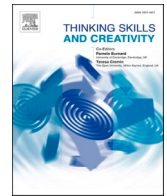




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Use of magic performance as a schema disruption method to facilitate flexible thinking

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ABSTRACT

The ability to think flexibly has become increasingly important for success in work, life, and learning in the 21st century. Flexible thinking enables students to overcome thinking fixedness and generate creative ideas and helps students to apply what they learned when faced with unknown or unfamiliar challenges. However, there has been a lack of effective and engaging teaching methods designed for teachers to facilitate students' thinking flexibility (Middleton, 2015). This study explored an innovative method based on the activity of magic performance with the aim of facilitating flexible thinking in an interactive and engaging way. An in-depth exploration of students' experience in this activity revealed how magic performance as a unique schema disruption stimulus influences students' flexible thinking. The results suggested three aspects of such influence: 1) Magic primes a childlike mindset in students and encourages them to use their imaginations, 2) The curiosity toward the secret of magic drives students to develop a flexible mindset, 3) The principles of magic promote flexible thinking transfer. The results may help creativity scholars understand why magic can be used to facilitate flexible thinking. The outcome may also help teachers form a deep understanding of how magic performance can be used to facilitate students' flexible thinking in class.

1. Introduction

Research has shown that students tend to make judgments based on their prior experiences and usually expect things to follow patterns from their real lives (Vilhauer, 2014). They also tend to propose solutions that are built on familiar knowledge within a specific domain. Although prior experiences and domain knowledge are important to creative performance (Jeon, Moon, & French, 2011), prior experiences or knowledge may also have negative effects that lead students to maintain outdated ideas and thus think less creatively (Chrysikou & Weisberg, 2005; Smith & Blankenship, 1989). These negative effects can be explained using the psychological phenomenon known as cognitive fixation.

Cognitive fixation refers to "something that blocks or impedes the successful completion of various types of cognitive operations, such as those involved in remembering, solving problems, and generating creative ideas" (Smith, 2003, p. 16). One reason for this constraint is that people tend to follow the path of least resistance and make assumptions based on the most common and accessible knowledge within a specific domain (Agogué et al., 2014). Creative ideas are stifled when students rely too much on familiar knowledge or experience and fail to use their imaginations to generate new ideas. Therefore, encouraging students to think flexibly is essential if we want students to generate creative ideas (Thurston & Runco, 1999).

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An intriguing development in creativity research suggests that thinking flexibility can be enhanced when students experience something that is inconsistent with their expectations (Ritter et al., 2012; Wan & Chiu, 2002). When individuals' schema or stereotypical thoughts are disrupted by certain counter-stereotypical stimuli, they tend to generate more creative ideas (Goclowska, Crisp, & Labuschagne, 2013) and provide more insightful solutions to problems (Vasiljevic & Crisp, 2013). Researchers refer to this strategy as schema disruption. However, the underlying cognitive mechanism explaining why this strategy works remains unclear, and there is no previous research indicating how to use schema disruption as a strategy to facilitate thinking flexibility. Therefore, this paper aims to reveal this mechanism and understand how schema disruption can be effectively used to reduce cognitive fixation.

To achieve this goal, magic performance was adopted by this study to investigate the influence of schema disruption on flexible thinking. For centuries, magicians have been developing methods to surprise their audiences and suspend their beliefs with magical illusions.

As such, the art of magic offers a psychological tool to elicit schema-disruptive mental states in the participants and provide insights for researchers into this cognitive process. Specifically, many creativity researchers have used magic to investigate thinking fixation and creative problem solving. For instance, Barnhart (2010) has shown how magicians rely on people's thinking fixation, such as traditional assumptions and heuristics, to create magic illusions and hide the secret method magicians use. Similarly, Thomas and Didierjean (2016) used magic performance to investigate how the presence of a false magic solution by a magician "fixed" the participants' minds from finding the true one. On the other hand, Danek, Fraps, von Müller, Grothe, and Öllinger (2014), Danek, Fraps, von Müller, Grothe, and Öllinger (2014) found that providing appropriate verbal hints and hues can help participants relax the constraints of thinking fixation and think more flexibly to find the true solution to the magic. The current study used magic performance as a unique stimulus to further investigate how schema disruption can facilitate flexible thinking. Specifically, in this article, based on an analysis of related theories and previous studies, the author developed an instructional strategy using magic performance to facilitate the flexible thinking of students. This strategy was implemented in an undergraduate level design class with a focus on investigating how schema disruption influences students' cognitive flexibility in design idea generation. The findings of this study provide insights into such influence.

This article has four major sections. First, the theoretical foundation for this research is outlined, specifically introducing the mindset change and mindset priming process underlying the schema disruption strategy. Second, the magic performance-based teaching method is introduced along with a detailed explanation of how magic performance could be used as a schema disruption stimulus to facilitate mindset change and mindset priming processes. Third, results from a case study on the implementation of this approach are presented, which explain how magic performance as a schema disruption stimulus influences flexible thinking. Fourth, the importance and implications of these findings are discussed along with ideas for future directions of study and design.

2. Schema disruption as a strategy to facilitate flexible thinking

A schema is a specific mental model that represents the abstract organization of information about a particular topic (Kellogg, 1995). Schemas function as cognitive mechanisms that enable people to have expectations about the world and manage their behavior based on those expectations (Roese & Sherman, 2007). Thus, students who possess a fixed or narrow mindset tend to rely on schema-based expectancies. They are more likely to produce ideas that are traditional and less novel. On the other hand, Sassenberg and Moskowitz (2005) found that students who had flexible mindsets were inclined to think beyond their schematic expectancies and generate more novel ideas. These studies suggest that to promote creativity, it is important to increase individuals' flexible thinking and reduce the reliance on the previous experiences.

Schema-disruptions, also called schema-violations, are stimuli that disconfirm people's schema- and stereotype-based expectancies (Goclowska, Baas, Elliot, & De Dreu, 2017). For example, a boat flying in the air violates our schematic expectations that a boat only moves on water. Previous research has suggested that schema disruption can help people to think more flexibly (Goclowska et al., 2017; Vasiljevic & Crisp, 2013). For instance, Goclowska et al. (2017) asked participants to memorize a series of photos that either matched with their expectations (e.g., an Eskimo walking on a snowy landscape) or were inconsistent with their expectations (e.g., an Eskimo walking in the desert). The results revealed that those who were given inconsistent photos and also enjoyed the task performed better on the flexible thinking test. Similar findings also can be found in social psychology literature. Vasiljevic and Crisp (2013) found that encouraging people to think about counter-stereotypic role models can lead to improved performance on a following creativity task. Even though this strategy has been shown to be effective, the reason why schema disruption can facilitate flexible thinking still remains unknown. Without understanding the cognitive mechanisms underneath, explanations regarding why and how schema disruption can facilitate flexible thinking remain incomplete. It is argued here that the reason why schema disruption facilitates flexible thinking can be attributed to two cognitive development processes—mindset priming and mindset change.

2.1. Mindset priming

The first related process is mindset priming. Priming refers to a temporary activation of a certain information or thinking by the stimuli, which exert an unintended influence on the responses to the following task or situation (Bargh & Chartrand, 2000). For instance, watching a commercial that introduces a newly released car will increase the possibility of this car being recalled. Recent studies have shown that it is also possible to prime a flexible mindset by using stimuli such as counterfactual events (i.e., scenarios that violates norms) or counter-stereotypical targets (such as a female engineer, a hippy lawyer, etc.) that disconfirm people's schema-based expectations (Goclowska et al., 2013). Supporting evidence can also be found in neuro-science studies. For instance, Ritter et al. (2012) found that participants who experienced counterfactual scenarios had active brain activity in the temporal parietal

junction (TPJ) area, which is a brain region related to flexible behavior (Greene, Nystrom, Engell, Darley, & Cohen, 2004). In essence, those counterfactual scenarios or concepts function as schema disruption stimuli to activate a mindset that considers alternative realities and perspectives. However, different stimuli may vary in their priming effectiveness on an individual's mind. In order to increase the likelihood of the activated mindset being applied in the future, the stimulus being used should be related to the individual's goals and values (Ferguson & Bargh, 2004). Higgins and Eitam (2014) emphasized the role of *motivational relevance* in priming, suggesting that the primed mindset should be relevant to individuals from three aspects: 1) Related: the activated mindset should be related to the participants' desired outcomes or goals; 2) Control: participants should feel confident in controlling and applying the primed mindset; 3) Truth: participants should regard the primed stimuli as true and real.

2.2. Mindset change

The other related process is mindset change. It is possible that schema disruption triggers a cognitive dissonance in individuals' minds and motivates them to change their mindset. Mindset change is different from the priming effect in that mindset change is a conscious process (i.e., with people's awareness). As suggested by Gill (2013), cognitive dissonances can be caused by logical inconsistency, or by disrupting a person's schematic expectations. When students experience something that is different from their schema, they actually experience an alternative reality that conflicts with their preexisting thoughts. They are encouraged to look at this world from a different perspective. Specifically, the stimulus triggers a dissonance between exclusively relying on the pre-existing schema and flexibly thinking of the alternative outcomes. Based on cognitive dissonance theory, when cognitive dissonance is triggered, people are motivated to return to a state of cognitive equilibrium (Heider, 1946). According to Piaget (1977), learning occurs by either assimilating the new information or experience into an existing schema or accommodating the new information by forming new schema. When students are confronted with a reality that is different from their expectations, they may question their past beliefs and rethink their current fixed mindset. If appropriate guidance is given, students might be willing to achieve balance by changing their mindsets. However, students may also choose to achieve balance by ignoring or avoiding the dissonance (Niaz, 1995). In order to elicit meaningful dissonance, researchers have suggested that motivational and affective factors should also be considered (Patrick & Pintrich, 2001; Pintrich, 1999). Specifically, students should be motivated and interested in the tasks which function as dissonance stimuli (Limón, 2001). Fig. 1 illustrates the underlying cognitive processes (mindset priming and mindset change) of using schema disruption to facilitate flexible thinking.

3. The framework of magic performance-based teaching method

This section introduces the rationale of using magic performance to facilitate flexible thinking and the detailed design of the magic performance-based teaching method.

3.1. The rationale of using magic

Magic performance was chosen as a schema disruption stimulus to promote both mindset priming and mindset change processes.

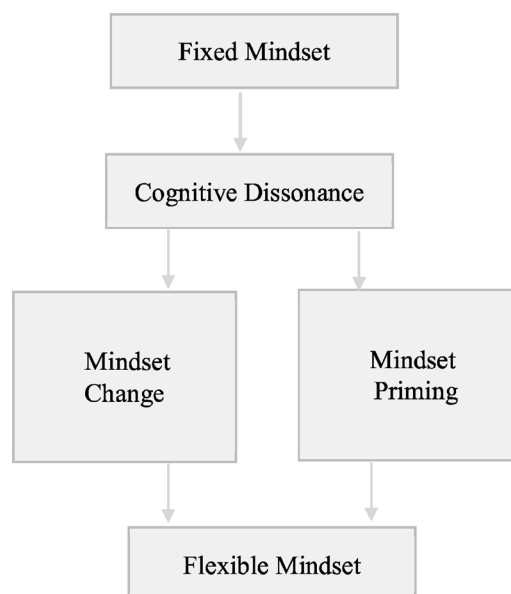


Fig. 1. The Cognitive Mechanism Underlying Schema Disruption Strategy.

Magic is a performing art that presents a reality that does not conform to the spectators' expectations. The unexpected reality creates a cognitive dissonance in the spectators' minds—a conflict between the knowledge and experience of the spectators and the seemingly unexplainable magic event they witness (Leddington, 2016). Such a magic experience differs from the experience obtained in other unexpected or surprising events. As described by Rensink and Kuhn (2015), watching a superhero movie showing a man flying across the sky is different from watching a well-executed magic performance, as the former is obviously explainable (e.g., using special video effects), while the latter is not. In addition, (Parris, Kuhn, Mizon, Benattayallah, & Hodgson, 2009) used fMRI to measure participants' brain activity under conditions of watching either magic performance or other surprising events that did not violate causality. The results showed that compared to other surprising stimuli, magic is more effective in activating the dorsolateral prefrontal cortex (DLPFC) and the anterior cingulate cortex (ACC). It is worth noting that the ACC plays a critical role in cognitive flexibility (Becker, Prat, & Stocco, 2016). Therefore, a magic trick, if performed properly, can function as a priming stimulus to activate the brain areas that control flexible thinking, which increases the chance for students to apply this mindset to other tasks.

Moreover, a magic trick can be viewed as a highly intriguing problem for the spectators to solve. Although the magic effect is seemingly impossible to explain, most of the audience still try to mitigate the dissonance by developing a plausible explanation (Leddington, 2016). To dissolve this dissonance state and find a solution, the spectators need to relax the constraints of their initial assumptions, which limit their solution searching space, and form a new understanding of the problem presented by a magician (Danek et al., 2014a, 2014b). This process provides a chance for students to practice flexible thinking, which will make a mindset change more likely.

In addition, this dissonance also represents a conflict between a flexible mindset held by the magician, who always imagines alternatives to reality, and a realistic or fixed mindset held by those who only rely on existing knowledge and familiar experience. Confronted with this dissonance in the class, students may realize the limitations of a fixed mindset, such as stereotypical thinking and personal bias. Also, they may see the benefit of a flexible mindset—turning the seemingly impossible into the possible, as in the magic performance demonstrated by the magician. If guided appropriately, students may become dissatisfied with a fixed mindset and look for alternatives to conventional thinking.

Of course, what makes a magic performance unique is that it is an entertaining activity that can raise people's situational interest. The illusions that are created by the magician are dramatic and novel, and are likely to elicit a strong cognitive dissonance that is enjoyable (Bagiński & Kuhn, 2019, 2020). Research has suggested that the high novelty of a stimulus can enhance its effect on thinking flexibility (Yagolkovskiy & Kharkhurin, 2015) and that the active engagement of the individuals is needed for this strategy to be effective (Ritter et al., 2012). Therefore, a magic performance is likely to be an effective stimulus.

3.2. The design of the magic performance-based teaching method

Fig. 2 illustrates this magic performance-based teaching method. The principles of effective mindset change and priming as discussed above were incorporated into the model's design. This method included five components: prediction, magic performance intervention, reflection and revelation, magic performance experience, and transfer. First, students were asked to give their responses regarding a certain event or problem based on their everyday experiences (prediction). Second, the instructor demonstrated how a magician would solve the problem using magic (magic performance intervention). After this, in the third step, students were led to reflect on their thinking fixation, to explore the creative mindset of magicians, and to learn the principles of magic that will enable them to develop creative solutions (reflection and revelation). Students then were given chances to learn and perform the magic trick for each other (magic performance experience). Finally, props were given to help students apply what they have learned from learning and performing the magic trick to their class projects (transfer). The following introduces the detailed design and rationale for each component.

3.2.1. Prediction

This step asked students to make a prediction about an event (e.g., What happens if we throw the ball upwards in the air?) or find a solution to a problem (e.g., How would you move a ring from one finger to another?). Most of the students tended to provide an answer based on their everyday experiences. For instance, when asked how to move a ring from one finger to another, most of the students gave an answer akin to using another hand to remove it from one finger and put it on another finger. This answer solves the problem but lacks originality. When they were shown how a magician approached this problem in a "magical" way, the students became aware of the inconsistencies between their expected solution and the magician's creative solution. By fostering awareness of inconsistencies and contradictions by making predictions of the event, students may realize they have fixed mindsets and might be more willing to explore other options (Watson & Konicek, 1990).

3.2.2. Magic performance intervention

After students made their prediction, they were shown how a magician "solves" the same problem, such as using "magic" to have the ring move by itself. The illusion functioned as a schema disruption stimulus to elicit a cognitive dissonance between the students' expected solutions developed in the first step and the discrepant outcome that was brought about by the illusion. As explained by Niaz (1995), without a meaningful stimulus, students will persist in their preconceptions by simply ignoring the cognitive dissonance. On the other hand, the priming effect will be more effective if participants regard the primed stimulus as true and real (Higgins & Eitam, 2014). Since the illusion happens in front of their eyes, students are more likely to believe that the magician truly makes the objects break the rules of nature, while also being curious about the secret behind the illusion. Research has shown that compared to other schema disruption stimuli, such as surprises, magic is more effective in raising people's motivation to solve the problem and find the

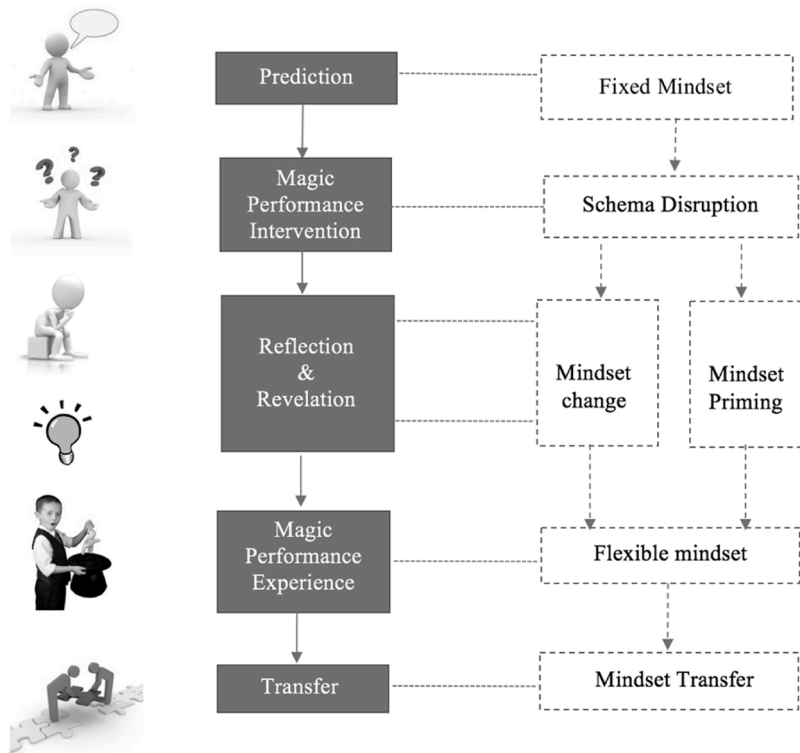


Fig. 2. The Magic performance-based Teaching Method.

solutions (Parris et al., 2009). Also, it is important not to reveal the secret too early so as to create an opportunity to capitalize on the students' inherent motivation to understand the phenomenon. As suggested by Moss, Irons, and Boland (2017), students might continue to ruminate over the explanation of the magic if the solution is concealed.

3.2.3. Reflection and revelation

After students watched the magic and thought about the solutions, they were guided to reflect on how a fixed mindset had led them to settle on a default solution (e.g., using the hand to take off the ring) and neglect other possible creative solutions (e.g., letting the ring move by itself). Following this, the magic trick was revealed. The method was then used as an example to help understand related principles used by magicians. The general principles were: analyzing traditional assumptions, challenging those assumptions, and developing as many alternative solutions as possible. Those principles were developed based on the author's own magic performing experiences and Cohen's book *Follow the Other Hand* (2006) (Cohen, 2006), in which Cohen explained how the magic creating process can benefit entrepreneurs. This step helps students to understand the benefits of flexible thinking and the related principles used by a magician to come up with creative magic ideas. Students are more likely to accept the new concept or the mindset if they regard it as intelligible, plausible, and fruitful (Posner, Strike, Hewson, & Gertzog, 1982).

3.2.4. Magic performance experience

The magic performance experience is an engaging activity designed to teach students how to perform the trick demonstrated earlier (see Fig. 2). Specifically, students were provided with the magic props and tutorial videos. They were asked to practice the magic independently first and then to perform the trick for each other. Research has shown that participants who actively experience the schema disruption performed significantly better in flexible thinking than participants who only watch others demonstrate schema disruption (Ritter et al., 2012). Additionally, performing magic will allow students to experience how magicians refine their performance by collecting feedback from their audience, which may help students learn the essence of prototyping in design. This is helpful for facilitating design flexibility, as suggested by studies showing that design fixation will be reduced if designers keep receiving feedback during the design process (Youmans, 2011). This feedback received may challenge the designers' own assumptions and encourage them to change and create more innovative designs. Teaching students to perform the trick will give them a chance to gain the experience of "doing things flexibly like a magician."

3.2.5. Transfer

In order to effectively prime a mindset, students should be able to control the mindset and understand how they can benefit from this mindset (Eitam & Higgins, 2010). In this step, participants were provided with exercises and materials to understand how to transfer the principles of a flexible mindset to new situations. Specifically, the similarity between a magician's and a creative designer's

general design processes was explained. In addition, selected creative design examples were presented to students to show how a designer innovatively solves design problems like a magician. For instance, a classic example was the “The Slow Elevator” design challenge, which presented a design problem in which a building manager keeps receiving complaints about how slow the elevator is. Students were asked to solve this problem for the manager. The creative solution recommended was that instead of focusing on upgrading the motor of the elevator, the manager could put up a mirror in the waiting area of the elevator. People who took the elevator might spend more time looking at themselves in the mirror, thus creating an illusive feeling of a shorter waiting time. In this example, the solution is simple but solves the problem in an unconventional way, which represents a similar flexible mindset held by magicians. This step not only aims to increase students’ confidence in controlling a flexible mindset but also makes the flexible mindset more closely related to students’ goals.

4. The study

The study was conducted in a design course at a public university in the southeastern United States. This course was designed to attract students from multiple disciplines and to provide them with opportunities to learn how to design and develop their own software applications. Students were required to generate their design ideas at the beginning of the semester and then to focus on design and development of their design product for the remaining semester. The instructor wanted to create a learning environment that valued creative ideas. To achieve this, he invited the investigator to implement this magic performance-based method in his class. As the instructor’s request, this method was included as one of the learning activities during the idea generation phase to help students understand how to think “outside the box” and come up creative design solutions.

4.1. Participants

The protocol of this research was approved by the institutional review board of the university. In total, 27 students were recruited for this study—15 students were female and 12 were male. The age range was from 20–23. All participated in the intervention activities and signed the consent form. Eighteen of the participants agreed to participate in semi-structured interviews; 11 interviewees were male, and 8 were female. Each interview lasted approximately 25 min. None of the participants had prior magic performing experience or knowledge of the methods of magic tricks performed by the investigator.

4.2. Materials

Semi-structured interview was adopted as the main data collection method to reveal participants’ experiences during the activity to answer the research question— how does a magic performance as a schema disruption stimulus influence students’ flexible thinking? The interview questions were informed by theories for mindset priming and mindset change. The main interview questions are presented in Table 1. Since the priming effect of schema disruption is difficult to be noticed by the participants, Guilford’s Alternative Uses Task (1967) was implemented prior to and again after the intervention. Participants were asked to contrast and describe their experiences of taking the pre- and post-Alternative Uses Task during the interview, by which the influence of the priming effect on students might be revealed.

The magic tricks used for this research were selected based on the strength of the cognitive dissonance elicited by the magic trick and the ease of the learning process for the students. As the investigator had previous performing experience in the classroom, three types of magic performance were selected based on the previously mentioned criteria, as presented in Table 2.

4.3. Procedure

The instructor informed the students in advance that the investigator would perform magic tricks in the class and conduct research accordingly. The recruitment process began in the classroom after the investigator introduced the research project. Students were informed that their participation was voluntary and that they could opt out at any time without penalty. After students signed the consent forms, they were asked to fill out a demography survey. Then the students were directed to take the Alternative Uses Task. The Alternative Uses Task was presented as a game to students, in which they were asked to write down all the alternative uses of a paperclip on a blank piece of paper.

The author then implemented this magic method in this course. The author repeated this intervention three times during two

Table 1
The Interview Questions.

Related Concepts	Interview Questions
Schema Disruption	How did you feel at the moment when magic happened in our class and you saw something that was completely unexpected?
Mindset Priming	Could you compare your experience in the pre- and post-Alternative Uses Task? How did the magic activity influence your experience in the post-Alternative Uses Task?
Mindset Change	How has your thinking changed because of your participation in this magic activity?
Reflection/ Revelation	What did you learn from the principles used by magicians to develop creative magic ideas? How did these principles influence your flexible thinking?
Transfer	Please tell me your experience of learning and practicing magic. How did this activity influence your everyday life and your design process?

Table 2
Information About the Magic Tricks Used in the Intervention.

Magic Trick	Magical Effects	Prop Used	Presentations/Leading Questions
The Magic Ring	“Teleportation”	“Odyssey” Inventor: Calen Morelli	The investigator showed students a ring on his index finger and asked them a question: How could you move a ring from one finger to another? The common solution given by most of the students was using the other hand to move the ring. The investigator showed students how he let the ring move from finger to finger by itself.
Coin Trick	“Coin Production/Vanishing”	“Super Triple Coin” Producer: Johnny Wong	The investigator started by showing that both hands were empty. Then he asked students whether it was possible to pull a coin out of the air. After receiving negative answers from most students, the investigator produced three coins and then made all of them vanish.
Rope Magic Trick	“Restoration”	“Four Nightmares” Producer: Tenyo Magic	The investigator demonstrated a short rope and a long rope to the audience and asked: How could you make these two ropes the same length? The common solution given by most of the students was using scissors to cut the longer rope so that the two ropes will look identical. Then the magician put the two ropes together. When he separated the two ropes, the short rope magically became longer and became the same length as the other rope.

weeks. Each intervention last around 30 min using different magic tricks as stimuli. For each intervention, students not only watched magic performance but also learned the secret of the magic and principles used by magicians. They were also guided to learn how to perform the trick so as to gain direct experiences of thinking and behaving like a magician. Creative design examples were also provided to students to help them understand how to apply the principles learned from magicians to their design projects.

After all the interventions were completed, participants were asked to retake the Alternative Uses Task. The object was changed from a paperclip to a brick for this test. Then the researcher scheduled an interview time with participants who signed the consent form and agreed to be interviewed.

4.4. Analytical approach and analytical process

Thematic analysis was adopted to analyze the interview data collected. Thematic analysis is an effective method for “examining the perspectives of different research participants, highlighting similarities and differences, and generating unanticipated insights” (Nowell, Norris, White, & Moules, 2017, p. 2). Although the intervention was developed based on the previous theories and research, I was aware that the theoretical framework might become my personal biases and limit myself from finding the emerging themes that were not covered by the codebook but important for understanding this specific phenomenon. Therefore, thematic analysis helped me find a balance between relying on the previous theory and discovering unexpected outcomes.

Initial codes were developed before starting the analyzing process. In this study, mindset change theory and mindset priming theory informed the design of this magic-based method and illuminated the possible factors that influence the effectiveness of schema disruption. Initial codes were developed based on theories regarding mindset priming and mindset change, which represented the specific pragmatic interest of myself as a researcher—to understand how those theory-based design decisions for using magic as a schema disruption stimulus influence students’ thinking flexibility. Examples of codes were thinking flexibility, cognitive dissonance, mindset change, mindset priming, mindset transfer, situational interests, etc.

After developing initial codes, I read the transcripts line by line and looked for patterns that were related to these codes. After iterative cycles of reading and coding, I removed the codes that did not represent the patterns of the data and added additional nodes that account for the patterns manifest by the data. The updated codebook consisted of 13 codes grouped into 3 main categories (see Table 3). Then I interpreted the meaning of those codes and summarized the insights generated into themes, which will be introduced in the next section.

Regarding the analysis the data of Alternative Uses Task, a paired *t*-test was adopted to compare the difference between the pre- and post-results. First, based on the Guilford Alternative Use Test Manual (Guilford, 1967), the total number of the categorical alternative uses each participant came up with for the target object in the pre- and post-test was calculated. Then the results were entered into SPSS Statistics for paired *t*-test. The Shapiro-Wilk test was used to verify that the normality of paired differences was not violated.

5. Findings

After conducting the data analysis introduced in the previous section, three main themes were found in the interview data. These main themes help understand how this magic performance-based method influenced students’ flexible thinking.

5.1. Theme 1: watching magic performance primes a childlike flexible mindset

After participating in the magic performance-based activity, participants began to understand the concept of multiple realities and look at their world from a childlike perspective. One participant commented on the experience of watching magic performance in the class, saying:

Table 3
Final Codes Grouped by Codes Type.

Category	Codes	Description	N
Childlike Inclination Priming Effect	Regain Childlike Feeling	Relates to participants' feeling of being a child.	8
	Belief in Impossibility	Relates to participants' belief that everything is possible.	15
	Think less realistically	Relates to the thinking of less realistic ideas.	6
	Sense of Wonder	Relates to the sense of wonder toward the world.	2
	Mindset priming	Relates to the feeling of being more flexible, especially when asked to compare pre- and post-Alternative Uses Task experiences.	16
Mindset Changing Process	Awareness of Thinking Fixation	Relates to participants' awareness of their thinking fixation.	15
	Divergent Thinking	Relates to signs that magic motivated participants to think from different perspectives.	17
	Mindset change	Refers to a conscious mindset change process of the participants.	17
	Curiosity	Relates to signs suggesting the factor of curiosity influenced thinking flexibility in this process.	14
	Flexible Thinking Attitude Improvement	Relates to any signs indicating that participants were influenced to form a positive attitude toward flexible thinking.	8
Mindset Transfer	Meaning Construction	Relates to participants' own interpretations of thinking flexibility.	12
	Flexibility in Everyday Life	Relates to the application of flexible thinking in everyday lives.	19
	Flexibility in Design	Relates to the application of flexible thinking in design projects.	22
Other	Design Empathy	Relates to any signs suggesting participants showed empathy for their audience.	7

“[Before watching the magic performance] You are assuming it’s going to happen in one way. Because your mind is trained to think this is used for that purpose and ignores other ways something could happen, which is how the magic happens.”

This statement showed that the magic performance demonstrated an alternative reality to participants different from their pre-determined thoughts or expectations. Prior to this experience, they assumed that everyday objects, such as a ring or a coin, could only be used for their intended purposes and probably never thought that they could be used to create magic tricks. Experiencing such an alternative reality inspired participants to look at objects in the world from new perspectives. Additionally, the boundary between the impossible and the possible also became blurred, as indicated by the participants:

“Yeah, magic makes me feel younger in this class. I felt like back to elementary school. We have as much fun as we would in elementary school. There is no pressure; there is no right answer, which drove our creativity.”

“The most practical reason [for thinking fixation] is that we feel that it’s impossible for [something] to happen like that [magic]. We are not open to the idea like magic. I feel like that’s how it plays in the role of children as we said before. Kids are so simple. For them, they just think of these ideas, because they are not so fixed on ‘Oh that’s impossible.’”

These statements showed that watching the illusion helped these participants rethink the definition of *impossible* and view the situation as a child. Such a playful, childlike mindset might facilitate creative originality because it frees their minds by encouraging them to think without the limitations of pre-existing ideas or experiences. The use of magic as a schema disruption stimulus might prime such a childlike mindset and thus facilitates flexible thinking.

The priming effect of magic was also found when asking participants to compare their Alternative Uses Task experience before and after the intervention. As stated by one student, “I like learning how you did the trick. It was also cool to see. I did the paperclip and [came up with] like 4–5 ideas. After we’ve done that, I can generate 10 ideas for the brick. [Magic] Just activating that part of my brain. It makes me think differently.” Another participant also expressed a similar thought: “Regarding the paperclip, I always focus on practical things. My mind always sticks to the original use of a paperclip. For the brick, I am not that practical anymore, not just [using it] for building a house.”

“Activating that part of my brain” suggests that the magic performance might function as a schema disruption stimulus that primed this participant’s mind for flexible thinking. Although the participant might not have intentionally thought divergently in the post test, his comments showed that the magic performance did influence his thinking process and made divergent thinking more accessible in the post-test. In addition, consistent with the interview data, the results of the paired *t*-test showed that participants’ average scores in the post-test ($M = 5.74, SD = 2.72$) were significant higher than the average scores in the pre-test ($M = 4.33, SD = 1.86$), $t = -3.61, p = 0.001$, as indicated in [Table 4](#).

5.2. Theme 2: curiosity toward the secret of magic drives the mindset change process

“I think it [the ring magic] is impossible, but it is actually happening. I started to think and to figure out how it happens. [Initially] I

Table 4
Paired *t*-test results comparing pre- and post-Alternative Uses Task scores.

	Pre-test ($n = 27$)		Post-test ($n = 27$)		<i>t</i>	<i>p</i>	<i>d</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Flexibility	4.33	1.86	5.74	2.71	-3.61	.001	.61

thought about it logically: why my belief [initial expectation for the outcome] is wrong...let me think...if that ring is a real ring, it is impossible for it to happen. I think of all other possibilities, so maybe his finger skill is really good, or that the ring is not real, that part I really like, it makes me think logically but also creatively.”

In this case, the cognitive dissonance elicited by the magic performance raised the curiosity of this participant, leading him to attempt an explanation of what he saw with everyday logic, which proved unsuccessful. This failure motivated him to deviate from convergent thinking, which only focuses on the most familiar solution, and move toward divergent thinking, which considers other possible explanations. Other participants also expressed similar experiences after seeing the trick:

“Yes, first it is logical, then when logic fails, that’s when imagination comes in.”

“One of my favorite things you did was you did a magic trick and then you let us just throw out ideas of how it could be done.

Whether rational or irrational, it doesn’t matter, just throwing out ideas So just using magic to stimulate creativity was awesome because it just made you think of the almost the irrational solutions just as good as the rational solutions.”

The novel magical effect motivated these participants to imagine different ways to solve the problem rather than only relying on their logical assumptions. “Irrational solutions as good as rational solutions” indicated a mindset of appreciating both rational thinking and flexible thinking. Research has shown that this “rational irrationality” can promote serendipitous discoveries (Gaut, 2012). People who process this mentality not only may look for solutions that are useful but also may be open to possibilities that lead to future breakthroughs. On the other hand, the cognitive dissonance participants experienced helped them to recognize the thinking fixation they processed. Evidence was also found that acknowledging thinking fixation motivated them to form positive attitudes toward flexible thinking. As stated by the participants:

“I want to know how you did that. When you showed us [the secret], it makes sense, and it is very simple. But we are so fixed on finding the most practical reason.”

“You know, you have this initial gut feeling when something happens. But magic tells us that things could be that and also could be this. So, magic just opens up your mind a little bit more to a range of possibilities.”

5.3. Theme 3: the principles of magic promote flexible thinking transfer

After watching the magic performance, participants were guided to learn the methods and principles used for the trick and to understand how a flexible mindset enables magicians to develop creative magic ideas. For instance, students learned how a magician allows the ring to jump from one finger to another. The secret lies in a special “ring” that actually is a rubber band with a hidden magnet gap that enables a magician to move the ring “magically.” Students were also introduced to the general thinking process magicians use to create special props like the ring. One participant commented on this, saying:

“I think it [this ring trick] expanded my thinking flexibility. We talked about something being flexible, to bend and shape things in different ways. I think when you talked about magic, that’s exactly what it is, just take an everyday object or something you have a predetermined thought about and reshape that. You can fold it in this way or that way. Flexibility is kind of openness to reshaping [something].”

Another participant expressed a similar thought:

“When you broke it down and showed us how you tricked us, just for this moment, one little trick made me realize even this little thing can make a drastic impact, and very powerful, which is really cool. Because I think a lot of times, especially in college, I have to put in so much work to get this amazing and crazy result. But sometimes if you do not get it, you would assume the whole process was wrong. Sometimes if you just tweak one thing, or think about one step differently, you can completely change your outcome, and make it really impressive and really creative.”

Therefore, through learning the secret of the magic and the principles used by magicians, participants understood that “reshaping predetermined thoughts” or “tweak one thing” can “create something big” and “completely change the outcome”. These remarks suggest that *reflection and revelation* helped participants not only to learn about the secret of magic but also to develop a deeper understanding of how to create their own magic—an openness to challenge or reshape traditional assumptions and ideas. Barron (1969) emphasized the importance of this openness to creativity: “Since human beings are not able to make something out of nothing, the human act of creation always involves a reshaping of given materials, whether physical or mental” (p. 10).

Additionally, influenced by this mindset of challenging traditional assumptions, participants began to rethink the design products in their everyday lives and to improve the unsatisfying design products. As one participant commented,

“You showed us like ... Ok, here is a basic coin and here is the magic trick with it... oh, wow, that’s so awesome... those are just little things, but they influenced me to look at things differently in my daily life. I remember when I walked into our house one day, we had a new rug, and the edges of the rug really rolled up, and I was like um... maybe that’s a problem, how can I fix that? Then I was trying to think of products or ideas like that...”

Another participant also expressed a similar thought:

“...when I see something that needs to be improved, I am little bit more aware what I am thinking about it. [I know] That is a problem rather than it is just the way it is. Like a broken door, you sit there either saying ‘Oh it is a broken door’ or you can think about how this could be better.”

These statements suggest that participants had developed a flexible mindset similar to that of magicians. They understood the meaning of the principles used by magicians and were able to use these principles to improve their everyday lives. In addition, it is

worth noting that a few participants were influenced by their experiences of performing magic tricks to recognize the importance of the audience in helping improve their performances. They were able to relate this principle to the design of their products and began to consider the needs of their target users, as indicated by these two participants:

“If there is no magic, we will not be able to view things from our audience perspective. Because when you make something, you assume that will work, and you have a plan how it works in your mind. When you hand it to others, if you never thought about how your audience feel about it, it is probably very hard for others to understand how it works. So, without magic, I would never have thought about that. With magic, I thought about how my users would use my app and how they felt about it.”

“It just like helping me to reevaluate it [my design] and bringing me back to think about my audience more. Because as I kept building my app, it was like I want it to look like this or look like that. And then, you just have to take a step back—I’m not building this for me. I have to make sure I’m tailoring to my audience. I need to take inspiration from my audience to build something that we would all want, not just me. It’s not what I want it to look like. What I mean, it’s partly what I wanted it to look like, but mainly I needed to pull from what my users want it be and design it accordingly.”

Recognizing the important role of the audience in improving magic performance encouraged these students to emphasize with the target users of their design products. These participants became less focused on their own assumptions and more considering their users’ needs and preferences.

6. Discussion and conclusions

This study introduced a method using magic performance as a schema disruption stimulus to facilitate flexible thinking. As discussed above, both priming theory and mindset change theory informed the design of this method. The findings of this study further explained how magic performance as a schema disruption stimulus facilitates these two related cognitive processes, which enhances flexible thinking at various levels.

First, watching magic performance might prime a childlike mindset in students, thus encouraging them to think from different perspectives and to become more willing to use their imaginations. In the interviews, participants used phrases such as “thinking like a child,” “start to believe everything is possible,” and “think less logically but more imaginatively” to describe their experiences after watching the magic performance. This evidence suggests that magic had activated a counterfactual thinking mindset in students. Counterfactual thinking is an inclination to imagine what might have been and consider “what if” alternatives to realities (Bonsignore et al., 2012). Counterfactual thinking encourages people to think using fantasy and imagination (Galinsky & Moskowitz, 2000; Markman, Lindberg, Kray, & Galinsky, 2007). Previous research has suggested that watching films (such as the *Harry Potter* series) with magical content encouraged children to use their imaginations and thus facilitates their counterfactual thinking (Subbotsky, Hysted, & Jones, 2010). This is consistent with the result of the current study that watching a magic performance might encourage students to think counterfactually. One possible explanation is that when they watched a magic performance, students were immersed in an imaginative scenario directed by magicians. The magical effects (such as vanishing, producing, etc.) violated the known principles of physical and mental causality and thus demonstrated an alternative reality to students. Situated in such an environment filled with unusual events, students were more likely to think beyond conventional thinking and develop alternative ideas. Another possible explanation is related to curiosity. It is possible that watching magic performance raised students’ curiosity and they became more willing to explore alternative solutions. Bagiński and Kuhn (2019), Bagiński and Kuhn (2020) reviewed previous studies on the use of magic performance to enhance wellbeing and concluded that watching magic performance can enhance people’s curiosity and increase their motivation to explore the tasks related to the trick. Harris (2012) also suggested that magic creates a sense of astonishment, which is an experience of a primal state of mind associated with a natural child mindset. This primed childlike mindset enables an adult to develop a broad repertoire of free flowing associations like a child, which facilitates flexible thinking and increases the originality of the ideas (Tsai, 2012).

Second, the result showed that the secret exploring process helped students realize their fixation and form a positive attitude toward flexible thinking. The seemingly impossible magic illusion evoked a strong and dramatic cognitive dissonance in participants. This unique dissonance raised students’ curiosity to know the secret of the magic trick. During this exploring process, many participants displayed dissatisfaction with their thinking fixation because a mindset focused on familiar experiences usually fails to explain a magic trick. As suggested by Danek et al. (2014a), (2014b), most of the audience tries to solve the magic problem with their previous assumptions and knowledge. But most of the methods used by magician are developed based on the principle of transforming everyday objects into magic “gimmicks”—special mechanisms disguised as common objects that make magic happen. Therefore, the audience pre-assumptions toward these everyday objects used by a magician might be biased and inappropriate, which establishes an incorrect representation of the problem and poses constraints on the searching space for possible solutions (Knoblich, Ohlsson, Haider, & Rhenius, 1999). Guiding students to realize the fixation they possessed and encouraging them to think of all possible solutions provided a chance to practice flexible thinking and learn how to relax the posed assumptions constraints, as indicated by the participants’ use of phrases such as “think logically and creatively” and “when logical fails, imagination comes in” to describe their experience in this secret exploring process. In addition, by revealing the secret, students understood how their assumptions limit their minds from finding possible answers and how a flexible mindset helps magicians create magic illusions. Therefore, they formed positive attitudes toward flexible thinking, which makes mindset change more likely to occur.

Furthermore, providing a successful experience for students to use these principles in class projects and in their lives will help them see the transferable power of a flexible mindset. Thus, deeper mindset change might occur. As suggested by Higgins and Eitam (2014), students are more likely to accept the activated mindset if the mindset is related to their desired outcomes or goals. In this study,

students were guided not only to perform magic but also to apply the principles they learned from magicians to their lives and design projects. Therefore, they formed a deeper understanding of the benefits of these principles and started to construct their own meanings of flexible thinking. After understanding the value of flexible thinking, they became more likely to deviate from traditional ideas and approach problems with a more flexible and divergent thinking process.

In conclusion, the findings of this study align with Norman's information processing theory. As suggested by Norman (2004), there are three levels in our brain for processing sensory stimuli: 1) visceral: an automatic, prewired reactions to stimuli; 2) reflective: a high level conscious meaning assignment or constructive process toward stimuli; and 3) behavioral: a subconscious motor response influenced by both visceral- and reflective-level experience. These three processing levels are different but affect and influence each other. In the current study, priming theory is aligned with the visceral level, in which students watch magic performance and react to it with childlike imaginative responses because a childlike counterfactual mindset has been activated. The novelty of the schema disruption stimulus plays an important role for the priming effect to be effective. A stimulus such as magic performance may influence students' cognitive systems and bring the sense of wonder to them. On the other hand, mindset change theory is related to the reflective level. It focuses on eliciting a meaningful and strong cognitive dissonance by reducing the satisfaction of students with the old mindset and increasing the perceived value of the targeted mindset. At reflective level, the curiosity to the secret of the magic drives students to find a solution or explanation to what they witness, which also provides an opportunity for instructors to guide students to reflect on their fixed mindsets and evaluate how meaningful a flexible mindset is to their lives and projects. If the flexible mindset is perceived as valuable and meaningful, students will be more likely to make changes and take actions toward the direction indicated by the flexible mindset, which is related to the behavioral level.

7. Limitations and future research

There are many important limitations to the study. Given that the recruitment of participants was based on students' willingness to participate, it is possible that the students who volunteered to be interviewed were more interested in magic than those who did not. Therefore, the data collected might not represent all participants' experiences. Also, since the intervention was implemented rather transparently, the participants may respond to the interview questions in a way that fits the results expected by the researcher rather than revealing their true experiences. Second, although the paired *t*-test suggested an improvement in flexible thinking, the results of the paired-*t* test cannot ensure that the improvement was caused solely by the intervention itself because a control group was not included in the study. As the results of this study mainly relies on the qualitative data, more controlled experiments need to be conducted to improve the generalizability of these results. Third, one goal of this study was to provide teachers with insights into how magic can be used in the class to facilitate creativity. But using this method may require teachers to learn and perform magic tricks, which may not be practical given the heavy workloads of most teachers. One possible alternative to performing magic in class is showing videos from YouTube that demonstrate magic tricks and also reveal their secrets. Another alternative involves self-working magic tricks that can be performed without too much practice. However, it is unclear whether these magic tricks would have the same influence on flexible thinking as the magic tricks used in this study. Fourth, although evidence suggested that magic as a schema disruption stimulus influenced flexible thinking on the visceral and reflective levels, more evidence is needed to show how magic performance influences the behavior change of students. It is also worth noting the age range of participants in this study, which is from 20–23. It has been suggested that children under the age of five cannot fully understand and enjoy a magic performance (Macknik, Martinez-Conde, & Blakeslee, 2010). This is because children cannot fully understand the causal relationships in the world, so the magic events that violate the laws of nature seem possible in children's minds. Therefore, this method might not be effective for young children.

Some suggestions and ideas for future research are offered. One interesting result emerging from this study is that students became more interested in their audience's experiences after learning and performing magic. The interview data indicate how this experience influenced them to focus on their targeted users when they design their digital products. Although this might seem beyond the scope of this study, it sheds light on future research that using magic as a way to facilitate design empathy. A few researchers have emphasized the need for more research to inform and inspire designers to create unique and enjoyable using experience for their targeted customers (Fulton Suri, 2003; Mattelmäki & Battarbee, 2002). Through learning and performing magic, designers may be influenced to develop such inclination that shows empathy to their users and provides a magical using experience for them through design products. A few studies have been conducted to explore the use of magic performance to enhance creativity in product design (Wiseman & Watt, 2020). Another potential idea is about the use of magic performance in facilitating the ambiguity tolerance of design students. Fields or situations that requires creative thinking are always filled with uncertainty and ambiguity. Individuals with high tolerance for ambiguity not only feel comfortable with working with those situations, but they are also intrinsically motivated to explore the uncertain design process and find a novel design solution (Zenasni, Besançon, & Lubart, 2008). By performing the magic trick but not revealing the secret behind it, teachers might help design students practice how to embrace ambiguity in order to guide them to appreciate a mindset of accepting uncertainty. By doing so, students may develop a positive tolerance and appreciation for ambiguity.

CRediT authorship contribution statement

Tong Li: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Visualization, Writing - review & editing.

Declaration of Competing Interest

None.

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