Feeling of Competence Affects Children's Curiosity and Creativity

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Abstract

Creative potential in childhood predicts creative achievements later in life. But relatively little is known about the factors and processes that promote creativity in children. A theoretical framework by Carr, Kendal, and Flynn (2016) identified several factors, including curiosity and exploration, that might facilitate creativity and innovation. Building on this framework, we propose another factor – children's feeling of competence – that might affect both curiosity and creativity. In the present study, 5- to 7-year-olds were induced feelings of high or low competence by solving math problems. Next, they completed three tasks that measured their curiosity and creativity. The findings showed that children who felt more competent explored more on a novel toy and showed better creative problem-solving abilities.

Keywords: creativity; innovation; curiosity; competence

Introduction

Creativity and innovation are the driving forces of all scientific, technological, and societal advances made in human history. Young children already possess creative and innovative potentials, as evident in their imagination and play. A longitudinal study showed that children's creative potential measured by the Torrance Test of Creative Thinking (TTCT) at school age (grade one through six) predicted their creative achievement fifty years later (Runco, Millar, Acar, & Cramond, 2010). However, another study found that since 1990, children and adults' TTCT scores decreased continuously, and the decrease was the most significant in kindergartners through third graders (Kim, 2011). In light of these findings, it is imperative for us to understand how we can promote creativity in children, so that they will make important contributions to the society one day.

Creativity: Definition and Theoretical Framework

The standard definition of creativity (Runco & Jaeger, 2012) states that something is creative if it is both original and useful. Creativity in children is commonly measured by divergent thinking tasks (e.g., the Torrance Test of Creative Thinking; Wallach & Kogan's (1965) Alternative Uses Task). Divergent thinking is defined as the ability to generate numerous new ideas, which leads to the potential for creative thinking (Runco & Acar, 2012). Although it is a reasonably valid predictor of creative achievement, divergent thinking does not necessarily lead to creativity – you can generate many ideas without having one idea that is both novel and useful (Runco & Acar, 2012). Thus, it is important to understand the processes besides divergent thinking that would facilitate creative thinking.

Carr et al., (2016) identified several factors that might lead to creativity and innovation. In their theoretical framework, curiosity and motivation give children the opportunity to explore. During exploration, children try novel actions and test novel ideas. If any of those actions or ideas turns out to be valuable in some way, it can lead to creativity and innovation.

Building on this framework, we will discuss two types of factors that are relevant for creativity: (1) the factors that facilitate curiosity and exploration, which in turn affect creativity, and (2) the motivation and competence factors, which affect both curiosity and creativity.

Curiosity and Exploration

The most influential theory of curiosity is the information-gap theory by Loewenstein (1994). The theory proposes that curiosity arises when the level of knowledge that one hopes to gain, which is the information reference point, is elevated above one's current level of knowledge.

Past research has demonstrated that children's curiosity is elevated when they realize that there are gaps in their knowledge. For instance, Schulz and Bonawitz (2007) found that children are more curious when they are shown confounded evidence. In the study, two groups of children saw evidence about the causal mechanism of a toy. One group of children saw ambiguous evidence about how the toy was activated, while the other group saw unambiguous evidence. Children who saw ambiguous evidence about the toy were more likely to choose to play with that toy over a novel toy. Another study by Bonawitz, van Schijndel, Friel, and Schulz (2012) found that children are more curious when they are shown evidence that violates their prior beliefs. Children were first assessed whether they believed that an object should balance at its geometric center or its center of mass. Then, they were shown new evidence that either supported or violated their prior beliefs. If the new evidence violated their prior belief, children spent longer time playing with the balance and blocks than with a novel toy.

These studies suggested that children are more curious and more likely to explore when they discover gaps in their knowledge, either because they have not figured out the causal mechanism of a stimulus yet, or because new evidence has invalidated their prior beliefs. In turn, the elevated curiosity and exploration leads to the potential for generating creative ideas and creative solutions to problems. However, are all children equally curious, and equally motivated to explore when they discover gaps in their knowledge? What individual and contextual factors affect children's curiosity, exploration, and creativity?

Motivation, Competence, and Self-Efficacy

Intrinsic motivation is considered important for both curiosity and creativity. In the framework of Cognitive Evaluation Theory (CET, Deci, 1975; Ryan & Deci, 2000), behaviors driven by curiosity are considered intrinsically motivated behaviors. Amabile & Hennessey (1992) proposed the *Intrinsic Motivation Principle of Creativity*, that people are most creative when they are motivated by the enjoyment and challenges of a task, rather than by external pressures. Following this principle, intrinsic motivation would facilitate creativity, while extrinsic motivation (e.g., induced by extrinsic reward) would impede creativity. A study by Amabile, Hennessey, & Grossman (1986) supported this prediction. Two groups of elementary school students were both given the opportunity to take two pictures with an instant camera. In the reward condition, using the camera was framed as a reward for telling a story later. In the no-reward condition, children simply used the camera, and then told a story. The stories told by children in the no-reward condition was rated as more creative than the ones told by children in the reward condition.

Where does intrinsic motivation come from? CET (Ryan & Deci, 2000) proposed that intrinsic motivation for an action is increased by interpersonal interactions such as rewards, communications, and feedbacks that promote feelings of competence during that action. Similarly, in Social Learning Theory (SLT), Bandura (1982) argued that one of the sources of intrinsic motivation is perceived self-efficacy gained from performance accomplishments and other information indicating one's efficacy. Supporting these predictions, Vallerand and Reid (1984) found a mediating effect of perceived competence on the relationship between verbal feedback and intrinsic motivation. When completing a motor task, participants who received positive feedback showed highest level of intrinsic motivation and perceived competence, followed by participants who received no verbal feedback and participants who received negative feedback. Path analysis showed a mediating effect of perceived competence – positive feedback led to an increase in perceived competence, which in turn led to an increase in intrinsic motivation.

Jirout & Klahr (2012) expanded Loewenstein's (1994) information-gap theory, and argued that for children to be curious, they not only need to realize that there is information that they do not know, but also need to believe that they are capable of figuring out that information. Therefore, there might be individual differences in the level of uncertainty that children feel capable of resolving. They designed a novel measure of curiosity. Children were given information about the kinds of fish they might see from each window on a submarine. Then, children made choices among options that varied in the amount of uncertainty (i.e., different degrees of their information gap). They found individual differences in the size of the information gaps that children preferred to resolve, which is an indication of their level of curiosity. Moreover, the level of curiosity was correlated with children's competence motivation.

Lastly, in a correlational study, Prabhu, Sutton, & Sauset (2008) measured university students' intrinsic motivation, self-efficacy and level of creativity through self-report questionnaires. The results showed that self-efficacy and creativity are positively corelated, and that this relationship is completely mediated by intrinsic motivation.

Therefore, perceived competence and self-efficacy play important roles in one's intrinsic motivation, which affects both curiosity and creativity. While Jirout & Klahr (2012) focused on competence motivation as an individual trait, the CET and the SLT recognized that perceived competence and perceived self-efficacy are influenced by contextual factors such as interpersonal interactions and performance accomplishment. The previous studies and theories were mainly concerned with perceived competence toward a specific task. It is also important to investigate whether perceived competence gained from performance on one task would lead to a general feeling of competence, which increases intrinsic motivation, curiosity and creativity in other tasks.

The Present Study

In the present study, we examined whether feeling of competence would affect children's curiosity and creativity. Children were induced feelings of high or low competence by solving math problems of varying difficulty. Then, they completed three tasks that measured their curiosity and creativity, in counterbalanced orders. In one task, children's curiosity was measured by their exploration on a novel toy. Children's creative problem-solving ability was measured with another task adapted from Sylva, Bruner, and Genova (1976). They had to retrieve a prize using various tools provided to them. It is an ideal measure of creativity since the solution needs to be both original (combining tools in a novel way) and useful (retrieving the prize). The last task was Wallach & Kogan's (1965) adaptation of Guilford's Alternative Uses Task (AUT). Although it is a measure of divergent thinking, which does not necessarily lead to creativity, we included it to compare the results with the creative problem-solving task.

We hypothesize that children who feel more competent are more curious and creative. Specifically, children who feel more competent will explore the novel toy for longer time, generate more unique actions, and discover more functions. They will require less time and fewer hints to solve the creative problem. They will generate more uses, more categories of uses, and more original uses in the AUT.

Methods

Participants

Fifty-three children between the ages of 5 and 7 years (27 females; mean age = 6.48; range = 5.08 to 7.92; *SD* = 0.80) participated in the experiment. Three children were excluded based on the exclusion criteria in manipulation check (see below). Participants were tested in a lab room at UC Berkeley, in a quiet room at elementary schools, or at a children's museum. Parents of the participants provided written informed consent prior to the experiment session.

Materials and Procedure

Competence manipulation Children were randomly assigned to receive either a set of math problems that was relatively easy for their age, or a set of math problems that was relatively hard for their age (Figure 1). For each problem, the experimenter read the problem to children, and recorded their answers. If children answered correctly, the experimenter said, "Good job, that is correct!" If children answered incorrectly, the experimenter said, "Okay, but that is not correct."

A.	B.	C.	D.
1 + 2 =	12 + 10 =	12 + 10 =	37 - 12 =
1 + 4 =	11 + 13 =	11 + 13 =	21 × 4 =
3 + 2 =	2 + 4 =	2 + 4 =	12 ÷ 2 =
3 + 7 =	10 + 11 =	10 + 11 =	29 - 14 =
2 + 2 =	7 + 13 =	7 + 13 =	13 × 12 =
1 + 3 =	1 + 3 =	1 + 3 =	27 × 5 =
2 + 10 =	14 + 12 =	14 + 12 =	6 + 3 =
3 + 3 =	14 + 20 =	14 + 20 =	7 × 12 =

Figure 1: Four sets of math problems used in the manipulation: a relatively easy set for 5- to 6-year-olds (A), a relatively hard set for 5- to 6-year-olds (B), a relatively easy set for 7-year-olds (C), and a relatively hard set for 7-year-olds (D).

Manipulation check The experimenter showed children the manipulation check scale (Figure 2), and asked, "How do you think you did on the math problems? Do you think you did really well? Or not so well?", while pointing to the respective faces. Regardless of which sets of math problems children were assigned to, if a child said that she did well on the math problems or pointed to the smiley face, we determined that she has been induced *high competence* (HC condition). If a child said that she did not do well or pointed to the frowny face, we determined that she has been induced *low competence* (LC condition). However, we excluded participants if their subjective evaluation did not match their actual performance: if they said that they did well on the math problems, but performed fewer than 3 problems correctly (3 participants were excluded based on this criterion), or if they said that they did not do well, but performed more than 6 problems correctly.

Figure 2: The manipulation check scale.

Then, children completed the following three tasks in counterbalanced orders.

Curiosity task A toy similar to the one used in Bonawitz, Shafto, Gweon, Goodman, Spelke, & Schulz (2011) was created (Figure 3). The toy had four non-obvious functions: it made a sound when a tube was pulled out (squeaker); pressing on a hidden button lit up the end of a tube (light); some music notes played when another button was pressed (music); a small mirror was hidden in one large tube (mirror).

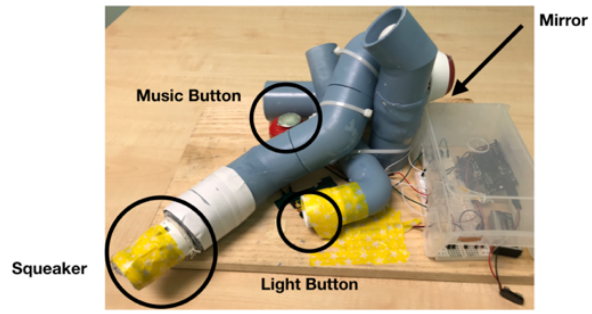

Figure 3: The toy used in the curiosity task.

Children were instructed to play with the novel toy and tell the experimenter when they were done playing with it. The experimenter terminated the task when the child said that she was done or stopped interacting with the toy for more than 5 consecutive seconds twice.

The following measures were coded from the video recordings: total playtime, the number of unique actions performed, and the number of functions discovered.

Creative problem-solving task A transparent box approximately 3.5×2.5×1.75 inches was placed on a table, 38 inches away from the child. On the door of the box is a c-shaped door handle. Children were instructed to retrieve a small prize in the box. They were given 3 colored sticks (two 12-inch sticks and one 6-inch stick) and 2 binder clips. On the end of a long stick, there was a hook which can be used to attach to the handle on the door and pull it open. The set-up is shown in Figure 4.

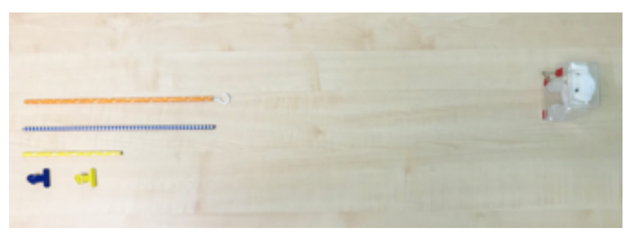

Figure 4: The set-up of the creative problem-solving task.

If children did not make progress toward solving the problem after one minute had passed, the experimenter gave children a hint. There were five hints in total, the experimenter gave children one hint per minute in the following order: (1) Have you used everything you can think of that might help you? (2) Can you think of a way that you can use the binder clips to help you? (3) Can you think of a way that you can use both the clips and the sticks to help you? (4) You can clip the two long sticks together and make a longer stick. (5) I will hold these two sticks together here. Can you clip them tightly together with this clip?

The number of hints that children needed was recorded by the experimenter. The total time that children needed to obtain the prize was coded from the video recordings.

Alternative uses task Children were asked to come up with different ways to use a set of common objects. The experimenter first provided some examples of ways to use an object not included in the actual task. After children understood the task, the experimenter asked children to name all the different ways that they could use the following objects: newspaper, key, and shoe. The experimenter encouraged children to come up with more uses, until they could not think of any more uses. The experimenter recorded all the acceptable uses that children came up with.

Three measures from children's responses were coded, following Wallach & Kogan (1965): (1) Fluency, which is the average number of acceptable uses generated per object; (2) Flexibility, which is the average number of different categories of uses generated per object (e.g., "making a paper hat" and "making a paper boat" would be considered the same category of uses); (3) Originality, which is the average number of acceptable uses generated that made up 1% or less of all the responses given by all participants per object.

Results

The dependent measures reported below were coded from the video recordings by two coders blind to the conditions that children were in. The interrater reliability for toy exploration time, the number of functions discovered on the toy, and the time needed to solve the creative problem-solving task was excellent (ICC_{toy_time} = 0.99; $ICC_{function}$ = 0.91; ICC_{prob_time} = 0.97), and the interrater reliability for the number of unique actions performed on the toy was good (ICC_{action} = 0.77). These four measures were averaged across coders for the following analyses.

Competence Manipulation

Thirty-four children were assigned the relatively hard sets of math problems for their age, 24 of whom reported performing not well on the problems, and 10 of whom reported performing well. Sixteen children were assigned the relatively easy sets of problems for their age, 14 of whom reported performing well, and 2 of whom reported performing not well. This resulted in 24 children (13 females; mean age = 6.63; *SD* = 0.79) in the HC condition, and 26 children (13 females; mean age = 6.39; *SD* = 0.83) in the LC condition.

Curiosity Task

In the curiosity task, children in the HC condition generated an average of 10.60 (*SD* = 4.62) unique actions on the toy, while children in the LC condition generated an average of 7.58 (*SD* = 4.85) unique actions (Figure 5). N-way ANOVA models with interaction were used to predict the number of unique actions children performed from condition, age[1], gender, testing location, and task order. No effect of age, gender, testing location or task order was found. The best-fitting model only included condition as a predictor; it outperformed the null model, (AIC_{cond} = 301.47, AIC_{null} = 304.51, $F(1, 48) = 5.09$, $p = 0.03$). According to this model, children in the LC condition performed 3.03 fewer actions than children in the HC condition ($\beta_{low} = -3.03$, $SE = 1.34$, $t(46) = -2.26$, $p = 0.03$).

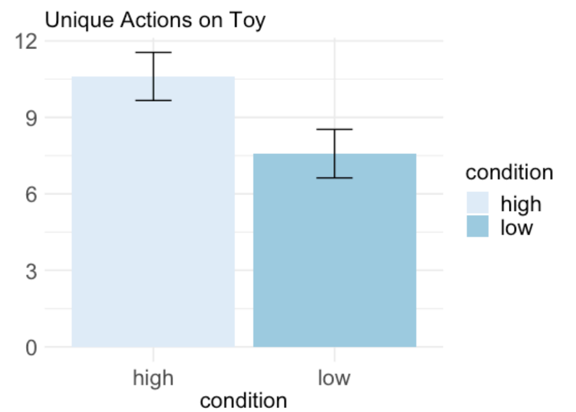

Figure 5: Average number of unique actions children performed on the novel toy, by condition.

Children in the HC condition explored the toy for an average of 170.69 seconds (*SD* = 110.00), and children in the LC condition explored for 153.48 seconds (*SD* = 85.07). They discovered similar numbers of functions on the toy (M_{HC} = 1.06, SD_{HC} = 0.99; M_{LC} = 0.77, SD_{LC} = 1.00). For both measures, comparisons of n-way ANOVA models with interaction did not find any effect of condition, age, gender, testing location, or task order. But the means of both measures were in the predicted direction.

Creative Problem-Solving Task

Some children were able to solve the problem spontaneously, without given any hints (i.e., they solved it within the first minute). In the HC condition, 70.83% (*SD* = 0.46) of children solved it spontaneously, while 34.62% (*SD* = 0.49) of children in the LC condition did (Figure 6). Generalized linear models (GLMs) were used to predict spontaneous solution (yes = 1, no = 0) from condition, age, gender, testing location, and task order. No effect of gender, testing location or task order was found. The best-fitting model predicted spontaneous solution from condition and age; it outperformed the null model ($AIC_{cond+age}$ = 57.92, AIC_{null} = 68.54, $\chi^2(2) = 14.62$, $p < 0.01$), the model that included condition alone (AIC_{cond} = 65.06, $\chi^2(1) = 9.14$, $p < 0.01$), the model that included age alone (AIC_{age} = 60.86, $\chi^2(1) = 4.94$, $p = 0.03$). The model

[1] The age of two children was missing. Any model that included age as a predictor excluded those two children's data.

that included the interaction between condition and age did not outperform the best-fitting model ($AIC_{cond*age}$ = 58.29, χ^2 (1) = 1.63, p =0.20). According to the best-fitting model, the odds of spontaneously solving the problem decreased for children who are in the LC condition (β_{low} = -1.48, SE = 0.69, z = -2.14, p = 0.03), and increased with age (β_{age} = 0.11, SE = 0.04, z = 2.73, p < 0.01).

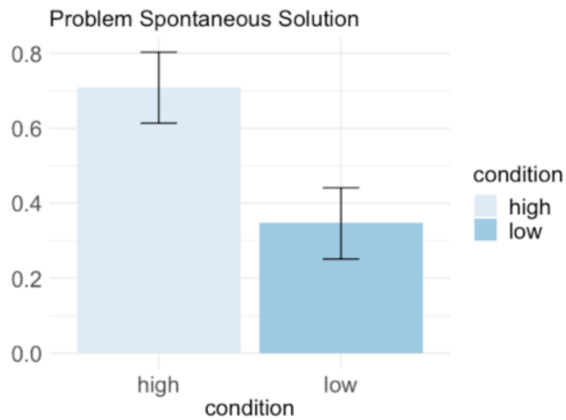

Figure 6: Proportion of children who solved the problem spontaneously, by condition.

Children in the HC condition needed 0.79 (SD_{HC} = 1.53) hints on average, while children in the LC condition needed 1.96 (SD_{LC} = 1.91) (Figure 7). Comparison of n-way ANOVA models with interaction found no effect of gender, testing location or task order. The best-fitting model included age alone as predictor; it outperformed the null model, (AIC_{age} = 60.86, AIC_{null} = 197.38, F(1, 46) = 8.21, p < 0.01), the model that included condition alone (AIC_{cond} = 194.80). The model that included both condition and age did perform better than the best-fitting model ($AIC_{cond+age}$ = 189.53, F(1, 46) = 3.88, p = 0.05). According to the best-fitting model, a child who is a year older than another child needed 0.07 less hint on average (β_{age} = -0.07, SE = 0.03, z = -2.87, p < 0.01).

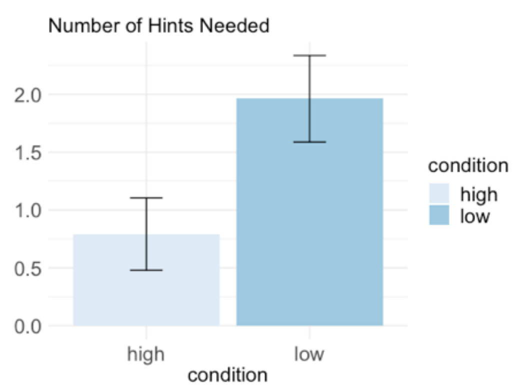

Figure 7: Average number of hints that children needed in the creative problem-solving task, by condition.

Children in the HC condition needed an average of 133.29 seconds (SD_{HC} = 102.89) to come up with the solution, while children in the LC condition needed 186.08 seconds (SD_{LC} = 119.90) (Figure 8). Comparison of n-way ANOVA models with interaction found no effect of condition, gender, testing location or task order. The best-fitting model included age alone as predictor; it outperformed the null model, (AIC_{age} = 586.89, AIC_{null} = 594.71, F(1, 46) = 10.45, p < 0.01). A child who is a year older needed 5.16 seconds less to come up with the solution (β_{age} = -5.16, SE = 1.60, z = -3.23, p < 0.01).

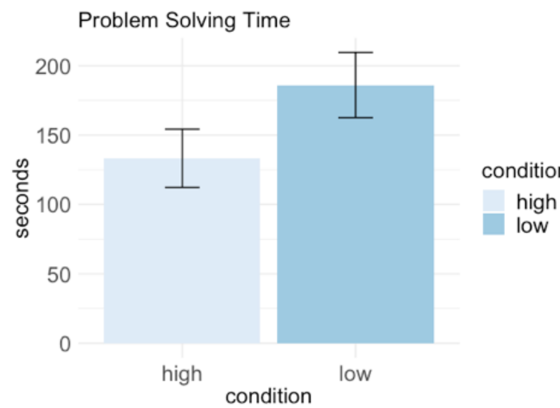

Figure 8: Average time that children needed in the creative problem-solving task, by condition.

Alternative Uses Task

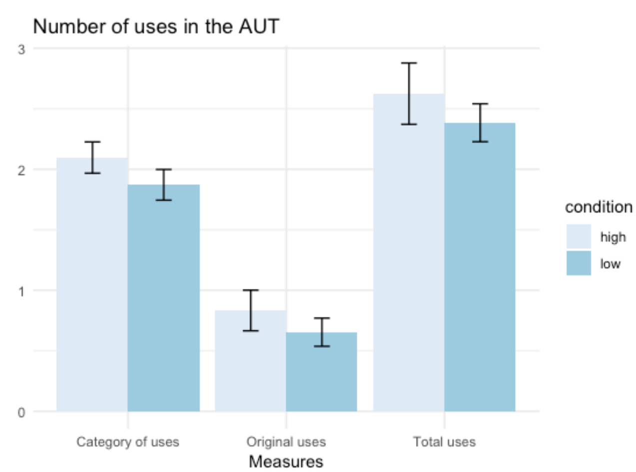

Figure 9: Average total uses, category of uses, and original uses that children generated in the AUT, by condition.

Children in the HC condition and the LC condition generated similar numbers of total uses (M_{HC} = 2.63, SD_{HC} = 1.24; M_{LC} = 2.38, SD_{LC} = 0.80), categories of uses (M_{HC} = 2.09, SD_{HC} = 0.63; M_{LC} = 1.87, SD_{LC} = 0.65), and original uses (M_{HC} = 0.83, SD_{HC} = 0.82; M_{LC} = 0.65, SD_{LC} = 0.59). The means of all three measures were in the predicted direction (Figure 9). Comparison of n-way ANOVA models with interaction found that only age was a significant predictor for total uses and categories of uses. For total uses, the best-fitting model that included age outperformed the null model, (AIC_{age} = 135.16,

AIC_{null} = 143.43, $F(1, 46) = 10.98$, $p < 0.01$). For categories of uses, the best-fitting model that included age outperformed the null model, (AIC_{age} = 83.41, AIC_{null} = 98.32, $F(1, 46)$ = 19.43, $p < 0.01$). A child who is a year older came up with 0.05 more uses ($\beta_{age} = 0.05$, $SE = 0.01$, $z = 3.31$, $p < 0.01$), and 0.03 more categories of uses ($\beta_{age} = 0.03$, $SE = 0.008$, z = 4.41, $p < 0.01$).

Discussion

Children were induced feelings of high or low competence by solving math problems of varying difficulty. Their performance on the subsequent tasks that measured curiosity and creativity differed based on their feelings of competence.

In the curiosity task, feeling of competence did not influence the duration of children's exploration on the novel toy, but it affected the number of unique actions that children performed during their exploration. Those who felt more competent generated more unique actions. This might suggest that children who felt more competent were more "efficient" in their exploration, such that in the same amount of time, they tried more actions that could potentially activate the functions on the toy.

Although children who felt more competent appeared to be more "efficient" in their exploration, they did not discover more functions of the toy. It might be because the functions were difficult to discover in general. Indeed, across the two conditions, children only discovered less than one function on average ($M = 0.91$, $SD = 1.00$). If some of the functions were made easier to discover, we might see a difference in the outcome of children's exploration.

Children who felt more competent were also better at solving a problem that required creative thinking. They were more likely to come up with the solution to the problem on their own, within the first minute that they were given the problem. Age also influenced children's performance on this task. Older children were more likely to spontaneously solve the problem, and required less time and fewer hints to solve it.

Feeling of competence seemed to have no effect on children's performance in the AUT. Age influenced children's performance, such that older children came up with more uses and more categories of uses, but they did not come up with more original uses.

Mechanisms of the Effects and Future Directions

Why would feeling of competence affect curiosity and exploration? One possibility is that children who feel more competent have stronger desires to acquire new information about their environment. Another possibility is that children who feel more competent are more persistent in their exploration, even in the face of difficulty. In an ongoing study, we are testing the second possibility by varying the difficulty of discovering the functions on the novel toy. Three of the functions are made easier to discover, while the last function is made harder to discover (i.e., a fan is activated when two of the twelve small buttons are pressed simultaneously). We are coding the amount of time that children spend on the fan function, as well as the number of times that children press the small buttons, as measures of their persistence in discovering this function.

Why would feeling of competence affect children's creative problem-solving? Children who feel more competent might try more combinations and test more hypotheses when they are solving a problem. We coded the number of different means that children used in trying to solve the problem in the present study, as a measure of the number of hypotheses that children tested. The result was in the predicted direction, but the difference was not statistically significant. In the ongoing study, we are giving children a similar creative problem-solving task with more available tools, so that children could generate more combinations of the tools.

However, feeling of competence did not affect the other measure of creativity – AUT. It might be the case that feeling of competence have a weaker effect on the process of generating novel ideas, and a stronger effect on generating useful ideas and solutions for problem-solving. However, since the results for all three measures of AUT were in the predicted direction, another possibility is that the set of common objects that we used in the task (i.e., newspaper, key, and shoe) were not objects that children see and play with regularly. In the ongoing study, we are using a different set of objects for this task: ball, chair, and pencil.

One limitation of the current study is that we cannot rule out the possibility that children's *actual competence*, rather than their *feeling of competence*, affected their curiosity and creativity. Although we tried to manipulate children's feeling of competence by randomly assigning them to solve an easy set of math problems (high competence manipulation) or a hard set (low competence manipulation), we could not control how well they performed or how they felt about their competence. As a result, some children who were assigned the low competence manipulation performed well on the math problems, felt competent, and ended up in the HC condition; some who were assigned high competence manipulation ended up in the LC condition. Thus, compared to children in the LC condition, children in the HC condition might be more competent in their actual math abilities, which could have affected their curiosity and creativity. To address this limitation, in the ongoing study, we use sets of easy and hard math problems that are more disparate in their difficulty. We hope that with this change, we would be able to manipulate children's feeling of competence (that is, regardless of their actual competence, most children who are assigned the easy sets would perform well and feel competent, and most children who are assigned the hard sets would perform poorly and feel less competent).

In conclusion, the present study provided the first evidence that feeling of competence promotes children's curiosity and exploration, as well as their creative problem-solving abilities. Further evidence is needed to determine why feeling of competence affect curiosity and creativity, and to identify the precise processes in exploration and creative thinking that are affected by feeling of competence.

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