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Are research studies too boring?: incorporating gamification elements in mental rotation for children.

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Abstract

Many cognitive tasks are perceived as boring by children due to their redundancy, lengthy trials, and required cognitive effort. Children's performance on these tasks might therefore be hampered, not by a lack of cognitive ability, but rather by a lack of motivation to complete these tasks. Mental rotation, a type of cognitive task, has been extensively studied, due to its prevalence in daily living, in activities such as loading a dishwasher or packing a car, and its relation to STEM success. However, similar to other cognitive tasks, mental rotation tasks often result in fatigue and boredom in children. Hence, the current study incorporated the gamification elements of a cover story, feedback, points, and rewards, into a classic mental rotation task. 100 children between the ages of 6 and 9 years old received either a gamified mental rotation task first or second, and their performance was compared to that of a non-gamified mental rotation task (i.e., baseline). The results found that performance increased for children receiving the gamified task following the baseline. More importantly, good performance was maintained from gamification to baseline conditions, suggesting that children's motivation remained intact even after the gamified elements were removed. Furthermore, the personality traits of Agreeableness and Openness to Experience correlated with performance but did not predict the gamification effects. The practical implications of this study suggest that gamification be incorporated in cognitive task design for children, whereas the theoretical implications demonstrate the relationship between motivation and cognition.

Keywords: mental rotation, gamification, personality traits, children

MONTCLAIR STATE UNIVERISTY

Are research studies too boring?: Incorporating gamification elements in mental rotation for children.

by

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ARE RESEARCH STUDIES TOO BORING?: INCORPORATING GAMIFICATION ELEMENTS IN MENTAL ROTATION FOR CHILDREN.

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INTRODUCTION

Children often perceive cognitive tasks as boring due to their redundant nature, lengthy trials, and the required cognitive effort. As a result, children experience fatigue and lose the motivation to complete these tasks. This posits the question- if children are exhibiting decreased motivation, is their performance an accurate representation of cognitive ability?

Mental rotation, one such cognitive ability, is often studied by cognitive developmental researchers due to its pertinence to daily living. Common manipulations employed by researchers in mental rotation studies include the type of stimuli and degrees of rotation. Similar to other cognitive tasks, children's performance is potentially hampered by study design. Merely reducing the number of trials risks reliability and incorporating engaging elements may not be sufficient enough.

Hence, the current study suggests the incorporation of gamification in a classic mental rotation task to determine whether performance among children between 6 and 9 years old will improve. However, not all children might need gamification to motivate them to do well. Some children might naturally perform to the best of their cognitive ability, while others might lose motivation, despite possessing the cognitive capacity to do well. Personality factors potentially correlate with performance on a gamified mental rotation task. The theoretical implications of this study are important as it provides insight into the relationship between motivation and cognition in children.

This literature review explores the development of mental rotation, gamification, and personality traits. Following this review will be the theoretical frameworks, methods, results, discussion, and then conclusion.

LITERATURE REVIEW

Mental Rotation

Mental rotation is the ability to mentally rotate the shape of an object (Shepard & Metzler, 1971). These abilities are typically observed in children around the age of 5 years old (Fernández-Méndez, Contreras, & Elosúa, 2018; Frick, Ferrara, & Newcombe, 2013; Frick, Hansen, & Newcombe, 2013; Hawes et al., 2015a) and continue to develop and improve throughout childhood and adolescence (Kail, Pellegrino, & Carter, 1980). Mental rotation ability is germane to daily living, as it assists in tasks such as placing dishes in a dishwasher or packing a car. More importantly, these abilities have been found to predict success in STEM fields (science, technology, engineering, and mathematics) and math performance in elementary school-aged children (Cheng & Mix, 2013; Moen et al., 2020).

There are two main types of mental rotation tests with different variations. The first was the original designed by Shepard & Metzler (1971), which consisted of two rotated, three-dimensional pairs that were either the same, in that they were rotated a certain degree in the picture plane or rotated in depth, or different, in that no degrees of rotation could result in the pair being the same. The chronometrical mental rotation test follows this original Shepard & Metzler (1971) design but differs as the experiment is presented on a screen (Scheer, Maturana, & Jansen, 2018).

Researchers must determine which type of mental rotation paradigm is appropriate for their participant's age range to ensure that the task does not exceed their cognitive capacities (Frick, Hansen, & Newcombe, 2013). When testing children, Shepard & Metzler's (1971) task is often adapted to be more child-friendly through reducing dimensionality (Lütke & Lange-Küttner, 2015) and changing stimuli to more concrete objects (e.g., Jansen et al., 2013; Marmor, 1975). Furthermore, explaining the mirror image concept to young children often proves difficult

(Frick & Pichelmann, 2023). Hence, other adaptations of the original task include shifting to a puzzle-like paradigm, in which two-dimensional mirror images of stimuli are presented and participants need to determine which would fit into a hole that is of a different orientation (Frick, Ferrara, & Newcombe, 2013; Frick, Hansen, & Newcombe, 2013).

Another frequently employed paradigm is the Mental Rotations Test (MRT), developed by Vandenberg & Kuse (1978), which consists of 24 multiple-choice items and uses block configurations similar to those of Shepard & Metzler (1971). There's a target figure (3D cube figure) on the left side of the page, followed by four alternatives on the right. Two of the response choices are rotated drawings of the target, and the other two are distractor images, in that they are entirely different structures or mirror images of the target. A popular iteration of the MRT is the redrawn version created by Peters et al. (1995), which accounts for only "copies of copies" of the original test remaining.

Vandenberg & Kuse's (1978) mental rotation task is typically used when testing adults (e.g., Peters et al., 1995) and has proven to be too complex for 7-8-year-old children due to its four answer options (Hoyek et al., 2012). Similar to the original Shepard & Metzler (1971) paradigm, aspects of Vandenberg & Kuse's (1978) paradigm, such as degrees of rotation or type of stimuli, are often adapted to be more child-friendly.

The role of stimuli

The mental rotation task comprises stimuli, the entities being mentally rotated. Stimuli are often categorized as being abstract (i.e., letters, lines, or cubes) or concrete (i.e., body parts, human and animal faces) (Iachini et al., 2019). Compared to abstract stimuli, concrete stimuli are often easier to rotate due to the familiarity they evoke (Doyle & Voyer, 2018) and their distinct features (Wimmer et al., 2015).

Stimuli can be presented as either two (2D) or three (3D) dimensional. 3D stimuli involve visualization of parts that are not directly observable (Kawamichi et al., 2007), whereas 2D stimuli are flat and rotated only within the picture plane (Hoyek et al., 2012). The additional level of complexity makes 3D stimuli more challenging to rotate (Linn & Petersen, 1985). Cubes, a common type of 3D stimuli, have yielded inconsistent results within the child mental rotation literature. When 2D representations of 3D cubes were incorporated, children between the ages of 8 and 10 performed beneath chance (Jansen et al., 2013; Moè, 2018). However, children exhibited noticeable improvement when physical 3D cubes were utilized (Hawes et al., 2015a). These results suggest that children's ability to mentally rotate cube stimuli should be further investigated.

When assessing mental rotation abilities in children, it is imperative to consider stimuli presentations. A stimuli's structure impacts encoding and recognition, ultimately affecting the rotation complexity (Bialystok, 1989). Researchers often employ "child-friendly" stimuli, such as familiar (Hoyek et al., 2012; Marmor, 1975) and concrete objects, when assessing mental rotation in children. The type of stimuli chosen for a mental rotation task is therefore crucial as it affects processing.

The role of rotation

Along with stimuli, another component of the mental rotation task is the degrees of rotation. Stimuli within the mental rotation task are rotated between 0 to 360 degrees and often occur in 30 (e.g., Fernández-Méndez, Contreras, & Elosúa, 2018; Frick, Hansen, Newcombe, 2013) to 45 (e.g., Frick, Ferrara, & Newcombe, 2013; Hawes et al., 2015a) degree increments. The rotation itself can occur in either a two-dimensional picture plane (i.e., clockwise or counterclockwise) or in an axis in depth (i.e., x, y, or z axis) (Cooper, 1975), with the latter being more complex (Stieff et al., 2018). The vertical rotation axis has been found to yield the fastest responses for rotations in depth compared to the horizontal rotation axis (Battista & Peters, 2010; Ganis & Kievit, 2015). Furthermore, the design of the stimuli also impacts a participant's ability to rotate an object. Perspective cues, such as shading and diminishing perspective, have been found to make rotating easier as spatial relationships can be determined more readily (Ganis & Kievit, 2015; Stieff et al., 2018). A linear relationship between angular disparity, the degrees of rotation that the stimuli is rotated from its canonical upright orientation, and reaction time also exists (Shepard & Metzler, 1971), with accuracy decreasing as angular disparity increases (Krüger, 2018) due to the required change in viewpoint (Cheung, Hayward, & Gauthier, 2009).

The role of reaction time

Researchers often include additional measures in mental rotation tasks to examine these abilities even further. One such measure is reaction time, which refers to how long it takes a participant to mentally rotate the stimulus and respond (Kelly, Murphy, & Backhouse, 2000). Although five-year-old children can solve a 2D mental rotation task, they exhibit slower reaction times than their eight-year-old counterparts (Marmor, 1975). Increasing angular disparity also increases reaction time (e.g., Wiedenbauer & Jansen-Osmann, 2008).

However, there are potential issues with measuring reaction time in mental rotation tasks. In children, boys often are found to respond faster than girls (Hodgkins, 2013), which further exacerbates the gender gap in mental rotation performance between men and women. Attentional demands for speeded responses may also make reaction time an inappropriate measure for children (Iachini et al., 2019).

The role of feedback

Another commonly used manipulation within mental rotation studies is to convey feedback, information provided by a source that pertains to one's performance (Hattie & Timperley, 2007). Feedback benefits participants as it increases motivation and engagement and results in them developing more efficient strategies for processing the information (Hattie & Timperley, 2007). Feedback is often incorporated in mental rotation studies through positive or negative presentations, such as a smiley face for correct responses and a frowny face for incorrect responses (e.g., Krüger, 2018).

The efficacy of feedback in mental rotation studies has yielded mixed results. One study by Rahe & Quaiser-Pohl (2020) examined fourth graders through a Shepard and Metzler (1971) style mental rotation assessment and provided positive feedback in the form of a green square and negative feedback in the form of a red square. They found that only boys benefited from the feedback as they reacted more quickly. More specifically, boys exhibited a boost in confidence, whereas girls demonstrated more caution and perceived the feedback as a means of controlling them (Katz et al., 2006; Rahe & Quaiser-Pohl, 2020). In another study, feedback was verbally provided to children between the ages of 3 and 5 years old as they were asked to choose between one of the two cut-out ghosts to determine which one fit into a hole on a board (Frick, Hansen, & Newcombe, 2013). If a child chose the wrong ghost, the experimenter would inform them that they were wrong and allow them to place the correct ghost in the hole, serving as feedback for the task. Only 5-year-old children benefited from this type of feedback as they were developmentally ready to process and learn from it. Furthermore, children who struggled to solve the mental rotation task became frustrated by the negative feedback and ultimately performed worse (Frick, Hansen, & Newcombe, 2013). Feedback should therefore be given with caution.

Gender differences in abilities

Throughout the mental rotation literature, gender differences in performance have also been explored. In their meta-analysis, Linn & Petersen (1985) found that this gender gap was consistent across ages, however, the extent to which these differences occurred was contingent on the type of mental rotation paradigm used. Gender differences in mental rotation appear to increase with age (Lauer, Yhang, & Lourenco, 2019; Voyer, Voyer, & Bryden, 1995) as they are relatively small at 6-years old and reach moderate size around early adolescence (Newcombe, 2020). Moreover, these gender differences often occur in favor of boys (e.g., Jansen et al., 2013).

Many researchers are interested in further exploring the relationship between gender differences and mental rotation abilities to understand the underlying causes. Moè (2018) utilized 2D animal stimuli (Titze et al., 2010) and 3D cube stimuli (Peters et al., 1995) and found a significant gender difference in favor of boys that was greater for the cubes than animal drawings that can be first observed at 8-years old. Jansen et al. (2013) also found that only letters and animal drawings rotated at 135 degrees yielded a significant difference in favor of boys. Other studies did not find gender differences in mental rotation abilities for children younger than 8 years old (e.g., Frick, Hansen, & Newcombe, 2013; Hawes et al., 2015a). Gender differences in performance are potentially further augmented by men's greater confidence in their mental rotation abilities than their female counterparts (Cooke-Simpson & Voyer, 2007; Rahe & Quaiser-Pohl, 2020).

Mental rotation has been extensively studied, with relatively consistent findings, such as these abilities developing around 5 years old and boys outperforming girls. Mental rotation competency in children depends on the type of stimuli and degrees of rotation, with familiar, concrete stimuli rotated in the picture plane being easier to encode. Paradigm also plays a role in performance for children with mirror images and four answer options being too difficult to differentiate. Reaction times complicate attentional demands, while caution must be exercised when implementing feedback. However, these considerations may not be sufficient enough. One potential solution for sustaining children's motivation is the incorporation of gamification.

Gamification

Gamification is the incorporation of game-like elements in non-game settings (Deterding et al., 2011). Participants are engaged by the sense of purpose and goal to achieve (O'Donovan, 2012). Gamification elements include points, levels, stages, badges, leaderboards, prizes, rewards, progress bars, storylines, and feedback (Nah et al., 2014).

Most commonly, gamification occurs in classroom settings. This gamified learning involves augmenting a learning paradigm to consist of more game-like features (Landers et al., 2018), which in turn increases student motivation and enhances their learning experience (da Rocha Seixas et al., 2016; Hamari, Koivisto & Sarsa, 2014). Students often receive tickets or points for desired behaviors, such as good grades, adequate classroom conduct, or following instructions, which later are redeemed in a classroom prize box. Even adults benefit from gamification. Undergraduate students enrolled in a gamified course, which provided rapid feedback on assignments, rewarded badges, and used leaderboards, performed better than their counterparts in a non-gamified course (Tsay, Kofinas, & Luo, 2018). Rewarding the achieved behavior boosts student engagement (Kiryakova et al., 2014), which leads to better performance outcomes.

Gamifying a study involving child participants can help motivate them to complete the task. Brewer et al. (2013) initially studied touch and gesture patterns in children, but most of them failed to complete the entire study. In their modified research design, for every trial completed, children earned points, which could be redeemed at the end of the session for a prize (costing no more than $0.50) from a prize box. Participant completion rates significantly increased as 6 of the 7 participants completed the entire task. This study suggests that the gamification elements do not have to be costly, especially when working with children.

The role of reward

Rewards, one of the elements of gamification, are an effective means for receiving a desired behavior (Bénabou & Tirole, 2003). They are driven by motivation, which could either be extrinsic, in that it motivates the behavior through the benefit outweighing the cost, or intrinsic, in that individuals engage in behaviors for the mere interest in doing so (Morris et al., 2022). Intrinsic motivation has been found to decline across the elementary school years (Harter, 1981; Newman, 1990) as it is replaced by extrinsic motivation (Lemos & Verissimo, 2014).

There is debate regarding the effectiveness of rewards. Critics of rewards argue that the more they are implemented, the more the individual will lose interest in the task (Kohn, 1993). More importantly, it is argued that rewards increase extrinsic motivation at the expense of intrinsic motivation. Researchers have investigated this relationship and found various results. In one study, preschoolers were either informed that they would receive a reward for their good drawing or not. Those who expected the reward exerted less effort in their drawings and later expressed less interest when asked to repeat the task, ultimately suggesting that rewards undermine intrinsic motivation (Greene & Lepper, 1974). Contrary to this finding, Bénabou & Tirole (2003) found the opposite, that rewards, particularly those that are discretionary, boost intrinsic motivation in that the participant interprets the reward as being due to their performance in a difficult task. They argue that these rewards are effective in that the desired behaviors are controlled for, meaning the participant perceives their reward as not being an entity that the experimenter was required to give to them but rather did due to their good performance.

The role of the cover story

In addition to rewards, many games are guided by a cover story, as it provides a sense of purpose. Stories are pervasive in various parts of children's lives as they promote their development, strengthen their communication skills, provide them with a means to make meaning of the world, and enforce their adult and peer relationships (Garzotto, Paolini, & Sabiescu, 2010). Kapp (2012) argues that people learn more efficiently when the information is presented in a story rather than a list. These stories do not have to be extravagant; rather, they can be simple. Relating to gamification, cover stories can connect with the reward system and enable participants to immerse themselves in the task (O'Donovan, 2012).

Cover stories have effectively conveyed learning in the classroom. Benefits include increasing student motivation to engage with the material (Shofiyyah et al., 2024). One study found that kindergarteners, who received a story-driven geometry curriculum, which included puppets, chants, movements, and poems, exhibited greater performance on a pre- and post-test compared to their control counterparts (Casey et al., 2008). Even university students, who were presented with discussion questions in the form of a game, found it more enjoyable than without (Lieberoth, 2015). These studies suggest that merely framing a task differently can boost participant engagement.

Although not explicitly stated, many research studies, particularly those involving children, incorporate cover stories in their design. Hawes et al. (2015a) told participants that they would be playing a "matching game" and that their role would be the "shape detective" in the 3D-mental rotation task. Although they suggest that the participants did better with the 3D mental rotation task rather than the 2D mental rotation task due to the fewer answer alternatives, their improved performance may have been impacted by the cover story. This suggests the benefits of incorporating a cover story as it could potentially improve mental rotation performance in children between the ages of 4 and 8 years old. Frick, Ferrara, & Newcombe (2013) also incorporated a cover story as children were asked to help a toy figure "fix his road so that he wouldn't fall into a hole." These cover stories, which are easy to create and implement, potentially help maintain participant's interest and thus result in better performance.

Personality Traits

Gamification manipulations have the potential to improve participant performance. However, certain individuals may respond differently to these elements. More specifically, personality traits may serve as predictors. Personality traits drive human behavior (Costa & McCrae, 1992) and are thought to contribute to one's sense of identity (Lounsbury et al., 2007). They are often categorized into the Big Five Factors: Extraversion (social, assertive), Agreeableness (warm, friendly, altruistic), Neuroticism (experiencing negative emotions, such as anxiety or sadness), Conscientiousness (hard-working, delaying gratification, following the rules), and Openness to Experience (curious, original, open-minded) (John & Srivastava, 1999; McCrae & Costa, 1996). To assess personality traits, people complete personality inventories in which they rate themselves on a Likert Scale. With these results, individuals can be categorized as scoring high or low on each trait.

As personality traits play a pertinent role in identity, such could predict how individuals perform on tasks. An online survey found that people between the ages of 18 and 55+ years old who score high on Extraversion prefer points, levels, and leaderboards as they are motivated by the idea of showing off their achievements, whereas individuals with high levels of emotional stability (i.e., Neuroticism) may not find such gamification manipulations effective (Jia et al., 2016). Furthermore, undergraduates were asked to complete a project, which provided them with feedback in the form of grades (points), verbal and written recognition (badges), and extra credit (rewards). Highly Conscientious individuals perceived leaderboards negatively and those scoring low on Extraversion (i.e., introverts) preferred badges more than those scoring high on Extraversion (i.e., extroverts) (Codish & Ravid, 2014).

Relationships have also been found between personality traits and academic performance. Predictors of better (i.e., increased) Grade Point Averages include high Agreeableness in children between second and fourth grade and high Conscientiousness in children between sixth and twelfth grade (Laidra, Pullmann, & Allik, 2007). This finding relates to that of Furnham, Chamorro-Premuzic, & McDougall (2003), who found a positive correlation between Conscientiousness and academic performance in undergraduate students, suggesting that this relationship in childhood carries over into adulthood.

Incorporating gamification elements into utilitarian activities, particularly those designed for children, should increase engagement and motivation. However, not everyone may perceive it positively (Agarwal & Karahanna, 2000). More specifically, children scoring high on certain personality traits may respond differently to the gamification manipulations. Personality traits may therefore serve as predictors for performance in a gamified mental rotation task.

THEORETICAL FRAMEWORKS

As demonstrated by this literature review, cognitive tasks are often redundant and cognitively demanding for children (Bernecker & Ninaus 2021), which results in fatigue (Borragán et al., 2017) and subsequent guessing (Wise & Smith, 2011). Although reducing the number of trials might appear to be an easy solution, such reduces the reliability of the study.

Vroom's (1964) Expectancy Theory argues that expected outcomes influence behavior. More specifically, if motivation is low, then performance will be low, whereas if motivation is high, performance will be high. Therefore, if children, regardless of their mental rotation capabilities, are motivated to do well, they will perform well. This posits the question: How can children be motivated to perform to the best of their ability on a mental rotation task?

Gamification therefore serves as a viable solution. These elements motivate people to perform desired behaviors in tasks that they otherwise would perceive as boring (Medica Ružić & Dumančić, 2015). If gamification motivates children, their mental rotation performance should improve, with a more pronounced difference in performance between high and low ability children. Ultimately, this would suggest that mental rotation abilities are susceptible to non-cognitive factors, such as gamification. However, the rewards must be given with caution to avoid undermining intrinsic motivation (Greene & Lepper, 1974). To boost intrinsic motivation, children's reward must be contingent on their performance in the task (Bénabou & Tirole, 2003).

To that end, the current study investigated the relationship between gamification and mental rotation abilities in 6 to 9-year-old children. This age range is justified as children younger than 6 years old typically struggle with these abilities (Fernández-Méndez, Contreras, & Elosúa, 2018; Hawes et al., 2015a). To examine the efficacy of gamification, two conditions were created: the gamification condition, which consisted of a cover story, feedback, points, and reward elements; and the baseline condition, for which all of these elements were absent. This study followed a within-subjects design in that all participants received both conditions, with the order in which they were received being counterbalanced. As personality traits play a pertinent role in identity (Lounsbury et al., 2007), such were also assessed to determine whether they predict performance. Some children (e.g., highly Extraverted) may need an incentive to perform well, while others (e.g., highly Agreeable) may exhibit the opposite effect and perform worse (Codish & Ravid, 2014; Roccas et al., 2002). An exploratory analysis was also conducted to determine whether gender and age moderated gamification effects.

Hypotheses

H1: When the mental rotation task incorporates gamification elements, the performance of children between the ages of 6 and 9 years old should be better than without these elements.

H2: As the stimuli (L-shape, dots, and cubes) become more difficult, performance will decrease.

There may be an interaction between difficulty level and gamification elements as gamification might result in more improved performance for easier stimuli (L-shape) than for more difficult stimuli (cubes) compared to the baseline performance.

H3: The order in which participants receive the gamification vs baseline conditions will impact their performance on the mental rotation task. Children who receive the gamification condition first will maintain performance, while children who receive the baseline condition first will improve in performance in the gamified condition later on.

H4: Personality traits of children will correlate with their mental rotation performance.

METHODS

This study was preregistered using OpenScience Framework. The link to the preregistration can be found here:
https://osf.io/34z9x/?view_only=a9bcd5a551014fb5b1f6e995f464459a

Participants

100 children (*N* = 58 male) between the ages of 6 and 9 years old participated in this study. G*Power analysis suggested a minimum sample size of 34 participants, however, the current study opted to recruit 100 participants. There were numerous justifications for doing so. First, many mental rotation studies test anywhere between 60 to 100 children (e.g., Fernández-Méndez, Contreras, & Elosúa, 2018; Moè, 2018; Rahe & Quaiser-Pohl, 2020). Secondly,

increasing the sample size increases the study power (e.g., Boukrina, Kucukboyaci, & Dobryakova, 2020). However, to avoid attributing a statistically significant result to a small effect size (e.g., Brysbaert, 2019), effect sizes were reported. The sample consisted of mainly White participants (*N* = 56), followed by Asian (*N* = 21), Biracial (*N* = 11), African American (*N* = 5), Hispanic (*N* = 2), Multiracial (*N* = 1), and others (*N* = 4). Four additional participants were tested, but their responses were excluded due to their incompletion of the study. Participants were compensated with a $5 Amazon gift card for their time.

Measures

PPTQ-C

Comparable to the issue of many mental rotation studies, personality trait inventories are often lengthy, frequently ranging from 65 to 240 items (e.g., Barbaranelli et al., 2003). Moreover, they neglect to consider children's inability to think abstractly (Maćkiewicz & Cieciuch, 2016). These problems are addressed by the Pictorial Personality Traits Questionnaire for Children (PPTQ-C), a 15-item personality assessment measuring each of the Big Five traits 3 times (Maćkiewicz & Cieciuch, 2016). In this assessment, participants were introduced to a unisex, leading character wearing a striped scarf and told that the character was "doing two completely different things." The character's two different behaviors were represented by pictures, to help account for participants' difficulties in thinking abstractly (Maćkiewicz & Cieciuch, 2016). For each prompt, participants were asked to rate what they would "do most often in such a situation" on a 3-point scale: the left side representing the low level of a given trait, the middle being "It Depends," and the right side indicating a high level of the same trait. It was explained to participants that, if they "sometimes behave in one way and other times in another way", they should choose "It Depends." They were also instructed to choose only one answer for each prompt. All items and instructions remained the same except for participants being asked to verbalize their responses, rather than marking them on paper. This assessment took approximately 5 to 10 minutes for participants to complete. See Figure 1.

Figure 1

Sample Item from the Pictorial Personality Traits Questionnaire for Children (PPTQ-C)

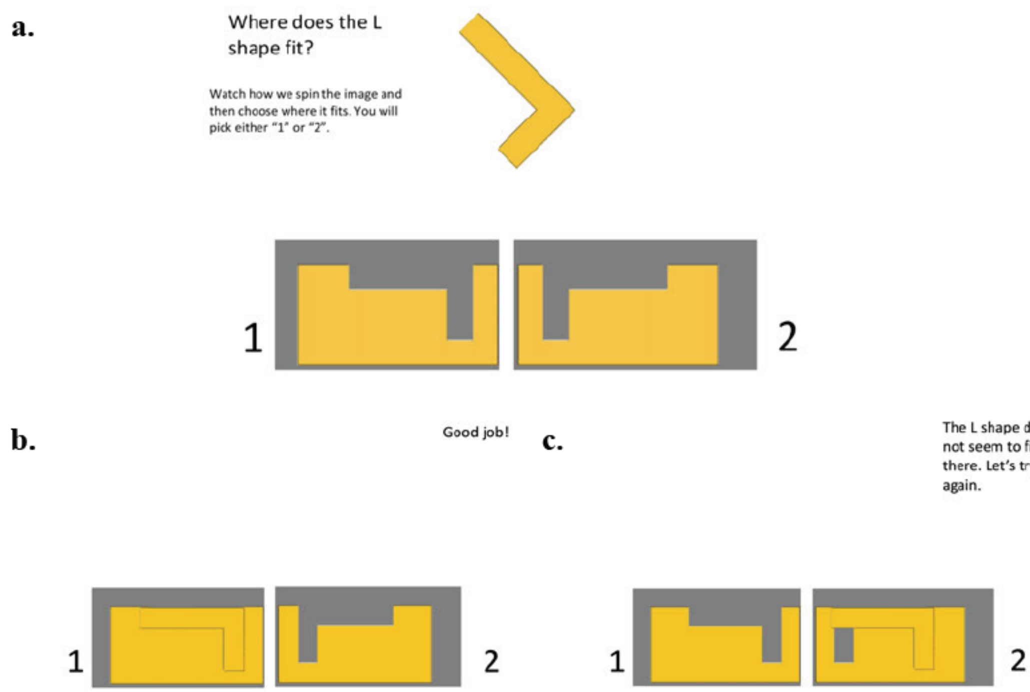
Note: Participants were read a prompt and asked to rate themselves on a 3-point scale based on what they would "do most often in such a situation" (Maćkiewicz & Cieciuch, 2016).

Practice Trials

Practice trials were given to participants before the actual mental rotation tasks. An animation of each type of stimuli (L-shape, dot, cube) was shown spinning 360 degrees clockwise, followed by two practice questions with two answer choices for a total of 6 questions. Stimuli were rotated 45 and 315 degrees for the L-shape, 45 degrees for the dots, and 50 degrees for the cubes. For incorrectly answered items, participants viewed the stimuli rotate to 0 degrees and not match with their chosen response. They were then prompted to select again. Following their correct choice, they were shown the stimuli rotating to 0 degrees and correctly matching with their response. See Figure 2.

Figure 2

Sample Practice Trial Question



Note: a. Sample practice trial question that prompted participants to mentally rotate the L-shape to fit into the open space. b. If a participant chose response #1, the L-shape would rotate to 0 degrees, fit into the open space and a "Good job!" message would appear. c. If a participant chose response #2, the L-shape would rotate to 0 degrees, not fit into the open space, and "The L-shape does not seem to fit there. Let's try again" message would appear.

Mental Rotation Task

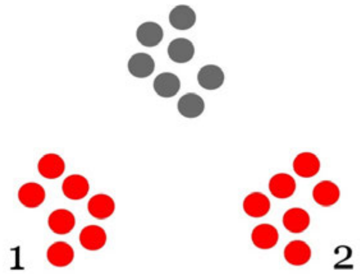
There were two mental rotation tasks: the gamification condition and the baseline condition. Both followed the puzzle-like paradigm (Frick, Ferrara, & Newcombe, 2013; Frick, Hansen, & Newcombe, 2013), which requires participants to choose between one of two mirror images that, when rotated, fit into a cutout hole. This paradigm compares to the Vandenberg & Kuse (1978) task, except only two, rather than four, answer choices were provided. Conditions were counterbalanced and participants were randomly assigned to receive either first. There were 48 trials in each condition.

Within each condition, there were 16 trials for each of the 3 levels: L-shape, dots, and cubes. The L-shape stimuli (Frick, Ferrara, & Newcombe, 2013) were manipulated at 0, 45, 90, 180, 270, and 315 degrees of rotation and the cutouts were either on the inside or outside. See Figure 3a. The dot stimuli (Stoet, n.d.) were manipulated at 0, 45, 90, 135, 180, 225, 270, and 315 degrees of rotation and were either typical or mirror pairs. See Figure 3b. The cube stimuli (Gamis & Kievit, 2015) were manipulated at 0, 50, 100, and 150 degrees of rotation. See Figure 3c. In the original study using the cube stimuli, undergraduate students were asked to determine whether the baseline and target objects were the same or different by rotating the objects around the vertical axis. To account for children's difficulty in making parity decisions of same vs different (Frick & Pichelmann, 2023), these stimuli were manipulated to match that of the L-shape and dots, instead of asking participants to choose which of the two baseline objects the target object would align with upon being rotated.

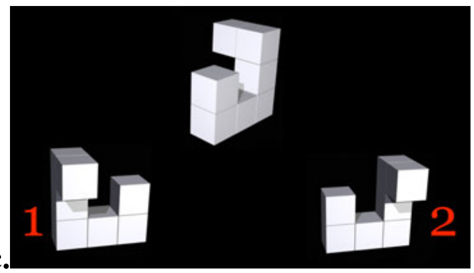
Figure 3

Sample Stimuli

a.



b.



c.

Note: a. Sample stimuli L-Shape rotated 315 degrees (or 45 degrees). b. Dots rotated 180 degrees. c. Cube rotated 150 degrees. The correct answers would be 2, 1, and 1, respectively.

Cover Story

The gamified condition included a cover story based on characters from the popular children's cartoon, *Wreck-It-Ralph* (Moore et al., 2012). Children were read a script in which they were told that they needed to "help Fix-It-Felix fix all of the objects that Wreck-It-Ralph destroyed." See Figure 4. In this "game," there were three levels, one for each of the three stimuli types. To better give children a sense of purpose (Rigby & Ryan, 2011), following the completion of a level, they were shown a "Level Complete" screen and told that the subsequent level would be more difficult. See Figure 5b. At the end of all three levels, participants were shown a screen thanking them for their help and the total number of points earned, which transferred into chances in a catching game. See Figure 5c.

Figure 4

Cover Story

Note: Cover story introduced in the gamification condition.

Feedback and Reward

In addition to the cover story, participants earned one point for every correct response and were shown a picture of a smiling Fix-It-Felix. See Figure 5a. Points carried over from one level to the next (i.e., if a participant earned 15 points in level one, they began level two with 15 points). To prevent participants from becoming frustrated by negative feedback (e.g., Frick, Hansen, & Newcombe, 2013), they did not lose points for incorrect responses. Rather, their score remained the same and they were shown a picture of a frowning Fix-It-Felix. Scores after all three levels ranged from 0 to 48 points.

Figure 5

Feedback and Points-System

a.

b.

c.

Note: a. Sample feedback for correct responses (left image) and sample feedback for incorrect responses (right image). b. Sample Level complete screen that was displayed after each of the 3 levels. c. The final score screen was displayed prior to the catching game (See *Catching Game* section). Participant's final score was contingent on their gamification condition performance.

Catching Game

Prior to receiving the mental rotation task in the gamification condition, participants were shown a brief 5-second clip of the catching game that they would have the opportunity to play at the end of all three levels. It was explained to them that the points earned across all three levels would transfer into chances in a catching game. Following the completion of the mental rotation task, participants were shown their final score and told that they would learn how to play the catching game. In this game, three objects (brick, hammer, and medal) fell from the sky and they earned points for collecting objects but lost chances for failing to collect them. Once participants ran out of chances, the game ceased and a final score message appeared. The catching game appealed to children as it resembled other arcade games they might have previously played and incorporated familiar elements of the *Wreck-It-Ralph* movie. See Figure 6.

Figure 6

Sample Catching Game Sequence

a.

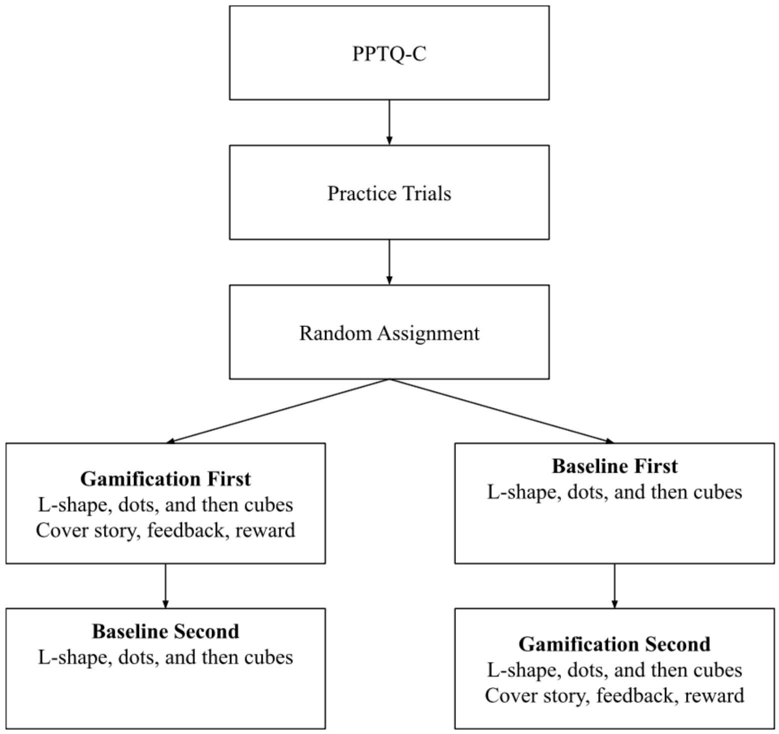
b.

Note: Sample sequence of the catching game.

Procedure

All parents consented to their child participating and filled out demographics forms before the session. At the beginning of the session, children were read assent forms. Participants were tested individually in single 30 to 40-minute Zoom sessions. They were first administered the PPTQ-C, followed by the mental rotation practice trials. Following these tasks, participants completed either the gamification or baseline condition first. In the gamification condition, responses in all 3 levels were followed by feedback, which was displayed for 2000 ms, and then the fixation cross, which was displayed for 745 ms. The baseline condition followed a similar sequence with the exclusion of feedback. See Appendix A for the baseline condition script and Appendix B for the gamification condition script.

Sequence of Events



RESULTS

Descriptive Statistics

Descriptive statistics for the effects of testing order (gamification first vs baseline first), condition (gamification vs baseline), and stimuli (L-shape, dots, and cubes) on mental rotation performance are presented in Table 1.

Table 1

Descriptive statistics in different conditions

	Gamification First		Baseline First		Total	
	Gamification	Baseline	Gamification	Baseline	Gam + Base	Gam - Base
	M (*SD*) *R*	*M* (*SD*) *R*	*M* (*SD*) *R*	*M* (*SD*) *R*	*M*(*SD)*	*M*(*SD)*

L-shape	14.36 (2.04)	14.14 (2.18)	15.06 (0.98)	14.28 (1.62)	28.92 (3.20)	0.50 (1.53)
	7-16	7-16	13-16	11-16		
Dots	11.14 (3.68)	12.24 (3.20)	12.30 (3.46)	11.44 (3.40)	23.56 (6.18)	-0.12 (3.10)
	4-16	5-16	5-16	4-16		
Cubes	12.34 (2.76)	12.52 (2.62)	13.16 (3.11)	11.84 (3.05)	24.93 (5.19)	0.57 (2.61)
	7-16	5-16	5-16	5-16		
Total	37.84 (6.93)	38.90 (6.53)	40.52 (5.97)	37.56 (6.41)	77.41 (12.16)	0.95 (4.74)
	20-48	26-48	29-48	27-48		

Note: The highest possible score is 16 for L-shape, dots, and cubes.

Repeated Measures ANOVA

Performance between groups was assessed using a 2 (testing order: gamification first vs baseline first) x 2 (condition: gamification vs baseline) x 3 (stimuli: L-shape, dots, cubes) mixed analysis of variance (ANOVA), with testing order as a between-subjects factor and condition and stimuli as within-subject factors. Post hoc tests were conducted accordingly using the Bonferroni adjustment. The standard $p < .05$ was used for determining significance.

The results indicated a significant main effect of condition, $F(1, 98) = 4.85$, $p = 0.030$, $\eta^2 = 0.05$. Pairwise comparisons using the Bonferroni corrected adjustment found that, regardless of testing order, the gamification condition performance ($M = 13.06$) was significantly better ($p = 0.03$) than baseline condition performance ($M = 12.74$). These results indicate that the gamification manipulations were effective among children as their average mental rotation scores were higher in the gamification condition than in the baseline condition.

A significant main effect was also found for stimuli, $F(2, 196) = 58.99$, $p < 0.001$, $\eta^2 = 0.38$. Post hoc tests demonstrated that performance was greatest with the L-shape stimuli ($M = 14.46$), followed by the cubes ($M = 12.47$), $p < 0.001$, with the worst performance being with the dots ($M = 11.78$), *p*s <= 0.03. The greatest performance with the L-shape stimuli suggests that those were the easiest for children to complete, while the worst performance with the dots suggests that those were the most difficult.

A significant interaction between condition and testing order was also found, $F(1, 98) = 21.70$, $p < 0.001$, $\eta^2 = 0.18$. Performance for participants who received the gamification condition first ($M = 12.61$) did not significantly change ($p = 0.09$) when they later received the baseline condition ($M = 12.97$). Participants were motivated by the gamification manipulations and this effect carried over into the baseline condition. For participants receiving the baseline condition ($M = 12.52$) first, their performance significantly improved ($p < 0.001$) when they received the gamification condition second ($M = 13.51$). Participants responded well to the gamification manipulations, as indicated by their improved performance. See Table 2.

Table 2

ANOVA on the number of correct responses

Source	df	F	p	η^2
Testing Order	(1, 98)	0.30	0.584	0.003
Condition	(1, 98)	4.85	**0.030**	0.047
Stimuli	(2, 196)	58.99	**<0.001**	0.376
Condition*Testing Order	(1, 98)	21.70	**<0.001**	0.181
Stimuli * Testing Order	(2, 196)	0.24	0.784	0.002
Condition*Stimuli	(1.82, 178.00)	2.60	0.082	0.026

Condition*Stimuli*Testing Order	(1.82, 98.00)	2.29	0.109	0.023

Note: $p < 0.05$ are bolded.

Bivariate Correlation

A bivariate Pearson two-tailed correlation analysis was run to determine whether personality traits predicted performance in the gamification or baseline conditions. Overall cognitive performance across both conditions was calculated by adding each participant's gamification and baseline scores. A weak negative correlation was found between overall cognitive performance and Agreeableness, $r = -0.25$, $N = 100$, $p = 0.013$, as well as Openness to Experience, $r = -0.21$, $N = 100$, $p = 0.04$.

The data file was split based on testing order for subsequent analyses. For the baseline condition first group, a weak negative correlation between Agreeableness and overall cognitive performance was found, $r = -0.38$, $N = 50$, $p < 0.001$. As for the gamification condition first group, none of the variables significantly predicted the overall cognitive performance or the difference between scores. See Table 3.

Table 3

Bivariate correlation between personality traits and mental rotation

	1	2	3	4	5	6	7
1.Gam - Baseline	__	-0.12	0.33	0.12	0.06	0.24	0.06
2.Gam + Baseline	0.09	__	**-0.38****	-0.02	0.12	-0.27	-0.16
3.Agreeableness	-0.04	-0.10	__	0.32	0.11	**0.50***	**0.29***
4.Conscientiousness	-0.10	-0.22	**0.35***	__	-0.21	0.28	0.28
5.Neuroticism	-0.07	0.20	**-0.31***	-0.10	__	-0.22	**-0.31***
6. Openness	0.001	-0.14	**0.30***	0.21	-0.21	__	**0.33***

7.Extraversion	0.01	-0.09	0.18	-0.06	**-0.29***	0.21	__

Note: The top diagonal showed data for the baseline first group and the bottom diagonal showed data for the gamification first group. **p* < 0.05; ***p* < 0.001.

Exploratory Analysis (not pre-registered)

To test for the effects of gender and age, both were included in the ANOVA model as a between-subjects factor and covariate, respectively. A significant main effect of gender was found, with boys (*M* = 13.24) on average scoring higher than girls (*M* = 12..46), suggesting that boys overall performed better than girls. There was also a significant main effect of age (p = 0.003), suggesting that mental rotation performance increased with age. See Figure 7. With the incorporation of gender and age into the model, only stimuli, F (2, 190) = 4.93, p = 0.008, η^2 = 0.05, and the interaction between condition and testing order, F (1, 95) = 21.52, p < 0.001, η^2 = 0.18, yielded significant results. See Table 4.

Figure 7

Scatterplot depicting the relationship between overall cognitive score and age

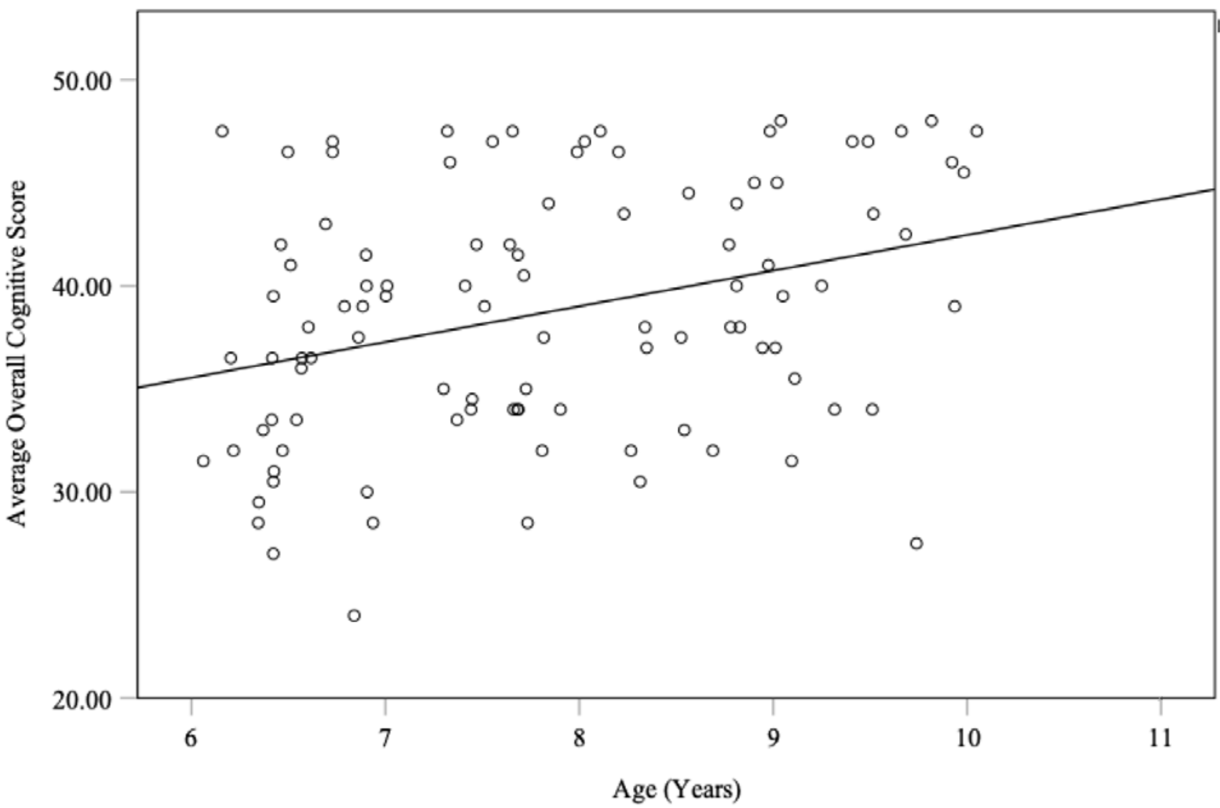


Table 4

Mixed ANCOVA with age as a covariate

Source	*df*	*F*	*p*	η^2
Age (covariate)	(1, 95)	10.81	**0.001**	0.102
Sex	(1, 95)	4.03	**0.047**	0.041
Condition	(1, 95)	0.23	0.634	0.002

Stimuli	(2, 190)	4.93	**0.008**	0.049
Testing Order	(1, 95)	0.10	0.758	0.001
Testing Order*Sex	(1, 95)	0.27	0.608	0.003
Condition*Age	(1, 95)	0.68	0.412	0.007
Condition*Sex	(1, 95)	0.86	0.356	0.009
Condition*Testing Order	(1, 95)	21.52	**<0.001**	0.184
Condition*Testing Order*Sex	(1, 95)	0.12	0.733	0.001
Stimuli*Sex	(2, 190)	1.59	0.207	0.016
Stimuli*Age	(2, 190)	1.67	0.190	0.017
Stimuli * Testing Order	(2, 190)	0.36	0.696	0.004
Stimuli*Testing Order*Sex	(2, 190)	0.98	0.379	0.010
Condition*Stimuli	(1.81, 172.11)	1.24	0.291	0.013
Condition*Stimuli*Age	(1.81, 172.11)	0.83	0.426	0.009
Condition*Stimuli*Testing Order	(1.81, 172.11)	1.93	0.152	0.020
Condition*Stimuli*Sex	(1.81, 172.11)	1.03	0.354	0.011
Condition*Stimuli*Testing Order*Sex	(1.81, 172.11)	0.11	0.875	0.001

Note: Results of the 2 (condition: gamification vs. baseline) x 2 (testing order: gamification first vs. baseline first) x 3 (stimuli: L shape, dots, cubes) x 2 (sex: boys vs. girls) mixed ANCOVA with age as a covariate. $p < 0.05$ are bolded.

DISCUSSION

Children require a motivating element for completing cognitively demanding tasks. This is imperative for increasing completion rates and improving overall scores. The current study's findings highlight gamification's potential to enhance performance on cognitive tasks. More specifically, incorporating a cover story, points, feedback, and reward improved performance on the mental rotation task.

Overall, performance in the gamification condition was better than that of the baseline condition, confirming Hypothesis 1. A relatively moderate effect size was found for this relationship, suggesting that the various gamification elements potentially played different roles in improving children's performance. Children's goal for the gamification condition was to earn as many points as possible through their correct responses for them to have more chances to play the catching game. However, the mental rotation paradigm utilized in the current study was within the children's cognitive ability, which resulted in the gamification manipulations' effectiveness. If the task were too difficult for children, they would have become discouraged and had reduced motivation (Kluger & DeNisi, 1996).

Gamification effects did not interact with task difficulty, disconfirming Hypothesis 2. However, the statistically significant result suggests that the type of stimuli had a large effect on performance. As the L-shape and dots stimuli were 2D figures and the cubes were 3D, it was predicted that the order of difficulty would be L-shape, dots, and then cubes. Although the L-shapes were the easiest as indicated by the high performance scores, the dots had the lowest scores, suggesting that these were the most difficult for children to mentally rotate. A potential explanation for this could be the cube stimuli consisting of shading, which has been found to make rotating easier as spatial relationships can be determined more readily (Ganis & Kievit, 2015; Stieff et al., 2018). The cube stimuli also only required vertical axis rotation, yielding faster responses than horizontal axis rotation (Battista & Peters, 2010; Ganis & Kievit, 2015). Furthermore, object familiarity plays a role in mental rotation ability (e.g., Doyle & Voyer, 2018; Wimmer et al., 2015). Potentially, children were more familiar with the cubes as they resembled Lego Blocks, which are prevalent in many classrooms for learning purposes (e.g., Schmitt et al., 2018; Trawick-Smith et al., 2017; Yelland, 2011), whereas the dots might have been more unfamiliar, resulting in children's difficulty to encode them (Hoyek et al., 2012). Taken together, the shading, axis of rotation, and object familiarity could have played a significant role in children's better overall performance on the cube stimuli than the dots. Future research should further explore this relationship.

The effects of gamification also interacted with testing order, confirming Hypothesis 3. The testing order was found to have a large effect on gamification and baseline condition performance. More specifically, performance increased when participants received the baseline followed by the gamification condition, suggesting that the manipulations motivated children. Although one could argue that the improved performance may be attributed to a practice effect as opposed to gamification, fatigue effects could also be argued due to the repetitive nature of the task and the use of 48 trials in each condition (Noreika et al., 2013). It is more plausible that gamification, not practice effects, resulted in children's improved performance. Furthermore, a significant difference was not found between scores for participants receiving the gamification followed by baseline conditions, indicating that the effects of the manipulation carried over to the subsequent condition. More importantly, this finding indicates that, when extrinsic motivators are removed, children can maintain their good performance.

How did the gamification manipulations, particularly the reward, prove effective? Children in the gamification condition were told that they would play a game after completing a task. Although every child was allowed to play the game, the number of chances to play was contingent on their performance across all three levels. As children were informed that each subsequent level (i.e., L-shape to dots to cubes) increased in difficulty, they perceived the catching game reward as meaningful, aligning with the theory set forth by Bénabou & Tirole (2003). More specifically, children interpreted the catching game reward as an entity that they earned for their good mental rotation performance. Contrary to the finding of Greene & Lepper (1974), the performance of children receiving the gamification condition first was maintained when they received the baseline condition that followed, suggesting that intrinsic motivation was not reduced, but rather maintained.

The relationship between personality traits and gamification was also explored to account for individual differences. Contrary to previous research (e.g., Jia et al., 2016), the current study partially found that personality traits were impacted by the gamification effects, partially confirming Hypothesis 4. Agreeableness negatively correlated with performance for the baseline first group. Participants who scored high on Agreeableness may have interpreted their high score earned in the gamification condition at the expense of others and thus did not respond positively (Roccas et al., 2002). These results indicate that children are susceptible to gamification manipulations, irrespective of their personality traits.

There were significant main effects of age, in that older children received higher mental rotation scores, and gender, with boys outperforming girls. These findings are consistent with the existing literature that gender differences in favor of boys exist (e.g., Moè, 2018; Lauer, Yhang, Lourenco, 2019; Rahe, Schürmann, & Jansen, 2023) and that mental rotation abilities improve with age (e.g., Jansen et al., 2013; Kail, Pellegrino, & Carter, 1980). However, neither age nor gender interacted with the gamification effects, suggesting that mental rotation abilities can be improved in young children and girls.

Mental rotation abilities interest researchers as they relate to STEM success. As women are often underrepresented in STEM fields (Fry, Kennedy, & Funk, 2021), many cognitive researchers have endeavored to identify ways to reduce this gap. One methodology includes training programs, which can enhance mental rotation skills (e.g., Hawes et al., 2015b), albeit at a significant expense of time and resources. Gamification serves as an easy-to-implement, cost-effective solution: a cover story could easily be created; feedback that relates to the cover story can be provided; children's correct responses can be rewarded with points that are redeemed for an inexpensive prize (e.g. Brewer et al., 2013) or an online game (Oyshi, Saifuzzaman, & Tumpa, 2018). Gamification is therefore a simple solution to boosting motivation and improving performance among children.

Furthermore, the present study has implications for other cognitive ability assessments involving children. Researchers could implement gamification in other spatial ability domains as such are highly malleable, especially in children (Uttal et al., 2013). As demonstrated by the present study, gamification could enhance mental rotation performance, suggesting the potential to improve other spatial domains, such as perspective taking, or even higher-order spatial abilities such as wayfinding (Merrill et al., 2016). Future research should explore these relationships.

The current study is not without limitations. Despite the G*Power analysis recommendation to test 34 participants, the current study opted to test 100 participants. Increasing the sample size could potentially pose challenges as it amplifies the likelihood of obtaining a statistically significant effect (e.g., Brysbaert, 2019). However, as exemplified by the relatively large effect sizes of the results, it can be concluded that these results have practical implications for incorporating gamification elements into research designs. Furthermore, a potential learning effect could have occurred as a result of the feedback and points provided in the gamification condition (e.g., Hattie & Timperley, 2007). Participants were shown their total score following each trial as a means of motivating them to continue their good performance so that they could have more chances in the catching game at the end. Future research should either provide feedback with no points in the baseline condition or not tell participants how many points were earned until the very end before the catching game in the gamification condition. The present study also did not consider the role of age in predicting the relationship between personality traits and overall cognitive score. As older children often perform better on mental rotation tasks than younger children (Kail, Pellegrino, & Carter, 1980), potentially there could also be differences in personality trait scores based on age. Finally, the present study does not independently examine each of the gamification manipulations (cover story, feedback/points, and reward). It is therefore unknown whether one type of manipulation had more of an effect on performance than the others.

CONCLUSION

Although gamification is a relatively new concept (Deterding et al., 2011), the current study demonstrates that it has numerous implications when testing children between 6 to 9 years old. Incorporating gamification elements, particularly in cognitively demanding tasks, motivates children to work to the best of their ability. Researchers should continue to explore this relationship between gamification and cognitive phenomena, especially in studies involving children.

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APPENDIX A

Script for Baseline condition

** Game opens up and research reads:*

For this task, you need to choose which shape fits. Are you ready to start?

** Participant responds and the researcher presses any key to move to the instructions screen. The researcher reads:*

You will see an L-shape in the center of the screen. At the bottom of the screen, there will be two yellow shapes with an open space. You will need to choose which yellow shape the L-shape fits into. Both of the yellow shapes will have a 1 or a 2. To pick the shape on the left side (the researcher uses the annotation feature and clicks a circle of hearts around the left-sided image)**, say "one." To pick the shape on the right side** (the researcher uses the annotation feature and clicks a circle of hearts around the right-sided image)**, say "two."**

**The researcher then clicks any key and the L-shape level begins*

**Once the L-shape level is complete, the instructions page for the dots will appear. The researcher reads the following:*

This level is very similar to the last level. The only difference is that there will now be dots. Just like last time, if you want the shape on the left side (the researcher uses the annotation feature and clicks a circle of hearts around the left-sided image)**, say "one". If you want the shape on the right side** (the researcher uses the annotation feature and clicks a circle of hearts around the right-sided image)**, say "two."**

**The researcher then clicks any key and the dots level begins*

**Once the dots level is complete, the instructions page for the cubes will appear. The researcher reads the following:*

For the final level, you will do the same thing that you did in the last two levels. The only difference is that you will now see cubes. Just like last time, if you want the shape on the left side (the researcher uses the annotation feature and clicks a circle of hearts around the left-sided image)**, say "one". If you want the shape on the right side** (the researcher uses the annotation feature and clicks a circle of hearts around the right-sided image)**, say "two."**

**The researcher then clicks any key and the cubes level begins*

**Following the cube level, the researcher will read the following off of the screen:*

Hooray! You did an awesome job. Thanks for playing!

**The experiment will then end*

End of Baseline Condition

APPENDIX B

Script for Gamification condition

** Game opens up and research reads:*

Oh no! Fix-it-Felix Jr. needs your help! Wreck-it-Ralph broke all of the shapes and needs your help repairing them. Do you think you can help him?

** Participant responds and researcher continues:*

For every correct response, you will see a smiley face and Fix-it-Felix Jr. will reward you with one point. Once all of the shapes are fixed, all of your points will be used to play a really fun catching game! Are you ready to start?

** Participant responds*

Great! I am going to go to the next screen and there you will see a quick video clip of the catching game that you're going to get to play at the end.

** The researcher presses any key and continues to the next screen. A video of the Catching Game appears and the researcher explains:*

As you can see, Fix It Felix is moving from side to side collecting everything that's falling from the sky. I will explain more on how to play this game later.

**Video stops and the instructions page for the first set of stimuli (the L-shapes) appears. The researcher reads the following:*

You will see an L-shape in the center of the screen. At the bottom of the screen, there will be two yellow shapes with an open space. You will need to choose which yellow shape the L-shape fits into. Both of the yellow shapes will have a 1 or a 2. To pick the shape on the left side (the researcher uses the annotation feature and clicks a circle of hearts around the left-sided image)**, say "one." To pick the shape on the right side** (the researcher uses the annotation feature and clicks a circle of hearts around the right-sided image)**, say "two."**

**The researcher then clicks any key and the L-shape level begins*

**Once the L-shape level is complete, a "LEVEL ONE COMPLETE" screen will display. The researcher will read the following:*

Wow! Fix-it-Felix Jr. is very happy for your help. But Wreck-It-Ralph is still wrecking things. Can you help Fix-It-Felix Jr. fix everything again?

**Participant responds*

**The researcher presses any key to go on to the next screen. The instructions page for the second set of stimuli (the dots) appears. The researcher reads the following:*

This level is very similar to the last level. The only difference is that there will now be dots. Just like last time, if you want the shape on the left side (the researcher uses the annotation feature and clicks a circle of hearts around the left-sided image)**, say "one". If you want the shape on the right side** (the researcher uses the annotation feature and clicks a circle of hearts around the right-sided image)**, say "two."**

**The researcher then clicks any key and the dots level begins*

**Once the dots level is complete, a "LEVEL TWO COMPLETE" screen will display. The researcher will read the following:*

You're on fire! But Wreck-It-Ralph is not happy and has wrecked even more things. Can you help Fix-It-Felix Jr. fix everything once more?

**Participant responds*

**The researcher presses any key to go on to the next screen. The instructions page for the last set of stimuli (the cubes) appears. The researcher reads the following:*

For the final level, you will do the same thing that you did in the last two levels. The only difference is that you will now see cubes. Just like last time, if you want the shape on the left side (the researcher uses the annotation feature and clicks a circle of hearts around the left-sided image)**, say "one". If you want the shape on the right side** (the researcher uses the annotation feature and clicks a circle of hearts around the right-sided image)**, say "two."**

**The researcher then clicks any key and the cubes level begins*

**Once the cubes level is complete, a "LEVEL THREE COMPLETE" screen will display. The researcher will read aloud the aforementioned title on the screen and then click to the next screen. They will then read it aloud:*

Hooray! You have helped Fix-It-Felix fix all of the shapes. Your final score is [total score earned across all 3 levels displays here]. Thanks for playing!

**The researcher clicks to the next screen. A picture of a computer keyboard will appear. The researcher then says:*

Now, I'm going to explain how to play the catching game. On your keyboard, do you see these two arrows at the bottom? (The researcher will use the annotation feature to click stars around the two left/right arrows).

*****_If the participant says "Yes," then continue. If the participant says "No," ask if their parent/guardian is there to help them._

These two arrows are how you're going to move Fix-It-Felix. He only goes side to side and not up and down.

DO NOT CONTINUE UNLESS THE PARTICIPANT UNDERSTANDS HOW TO USE THE TWO ARROWS*.**

And then do you know how to use the keypad or the mouse- the thing that you use to click things? (Use the annotation feature to click hearts around the keypad).

If the participant says "Yes," then continue. If the participant says "No," ask if their parent/guardian is there to help them.

DO NOT CONTINUE UNLESS PARTICIPANT UNDERSTANDS HOW TO USE THE TWO ARROWS AND THE MOUSE/KEYPAD*.**

** Once the participant understands that they are going to use the two arrows and the keypad, the researcher will click to go on to the next screen. This next screen will show 3 objects- a brick, hammer, and medal (in that order, placed vertically). To the right of each object will be two columns: point values and chance values respectively. The researcher will read the following:*

Now that you know what to do, I'm going to explain how to play. In this game, there's going to be 3 things falling from the sky. The first are bricks, so for every brick that you collect you're going to earn 100 points, but for every brick that you don't collect, that hits the bottom of the screen, you're going to lose 1 chance. Then there are hammers, so for every hammer that you collect you're going to earn 200 points, but for every hammer that you don't collect, that hits the bottom of the screen, you're going to lose 2 chances. And then there are medals, so for every medal you collect you're going to earn 300 points, but for every medal that you don't collect that hits the bottom of the screen, you're going to lose 3 chances. Since your final score was (state what their final score was in the game), **you're going to have** (final score) **chances to play! Do you have any questions?**

**If they say "Yes," answer their questions. If they say "No," continue:*

Great! I'm going to give you control of my screen.

**Using the Zoom remote control feature, give the participant control of the screen.*

Whenever you're ready, I want you to click on the hammer and as soon as you do, the game's going to start and you can immediately start playing.

**Participant clicks on the hammer. The game opens in a new tab and the participant can begin playing. The game continues until the participant has no more chances.*

**Once the participant runs out of chances, the following message will appear. The researcher reads it aloud:*

GAME OVER! Wow, you did AMAZING! Your final score: (state their final game score as it appears here)

End of Gamification Condition