations on EF performance as measured by the DCCS, further analysis suggests that creative manipulations may play a role for children who were lower in creativity. Overall, those who scored low in creativity seemed to perform best in the free color condition. More specifically, those who were high in typical fluency (i.e., those who get stuck on naming typical uses for common items and thus lack creative responses) performed worse in color card condition compared to both book condition and free color condition. Those low in atypical fluency, (i.e., those who do not name a number of unique uses for common items and thus lack creative responses) performed best in free color condition compared to both color card condition and book condition. Those low in flexibility (i.e., those who do not blur categorical boundaries so generate more common uses and thus lack creative responses) performed worse on color card condition compared to both free color and book. And finally, those low in originality (i.e., those who cannot generate uncommon, remote, and clever uses and thus lack creative responses) performed better in free color condition compared to color card condition. This result was contrary to my hypotheses, as I expected children to perform better in the color card condition thinking that this creative task might encourage children to internally represent task-relevant stimuli (i.e., the shape and color of the sorting and target cards, Zelazo, 2004), in addition to any benefits that might be obtained by a creative short term intervention (Suddendorf & Fletcher-Finn, 1999).

My results showed that an unstructured creative coloring intervention (i.e. free color) was the most beneficial for children who were low on creativity are not completely unsurprising, as research suggests all coloring intervention can be effective in lowering anxiety (Ashlock, Miller-Perrin, & Krumrei-Mancuso, 2018). Van der Vennet and Serice (2012) also found that structured art activities lowered anxiety in adults better than unstructured because participants often would not know what to draw. Furthermore, a study of the effect of structured and unstructured art on test anxiety in children also had no significant differences between structured and unstructured art (Carsley, Heath, & Fajnerova, 2015). However, all these studies looked at the effect of anxiety instead of EF connection and only one looked specifically at children so this may explain the different results.

Also important to note is the fact that structured creativity did not seem to help children any more than the control when they were low in creativity. Prior research suggests any art intervention should be helpful (Ashlock, L. E., Miller-Perrin, C., & Krumrei-Mancuso, 2018; Carsley, Heath, & Fajnerova, 2015). The reason a structured creative intervention may not aid children low in creativity is the lack of creative thought that goes into the physical art making of task-relevant stimuli. For example, in the free color condition, participants had to actively decide what to draw and how it would look while for the color card condition, participants simply colored in the lines. In essence, free color condition seemed to ask participants to be creative prior while color card condition merely asked them to complete a task.

It was also interesting to note that those who were already high in creativity received no benefit from creative manipulations save for those scoring high in flexibility performing marginally better in the structured color card condition. This suggests a structured creative manipulation meant to draw children's focus to task-relevant stimuli may help them perform an EF task, however only for those that are already high in creativity. Previous work has found that EF gains are typically dependent on individual differences (e.g., those who see the most EF improvement in structured intervention are those with low EF, Diamond & Lee, 2011). Therefore, those high in creativity perhaps did not benefit from the creative intervention because their creativity was already high.

In addition, the present results may point to other individual differences that may be important to measure when examining the effectiveness of a structured and unstructured intervention (e.g., base abilities in creativity may be important to understanding how a creative art based intervention may work). These results might also explain why creativity and EF research has been contested. Before, studies have not closely examined individual differences in multiple aspects of creativity (e.g., atypical and typical fluency). By conducting more studies with these variables in mind, more reliable research may reveal a better understanding of the connection between EF and creativity.

There are many possible implications of this research. For example, several types of therapy focus on using creative art-based intervention to improve children's regulation and EF. The practice of art therapy has been suggested as an approach to speech language pathology practices. Art therapy is an expressive psychotherapy that uses creativity as a process to improve social, mental, and emotional functioning and increase feelings of well-being. This is accomplished by healing through nonverbal communication, exploration of feelings, self discovery, and catharsis (Malchiodi, 2011). This study likely focused more on the efficacy of creative art-based interventions and on the improvement of mental and emotional functioning in regulation and links between regulation and creativity. Based on these results, it may suggest that creative interventions may positively impact EF. Applied to speech language pathologists (SLPs), this suggests that SLPs may find it useful to consider adding art therapy techniques into their practice. Many different types of clients of SLPs will exhibit deficits in EF including clients with ADHD, Autism Spectrum Disorder (ASD), Prader-Willi syndrome, and Down syndrome (Brunamonti et. al, 2011; Chevalère et. al, 2019;Pennington & Ozonoff, 1996). By adding art therapy ideas into speech language therapy sessions, there is more potential to increase EF, but more research is needed to fully understand how a creative intervention will impact EF.

Some limitations include a small sample size of only 49 participants. In the future, a bigger number of participants should participate to increase the reliability of the study. Also, only one measure of creativity and two measures of EF was conducted. Other studies used different measures which may account for the differences in the link between creativity and EF. While my study found no connection between creativity and EF, repeating this study with different creativity and EF measures may produce different results. Likewise, this study repeated with the creative conditions before a different EF task may also produce different results. A future direction for this research would be to extend this research to art therapy affecting EF skills, especially to see if the effects are lasting. Further research should also focus on the efficacy of adding art therapy into speech and language therapy to see if it produces higher EF improvements.

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