Journal of Experimental Child Psychology 207 (2021) 105091

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Examining the impact of children's exploration behaviors on creativity

Natalie S. Evans [a,*], Rachael D. Todaro [a], Molly A. Schlesinger [a], Roberta Michnick Golinkoff [b], Kathy Hirsh-Pasek [a,c]

[a] *Department of Psychology, Temple University, Philadelphia, PA 19122, USA*
[b] *School of Education, University of Delaware, Newark, DE 19716, USA*
[c] *Brookings Institution, Washington, DC 20036, USA*

ARTICLE INFO

Article history:
Received 25 May 2020
Revised 7 January 2021
Available online 4 March 2021

Keywords:
Creativity
Exploration
Divergent thinking
Convergent thinking
Creative problem solving
Preschool children

ABSTRACT

Creativity is typically measured using divergent thinking tasks where participants are asked to generate multiple responses following a prompt. However, being able to generate responses captures only a partial picture of creativity. Convergent thinking, in which a single solution is chosen, is an equally important part of creativity that is often left out of divergent thinking assessments. Moreover, as the field of creativity evolves, exploration is starting to be recognized as an understudied component of how children generate and apply creative solutions. The current study moved beyond typical divergent thinking tasks and examined a measure of creativity that also captured 4- to 6-year-old children's convergent thinking and exploration behaviors. A total of 130 children participated in a creative problem-solving task where they were asked to remove a ball from a jar using everyday objects. Children's actions were coded as divergent thinking, convergent thinking, or exploration behaviors. Results demonstrated that divergent and convergent thinking performance was not associated with success on the task, indicating that simply generating and selecting more responses is not always enough to achieve a creative outcome. Children's exploration behaviors were positively associated with success on the task. Exploration behaviors were more likely to lead to success if they were purposeful and iterative. These findings provide some of the first evidence that children's exploration is a vital component of creativity.

* Corresponding author.
E-mail address: tug49568@temple.edu (N.S. Evans).

https://doi.org/10.1016/j.jecp.2021.105091
0022-0965/

Introduction

A 2010 survey probed chief executive officers worldwide about the skills needed for the 21st-century workforce. Creativity surfaced as a top competency (IBM Corp, 2010). This finding had cascading effects on educational systems looking to heighten the focus on creativity and on scientists looking anew at how to define and measure creativity (Lucas, 2016). Although there has been some traction in defining the construct of creativity (Carr, Kendal, & Flynn, 2016; Lubart, Zenasni, & Barbot, 2013; Plucker, Beghetto, & Dow, 2004; Runco & Jaeger, 2012), there has been little progress in probing new measures that reflect these advances in definition, especially for measuring young children's creativity. Namely, one component of children's creativity that has yet to be empirically tested is exploration (Carr et al., 2016). In this study, we proposed and tested a new measure of creativity for young children and examined how exploration can spark the generation and application of solutions that result in successful creative problem solving.

Defining creativity

Creativity has been studied for decades (Guilford, 1950), yet researchers struggle with the definition. An analysis of 90 peer-reviewed articles published from 1996 to 2002 revealed that only 38% of authors provided a definition of the construct (Plucker et al., 2004), assuming that creativity is just an everyday term that is intuitive to comprehend. Scientifically speaking, however, creativity is a complex construct. Guilford (1950) laid a foundation for understanding and defining creativity as multifaceted. In Guilford's model, creativity involves both *divergent* thinking (i.e., coming up with many possible solutions to a prompt or problem) and *convergent* thinking (i.e., zeroing in on one possible solution). Guilford's model demonstrates that creativity involves both creative *processes,* such as divergent thinking, and creative *products,* which are the result of convergent thinking. More recent definitions acknowledge the convergence of process and product (Lubart et al., 2013; Plucker et al., 2004; Runco & Jaeger, 2012). By synthesizing these comprehensive definitions, we define creativity as an interaction among factors of creative *processes* (e.g., divergent thinking) in addition to personal factors (e.g., temperament) and environmental contexts (e.g., supported learning environment), ultimately leading to a novel and useful creative *outcome* (Lubart et al., 2013; Plucker et al., 2004; Runco & Jaeger, 2012).

Innovation, curiosity, and exploration

Parallel developments in the study of innovation also lend support to our understanding of creativity. Carr et al. (2016) proposed a framework for understanding creativity and its role in the context of innovation. At the base of this framework is curiosity, which occurs when an individual senses a gap in understanding or a lack of information (Jirout & Klahr, 2012; Loewenstein, 1994). Curiosity can be measured as both a state and a trait (Hassinger-Das & Hirsh-Pasek, 2018) H H and is associated with academic outcomes, such as reading and math skills, in kindergarten children (Shah, Weeks, Richards, & Kaciroti, 2018). Curiosity prompts and can spark exploration behaviors where individuals interact with their surroundings to learn more about their environment.

Indeed, Piaget (1930) was one of the first to suggest that children learn about the world around them through exploration in play. The study of exploration behaviors has investigated how children learn about cause and effect (for a review, see Gopnik & Wellman, 2012), children's divergent thinking (Dansky & Silverman, 1973, 1975; Pellegrini & Greene, 1980; Pellegrini, 1981; Smith & Whitney, 1987), and how children discover properties of novel objects (Bonawitz et al., 2011). For example, children demonstrated fewer exploration behaviors when adults explicitly taught them the exact function of a novel toy when compared with receiving no prior instructions with the toy (Bonawitz et al., 2011).

Children's exploration behaviors often occur for their own sake, may be influenced by environmental factors, and may also represent a vital component in creative problem solving. Engaging in exploration behaviors can uniquely set the stage for how young children consider and generate multiple solutions (i.e., divergent thinking) when faced with a creative problem. Exploration can naturally occur during play (Piaget, 1930). Some argue that play and exploration should be considered separate because exploration is goal oriented (Smith & Pellegrini, 2013). Zosh et al. (2018) clarified that although not all exploration is play, play can include exploration that is enjoyable to children. Early research suggests that children's exploration of objects during play is positively related to higher performance on divergent thinking tasks when compared with children watching others interact with the objects (Dansky & Silverman, 1973, 1975). Follow-up work examining the role of question asking in divergent thinking indicated that asking questions about objects supported children's divergent thinking when compared with free-play and control conditions (Pellegrini & Greene, 1980; Pellegrini, 1981). Although this research suggests a promising link between children's exploration and divergent thinking, a recent literature review determined that the experimenters in the studies were not blind to children's experimental condition and therefore experimenter effects on the Alternative Uses Task (AUT) were possible (Lillard et al., 2013). In addition, even when the replication study included a blind experimenter, no condition differences were indicated (Smith & Whitney, 1987).

Other empirical studies examined the influence of exploration on creative problem solving in which children were assigned to free play or instructional conditions and asked to solve tasks using everyday materials (i.e., connect sticks to retrieve a marble; Sylva, Bruner, & Genova, 1976). Smith and Dutton (1979) found that children who engaged in free play were just as likely to solve the task as children who were given an instructional demonstration using the materials. Using the same task, Vandenberg (1978) and Cheyne and Rubin (1983) extended this work by asking questions about the materials. Children in the play group were more likely to solve the task. Although these studies provide some evidence that exploration is likely to occur during play activities and could support children's creative processes and their ability to problem solve, this research does not directly address the role of children's exploration behavior and how it may relate to creative outcomes.

Measures of creativity

Researchers' measurement of children's creativity is often limited to divergent thinking assessments that capture their ability to generate multiple responses to a prompt. Divergent thinking measures are the dominant method for testing creativity and are used in approximately 80% of the studies that investigate creative processes in adults (Said-Metwaly, Van den Noortgate, & Kyndt, 2017) and children (Evans et al., in press). Traditional divergent thinking assessments typically ask participants to generate multiple responses to figural, motor, or verbal prompts. In a figural task, such as the Torrance Test of Creative Thinking (TTCT; Torrance, 1972), children may transform a given array of circles to draw a picture. In a motor task, such as Torrance Thinking Creatively in Action and Movement (TCAM; Torrance, 1981), children may be asked to move around a room in as many ways as possible. In a verbal task, such as the widely used AUT (Wallach & Kogan, 1965), a child names aloud all the ways in which an object (e.g., newspaper, tire) can be used.

Divergent thinking tasks indeed capture a portion of creative processes and represent an essential component of creativity; however, simply generating a large *quantity* of responses or solutions is not enough to be considered creative because there is no guarantee that what is generated will be useful or original (Runco & Acar, 2012). For instance, the total number of actions preschool children demonstrated while solving a task was not associated with success on the task (Vandenberg, 1978). In addition, without including convergent thinking in conjunction with divergent thinking, we cannot fully capture a comprehensive picture of creativity.

Convergent thinking is often measured by creative outcomes or accomplishments. For example, in the Consensual Assessment Technique (CAT; Amabile & Gitomer, 1984), a group of expert judges rate a creative accomplishment based on a predetermined rubric. For example, after receiving clay modeling lessons, young children were asked to create clay models of objects and were graded on technical and decorative competency and aesthetic appeal (Anderson & Yates, 1999). Whereas the CAT serves the purpose of measuring convergent thinking by way of rating and distinguishing between creative outcomes, it is limited in that it cannot provide any information about an individual's divergent thinking abilities, an essential component of one's creative process.

Recent measures capture both creative process and outcome and require the use of multiple modalities (e.g., verbal, figural). One such example is the Evaluation of Potential Creativity (EPoC; Barbot, Besançon, & Lubart, 2016), which measures both divergent and convergent thinking. In one subset of the EPoC, for example, divergent thinking is measured by producing as many endings as possible to the beginning of a story (verbal) or by producing as many drawings as possible using an abstract shape (figural). Children's divergent thinking scores are determined by the total number of responses generated. In the convergent thinking tasks, participants are asked to write a story based on a given title (verbal) or to make a drawing using a set of abstract shapes (figural) and are rated using predetermined creativity rubrics. The EPoC measure has been tested with older children and adolescents (mean age of 11.7 years) and involves both verbal and figural measures. Although this assessment advances previous measures by capturing divergent and convergent thinking across multiple modalities, the composition of this assessment is such that divergent and convergent measures are isolated rather than integrated.

Using exploration as a measure of creativity

Exploration is a natural behavior that helps young children to discover and understand the world around them (Piaget, 1930). Extant literature demonstrates that children explore their environment and act as "little scientists" (for a review, see Gopnik & Wellman, 2012), and this motivated us to examine the role of exploration in creative problem solving in the current study. One way in which exploration behaviors have been measured is by using a novel toy paradigm where the researcher records the amount of time children choose to play with the toy and the number of unique functions they discover (e.g., pulling a gear to make a quack sound). Similarly, the Unusual Box test (Bijvoet-van den Berg & Hoicka, 2014) was designed as a divergent thinking measure in which children explore a multifunctional toy box and five novel objects. As is traditional in other divergent thinking tasks such as the AUT (Wallach & Kogan, 1965), fluency and originality scores are calculated based on the number and rarity of children's exploration behaviors performed on the box and novel objects, respectively. Whereas the novel toy paradigm and Unusual Box test are similar measures of exploration and divergent thinking, neither offers a comprehensive measure of creativity given that both tasks lack a creative outcome that requires the use of convergent thinking (Guilford, 1950). To truly be useful in the context of creativity, exploration needs to be an integral part of solving a problem, and this requires that individuals have an outcome to work toward.

The Ball and Jar Task

In this study, we examine a measure of creativity that prompts exploration behaviors and moves beyond traditional divergent thinking tasks by also integrating a measure of convergent thinking. We named this the Ball and Jar Task, and it was inspired by a task that was first used in the field of analogical reasoning (Daehler & Chen, 1993). Children were given a story with a problem and a solution. For instance, the child in a story would lose a soccer ball down a hole and then attach a broom and ball of tape to retrieve it. Children then would be given an analogous task and asked to retrieve a ball from a jar using a selection of everyday objects. Children would analogously solve the subsequent task if they attached a sticky substance to a long chopstick and used it to retrieve the ball. Similar tasks, such as the Floating Peanut and Hook Tasks, have also been used to study tool innovation. In these tasks, children are asked to remove a small toy from a long tube with one object. For instance in the Hook Task, children are given a pipe cleaner that must be bent into a hook to solve the task (Beck, Apperly, Chappell, Guthrie, & Cutting, 2011; Cutting, Apperly, & Beck, 2011; Cutting, Apperly, Chappell, & Beck, 2014; Nielsen, Tomaselli, Mushin, & Whiten, 2014).

There are four main reasons that make the Ball and Jar Task ripe for examining creativity. First, children have the opportunity to explore the properties of the objects they are given. For instance, by manipulating the clay, children can discover that it is sticky and malleable and can be attached to other objects that are long enough to reach the ball such as the chopstick. Second, children can manipulate objects to generate several unique solutions (i.e., divergent thinking), such as using the spool to connect the knitting needle and spoon, before zeroing in on a combination of objects (i.e., convergent thinking), which results in an attempt to solve the creative problem. Third, children are provided with an end goal (i.e., retrieving the ball from the jar) that keeps thoughts constrained to reach a solution. Finally, the Ball and Jar Task can also be given fluency and originality scores just like a typical divergent thinking task (AUT: Wallach & Kogan, 1965; Unusual Box test: Bijvoet-van den Berg & Hoicka, 2014) by examining the total number of actions (fluency) and the number of unique actions a child performs relative to the other children in the group (originality).

Importantly, previous work used the Ball and Jar Task (Daehler & Chen, 1993) and other similar tasks (Floating Peanut and Hook Tasks) only as outcome measures that primarily examined whether children succeeded at the task by retrieving a ball or small toy. In contrast, the current study captured the full potential of the Ball and Jar Task by measuring children's exploration, divergent, and convergent behaviors as children tried to solve the task. Furthermore, the Ball and Jar Task examines these components of creativity independently and in tandem with one another. Doing so allows researchers to assess the potential balance of exploration, divergent, and convergent behaviors to determine which behaviors may be more indicative of success. For example, if children only make attempts without exploring the properties of the objects, then it is less likely that they will succeed. Likewise, if children only explore the objects or generate solutions and never make an attempt to solve the problem before them, they cannot possibly succeed. We predicted that exploration behaviors would ultimately be more useful than convergent behaviors for success on this task because exploration sets the stage for generating more solutions and leads to more meaningful attempts. That is, to succeed on the Ball and Jar Task, children need to explore and manipulate the objects' properties (exploration behavior) to generate multiple solutions to the problem (divergent thinking) and then choose which solution will be most useful and attempt to retrieve the ball (convergent thinking).

The current study

The goal of the current study was to examine the importance of exploration behaviors for creative problem solving using the Ball and Jar Task. First, we examined a key theoretical nuance of divergent thinking that has not yet been empirically tested—exploration behaviors (Carr et al., 2016)—and whether engaging in more exploration behaviors leads to more success. We also conducted exploratory analyses to further investigate how nuanced types of exploration behaviors and time spent on exploration and convergent behaviors during the Ball and Jar Task related to success. Second, we examined the impact of convergent behaviors on success. Third, we investigated whether divergent behaviors on the Ball and Jar Task are related to success on the task itself. Fourth, we examined whether children's fluency scores (i.e., total number of actions) and originality scores (i.e., unique actions relative to others) on a traditional divergent thinking task, the AUT (Wallach & Kogan, 1965), are associated with their fluency and originality scores on the Ball and Jar Task.

In this study, all children completed the Ball and Jar Task and a subset of children also completed the AUT (Wallach & Kogan, 1965). Three hypotheses guided our inquiry. First, we hypothesized that the number of exploration behaviors (e.g., manipulating objects) children performed would account for unique variance on successfully retrieving the ball from the jar. Second, we hypothesized that the number of convergent behaviors (attempts), the number of overall actions (Ball and Jar Task fluency), and the number of unique actions (Ball and Jar Task originality) would not account for unique variance on successfully retrieving the ball because increasing the number of attempts, overall actions, or unique actions does not guarantee successful creative problem solving. Instead, we posited that exploring more would afford children the opportunity to engage in more thoughtful actions and make better-quality attempts necessary for success. Third, we hypothesized that Ball and Jar Task fluency and originality scores and AUT scores would be positively related such that children who demonstrated higher fluency and originality scores on the Ball and Jar task would score higher on AUT fluency and originality measures. These measures are facilitated through different modalities (i.e., verbal and physical), but we predicted that they would be dependent on similar processes.

Method

Participants

A total of 130 children (54.6% girls) were recruited at a children's museum in Philadelphia, PA, in the eastern United States. Children were aged 4 to 6 years, with 34 4-year-olds (62% girls), 46 5-year-olds (50% girls), and 50 6-year-olds (54% girls) participating in the study and receiving a small prize. No other demographic data were collected from children and parents.

Materials and measures

Ball and Jar Task

Seated at a table, children were shown a 9-inch tall jar containing a 1.40-inch diameter white Styrofoam ball. Children had access to a chopstick, spoon, ball of sticky clay, magnet, clip, popsicle stick, rubber band, pipe cleaner, spool, cork, knitting needle, and ball of yarn to try to remove the ball from the jar (Fig. 1). All children received the same instructions: "In this game we need to get this ball out of the jar, but you cannot put your hands in the jar and you cannot tip the jar over. You can use any of the objects on the table to help get the ball out."

Divergent thinking: Alternative Uses Task

Children were asked to come up with alternative uses for six common objects until they said they did not know any more answers (AUT: Wallach & Kogan, 1965). Children received the following instructions: "Now, in this game I am going to name an object—any kind of object, like a lightbulb or the floor—and it will be your job to tell me lots of different ways that object can be used. Any object can be used in lots of different ways. For example, think about string. What are some ways you can think of that you might use string?". The experimenter and children would then exchange examples using string as a practice item. For example, the experimenter might say that the string could be used as a jump rope and children might say that it could be a clothesline. Children were then asked about six test items: newspaper, ball, key, tire, button, and shoe.

Procedure

Children and their parents visiting a local children's museum were invited to participate in the study. Parents were given a brief description of the study in the museum hallway, and after entering the study room with their children the first author gave parents a thorough description as well as consent forms to review and sign. A trained research assistant who was blind to the study's hypotheses

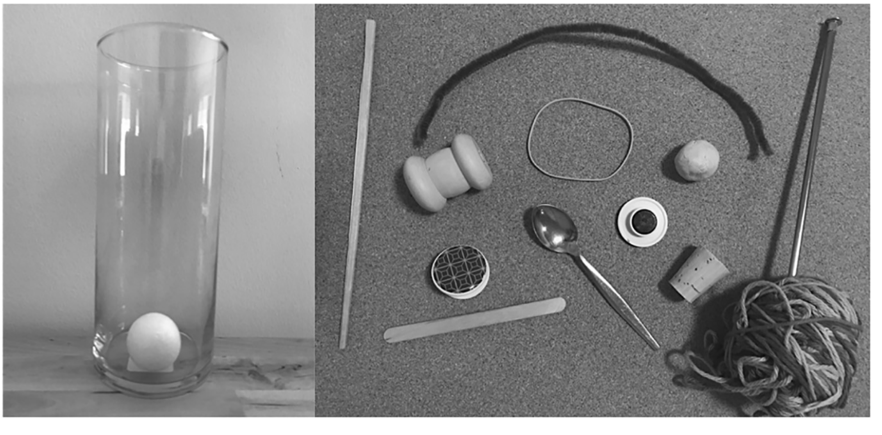

Fig. 1. Ball and Jar Task materials.

then conducted the study in a room in the museum that was separated from the exhibits. Participating children provided verbal assent after being told that they would be doing science activities where they would do some problem-solving games. Parents were not involved in any study procedures and were seated on the opposite end of a large room out of children's sight and hearing range. If parents chose to watch the study, they were seated in a position where their children could not see them. All parents were advised not to interact with their children during the study. All procedures were approved by the university's institutional review board.

The experimenter presented children with a jar containing a Styrofoam ball, and children were told that in this game they needed to get the ball out of the jar but could not put their hands in the jar or tip the jar over. The experimenter then spread 12 everyday objects on the table at random and told children that they could use any of the objects to help retrieve the ball. Children were given 8 min to complete the task, although they were not informed of the time limit. If children successfully retrieved the ball, they were told, "Good job. Can you figure out a different way to get the ball out?" If children seemed out of ideas, the experimenter would prompt, "Remember, you can use any of the objects on the table." If needed, the experimenter would also remind children of the rules: "Remember, we can't put our hands in the jar." At the end of 8 min, children were shown one method to retrieve the ball if they had not been successful during the task. Because of initial time constraints, the AUT (Wallach & Kogan, 1965) was added to the study procedure after data collection was already in progress to examine the relation between a conventional divergent thinking task and the Ball and Jar Task. The AUT was administered to 54 5-year-olds (n = 28; 13 girls) and 6-year-olds (n = 26; 9 girls) during data collection. In addition, research assistants were not aware of children's exact ages, so 4-year-olds (n = 15; 10 girls) were also administered the AUT but were excluded from analyses because the AUT was designed for children over 5 years of age (Wallach & Kogan, 1965).

Coding

Using the 8-min videotaped study sessions, coders coded each action a child demonstrated during the Ball and Jar Task. Each instance in which a child distinctly handled an object or set of objects was coded as a separate action. For example, a child might roll the clay (Action 1), stick the chopstick into the clay (Action 2), tie the pipe cleaner around the chopstick (Action 3), and then remove the clay (Action 4). The coder recorded the time (in seconds) of each action and classified each one as either a touch, a manipulation, or an attempt.

A coder assigned a *touch* classification to an action when children only picked up or made basic physical contact with an object or set of objects. A *manipulation* classification represented an action where children tested the properties of or physically manipulated an object such as stretching out the sticky clay or bending the pipe cleaner. This classification was also assigned when children used one object to act upon another object such as attaching the clay to the chopstick. An *attempt* classification represented an instance where children brought an object or combination of objects to the opening of the jar to retrieve the ball. If children transitioned between two classifications using the same objects, a separate action was recorded. For example, children might connect the spool to the needle (Action 1: manipulation) and then use those objects to try and retrieve the ball (Action 2: attempt). Two trained coders coded the videos, and 22% of the videos were double coded for interrater reliability, with an average Cohen's kappa of .86.

Exploration behaviors

Exploration behavior was indexed by examining the number of manipulations children performed during the Ball and Jar Task. Manipulations represent exploration behavior because actions were classified as a manipulation if children explored the properties of the objects or discovered ways in which to combine objects together. Exploration behavior was calculated by summing the actions in which children manipulated objects and ranged from 0 to 53.

Exploratory analyses: Functional and nonfunctional manipulations. One focus of the exploratory analyses distinguished between functional and nonfunctional manipulations. A manipulation was coded as functional if it demonstrated one of two functions that had the potential of leading to success. Functional manipulations included (a) adding an attachment to another object that could adhere to or scoop the ball, such as adding the clay to the chopstick, and (b) making an object or set of objects long enough to reach the ball, such as attaching the pipe cleaner to the spoon. Nonfunctional manipulations included single object manipulations, such as opening and closing the clip, and manipulations that could not possibly influence success, such as attaching the clip to the middle of the chopstick. For these manipulations, 20% of the videos were double coded for inter-rater reliability, with an average Cohen's kappa of .96. The number of functional manipulations was calculated by summing the number of manipulations that were coded as functional. The number of functional manipulations ranged from 0 to 18.

Exploratory analyses: Manipulation chains. Another focus of the exploratory analyses was to examine the relation between multiple unique manipulations and success on the Ball and Jar Task. For instance, children may demonstrate multiple unique manipulations with objects before making an attempt to retrieve the ball. For this reason, if there were at least two consecutive actions classified as manipulations that continued to have an object in common before making an attempt to retrieve the ball from the jar, we coded these behaviors as a "manipulation chain." For instance, if children rolled the clay into a ball (first manipulation), then stuck the clay to the end of the chopstick (second manipulation), and then attached the clip to the middle of the chopstick (third manipulation) before attempting to retrieve the ball, we would classify this series of actions as a manipulation chain. In coding manipulation chains, both functional and nonfunctional manipulations were included. For manipulation chains, 20% of the videos were double coded for inter-rater reliability, with an average Cohen's kappa of .99. The total number of chains was summed for each participant. This amount ranged from 0 to 8.

Convergent thinking behaviors

Convergent behavior was indexed in this study by examining the number of attempts. Attempts represent convergent behavior because making attempts indicates that children have engaged in the process of zeroing in on an object or combination of objects to use to retrieve the ball. It is also important to note that attempts result in either a successful outcome or an unsuccessful outcome. Convergent behavior was calculated by totaling the number of children's attempts and ranged from 1 to 41.

Exploratory analyses: Proportion of time

Exploratory analyses allowed us to investigate how time spent on exploration and convergent behaviors may differ between children who successfully retrieved the ball on the Ball and Jar Task and children who did not. We calculated the proportion of time children spent touching, manipulating, and attempting by taking the time spent in each classification category and dividing it by the total time on task.

Divergent thinking behaviors

Ball and Jar Task. The action coding was used to calculate children's fluency and originality scores on the Ball and Jar Task. The fluency score was calculated by summing the total number of actions demonstrated during the task. The originality score was calculated by totaling the number of times children manipulated objects into a unique combination relative to all other participants' combinations (Bijvoet-van den Berg & Hoicka, 2014). Fluency scores ranged from 18 to 81, and originality scores ranged from 0 to 13.

Alternative Uses Task. Children's responses to six items on the Alternative Uses Task (Wallach & Kogan, 1965) were scored for fluency and originality. Children received 1 point for fluency for each response they gave summed across the six items. Children were given 1 point for originality if they gave a unique response to a particular item compared with all the other responses given by other children to the same item. Two coders independently coded the responses to eliminate nonsense responses. For instance, 1 child stated that a newspaper could be used as a microwave. The coders agreed 98% of the time about which responses to keep or discard, and discrepancies were settled through discussion between the coders. In total, 19 of 558 responses were discarded across the six items and were not included in fluency and originality scores. Children also did not receive 1 point for fluency or originality if they repeated an answer from a previous item for a new item. The codes for all six items were summed, resulting in two AUT scores of fluency, ranging from 4 to 31, and originality, ranging from 0 to 17, with higher scores representing stronger divergent thinking for both variables.

Results

Ball and Jar Task performance

About 41.5% of children (54 of 130) who participated in the task successfully retrieved the ball from the jar at least once, and only about 9% of children (12 of 130) retrieved the ball more than once. Because so few children retrieved the ball more than once, successfully retrieving the ball was analyzed as a dichotomous variable (i.e., success and nonsuccess).

We conducted a series of binary logistic regressions to first examine whether or not success on the Ball and Jar Task differed by gender and age. Children's gender did not significantly account for unique variance on successfully retrieving the ball from the jar, $\chi^2(1, N = 130) = 0.031, p = .86$. Results revealed that age significantly accounted for 4.5% of the variance of success on the Ball and Jar Task, $\chi^2(1, N = 130) = 4.457, p = .04$. About 32% percent (11 of 34) of 4-year-olds, 35% (16 of 46) of 5-year-olds, and 54% (27 of 50) of 6-year-olds were successful at retrieving the ball from the jar (Fig. 2).

Because initial results demonstrated that age increases the likelihood of success on the Ball and Jar Task, we included age as an independent variable on all subsequent analyses. Age was divided into three groups—4-, 5-, and 6-year-old children—to control for its impact on exploration and convergent thinking behaviors. Groups were dummy coded to highlight any age differences. The 6-year-olds were the reference group because they were the most successful age group, and 4- and 5-year-olds demonstrated similar rates of success. Therefore, age variables in the full models represent the differences between 4- and 6-year-olds and between 5- and 6-year-olds.

Exploration behavior

We examined the role of exploration behavior in Ball and Jar Task performance by tracking the number of manipulations children performed and conducting a logistic regression. The mean number of manipulations made by children during the Ball and Jar Task was 18.69 (*SD* = 12.21). The results of the logistic regression (see Table 1) suggest that the model did distinguish between those who had successfully retrieved the ball and those who had not, $\chi^2(1, N = 130) = 5.664, p = .02$. In addition, 4.3% to 5.8% of the variance was accounted for by the number of manipulations, and the model was able to correctly identify 60.8% of the cases. The number of manipulations children made was a significant predictor of success on the Ball and Jar Task ($p = .02$, odds ratio = 1.04). When age was entered

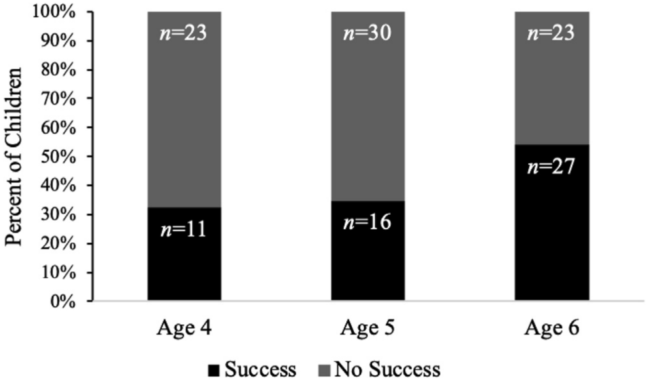

Fig. 2. Percentage of success on the Ball and Jar Task by age.

Table 1
Logistic regression of number of manipulations predicting success.

Variable	Cox & Snell R^2	Nagelkerke R^2	χ^2	*B*	*SE*	Wald	*p*	OR	95% CI
Model 1 (constant)	.043	.058	5.664	−1.02	0.349	8.64	<.01	0.36	
Number of manipulations				0.04	0.015	5.45	.02	1.04	1.01–1.07
Model 2 (constant)	.070	.094	9.394	−0.54	0.449	1.42	.23	0.59	
Number of manipulations				0.03	0.016	4.02	.05	1.03	1.00–1.07
4-year-olds				−0.63	0.486	1.66	.20	0.54	0.21–1.39
5-year-olds				−0.77	0.43	3.24	.07	0.46	0.20–1.07

Note. OR, odds ratio; CI, confidence interval.

into the full model, 7.0% to 9.4% of variance was accounted for, and the model was able to correctly identify 63.1% of the cases, $\chi^2(3, N = 130) = 9.394$, $p = .02$. The full model was a better fit for the data compared with the first model. The number of manipulations children demonstrated was still a significant predictor of success on the Ball and Jar Task ($p = .05$, odds ratio = 1.03), indicating that for every 1 manipulation increase, children's odds of success increased by 3%. However, neither 4-year-olds ($p = .20$) nor 5-year-olds ($p = .07$) significantly differed from 6-year-olds on the number of manipulations as a predictor of success on the Ball and Jar Task.

Functional and nonfunctional manipulations.. The mean number of functional manipulations made by children during the Ball and Jar Task was 4.17 (*SD* = 3.62). A logistic regression (see Table 2) was conducted to investigate the relation between the number of manipulations and success. The model was statistically significant, $\chi^2(1, N = 130) = 13.637$, $p < .001$, suggesting that the model distinguished between those who had successfully retrieved the ball and those who had not. In addition, 10.3% to 13.8% of variance was accounted for, and the model was able to correctly identify 64.6% of the cases. The number of functional manipulations was a significant predictor of success ($p < .01$, odds ratio = 1.22), indicating that for every increase of 1 functional manipulation, children's odds of success increased by 22%. This finding suggests that not all exploration is equally useful. When children directed their exploration to objects that could attach to the ball and/or objects that could help them reach the ball, they performed functional manipulations that gave them a better chance of success.

Manipulation chains.. The mean number of manipulation chains made by children during the Ball and Jar Task was 2.42 (*SD* = 2.24). A logistic regression was conducted to investigate the relation between the number of manipulation chains and success. The results of the logistic regression (see Table 3) revealed that the model distinguished between those who had successfully retrieved the ball and those who had not, $\chi^2(1, N = 130) = 8.583$, $p < .01$. The model accounted for 6.4% to 8.6% of the variance and correctly identified 63.1% of the cases. The number of manipulation chains was a significant predictor of success ($p < .01$, odds ratio = 1.27), indicating that for every increase of 1 manipulation chain, children's odds of success increased by 27%. The results suggest that exploration is an iterative process and that manipulations were more likely to be useful if they built on prior manipulations (i.e., manipulation chains). Moreover, this finding also suggests that children may have recognized that manipulating objects into combinations was more effective than using one single object to retrieve the ball.

Table 2
Logistic regression of number of functional manipulations predicting success.

Variable	Cox & Snell R^2	Nagelkerke R^2	χ^2	*B*	*SE*	Wald	*p*	OR	95% CI
Model 1 (constant)	.103	.138	14.071	−1.19	0.307	14.87	<.001	0.31	
Number of functional manipulations				0.20	0.056	12.43	<.001	1.22	1.09–1.36

Note. OR, odds ratio; CI, confidence interval.

Table 3
Logistic regression of number of manipulation chains predicting success.

Variable	Cox & Snell R^2	Nagelkerke R^2	χ^2	*B*	*SE*	Wald	*p*	OR	95% CI
Model 1 (constant)	.064	.086	8.583	−0.94	0.281	11.07	<.01	0.39	
Number of manipulation chains				0.24	0.084	8.05	<.01	1.27	1.08–1.50

Note. OR, odds ratio; CI, confidence interval.

Convergent behavior

We examined the role of convergent behavior on Ball and Jar Task performance by tracking the number of attempts children performed and conducting a logistic regression. The mean number of attempts made by children during the Ball and Jar Task was 15.02 (*SD* = 8.25). The results of the logistic regression (see Table 4) determined that the model did not distinguish between those who had successfully retrieved the ball and those who had not, $\chi^2(1, N = 130) = 3.058$, $p = .09$. This evidence suggests that the number of attempts does not predict success. Because the number of attempts did not predict success on the Ball and Jar Task, we did not test age in the model.

Proportion of time

Although the number of attempts did not significantly relate to success on the Ball and Jar Task, it was noted that some participants spent a lot of time perseverating on an unsuccessful attempt such as stirring the ball around inside the jar with the chopstick. Spending too much time on useless attempts allowed less time to explore the objects. Fig. 3 displays a notable difference between how successful and unsuccessful children spent their time. Therefore, we conducted independent-sample *t* tests to determine whether successful children differed from unsuccessful children in how they spent their time. Results revealed no difference in the proportion of time spent touching objects between successful and unsuccessful children, $t(128) = 0.26$, $p = .80$, $d = 0.05$. Children who successfully retrieved the ball spent significantly more time manipulating objects ($M = .48$, $SD = .23$) than children who were not successful ($M = .37$, $SD = .27$), $t(128) = 2.42$, $p = .02$, $d = 0.44$. Finally, children who successfully retrieved the ball spent significantly less time attempting ($M = .34$, $SD = .21$) than children who were not successful ($M = .45$, $SD = .27$), $t(128) = 2.62$, $p = .01$, $d = 0.45$. These findings indicate that the time children spend engaging in exploration and convergent behaviors may be just as important as the number of actions they perform.

Divergent thinking

We hypothesized that children who demonstrate higher fluency scores on the Ball and Jar Task would not necessarily be more successful at retrieving the ball because fluency scores simply represent the quantity of all actions (touches, manipulations, and attempts) children performed. The average fluency score for the Ball and Jar Task was 55.42 (*SD* = 14.25), and the average originality score was 1.68 (*SD* = 1.72). A logistic regression was conducted to investigate the relationship between Ball and Jar Task fluency and success. Results showed that the model was not able to distinguish between those who had successfully retrieved the ball and those who had not, $\chi^2(1, N = 130) = 1.842$, $p = .18$ (see Table 5). Therefore, there was no evidence that the Ball and Jar Task fluency score predicted success,

Table 4
Logistic regression of number of attempts predicting success.

Variable	Cox & Snell R^2	Nagelkerke R^2	χ^2	*B*	*SE*	Wald	*p*	OR	95% CI
Model (constant)	.023	.031	2.99	0.23	0.376	0.39	.54	1.26	
Number of attempts				−0.04	0.023	2.92	.09	0.96	0.92–1.01

Note. OR, odds ratio; CI, confidence interval.

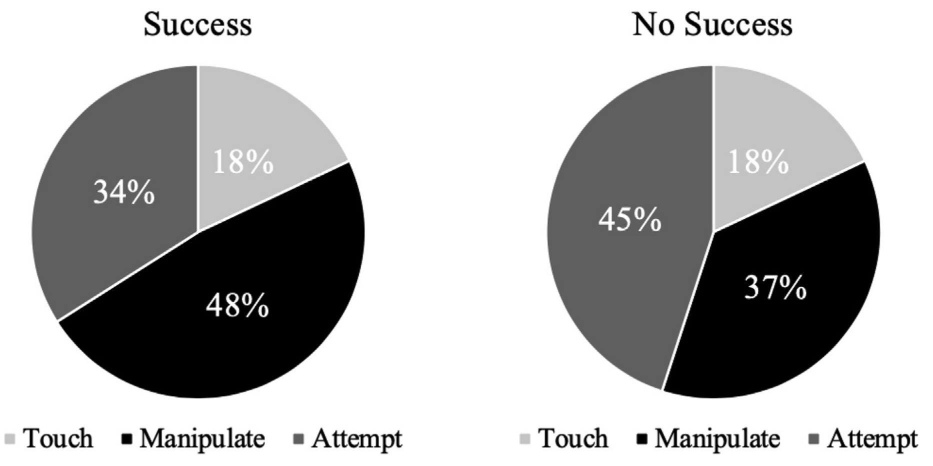

Fig. 3. Time spent in each classification category by success.

Table 5
Logistic regression of Ball and Jar Task fluency predicting success.

Variable	Cox & Snell R^2	Nagelkerke R^2	χ^2	*B*	*SE*	Wald	*p*	OR	95% CI
(Constant)	.019	.025	1.842	−1.32	0.864	2.35	.13	0.27	
Ball and Jar Task fluency				0.02	0.015	1.78	.18	1.02	0.99–1.05

Note. OR, odds ratio; CI, confidence interval.

suggesting that the number of actions on the Ball and Jar Task did not necessarily lead to successful problem solving.

We predicted that originality scores on the Ball and Jar Task would not be related to success because unique actions are not necessarily useful actions. A logistic regression was conducted to investigate this relation and determined that the model did not distinguish between children who had successfully retrieved the ball and those who had not, $\chi^2(1, N = 130) = 0.501$, $p = .48$ (see Table 6). This finding suggests that Ball and Jar Task originality was not predictive of successfully retrieving the ball from the jar.

Table 7 displays the means, standard deviations, and correlations between the Ball and Jar Task measures and AUT fluency and originality. We predicted that higher fluency and originality scores on the Ball and Jar Task would be positively associated with fluency and originality scores on the AUT. The 4-year-old children were excluded from this analysis because the AUT was designed for children over 5 years of age (Wallach & Kogan, 1965). A total of 54 5- and 6-year-old children were included in the analysis (22 girls). On the AUT, the average fluency score was 16.07 (*SD* = 7.15) and the average originality score was 6.24 (*SD* = 6.07). Simple bivariate correlations were conducted to examine the relation between AUT fluency and originality and Ball and Jar Task fluency and originality, respectively. There was a significant positive correlation between AUT fluency and Ball and Jar fluency

Table 6
Logistic regression of Ball and Jar Task originality predicting success.

Variable	Cox & Snell R^2	Nagelkerke R^2	χ^2	*B*	*SE*	Wald	*p*	OR	95% CI
(Constant)	.004	.005	0.501	−0.42	0.208	4.02	.04	0.66	
Ball and Jar Task originality				0.04	0.063	1.50	.48	1.05	0.93–1.18

Note. OR, odds ratio; CI, confidence interval.

Table 7
Means (and standard deviations) and correlation matrix of Ball and Jar Task and Alternative Uses Task.

	1	2	3	4	5	6
Mean	55.42	1.66	16.07	6.24	18.69	15.02
Standard deviation	(14.25)	(2.83)	(7.15)	(6.07)	(12.21)	(8.25)
1. Ball and Jar Task fluency	–					
2. Ball and Jar Task originality	.26**	–				
3. AUT fluency	.30*	.16	–			
4. AUT originality	.32*	.28*	.85***	–		
5. Number of manipulations	.49***	.51***	.31*	.26	–	
6. Number of attempts	.30**	−.18*	−.01	.07	−.47***	–

Note. Fluency and originality values represent data from 5- and 6-year-olds; see explanation in text. AUT, Alternative Uses Task.
*$p < .05$.
**$p < .01$,
***$p < .001$,

and between AUT originality and Ball and Jar Task fluency. There was not a significant correlation between AUT fluency and Ball and Jar Task originality. There was a significant and positive correlation between AUT originality and Ball and Jar Task originality.

Discussion

In the current study, we conducted planned and exploratory analyses to examine a new measure of creativity that captures children's engagement in both divergent and convergent thinking behaviors while also investigating the unique role of exploration in creative problem solving. Using a more comprehensive measure that examines the role of exploration behaviors as well as divergent and convergent thinking gives us theoretical and practical insight into children's creative processes necessary for solving creative problems.

We found evidence that success on the Ball and Jar Task is reliant on children's exploration behaviors, which we assessed by the number of manipulations children performed during the task. We further examined the underpinnings of exploration behaviors children demonstrated during the Ball and Jar Task, and results indicated that functionality of manipulations and manipulation chains significantly predicted success. We did not find that the number of convergent behaviors (i.e., attempts) demonstrated by children predicted success, and children who successfully retrieved the ball spent less time making attempts than their unsuccessful peers. In addition, we did not find that the overall quantity of behaviors (fluency) or unique behaviors (originality), which are traditional markers of divergent thinking, predicted whether or not children would successfully retrieve the ball. Finally, divergent thinking scores on the Ball and Jar Task were positively associated with scores on a traditional divergent thinking task (the AUT), indicating that the Ball and Jar Task was able to assess children's ability to generate many original solutions.

Exploration behaviors

This study provides supporting evidence that exploration is essential to children's creative problem solving. The Ball and Jar Task is a creative problem-solving measure that taps into exploration behaviors that relate to creative processes (i.e., divergent thinking) and behaviors that result in creative outcomes (i.e., convergent thinking). Exploration sets the stage for creativity because it encourages children to consider multiple solutions to a problem (Carr et al., 2016). In considering a variety of solutions, children contemplate which objects may be most useful for retrieving the ball from the jar. Through the Ball and Jar Task, we captured how children explored the properties of objects by classifying manipulation behavior. We found that children who performed more manipulations were more likely to successfully retrieve the ball. It is possible that an increase in exploration behavior resulted in a higher likelihood of success because these behaviors may afford children the opportunity to better understand the properties of the objects and how they serve in the current problem. In turn, understanding the functional features of objects and their potential utility as tools in a novel creative problem-solving task allows children to make more thoughtful and deliberate attempts at successfully solving the problem (Voigt, Pauen, & Bechtel-Kuehne, 2019). For example, if children explored the clay and learned that it was sticky, this discovery may lead them to attach the clay to the chopstick to extract the ball from the jar.

On delving deeper into the manipulations, we found that children who engaged in more *functional* manipulations were more likely to be successful in retrieving the ball from the jar. For an attempt to be successful, a set of objects needed to attach to the ball and be long enough to reach the ball. Achieving these two criteria of functional manipulations did not always guarantee success, but success would be impossible without both present. These findings highlight that not all exploration behaviors are equally useful. Children engaged in many superfluous manipulations, such as adding the clip to the middle of the chopstick, that could not possibly help them reach the ball. This does not mean that these manipulations were useless given that they still helped children to learn about the object's properties. To successfully solve the problem, children's manipulations needed to meet a certain level of functionality that addressed the specific features of the task.

In the context of creative problem solving, exploration can involve multiple steps that build on one another to reach a solution. We found evidence that when children created more manipulation chains (e.g., rolling sticky clay to discover its adhesive property and attaching it to a chopstick), they were more likely to achieve success on the Ball and Jar Task. Therefore, we posit that manipulation chains speak to children's exploration processes. Put differently, a greater number of manipulation chains was associated with success because children's initial exploration behaviors informed subsequent exploration behavior that helped in devising a solution to a problem. For example, when children explored the spoon and discovered that it was too short to reach the ball in the jar, they may have used the clip to attach the popsicle stick to one end of the spoon to make the set objects long enough to reach the ball. As children learned about the properties of an object, their discoveries informed further exploration and led them to generate multiple solutions. These findings support the theoretical idea that exploration is a major stepping stone to divergent thinking that underlies creative problem solving (Carr et al., 2016).

Convergent behaviors

One of the goals of the current study was to examine how convergent behaviors relate to success on the Ball and Jar Task. The quantity of convergent behaviors (i.e., attempts) did not predict success on the Ball and Jar Task. Children may have engaged in a large quantity of attempts, but these were not useful if not preceded by exploration. In fact, when we examined how successful and unsuccessful children spent their time, analyses revealed that spending too much time on attempts was detrimental to success. Whereas there were no differences in the number of attempts made by successful and unsuccessful children, unsuccessful children spent significantly more time attempting to retrieve the ball from the jar. Because these children were spending more time making attempts, results demonstrated that they were subsequently spending a smaller proportion of time engaging in exploration behaviors. Children who attempted more and explored less may have had a limited understanding of the objects' properties and how they could be used to solve the problem. An alternative explanation is that children who spent more time attempting may have used a trial-and-error approach rather than exploring and thinking through how to use the objects before making their attempts.

Ball and Jar Task and Alternative Uses Task

The Ball and Jar Task divergent thinking scores were not related to success on the Ball and Jar Task. Because Ball and Jar Task fluency represents all actions (exploration and convergent) demonstrated by children, these findings indicate that simply doing *more* actions was not enough to succeed on the task—the *type* of action mattered. These results are consistent with previous work indicating that the number of actions children perform during play is not related to successful problem solving (Vandenberg, 1978). Children's originality scores were also not related to success on the Ball and Jar Task. Although some children performed unique actions, which took the form of manipulating objects into original combinations, these combinations were not necessarily useful, which is an essential characteristic for something to be considered creative (Runco & Jaeger, 2012). Most children who successfully retrieved the ball did so by manipulating two or three objects. Children who received points for Ball and Jar originality often created object combinations by manipulating four or more objects. As such, there were several useless object combinations or object additions within a combination that were not necessarily helpful for retrieving the ball.

Children's fluency and originality scores on the Ball and Jar Task were positively associated with their fluency and originality scores on the AUT (Wallach & Kogan, 1965). This finding is similar to that of Bijvoet-van den Berg and Hoicka (2014), who also found that the total number of actions (fluency) and the number of unique actions (originality) performed on a novel task were associated with scores on a traditional divergent thinking task. However, by using the Ball and Jar Task to measure fluency and originality, these findings highlight challenges associated with traditional divergent thinking tasks. Children do well on traditional divergent thinking tasks if they perform more actions or generate more responses (higher fluency). Ultimately, it did not matter how many actions were generated or how unique actions were if they were not useful for solving the problem (Runco & Acar, 2012). Another challenge to using fluency and originality as proxies for creativity is that it is impossible to examine children's processes for how they generate and select certain responses. By closely examining exploration, we were better able to investigate other underlying behavioral processes involved in children's successful creative problem solving.

The current work tested a creativity task that captured children's divergent, convergent, and exploration behaviors by prompting children to solve a creative problem. In using a more comprehensive measure of creativity, the Ball and Jar Task, we were able to observe the relative contributions of these behaviors and how they relate to successful problem solving. The findings in this study provide evidence that exploration is an important component of children's creative problem solving above and beyond generating many original solutions or making multiple attempts. Specifically, we found that exploration is most useful when it is functional and builds on itself. Through this type of exploration, children can use what they learn to inform future exploration, actions, and attempts needed to successfully solve a creative problem.

Limitations and future directions

Using the Ball and Jar task allowed us to examine exploration and convergent thinking while also investigating the relation between Ball and Jar Task divergent thinking behaviors and AUT divergent thinking behaviors. We chose to use the AUT because it is a common measure of divergent thinking for children and adults (Evans et al., in press; Said-Metwaly et al., 2017). However, not all children in our sample participated in the AUT, and the task was not appropriate for the 4-year-old participants involved in the study. Future work should compare the Ball and Jar Task fluency and originality scores with a more age-appropriate divergent thinking task such as the Unusual Box task (Bijvoet-van den Berg & Hoicka, 2014). Examining the relation between the indices of divergent thinking on a more age-appropriate task and the Ball and Jar Task can provide us with stronger insight into emerging creative processes in young children.

Our study demonstrated that some children readily engaged in exploration behaviors, whereas others did not. However, this study did not examine the role of children's individual differences on creative problem solving. For instance, examining children's curiosity would provide insight into their exploration behaviors and may help to explain why some children spent more time attempting to solve the task rather than manipulating and combining objects. Curiosity is the base of Carr et al. (2016) framework and is considered the initial spark that inspires exploration. Future work should collect participants' demographic information, such as socioeconomic status and cultural background (Rogoff, Dahl, & Callanan, 2018), because these factors may play a role in how children engage in exploration behavior during a creative problem-solving task. For instance, some evidence exists that children from middle and lower socioeconomic levels have different strengths in creative expression (Haley, 1984).

External factors, such as the influence of adults, can also affect children's creativity and may significantly affect their exploration behaviors. For instance, when adults directly instruct children to attend to a specific function of a novel toy, the children spend less time exploring and discover fewer functions (Bonawitz et al., 2011). Therefore, when receiving direct instruction from an adult, exploration behaviors may be more limited and children's creative problem solving may suffer. On the other hand, it is possible that adults can also foster exploration and creativity through guided play. Guided play occurs when an activity is child led and supported by an adult. Providing children with a guided play environment may better foster creative problem-solving skills because children have the agency to explore objects and solutions with the right amount of adult support that can help them to achieve a creative outcome (Zosh et al., 2018).

Conclusion

Creativity is an essential skill needed for success during the 21st century (Lucas, 2016). The first step to understanding creativity in children is being able to measure it and the components that affect it. The major advantage of the Ball and Jar Task is that it addresses exploration in addition to divergent and convergent thinking behaviors by evaluating children's actions with a variety of objects. This work uniquely contributes to the field of creativity research for three main reasons. First, this work is one of the first to examine exploration behaviors as a key component of successful problem solving. Second, this is one of the first pieces of empirical evidence demonstrating that an increase in exploration behaviors leads to successful solutions on creative problem-solving tasks. Third, this article highlights the challenges in using fluency and originality scores as measures of creativity and proposes the Ball and Jar Task as an alternative measure for children. As educators, scientists, and business leaders seek to heighten a focus on creativity, these findings represent an important first step in understanding how exploration behaviors can set the stage for generating many unique and creative solutions in an ever-changing world.

Acknowledgments

This work was supported in part by a grant from the LEGO Foundation to the last author. The funding source was not involved in the collection and analysis of data or in the writing of this manuscript. The authors thank the members of the Temple Infant and Child Lab and the families who participated.

References

Amabile, T. M., & Gitomer, J. (1984). Children's artistic creativity effects of choice in task materials. *Personality and Social Psychology Bulletin, 10*, 209–215.

Anderson, A., & Yates, G. C. R. (1999). Clay modelling and social modelling: Effects of interactive teaching on young children's creative artmaking. *Educational Psychology, 19*, 463–469.

Barbot, B., Besançon, M., & Lubart, T. (2016). The generality–specificity of creativity: Exploring the structure of creative potential with EPoC. *Learning and Individual Differences, 52*, 178–187.

Beck, S. R., Apperly, I. A., Chappell, J., Guthrie, C., & Cutting, N. (2011). Making tools isn't child's play. *Cognition, 119*, 301–306.

Bijvoet-van den Berg, S., & Hoicka, E. (2014). Individual differences and age-related changes in divergent thinking in toddlers and preschoolers. *Developmental Psychology, 50*, 1629–1639.

Bonawitz, E., Shafto, P., Gweon, H., Goodman, N. D., Spelke, E., & Schulz, L. (2011). The double-edged sword of pedagogy: Instruction limits spontaneous exploration and discovery. *Cognition, 120*, 322–330.

Carr, K., Kendal, R. L., & Flynn, E. G. (2016). Eureka!: What is innovation, how does it develop, and who does it?. *Child Development, 87*, 1505–1519.

Cheyne, J. A., & Rubin, K. H. (1983). Playful precursors of problem solving in preschoolers. *Developmental Psychology, 19*, 577–584.

Cutting, N., Apperly, I., & Beck, S. R. (2011). Why do children lack the flexibility to innovate tools?. *Journal of Experimental Child Psychology, 109*, 497–511.

Cutting, N., Apperly, I. A., Chappell, J., & Beck, S. R. (2014). The puzzling difficulty of tool innovation: Why can't children piece their knowledge together?. *Journal of Experimental Child Psychology, 125*, 110–117.

Daehler, M. W., & Chen, Z. (1993). Protagonist, theme, and goal object: Effects of surface features on analogical transfer. *Cognitive Development, 8*, 211–229.

Dansky, J. L., & Silverman, I. W. (1973). Effects of play on associative fluency in preschool-aged children. *Developmental Psychology, 9*, 38–43.

Dansky, J. L., & Silverman, I. W. (1975). Play: A general facilitator of associative fluency. *Developmental Psychology, 11*, 104.

Evans, N. S., Schlesinger, M. A., Hopkins, E. J., Jaeger, G. J., Golinkoff, R. M., & Hirsh-Pasek, K. (n.d.). Are preschoolers creative? A review of the literature. In Hoffmann, J., Kaufman, K., & Russ, S. (Eds.), Cambridge handbook of lifespan development of creativity. Cambridge University Press. In press.

Gopnik, A., & Wellman, H. M. (2012). Reconstructing constructivism: Causal models, Bayesian learning mechanisms, and the theory theory. *Psychological Bulletin, 138*, 1085–1108.
Guilford, J. P. (1950). Creativity. *American Psychologist, 5*, 444–454.
Haley, G. L. (1984). Creative response styles: The effects of socioeconomic status and problem-solving training. *Journal of Creative Behavior, 18*, 25–40.
Hassinger-Das, B., & Hirsh-Pasek, K. (2018). Appetite for knowledge: Curiosity and children's academic achievement. *Pediatric Research, 84*, 323–324. https://doi.org/10.1038/s41390-018-0099-4.
IBM Corp. (2010, May 18). IBM 2010 Global CEO study: Creativity selected as most crucial factor for future success [press release]. Retrieved from http://www-03.ibm.com/press/us/en/pressrelease/31670.wss#release.
Jirout, J., & Klahr, D. (2012). Children's scientific curiosity: In search of an operational definition of an elusive concept. *Developmental Review, 32*, 125–160.
Lillard, A. S., Lerner, M. D., Hopkins, E. J., Dore, R. A., Smith, E. D., & Palmquist, C. M. (2013). The impact of pretend play on children's development: A review of the evidence. *Psychological Bulletin, 139*, 1–34.
Loewenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin, 116*, 75–98.
Lubart, T. I., Zenasni, F., & Barbot, B. (2013). Creative potential and its measurement. *International Journal of Talent Development and Creativity, 1*(2), 41–51.
Lucas, B. (2016). A five-dimensional model of creativity and its assessment in schools. *Applied Measurement in Education, 29*, 278–290.
Nielsen, M., Tomaselli, K., Mushin, I., & Whiten, A. (2014). Exploring tool innovation: A comparison of Western and Bushman children. *Journal of Experimental Child Psychology, 126*, 384–394.
Pellegrini, A. (1981). A sequenced questioning paradigm as a general facilitator of preschoolers' associative fluency. *Perceptual and Motor Skills, 52*, 649–650.
Pellegrini, A. D., & Greene, H. (1980). The use of a sequenced questioning paradigm to facilitate associative fluency in preschoolers. *Journal of Applied Developmental Psychology, 1*, 189–200.
Piaget, J. (1930). *The child's conception of physical causality*. New York: Harcourt, Brace.
Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist, 39*, 83–96.
Rogoff, B., Dahl, A., & Callanan, M. (2018). The importance of understanding children's lived experience. *Developmental Review, 50*(Pt A), 5–15.
Runco, M. A., & Acar, S. (2012). Divergent thinking as an indicator of creative potential. *Creativity Research Journal, 24*, 66–75.
Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal, 24*, 92–96.
Said-Metwaly, S., Van den Noortgate, W., & Kyndt, E. (2017). Approaches to measuring creativity: A systematic literature review. *Creativity: Theories–Research–Applications, 4*, 238–275.
Shah, P. E., Weeks, H. M., Richards, B., & Kaciroti, N. (2018). Early childhood curiosity and kindergarten reading and math academic achievement. *Pediatric Research, 84*, 380–386.
Smith, P. K., & Dutton, S. (1979). Play and training in direct and innovative problem solving. *Child Development, 50*, 830–836. https://doi.org/10.2307/1128950.
Smith, P. K., & Pellegrini, A. (2013). Learning through play. In R. E. Tremblay, M. Boivin, & R. D. Peters (Eds.), Encyclopedia on early childhood development [online]. Montreal, Quebec, Canada: Centre of Excellence for Early Childhood Development. Available at http://www.child-encyclopedia.com/sites/default/files/textes-experts/en/774/learning-through-play.pdf.
Smith, P. K., & Whitney, S. (1987). Play and associative fluency: Experimenter effects may be responsible for previous positive findings. *Developmental Psychology, 23*, 49–53.
Sylva, K., Bruner, J., & Genova, P. (1976). The role of play in the problem-solving of children 3–5 years old. In A. J. J. Bruner & K. Sylva (Eds.), *Play: Its role in development and evolution* (pp. 244–257). New York, NY: Basic Books.
Torrance, E. P. (1972). Predictive validity of the Torrance Tests of Creative Thinking. *Journal of Creative Behavior, 6*, 236–252.
Torrance, E. P. (1981). *Thinking creatively in action and movement*. Bensenville, IL: Scholastic Testing Service.
Vandenberg, B. (1978, August). The role of play in the development of insightful tool-using abilities. Paper presented at the meeting of the American Psychological Association, Toronto, Ontario, Canada.
Voigt, B., Pauen, S., & Bechtel-Kuehne, S. (2019). Getting the mouse out of the box: Tool innovation in preschoolers. *Journal of Experimental Child Psychology, 184*, 65–81.
Wallach, M., & Kogan, N. (1965). *Modes of thinking in young children*. New York: Holt, Rinehart & Winston.
Zosh, J. M., Hirsh-Pasek, K., Hopkins, E. J., Jensen, H., Liu, C., Neale, D., ... Whitebread, D. (2018). Accessing the inaccessible: Redefining play as a spectrum. *Frontiers in Psychology, 9*. https://doi.org/10.3389/fpsyg.2018.01124.