

Can A Crab Walk in The Air or Walk Through Walls?
Impact of Watching Fantastical Content on Young
Children's Cognitive Skills

by

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in Partial Fulfillment of the Requirements for
the Degree of
Master of Arts

in

Developmental Psychology



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September 11, 2023

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ABSTRACT

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Executive function (EF) refers to high-order cognitive processes underlying conscious control of thought and action and is vital for children's social and academic success. Past studies showed that watching fantastical content has immediate negative effects on young children's executive function skills. Due to its unexpected and incomprehensible nature, fantastical content might tax cognitive resources, resulting in poor performances on subsequent EF tasks. There is yet no study investigating how long it takes for the negative effects to wear off and whether the negative effects apply or extend to other cognitive skills. The current experimental study aimed to (1) detect how long fantastical content affects children's EF performance, and (2) examine whether watching fantastical content negatively affects children's other (non-EF) cognitive task performance, namely mental rotation. One hundred twenty 5- to 6-year-old children ($M(SD)=66(5.52)$ months) were randomly assigned to one of the four following conditions: a) immediate testing after watching an 8-min realistic cartoon (Caillou), b) immediate testing after watching an 8-min fantastical cartoon (SpongeBob), c) 10-min delayed testing after watching the fantastical cartoon, and d) immediate testing after an 8-min free play (control condition). After the experimental session, all children were tested on EF measures of working memory, inhibitory control, and cognitive flexibility, along with a measure of 2-D mental transformation. Results showed that children's performance for working memory in the

fantastical cartoon-immediate testing condition was lower than in the control condition. Children in the fantastical cartoon-immediate testing condition performed worse in inhibitory control than children in the other three conditions. Groups did not differ on cognitive flexibility and mental transformation. As in previous studies, watching fantastical content negatively affected children's EFs (i.e., working memory and inhibitory control), but this negative impact disappeared in a few minutes and seems unique to EFs. These results suggest that fantastical content may temporarily affect attentional and information processing systems related to EFs, which may require more controlled activity than the processing of 2-D mental transformation.

Keywords: preschool children, fantastical television content, executive functions

ÖZETÇE

Bir Yengeç Havada Yürüyebilir veya Duvarın İçinden Geçebilir Mi? Fantastik İçerik İzlemenin Küçük Çocukların Bilişsel Becerileri Üzerindeki Etkisi

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Yürütücü işlevler, düşünce ve eylemlerin bilinçli bir şekilde kontrol edilmesini sağlayan üst düzey bilişsel süreçleri ifade eder ve çocukların sosyal ve akademik başarıları için hayati önem taşımaktadır. Geçmiş araştırmalar, fantastik içerik izlemenin küçük çocukların yürütücü işlev becerileri üzerinde kısa süreli olumsuz etkilere sahip olduğunu göstermiştir. Beklenmedik ve zor anlaşılır doğası ile fantastik içerik bilişsel kaynakları tüketerek sonraki karmaşık yürütücü işlev görevlerinde düşük performansa neden olabilir. Bu zamana kadar hiçbir çalışma bu olumsuz etkilerin ne kadar sürede ortadan kalktığını ve bu olumsuz etkilerin diğer bilişsel beceriler için de geçerli olup olmadığını incelememiştir. Bu deneysel çalışma (1) fantastik içeriğin çocukların yürütücü işlev becerilerini ne kadar süre etkilediğini tespit etmeyi ve (2) fantastik içeriğin çocukların yürütücü işlev becerileri dışındaki diğer bilişsel becerilerini de olumsuz bir şekilde etkileyip etkilemediğini incelemeyi amaçlamaktadır. Bu amaç doğrultusunda, 5 ila 6 yaş arasındaki 120 çocuk ($M(SS)=66(5.52)$ ay) dört koşuldan birine rastgele atanmıştır: a) 8 dakikalık gerçekçi bir çizgi film (Caillou) izledikten hemen sonra test, b) 8 dakikalık fantastik bir çizgi filmi (Sünger Bob) izledikten hemen sonra test, c) aynı fantastik çizgi filmi izledikten 10 dakika sonra test ve d) 8 dakikalık serbest oyundan hemen sonra test (kontrol grubu). Bütün çocuklar buldukları koşula bağlı olarak deneysel manipülasyondan ya hemen ya da 10 dakika sonra yürütücü işlev (çalışma belleği,

ketleyici kontrol, bilişsel esneklik) ve 2 boyutlu zihinsel döndürme görevleri üzerine test edilmiştir. Araştırma sonuçları, fantastik çizgi film anında test koşulundaki çocukların çalışma belleği görevinde kontrol koşulundaki çocuklara kıyasla daha düşük skorlara sahip olduğunu göstermiştir. Aynı zamanda, fantastik çizgi film anında test koşulundaki çocuklar, ketleyici kontrol görevinde de diğer üç koşuldaki çocuktan daha kötü performans sergilemiştir. Bilişsel esneklik ve zihinsel döndürme görevlerinde gruplar arası farklılık gözlenmemiştir. Önceki çalışmalarda olduğu gibi, fantastik içerik izlemek çocukların yürütücü işlev performanslarını (çalışma belleği ve ketleyici kontrol) olumsuz yönde etkilemiştir. Ancak bu olumsuz etkiler birkaç dakika içinde ortadan kaybolmuştur ve zihinsel döndürme görevinde gözlenmeyerek sadece yürütücü işlev becerilerine özgü görünmektedir. Bu sonuçlar, fantastik içeriğin, 2 boyutlu zihinsel döndürmeden daha kontrollü bir işleme gerektirebilecek yürütücü işlevlerle ilgili dikkat ve bilgi işleme sistemlerini geçici olarak etkileyebileceğini önermektedir.

Anahtar kelimeler: okul öncesi dönem; fantastik içerik; yürütücü işlevler

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Chapter 1

INTRODUCTION

Executive function (EF) skills are high-order cognitive processes underlying control of thoughts and actions (Zelazo & Müller, 2011). EF skills have great importance in every aspect of life, such as school readiness, academic success, and social competence (Blair & Razza, 2007; Diamond, 2013; Pellicano et al., 2017; Razza & Blair, 2009) and show rapid development during the preschool years (Welsh et al., 2010; Zelazo et al., 2003). Therefore, factors related to EF in young children have gained much attention from researchers. Recent research focusing on the influence of screen media on preschoolers' EF indicated that watching fantastical content (physically impossible events) has immediate negative effects on children's EF, such that children watching a fantastical cartoon perform worse on EF tasks compared to children watching a non-fantastical cartoon when tested immediately afterward the exposure (e.g., Li et al., 2020; Lillard et al., 2015a). To explain the negative effects of exposure to fantastical content on children's EF, it was suggested that fantastical events might consume cognitive resources excessively because of their unexpected and incomprehensible nature, resulting in insufficient resources for subsequent complex EF measures (Jiang et al., 2019; Lillard et al., 2015a). There is yet no study investigating how long it takes for the negative effects of viewing fantastical content to wear off and whether the negative effects are specific to EF skills or extend to other (non-EF) cognitive skills. The present experimental study aimed to (1) detect how long the negative effects persist by testing children either immediately or after 10 min of watching a fantastical cartoon, and (2) examine whether the negative effects apply to children's mental rotation skills by comparing their performance on a 2-D mental transformation task after watching a fantastical cartoon or

a realistic cartoon or playing. Findings from the current study would give insight into the reason for the negative effects of watching fantastical events on children's cognitive skills. The hypothesis that watching fantastical content might tax cognitive resources, resulting in poor performance on immediate EF tasks, would be supported if the negative effects on EFs disappear after a while and extend to mental transformation task. Precisely, negative effects might disappear after 10 min due to recovering resources consumed excessively by fantastical content, and any subsequent complex cognitive task relying on the cognitive resources might be affected by watching fantastical content that uses these resources overly.

1.1 Executive Functions and TV Exposure in Young Children

Executive functions refer to top-down processes that aid individuals to engage in goal-directed behaviors and monitor and control thought and action (Diamond, 2016; Miller & Cohen, 2001). EF is often conceptualized as a unitary construct with three core, dissociable components: working memory, inhibitory control, and cognitive flexibility (Miyake & Friedman, 2012). These complex skills enable storing and manipulating information, inhibiting prepotent responses and behaviors, and flexibly adjusting to new demands or changing perspectives, respectively (Garon et al., 2008; Miyake & Friedman, 2012). Better EF skills in young children predict later achievements in academic and social life (Jacobson et al., 2011; Kim et al., 2013; Mischel et al., 1989; Ponitz et al., 2009). Past research found relations between EF skills and various outcomes, including school readiness (Monette et al., 2011; Pellicano et al., 2017), literacy skills (Cartwright, 2012), school and job success (Blair & Razza, 2007; Diamond, 2016; McClelland et al., 2007), internalizing (Wang & Zhou, 2019) and externalizing (Schoemaker et al., 2013) behaviors, social competence (Razza & Blair, 2009), even marital harmony (Eakin et al., 2004) and public safety (Diamond, 2013). EFs are closely related to the prefrontal cortex

functions, and EF development is found to be parallel to the development of the prefrontal cortex (Cohen, 2017; Funahashi & Andreau, 2013; Welsh et al., 2006). It emerges in infancy, develops rapidly in early childhood, shows gradual development from childhood to adolescence, then starts to decline in old age (Davidson et al., 2006; Diamond, 2002; Müller & Kerns, 2015). Investigating factors that may influence young children's EF is valuable because EF has great importance throughout the lifespan, and preschool years are the critical period for its development.

The fact that screen-based media use is visibly increasing among children younger than six (Goode et al., 2019; Chassiakos et al., 2016) leads to the examination of the possible effects of screens on EF skills. Preschool children spend a considerable amount of time in front of various screen-based media devices (McNeill et al., 2019; Shah et al., 2019). Although mobile devices, including tablets and smartphones, are gaining prominence in children's daily lives, traditional media like TV and video/DVD are still the predominant media types children spend time with during everyday life (Kostyrka-Allchorne et al., 2017a; Rideout, 2017). Extensive survey studies conducted in diverse countries such as US and China indicated that children aged between 2 and 5 years watch TV at least 2 hours per day (Dong et al., 2015; Tandon et al., 2011), and half of them even have their own TV in their bedroom (Kabali et al., 2015; Wartella et al., 2013). Researchers conducted numerous studies to investigate the relationship between TV viewing and EF in preschool children. The majority of the studies found that longer TV time is negatively related to EF skills in children (e.g., Hu et al., 2020; Ribner et al., 2017; Rosenqvist et al., 2016). In contrast, some studies reported positive relations (e.g., Yang et al., 2017) and null findings (e.g., Jusiené et al., 2020). These mixed results suggest that TV time is not sufficient by itself to explain the relationship between TV exposure and EFs in children since the relationship between TV time and EF depends on the content

children consume on TV (Barr et al., 2010; Foster & Watkins, 2010; Uzundağ et al., 2022). In other words, as Kostyrka-Allchorne et al. (2017b) indicate, what children watch on TV is more important than how long they watch.

1.2 Executive Functions and Fantastical Content

Research focusing on the impact of a number of TV content on preschoolers' EFs consistently showed immediate disruptions in children's EFs after watching TV programs including fantastical events (e.g., Fan et al., 2021; Lillard et al., 2015a). Fantastical events refer to physically impossible events (Woolley, 1997), which are abundant in child-directed TV programs (Chlebuch et al., 2023; Goldstein & Alperson, 2020; Taggart et al., 2019). They include impossible transformations (e.g., changing objects' or characters' shape and identity in impossible ways), impossible attributes (e.g., violations of gravity), and magical genesis (e.g., objects and characters appearing out of nowhere) (Lillard et al., 2015a). Coffee changing into a man, a boy flying on a broom, and a child making a bear appear by pressing a button are examples of fantastical events commonly used in child-directed TV (Li et al., 2015). As a possible explanation for the negative effects of viewing fantastical content on EFs, it has been suggested that processing fantastical events, which are novel for young children, consumes cognitive resources, resulting in insufficient resources to complete subsequent complex EF tasks (Jiang et al., 2019; Lang, 2000; Lillard et al., 2015a, 2015b).

Fantastical or physically impossible events require relatively intense processing in young children because of their novelty and rarity in daily life (Fan et al., 2021; Rhodes et al., 2020). When children watch events in TV shows, they merge and interpret incoming information by comparing them with prior experience and schema knowledge stored in the long-term memory based on how events typically occur. There is no existing

experience and schema to make sense of events with fantastical elements that are entirely new to young children (Lang, 2000; Lillard & Peterson, 2011). Moreover, whereas familiar events have established neural circuitry to be encoded (Posner & Rothbart, 2007), fantastical events, with their novel and unexpected nature, have no such circuitry. Therefore, the brain trying to find appropriate knowledge and schema to process the event goes into an extended search (Lillard et al., 2015a, 2015b). Such neurocognitive efforts occur in the prefrontal cortex and deplete cognitive resources. These efforts result in a temporary lack of resources for subsequent cognitive tasks that also need them because cognitive resources are not infinite and need to recharge (Baumeister, 2014; Baumeister et al., 2007; Brzezicka et al., 2013; Gailliot & Baumeister, 2007; Hagger et al., 2010; Lin et al., 2020; Petruo et al., 2018; Randles et al., 2017; Sarter et al., 2006). EF tasks also rely on the prefrontal cortex and need more resources to be completed because of their complexity (Blain et al., 2016; Persson et al., 2013; Petruo et al., 2018; Shenhav et al., 2013). Accordingly, processing fantastical events may consume cognitive resources necessary for subsequent complex EF tasks and lead to poor performance on these tasks.

On the other hand, even infants as young as 14 weeks have expectations of how events should happen and become surprised when their expectations are violated (Baillargeon, 2002; Shtulman & Carey, 2007). That means human beings from infancy have innate knowledge about physical laws about how events proceed (Carey, 2009; Spelke & Kinzler, 2007). As children experience the external world, their understanding of physical laws gradually increases (Piaget, 1967). Fantastical content is based on violations of these innate expectations making the events challenging to comprehend and incorporate into stored patterns (Rhodes et al., 2020). The frequent violations of expectations may create overload effects on cognitive processing. Overall, processing fantastical events that violate real-world expectations is difficult for young, naïve

physicists because they cannot assimilate them into stored patterns. This processing tends to overtax cognitive resources, which may reduce the availability of resources for subsequent cognitive tasks.

1.3 Findings from Previous Studies

The findings from a series of studies show the negative effects of viewing fantastical content on young children's EFs. Rhodes et al. (2020) examined the short-term effects of fantastical content on individual components of EF: working memory, inhibitory control, and cognitive flexibility. They found that 6-year-olds who watched a fantastical cartoon (Little Einsteins) performed worse in the three measures of EF applied immediately after the watching session compared to children who watched a non-fantastical cartoon (Little Bill). Lillard et al. (2015a) obtained similar results in two other experiments. Experiment 1 showed that 4- and 6-year-old children watching fantastical cartoons (SpongeBob or FanBoy) had lower composite EF scores composed of inhibitory control, rule switching/inhibition, and working memory than children who were playing. There were no differences between the two fantastical cartoon conditions. Experiment 2 tested whether the negative effects of fantastical content would apply only to entertainment shows or might also extend to shows intended to be educational. They assigned 4-year-old children to watch a fantastical cartoon (SpongeBob), watch a fantastical educational cartoon (Martha Speaks), or listen to an educational audiobook (based on Martha Speaks but without fantastical elements). Results indicated that the performances after watching SpongeBob and watching Martha Speaks were about the same. However, watching a fantastical show designed to be educational still led to a lower composite EF score than listening to a book.

Past studies investigating the impact of audio-visual features of the TV, namely pacing, on EFs also emphasize the detrimental effects of watching fantastical events (Lillard & Peterson, 2011; Sanketh et al., 2017). In these experimental studies, it was hypothesized that compared to slow-paced TV, fast-paced TV might capture attention in a bottom-up fashion, which would lead to a decrease in EF because EF relies on top-down attentional control that refers to a more controlled and goal-directed processing mechanism (Lillard & Peterson, 2011). Results showed that watching fast-paced TV cartoons (SpongeBob and Tom and Jerry) resulted in a lower score on a composite EF measure (composed of planning, rule switching/inhibition, and working memory) and motor EF tasks than watching slow-paced TV cartoons (Caillou and Barney) and drawing for children between 4 and 6 years old. While the research pointed to the potential negative impact of fast pacing on preschoolers' EF, the abundant presence of fantastical events in fast-paced TV cartoons blurred the findings. It remained unclear whether worse EF performance after watching a fast-paced TV was due to the pace, extent of fantastical events, or an interaction of these two factors.

Several experimental studies have been conducted to differentiate the impacts of pace and fantastical content on preschoolers' EF. In these experiments, children were immediately tested on working memory, inhibitory control, and cognitive flexibility after viewing cartoons that varied in fantasy and pacing. For instance, children were tested after watching (1) fast-paced fantastical content (Spongebob/Room on the Broom), (2) fast-paced realistic content (Phineas and Ferb/Charlie and Lola/Boonie Bear), (3) slow-paced fantastical content (Little Einsteins/Tom and Jerry), (4) slow-paced realistic content (Little Bill//Big Head Son and Little Head Father). None of the studies showed a significant effect of pace on children's EFs (Fan et al., 2021; Kostyrka-Allchorne et al., 2019; Lillard et al., 2015a). However, children who viewed fantastical cartoons had lower

EFs than children who viewed realistic cartoons (Fan et al., 2021; Lillard et al., 2015a). On the other hand, Kostyrka-Allchorne et al. (2019) reported an opposite finding: an increase in children's inhibitory control after watching fantastical content despite the small effect size ($\eta_p^2 = .025$). The possible explanation for the only contradictory result is that an adult narrator and still images were used in the study of Kostyrka-Allchorne et al. (2019) as opposed to animations used in the remaining studies. Altogether, these findings indicate that the presence of fantastical events, not the pace, leads children to demonstrate different performance on EF tasks.

Studies consistently showed the impact of fantastical content both on composite EF measure and individual EF measures (i.e., working memory, inhibitory control, and cognitive flexibility), but does it matter how many fantastical events the TV content contains for the effects on EF to show up? In order to determine whether a certain threshold number of fantastical events in TV shows decreased young children's EF performance, Jiang et al. (2019) tested 5 to 6-year-old children in three conditions (high-, mid-, and low-fantasy) by using three episodes of the same cartoon (Pleasant Goat and Big Big Wolf) that varied on the number of fantasy events. They found no difference in working memory scores across conditions. Children in the low-fantasy condition demonstrated the best performance in inhibitory control and cognitive flexibility tasks than children in the high-fantasy and mid-fantasy conditions. However, contradictory to expectations, children in the high-fantasy condition had higher scores on inhibitory control and cognitive flexibility than children in the mid-fantasy condition. As an explanation for this unexpected finding, the authors argued that the high number of fantastical events increased the processing load and distracted children's attention so much that there emerged a failure to notice all the fantastical events presented.

The studies aimed to identify potential physiological and neural mechanisms underlying the negative effects of fantastical content shown with behavioral measures supported the suggestion that viewing fantastical events is a load on children's cognitive processing. Using functional near-infrared spectroscopy (fNIRS), Li et al. (2020) found that 4- to 6-year-olds who watched a cartoon with a high number of fantastical events (Tom and Jerry) showed more brain activation in the prefrontal cortex, an area also related to EFs, than those who watched a cartoon with a low number of fantastical events (Mickey Mouse Clubhouse). Moreover, the examination of children's eye movements while watching the videos demonstrated that children viewing high amount of fantastical events had more frequent but shorter fixations, which may be the signal of greater cognitive effort/load, compared to children viewing low fantastical events. Their results also replicated the previous studies, such that children in the high fantasy group performed worse on behavioral measures of EF components than children in the low fantasy group. Similar findings were reported by Li et al. (2018) investigating the changes in children's brain activation while they watched and interacted with (e.g., played video game) the fantastical content. Their results indicated that when children watched the fantastical events, they showed higher activation in their dorsolateral prefrontal cortex than when they interacted with fantastical events. Altogether, Li et al. (2018, 2020) findings indicate that processing fantastical events is cognitively taxing for young children; however, viewing fantastical events requires greater cognitive resources than interacting with them.

Interacting with fantastical events may alleviate the previously documented disruptive effects of fantastical content on children's EFs because interaction with fantastical events via screens may lead to fantastical events to be perceived as less fantastical, therefore less taxing in terms of cognitive resources (Li et al., 2018). To test this hypothesis, Li et al. (2018) conducted an experiment to compare 4- and 6-year-olds'

inhibitory control before and after playing a fantastical video game (Dr. Panda in Space) or watching a video clip depicting a series of fantastical events from the same game. Results supported their expectations by showing that children watching the video perceived fantastical events as more fantastical than children playing the video game. In the watching video condition, children's inhibitory control performance on the post-test was lower than the pre-test, while no such effect was found for playing video game. In a separate experiment, they tested whether the findings of Experiment 1 would also be applied to realistic events. Using the same procedure except that children either watched or interacted with real events (Dr. Panda's Home), they found children in the video condition to perceive real events as less real than children in the video game condition and a significant increase in inhibitory control performance after watching and interacting with realistic events. Overall, the disruption in the inhibitory control was only pertinent to viewing fantastical events. A recent study aimed to replicate and extend the findings of Li et al. (2018) by exploring whether the same effects were observed for the other component of EF, cognitive flexibility (Wang & Moriguchi, 2023). Results by cognitive flexibility task and fNIRS measure indicated no behavioral or neural changes after viewing or playing "Dr. Panda in Space." Stimulus intensity was given as a possible explanation for the inconsistent findings. Although the same fantastical content was used in the two studies, the stimulus in the study of Wang and Moriguchi (2023) included fewer fantastical events.

To summarize, the majority of experimental studies demonstrate that watching fantastical content causes disruptions in young children's EFs, such that children who watch fantastical cartoons perform worse on the EF tasks applied immediately after watching than children who watch realistic cartoons or play (Fan et al., 2021; Lillard et al., 2015a; Rhodes et al., 2020). For these negative effects, the following suggestion is

provided. As an event becomes more novel, the demand for cognitive resources to process the event increases. Fantastical content violating the expectations of physical laws is highly novel and incomprehensible for preschool children; thus, its processing is difficult and requires more cognitive resources. Cognitive resources are not finite; hence, the consumption of resources in one task inevitably impacts the availability of resources for another task. Because viewing fantastical content exhausts these resources, fewer cognitive resources are available for the subsequent complex EF tasks, resulting in poor performance after watching a fantastical cartoon. A recent study by Essex et al. (2022) showed the cognitively challenging nature of fantastical cartoons from a different perspective. By making a quantitative content-based analysis, they found an increased situational change in the TV programs previously shown to decrease EFs after viewing. Situational information such as time and place in which the events occur, the entities in the event (people, objects, animals), features of the entities (e.g., sizes, colors, emotions), and the actions of the agents is essential to perceive events. Frequent changes in them make event comprehension complicated. TV content with cognitively demanding fantastical events, together with cognitively demanding properties (e.g., frequent situational changes), may particularly exhaust resources.

1.4 Fantastical Content and Other (non-EF) Cognitive Skills

Studies investigating the impact of fantastical content on children's cognitive development have focused on only one of the cognitive skills, namely EFs. However, if the cognitive resources of young children are depleted after watching fantastical events, it should be considered the possibility that other (non-EF) cognitive skills may be affected by watching fantastical content. Mental rotation skill may be a good candidate to be examined in this context because of its close relation to EFs (e.g., Hawes et al., 2015a; Kaufman, 2007; Miyake et al., 2001). Mental rotation is one of the aspects of spatial

thinking (Hawes et al., 2015a) and requires the manipulation of information about objects and space (Verdine et al., 2017). It has been established that mental rotation is related to achievement in maths, science, technology, and engineering (e.g., Black, 2005; Mix & Cheng, 2012; Quaiser-Pohl et al., 2014; Wai et al., 2009). The tasks aiming to measure mental rotation skill are mostly based on the representations of 2-D and 3-D objects (Hawes et al., 2015b). To complete these tasks successfully, participants should hold and manipulate information in mind, suppress impulsive responses, shift between perspectives, and maintain their goals, and these are skills dependent on executive functioning (He et al., 2019). Overall, it is important to test whether fantastical content disrupts preschool children's mental rotation skill because it may illuminate the negative effects of watching fantastical events on EF skills demonstrated by previous studies.

1.5 Current Study

Literature indicates that preschoolers watching fantastical content demonstrate poorer performance on working memory, inhibitory control, and cognitive flexibility tasks when tested immediately after the exposure compared to those watching realistic content or playing (e.g., Lillard et al., 2015a). For this short-term impact, it is suggested that watching fantastical events consumes the cognitive resources required for the subsequent complex EF measures, reducing children's performances (e.g., Fan et al., 2021). Until now, no research has been done to examine how long this impact on EFs persists and whether there are other cognitive outcomes of watching fantastical content.

The first goal of the current study was to examine how long the fantastical content affected children's EF performances. To address this goal, two conditions were used in the experiment. Children in both conditions watched the same fantastical cartoon. However, children in one condition were tested on EF and mental rotation tasks as soon

as the cartoon finished. In contrast, children in the other condition waited 10 minutes after watching the cartoon to be tested on the tasks. It is important to determine the duration of time necessary for the negative short-term effects to disappear because it may give us an insight into the reason for the negative effects of watching fantastical content.

If the aforementioned negative effects fade in a few minutes, the suggestion that fantastical content might tax cognitive resources, resulting in poor performances on complex tasks such as EF measures, is supported. Because that means the reduced performance might disappear after a while due to recovering resources. Evidence shows that declines in the performance of cognitive tasks due to mental fatigue can be eliminated by taking breaks that charge the cognitive resources (e.g., Albuлесcu et al., 2022; Hunter & Wu, 2016; Sievertsen et al., 2016). For example, it is found that participants taking breaks varying between 5 and 15 minutes after cognitively demanding tasks perform better on inhibitory control and selective attention compared to those not taking any breaks (Gilsoul et al., 2022; Janssen et al., 2014). Accumulating evidence from neurophysiological investigations also proves the effectiveness of breaks on cognitive recovery. Functional imaging studies demonstrate that the disintegration of brain networks observed after a demanding cognitive task is restored by a break (Proost et al., 2022; Qi et al., 2019). Additionally, EEG data indicates that high delta band level (as a biomarker of mental fatigue) occurring after a task that requires sustaining attention for a long period decreases following a break session (Gao et al., 2022; Wang et al., 2022). Thus, waiting for a while after watching fantastical content to apply EF tasks can eliminate the previously documented negative effects of fantastical content because the wait recovers the cognitive resources necessary to complete the tasks.

The second goal of the current study was to examine whether watching fantastical content negatively affected children's other cognitive performance, particularly mental

rotation performance. To address this goal, three conditions were used in the experiment. Children in one condition watched a fantastical cartoon and completed EF and mental rotation tasks immediately after the cartoon finished. Similarly, children in the other two conditions completed the tasks immediately; however, instead of watching a fantastical cartoon, children either watched a realistic one or played. It is important to examine the other cognitive outcomes of watching fantastical content because it may give us insight into the reason for the negative effects. Previous studies suggested that fantastical content consumes cognitive resources excessively, resulting in insufficient resources for subsequent tasks (e.g., Rhodes et al., 2020). If the reduced EF performance in young children is because of resource depletion, other (non-EF) cognitive skills may also be affected by watching fantastical content. Thus, the previously documented negative effects of watching fantastical content on EF tasks due to insufficient cognitive resources may be extended to mental rotation task related to EFs.

As a whole, children in this experiment were randomly assigned to one of the four following conditions: a) immediate testing after watching an 8-min realistic cartoon, b) immediate testing after watching an 8-min fantastical cartoon, c) 10-min delayed testing after watching the fantastical cartoon, and d) immediate testing after an 8-min free play (control condition). After the experimental session, all children were tested on EF measures of working memory, inhibitory control, and cognitive flexibility, along with a measure of 2-D mental transformation. In past studies, the performance of children watching fantastical content was compared with that of children watching non-fantastical content or drawing and playing (e.g., Fan et al., 2021; Lillard et al., 2015a; Lillard & Peterson, 2011). The current study used a realistic cartoon and free play (nonmedia comparison activity) to replicate their findings.

On the other hand, the waiting duration in the delayed testing condition was based on the evidence showing that 10 min rest rather than 1 or 3 min replenishes cognitive resources necessary for self-regulatory skills (Bennett et al., 2020; Tyler & Burns, 2008). If the negative effects of fantastical content on EF skills stem from consuming cognitive resources, resting for 10 minutes may alleviate the negative impact by refueling resources. Previous research (e.g., Mahy & Moses, 2011) used easy drawing/coloring activities to keep children busy during the delay periods while not inadvertently influencing their performance on the following tasks. For the current study, a free play activity, including drawing/coloring, was designed for children in the delayed testing condition.

The cartoon episodes used in the past studies (Lillard et al., 2015a; Lillard & Peterson, 2011) were also used in the current experiment to extend their findings by keeping every content and production feature (e.g., pace, number of fantastical events, or comprehensibility) constant in the TV programs. Children watched the full episode of the TV shows to see the whole story, which may impact their comprehension of the content. Finally, a parent questionnaire assessing children's EF skills and attention-related problems was used to ensure children did not differ on these variables before the experimental session. Children's attention skills were examined because it is known that attention has a foundational role in EFs (e.g., Blair, 2017; Decker et al., 2016; Garon et al., 2008; Wass et al., 2011, 2012).

As a final note, this experimental study was initially planned to be conducted in a between-subjects pretest-posttest design to detect the changes in children's performance better. After the pilot study with eight children conducted with different pre-and post-test tasks, this design was found to be non-feasible. Children had to complete four pre-and four post-test tasks. This long experiment session bored them, and they wanted to quit the

experiment. Based on the pilot study's observations, the study was tuned to the between-subjects comparisons.

Considering the suggestion that fantastical content taxes cognitive resources, resulting in insufficient resources for subsequent cognitive tasks such as EF measures, and these resources need some time to be regulated/replenished, we hypothesized:

1. Children tested immediately after watching a fantastical cartoon perform worse on EF tasks than children tested after 10 min because cognitive resources may not have enough time to be recovered for the subsequent tasks,
2. Children in the fantastical cartoon-immediate testing condition perform worse on mental rotation task than children in the realistic cartoon-immediate testing condition and children in the playing-immediate testing condition because only watching fantastical events may lead to insufficient cognitive resources,
3. Replicating the previous findings, the performance of children in the fantastical cartoon-immediate testing condition becomes lower on EF tasks than children in the realistic cartoon-immediate testing condition and children in the playing-immediate testing condition.

Chapter 2

METHOD**2.1 Participants**

Children were recruited through announcements in kindergartens in Turkey. A total of 126 typically developing 5- to 6-year-old children participated in the study. Six children were excluded because one parent did not fill out the questionnaire related to children's demographics, EF, and attention skills, two children had a language deficit reported by parents, one child in the delayed testing condition cried while waiting and refused to continue, one child did not reply to questions, and one child experienced a technical error (the child watched the cartoon in a deficient volume because of the speaker's low battery). The final valid sample consisted of 120 children (M = 66 months; SD = 5.52; 51.7% boys). The demographic data of children across the conditions are shown in Table 1.

Table 1. Demographic Information Among the Four Groups.

	Age (months)				Sex	
	M	SD	Minimum	Maximum	Boys	Girls
Realistic Cartoon- Immediate Testing	65.1	5.68	55	76	15 (50%)	15 (50%)
Fantastical Cartoon- Immediate Testing	65.6	6.14	55	76	15 (50%)	15 (50%)
Fantastical Cartoon- Delayed Testing	66.0	4.73	56	74	16 (53.3%)	14 (46.7%)
Playing- Immediate Testing	67.3	5.46	54	76	16 (53.3%)	14 (46.7%)

Note. M = Mean, SD = Standard Deviation.

2.2 Procedure

The experiment took place in the kindergartens. The children whose parents signed the consent form and filled out the parent questionnaire participated in the experiment. The whole procedure was conducted with each child individually in a quiet room located in the kindergarten and lasted approximately 20 minutes. Children were randomly assigned to one of the four conditions, but with the consideration that an equal number of girls and boys were in each condition. The experimenter and the child sat across from each other at a low table. In the beginning, the experimenter briefly explained the procedure to each child. Children in *the realistic cartoon-immediate testing condition* watched a realistic cartoon for 8 minutes and instantly completed the test battery of EF tasks and a mental rotation task. Children in *the fantastical cartoon-immediate testing condition* were shown a fantastical cartoon for 8 minutes and were instantly tested on the battery. Children in *the fantastical cartoon-delayed testing condition* watched the same fantastical cartoon but waited 10 minutes to be tested on the battery. During this waiting period, children were offered various blank pages, coloring pages, and crayons. They were free to do whatever they wanted to do with these pages and crayons. At the end of the 10 minutes, the test battery was applied. Cartoons in the watching conditions were shown to children on an 11-inch tablet screen. Finally, children in *the playing-immediate testing condition* were given play doughs and tools and spent their time freely with these toys for 8 minutes. After 8 minutes, they were tested on the battery. While children were drawing/coloring or playing, the experimenter was ostensibly busy with her own jobs on a book. All tasks in the test battery were administered in a fixed order. At the end of the experiment, each child received a coloring book as a token of gratitude. Figure 1 shows a visual representation of the four experimental conditions.

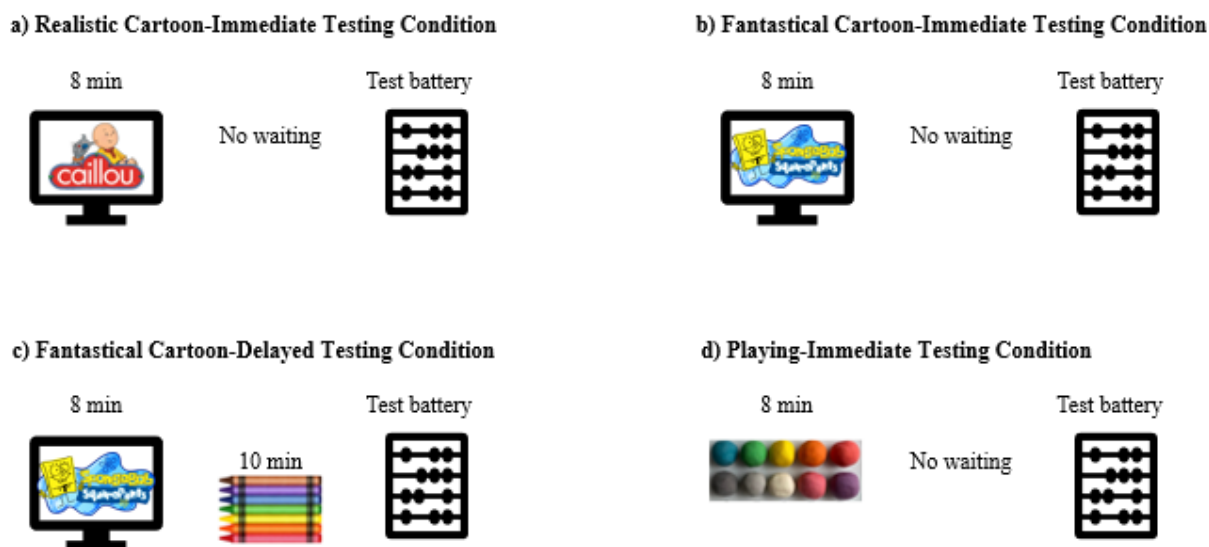


Figure 1. The experimental procedure that was followed in each condition.

2.3 Materials

2.3.1 Cartoons

As in the previous studies (Lillard et al., 2015a; Lillard & Peterson, 2011), Caillou was used as the realistic cartoon and SpongeBob as the fantastical cartoon in the present experiment. Caillou is a cartoon based on everyday issues in the life of a family. The episode used from Caillou is called *April Fools*, which does not include any fantastical events. In this episode, Caillou and his friend make small jokes. SpongeBob is a cartoon based on the life of a talking kitchen sponge that lives in a pineapple under the sea. The episode used from SpongeBob is called *Bad Guy Club for Villains*, which includes 3.99 fantastical events per minute. In this episode, SpongeBob and Patrick watch a DVD of their favorite superheroes. There are fantastical events throughout the episode, such as a man hanging in the air or a talking hand.

2.3.2 Test Battery

The test battery included Backward Word Span Task to measure working memory, Simon Says Task to measure inhibitory control, and Flexible Item Selection Task to measure

cognitive flexibility. Children's Mental Transformation Task was used to measure mental rotation skills.

2.3.2.1 Backward Word Span Task

The Backward Word Span Task is designed to assess the ability to manipulate information held in short-term memory (Engle et al., 1999). In the task, children are asked to repeat a sequence of words in reverse order (Conway et al., 2005). For instance, when the experimenter says "curtain, garden," children are expected to say "garden, curtain." The version prepared by Adıgüzel et al. (2022) was used in the current study. In this version, sequences are gradually made difficult by increasing the number of words in sequence and syllables in words (i.e., word length). The task starts with practice trials of two "2 words with two syllables" strings. During these practice trials, the experimenter gives feedback by reminding the rule and providing the correct answer. Test trials begin with "2 words with one syllable" strings, followed by "2 words with two syllables", "3 words with three syllables", and "4 words with four syllables" strings. There are two trials for each string type which means the total number of test trials is 8. The task is stopped when the children incorrectly answer on two successive test trials with the same string type. For each correct answer, children receive 1 point, and the total scores of correct answers are calculated, ranging from 0 to 8.

2.3.2.2 Simon Says Task

The Simon Says Task is designed to assess the ability to suppress salient responses that are not relevant to the goal (Carlson & Wang, 2007). In the task, children are instructed to imitate the actions that the experimenter models only when the words "Simon Says" come before the commanded action. Otherwise, children must remain entirely still. The experimenter models all actions, regardless of whether the words "Simon Says" is preceded by the action. Actions preceded by "Simon Says" are called imitation trials,

whereas actions that are not preceded by "Simon Says" are called anti-imitation trials. The task starts with the experimenter performing ten simple actions and asking children to demonstrate them (e.g., "touch your eyes"). Then, the experimenter explains the rules of the game and gives two practice trials (one for the imitation trial and one for the anti-imitation trial), followed by a verbal rule check ("So, when I say "Simon Says" do you do what I say and what I do? And when I don't say "Simon Says," do you do what I say and what I do?"). There are 10 test trials composed of five imitation and five anti-imitation trials in a fixed order: Simon, Simon, no Simon, Simon, no Simon, rule reminder, no Simon, Simon, no Simon, no Simon, Simon. For the test trials, there is no feedback. Children's responses are scored on a 4-point scale. For imitation trials: 0 = no movement; 1 = flinch; 2 = partial commanded movement; 3 = full commanded movement. In contrast, for anti-imitation trials: 0 = full commanded movement; 1 = partial commanded movement; 2 = flinch; 3 = no movement. The total scores of correct answers are calculated, ranging from 0 to 30.

2.3.2.3 Flexible Item Selection Task

The Flexible Item Selection Task is designed to assess the ability to switch flexibly between dimensions (Campbell et al., 2013; Jacques & Zelazo, 2001; Şahin & Arı, 2017). In the task, children are asked to select cards that are the same on a particular dimension. For the task, 54 white cards are used. Each card demonstrates an item represented in one of three dimensions: shape, color, and size. The shape dimension includes a boat, a shoe, or a teapot; the color dimension includes blue, yellow, or red; and the size dimension includes small (approximately 4 cm^2), medium (approximately 13 cm^2), or large (approximately 40 cm^2). For example, one card may depict a small blue boat, whereas another card may depict a large yellow teapot. There are 18 trials consisting of one demonstration trial, two practice trials, and fifteen test trials. For each of these trials, a set

of three cards is used. These three cards are identical on one dimension (e.g., size) but different on the other two relevant dimensions (e.g., shape and color) (see Figure 2). In the demonstration trial, the experimenter introduces the selections "I'm going to pick two cards that are the same in one way. So I'll pick these two cards [simultaneously pointing to the yellow shoe and yellow teapot in Figure 2] because these two cards are the same in one way. But, that card [simultaneously pointing to blue teapot] is different from those two cards. Now I'm going to pick two cards that are the same but in a different way. So I'll pick these two cards [simultaneously pointing to the yellow teapot and blue teapot] because these two cards are the same in a different way. But, that card [simultaneously pointing to yellow shoe] is different from those two cards". In the practice trials, children are instructed to "show two cards that are the same in one way" (Selection 1). After children respond, they are instructed to "show two cards that are the same in another way" (Selection 2). During practice trials, feedback is given to children. Once children complete both practice trials, 15 test trials begin. All children take the trials in the same order. Instructions in the test trials are identical to those used in the practice trials, but there is no feedback in the test trials. On each trial, children receive 1 point for each correct selection, but only if children complete their first selection correctly. The children who incorrectly make the first selection do not receive any point for their second selection either. Given that incorrect first selection means that the other two remaining cards are inevitably correct, this scoring system is applied. The total scores of correct answers are calculated, ranging from 0 to 30.

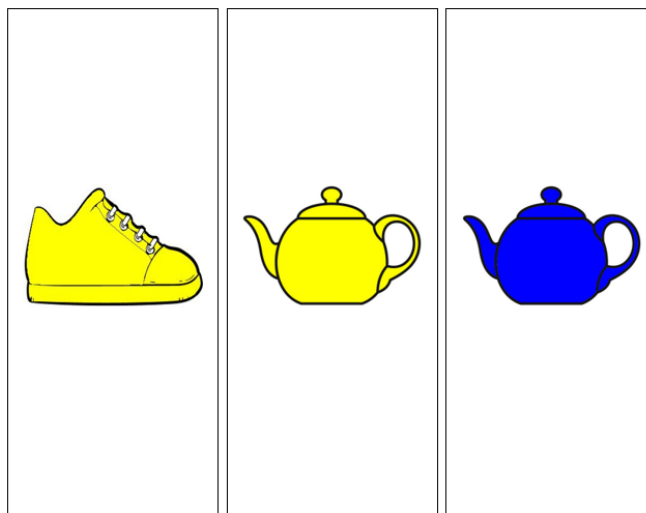


Figure 2. Example cards presented in the task, adapted from Jacques and Zelazo (2001) and Şahin and Arı (2017). These three cards are identical in **size dimension**. But, two cards demonstrating a yellow shoe and yellow teapot are identical to each other in **color dimension**, whereas two cards demonstrating a yellow teapot and blue teapot are identical to each other in **shape dimension**.

2.3.2.4 Children's Mental Transformation Task

The Children's Mental Transformation Task is designed to assess the ability to mentally rotate spatial stimuli (Levine et al., 1999). In the task, children are asked to select the shape created by the integration of two separate parts. In each trial, there are two cards: one is a "pieces card" showing the two target pieces that needed to be put together, and another is a 2X2 "choice card" array including the target shape formed by the two target pieces and three foils. Each test item includes one of the four types of transformations, all of which tap 2-D mental transformations: 1) direct translation, 2) diagonal translation, 3) direct rotation, and 4) diagonal rotation (see Figure 3). All cards are presented to children by putting the pieces card closer to the children and the choice card right above it. The task starts with two practice trials. The experimenter demonstrates the first practice trial by gesturing to the target pieces and saying, "Look at these pieces. Look at these pictures. If you move the pieces together, they will make one of the pictures (pointing to the correct

choice)." On the second practice trial and the subsequent test trials, children are asked, "Show me the picture the pieces make." Feedback is given only for the second practice trial, and no feedback is given on test trials. There are 10 test trials, and all children take the trials in the same order. For each correct answer, children receive 1 point, and the total scores of correct answers are calculated, ranging from 0 to 10.

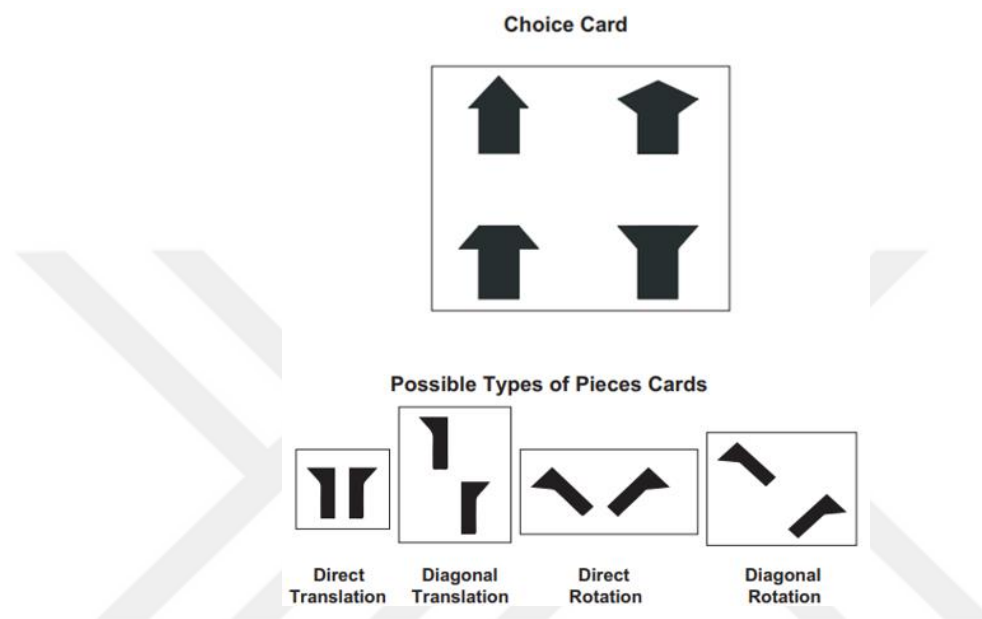


Figure 3. Example of four different types of spatial transformations adapted from Levine et al. (2018). Only one transformation is displayed for each trial.

2.3.3 Parent Questionnaire

Parents filled out a survey about children's demographics (age and sex), EF skills, and attention-related problems. Childhood Executive Functioning Inventory (CHEXI) developed by Thorell and Nyberg (2008) and adapted to Turkish by Hamamcı et al. (2021) was used to assess the EF skills of children before the experimental manipulation. CHEXI consists of 24 items for two factors (13 for working memory and 11 for inhibitory control). Example items are "Has difficulty with tasks or activities that involve several steps" and "Has difficulty holding back his/her activity despite being told to do so." Parents were asked to rate the items on a 5-point scale (1 = definitely not true, 5 = definitely true of the child). All items were reverse scored, and the total scores were

calculated. Thus, high scores indicated better EF skills. Cronbach's alpha is .90 for the working memory and .78 for the inhibitory control. Attention-related problems were measured via the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) adapted to Turkish by Güvenir et al. (2008). Hyperactivity-inattention subscale composed of 5 items was used. Parents rated these items on a 3-point scale (1 = not true, 2 = somewhat true, or 3 = certainly true of the child). The items are: "restless, overactive, cannot stay still for long"; "constantly fidgeting or squirming"; "easily distracted, concentration wanders"; "thinks things out before acting"; and "good attention span, sees chores or homework through to the end." The last two items were reverse scored, and the total scores were calculated. Thus, high scores indicated more attention-related problems. Cronbach's alpha is .80 for the subscale.

Chapter 3

RESULTS

3.1 Preliminary Analyses

Parent questionnaires and behavioral measures data were screened for missing data, outlier scores, and normality checking. Missing data was only identified on the pre-EF measure: Four parents skipped some items on this questionnaire. Given that responding to 90% of the questionnaire is sufficient to be included in the data (Bennett, 2001), responses of two parents skipping two items on the EF measure were included, but those two skipping half of the items were excluded. Considering "mean \pm 3 *SD" as a cutoff, no outliers were detected. Regarding the normality checking of data, the Shapiro-Wilk test was performed and did not show evidence of normality ($p < .05$). Therefore, Kendall's Tau correlation coefficient to examine associations and Kruskal-Wallis H test to investigate group differences were used in the following analyses.

The four conditions were first compared on the age variable, parent-reported pre-EF skills and attention-related problems. Kruskal-Wallis H test indicated that groups did not differ on these variables, $H(3) = 2.78, p = .427$; $H(3) = .814, p = .846$; $H(3) = .435, p = .933$, respectively. Thus, these variables were not considered in the subsequent analyses. Next, correlations between behavioral tasks were examined (see Table 2).

Table 2. Correlations Among Cognitive Task Scores.

	1	2	3	4
1. Backward Word Span	-			
2. Simon Says	.336*	-		
3. Flexible Item Selection	.122	.193*	-	
4. Mental Transformation	.224*	.102	.183*	-

5. Age (months)	.253*	.081	.193*	.211*
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Note. * $p < .01$ (2-tailed).

3.2 Main Analyses

The descriptive statistics of cognitive tasks across four conditions were presented in Table 3.

Table 3. Descriptive Statistics for Cognitive Tasks and Parent Questionnaires in Each Condition.

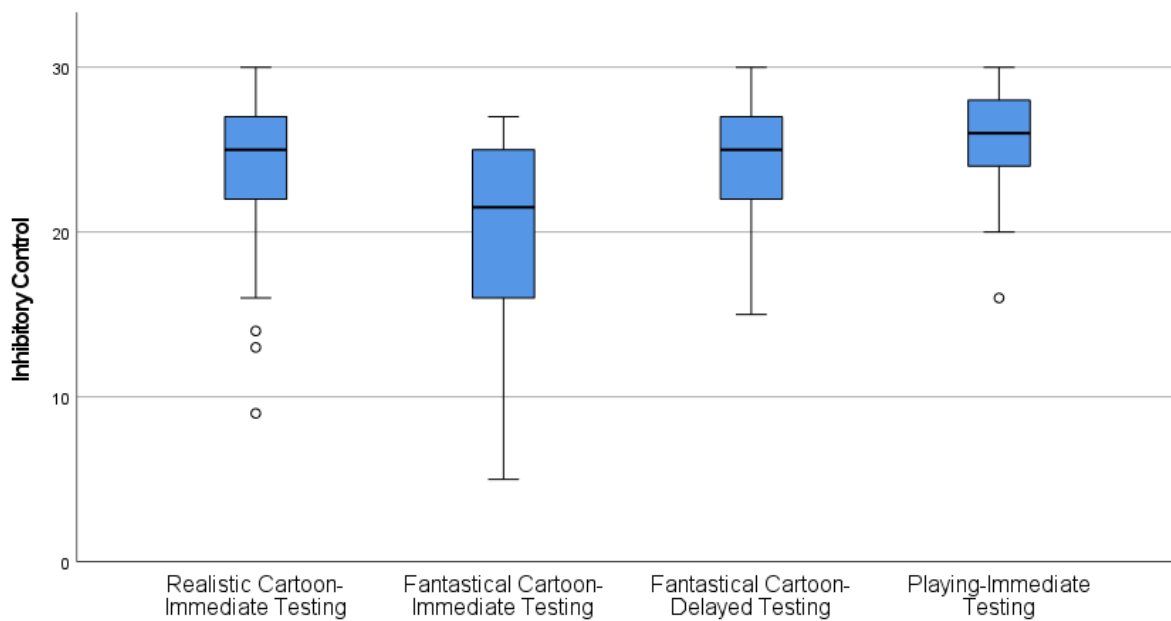
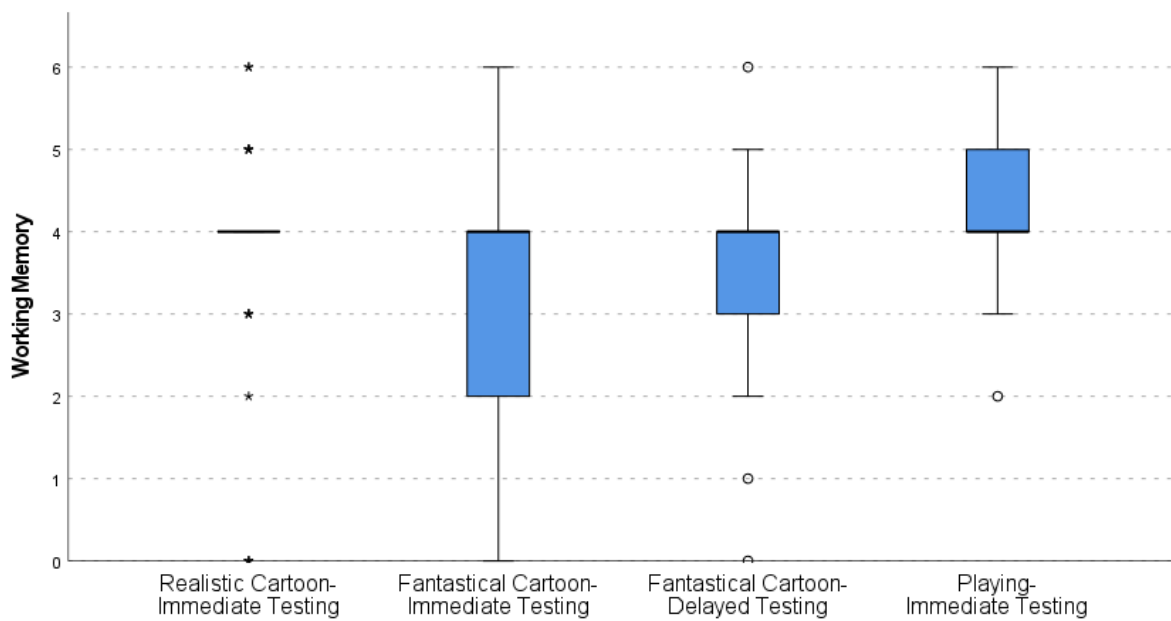
	Realistic Cartoon- Immediate Testing	Fantastic Cartoon- Immediate Testing	Fantastic Cartoon- Delayed Testing	Playing- Immediate Testing (Control)
	M(SD) [Range]			
Working Memory (0 – 8)	3.70 (1.49) [0, 6]	3.10 (1.83) [0, 6]	3.57 (1.28) [0, 6]	4.40 (1.04) [2, 6]
Inhibitory Control (0 – 30)	23.8 (5.05) [9, 30]	20.6 (5.18) [5, 27]	23.9 (4.08) [15, 30]	25.7 (3.32) [16, 30]
Cognitive Flexibility (0 – 30)	24.8 (4.64) [12, 30]	22.3 (5.05) [14, 30]	24.4 (4.07) [15, 30]	25.0 (4.11) [16, 30]
Mental Transformation (0 – 10)	5.90 (2.06) [2, 10]	5.53 (2.00) [1, 8]	5.23 (1.92) [1, 9]	5.60 (1.63) [3, 10]
Pre-EF Skills (24 – 120)	85.4 (10.2) [58, 112]	81.8 (19.7) [39, 110]	82.6 (16.7) [44, 116]	85.6 (10.9) [56, 103]
Attention Problems (0 – 10)	3.50 (1.94) [0, 8]	3.93 (2.85) [0, 9]	3.50 (2.19) [0, 8]	3.80 (2.29) [0, 9]

Kruskal-Wallis H test found significant differences in groups for working memory and inhibitory control, $H(3) = 9.61, p = .022$; $H(3) = 18.23, p < .001$, respectively. There were no significant differences in groups for cognitive flexibility and mental

transformation, $H(3) = 5.97$, $p = .113$; $H(3) = 1.49$, $p < .684$, respectively. Post hoc analysis was conducted using the Dwass-Steel-Critchlow-Flinger (DSCF) pairwise comparisons test (see Table 4). Results showed that children in the fantastical cartoon-immediate testing condition performed worse in working memory than children in the control condition ($p = .028$). Additionally, children's performance in the fantastical cartoon-immediate testing condition for inhibitory control was lower than the realistic cartoon-immediate testing ($p = .032$), fantastical cartoon-delayed testing ($p = .027$), and control ($p < .001$) conditions. Box plots were depicted in Figure 4.

Table 4. DSCF Pairwise Comparisons (only significant results were presented).

		W	p
Working Memory			
Fantastical Cartoon- Immediate Testing	Playing- Immediate Testing	3.92	.028
Inhibitory Control			
Fantastical Cartoon- Immediate Testing	Realistic Cartoon- Immediate Testing	3.86	.032
Fantastical Cartoon- Immediate Testing	Fantastical Cartoon- Delayed Testing	3.95	.027
Fantastical Cartoon- Immediate Testing	Playing- Immediate Testing	5.75	< .001



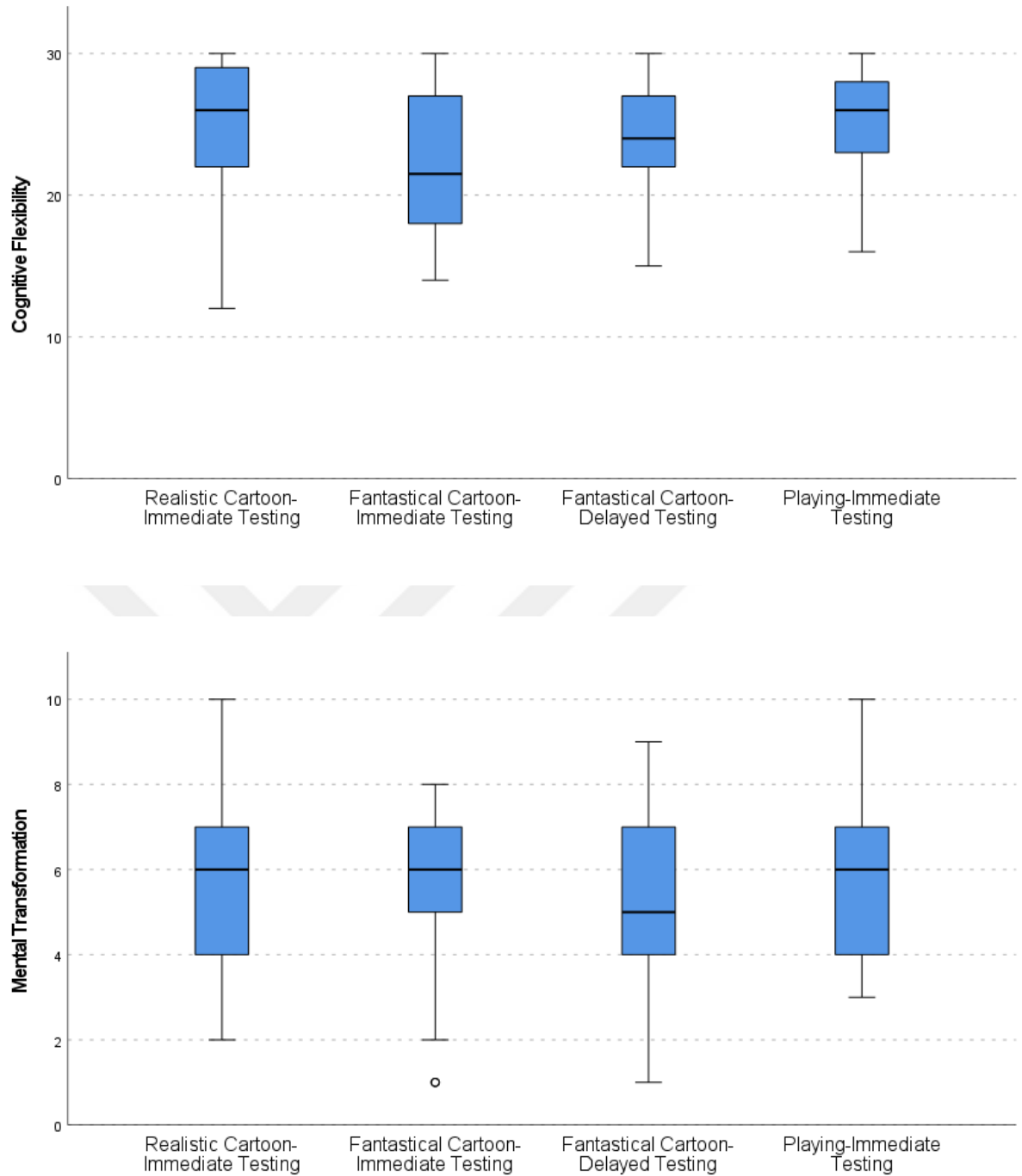


Figure 4. Box plots of cognitive task performances across groups.

Chapter 4

DISCUSSION

4.1 Fantastical Content and Cognitive Skills

Previous studies showed that children watching fantastical content perform worse on EF tasks than children watching realistic content or playing when they are tested immediately after the watching session (e.g., Fan et al., 2021; Li et al., 2020; Lillard et al., 2015a). For these negative effects, it is hypothesized that watching fantastical content consumes cognitive resources excessively due to its novel and incomprehensible nature, resulting in poor performance on subsequent complex tasks, such as EF measures requiring these resources. In the present study, we hypothesized that (a) a delay between watching and testing sessions can eliminate this negative impact on EFs because cognitive resources will have sufficient time to be recovered, and (b) this impact may extend to children's mental transformation performance because mental rotation skills related to EFs can also be affected by the availability of these cognitive resources. Consistent with the expectation, firstly, the results of this study demonstrated that children waiting 10 min to be tested after watching a fantastical cartoon had higher scores on inhibitory control task than children tested immediately. Contrary to the expectation, secondly, watching fantastical content was not followed by a decrease in mental transformation performance: Children who watched a fantastical cartoon performed similarly on the task with the children who watched a realistic cartoon or played.

The disappearance of the disruptive impact of fantastical content on inhibitory control after 10 min may be due to the recovery of cognitive resources. Cognitive resources are limited but renewable resources. As we perform cognitive tasks, they are depleted; as a result, performance on other tasks that require these resources declines (Flanagan & Nathan-Roberts, 2019). In a series of experiments, it was found that difficult

tasks (such as controlling visual attention for an extended period, inhibiting predominant writing tendencies, and exaggerating emotional expressions) undermined performance on subsequent working memory, response inhibition, problem-solving, reasoning, and reading comprehension tasks (Schmeichel, 2007; Schmeichel et al., 2003). A large body of literature reveals that resource depletion stemming after completing cognitively demanding tasks is restored by taking rest breaks (e.g., Chen et al., 2018; Gilsoul et al., 2022). For instance, participants who took 5 min rest after arithmetic tests had higher scores on a problem-solving test than those who moved immediately to the test (Ginns et al., 2023). Consistent with this evidence, in the present study, children in the fantastical cartoon-delayed testing condition demonstrated better performance on the inhibitory control task than children in the fantastical cartoon-immediate testing condition. This is because after watching a fantastical cartoon as a cognitively challenging task, children in the delayed testing condition may have time to restore cognitive resources available for subsequent inhibitory control. Moreover, Nelson et al. (2009) indicated that even commercial breaks are useful for viewers since advertisements can reduce the cognitive burnout of successive minutes of watching.

The disruptive impact of fantastical content on EFs did not extend to mental rotation task, maybe because 2-D object transformation tasks are easier than other tasks such as perspective-taking, mental folding, or working memory (e.g., Crescentini et al., 2014; Frick et al., 2014; Harris et al., 2013; Lehmann et al., 2014). Across three studies, Schmeichel et al. (2003) indicated that cognitively less demanding tasks were unaffected by prior resource depletion; in other words, these tasks were not dependent on whether cognitive resources were fully available or consumed. Their studies tested participants on diverse cognitive tasks varying in demanding levels after participants' cognitive resources were depleted by attention or emotion regulation. Results showed that depleted

participants performed worse on the more challenging cognitive tasks (tests of logic and reasoning, cognitive extrapolation, and reading comprehension) but not on the less demanding tasks (general knowledge test and a nonsense syllable memorization task) compared to non-depleted participants. Demanding tasks such as EF measures require controlled processing, such as active deliberation, inhibiting automatic responses, sustained attention, and drawing conclusions from knowns to generate ideas about unknowns (Burgoyne et al., 2023; Kodituwakku et al., 2001; Rouder et al., 2023; Schmeichel et al., 2003). This kind of processing is more demanding of cognitive resources (Révész, 2014; Weissman & Banich, 2000). Unlike these tasks, less challenging tasks involve just one or a few steps necessary to be completed (Siddiqui et al., 2014; Wood, 1986) and thus are less demanding of resources (Weissman & Banich, 2000; Xu et al., 2022). It is likely that not all cognitive processing is affected by the depletion of resources, and high levels of processing can be particularly susceptible to being impaired by prior acts (in that case, watching fantastical content) that have already expended the resources.

On the other hand, it is possible that fantastical content is more costly for EFs than other cognitive skills because both viewing fantastical events and EF tasks rely on the same prefrontal regions. The Anterior Cingulate Cortex (ACC) is one of the centers for cognitive functions, such as response-conflict monitoring, prediction of action outcomes, error detection, and deviation from expectancy (Alexander & Brown, 2011; Dehaene et al., 1994; Gehring et al., 1993; Oliveira et al., 2007; Van Veen et al., 2001). Processing fantastical events that conflict with physical facts or rules in the real world presumably exercises these functions and needs to activate ACC (Fan et al., 2021; Lillard et al., 2015a; Sarter et al., 2006). It is also found that the inhibitory control task needs the participation of the ACC (Falkenstein et al., 1999; Shenhav et al., 2013). Accordingly, having been

activated frequently by fantastical events, resources in ACC may be consumed, and this may cause poorer performance in the subsequent inhibitory control task due to temporary resource depletion.

In addition to introducing the two elements to the literature, the present research replicated the findings of the previous studies by showing that fantastical content had a negative impact on working memory and inhibitory control in young children. Children who viewed a cartoon including fantastical events performed worse in working memory task than children who played freely and performed worse in inhibitory control task than children who viewed a cartoon including realistic events or played. Some past research provided the same results by focusing on the composite EF created by summing the scores on the tasks of three EF components (Li et al., 2020; Lillard et al., 2015a; Lillard & Peterson, 2011), some by focusing on three components individually (Fan et al., 2021; Jiang et al., 2019; Rhodes et al., 2020), and others by focusing on only one component, namely inhibitory control (Kostyrka-Allchorne et al., 2019; Li et al., 2018). In all, these findings, together with the contributions of the present study, repeatedly demonstrate that watching fantastical content can overload cognitive processing.

As explained earlier, fantastical events do not correspond to stored patterns and even violate the inherent and well-rehearsed strong patterns or expectations about the external world (e.g., Fan et al., 2021). Processing these events can be cognitively demanding for young viewers because of their novelty, unpredictability, and incongruence with laws. This processing requires re-assessment and re-arrangement of representations and knowledge. In the current study, some children's experiences and self-reports may be a sign of the cognitive fatigue that they experienced after watching the fantastical content. A few children in the fantastical cartoon conditions did not recognize that the cartoon was over and continued to look at the screen. Additionally, a few children

in the same conditions reported being tired without being asked at the end of the watching session. That some content can be exhausting is demonstrated in adult studies as well. For instance, Geiger and Reeves (1993) investigated the impact of watching semantically related and unrelated scene changes on attention. They found that processing unrelated sequences of scenes consumed cognitive resources more detected by longer reaction times to a secondary task while watching unrelated sequences compared to related sequences. Like viewing fantastical events, unrelated scene changes violate audiences' expectations, reorienting them to incorporate this novel and new information, thereby employing high levels of resources.

An unexpected finding in the present study is not observing a negative impact of fantastical content on cognitive flexibility. Although there is a trend ($p = .113$) in the data of this study showing that children in the fantastical cartoon-immediate testing condition performed worse in cognitive flexibility than children in the other conditions, the comparison between groups is not statistically significant. This null finding contrasts with most of the past research (e.g., Fan et al., 2021; Jiang et al., 2019; Rhodes et al., 2020) but is consistent with one recent study (Wang & Moriguchi, 2023). One possible explanation for the inconsistent evidence is to use different measures of cognitive flexibility. It is indicated that cognitive flexibility has distinct kinds that have different developmental trajectories and are assessed by different tasks and scoring (Blakey et al., 2016). In the studies examining the impact of fantastical content, a range of preschool cognitive flexibility measures, such as the Dimensional Change Card Sort (Zelazo, 2006), the Flexible Item Selection (Jacques & Zelazo, 2001), and the Head-Toes-Knees-Shoulders (Ponitz et al., 2009), were used. It is likely that one kind of cognitive flexibility might be strongly affected by watching fantastical content, whereas the other might be mildly impacted. On the other hand, the same task (Backward Span, Carlson, 2005; Davis

& Pratt, 1995) was used to measure working memory across the studies. And, all tasks (Go-No-Go, Wiebe et al., 2012; Flanker Inhibitory Control and Attention, Zelazo et al., 2013; Day/Night, Gerstadt et al., 1994) used to measure inhibitory control was based on the same principle which is responding to the cues that are relevant to the goal and suppressing responses to the cues that are not relevant to the goal.

It is also important to consider that watching fantastical content in the current study did not affect the skills measured by visual tasks. The present study used verbal tasks to assess working memory and inhibitory control. However, tasks including visual stimulus assessed cognitive flexibility and mental transformation. There is evidence showing that nonverbal tasks are easier for preschool children than verbal tasks because visual stimuli as external objects are encoded and represented easily (Jordan et al., 1992; Rasmussen & Bisanz, 2005). Given that some tasks, particularly difficult tasks, may be more susceptible to being affected by the depletion of resources, it is possible that watching fantastical content has more negative effects on the children's verbal cognitive task performances.

Additionally, not all three EF components were related to each other in this study. Inhibitory control was correlated with cognitive flexibility, whereas working memory was associated with inhibitory control but not cognitive flexibility. That there is no relation between individual EF tasks in preschool children or that intercorrelations among them are not particularly high is a frequently observed situation (Willoughby et al., 2011). This situation is speculated to result from the fact that although three EF components develop rapidly in preschool years, each of them has different developmental trajectories during these years (e.g., Anderson et al., 2010; Buttelmann & Karbach, 2017; Lillard et al., 2015a; Morasch & Bell, 2011). From that, some researchers even argue that EF

components should be treated as distinct features of executive functioning and investigated individually (e.g., Jiang et al., 2019; Memisevic & Biscevic, 2018).

4.2 Study Strengths and Limitations

The research went beyond the replication of previous studies by addressing two substantial gaps in the literature. Firstly, it examined how long fantastical content affected EFs in young children; secondly, it investigated whether fantastical content disrupted children's other cognitive skills. This study has some additional strengths. All EF components were examined individually in the present research rather than aggregating EF scores or focusing on single components. Considering that each EF component has distinct developmental trajectories and roles in cognition (e.g., Wu et al., 2011), it is important to examine the effects of fantastical content on individual aspects of EF. Also, there was a random assignment to conditions, and children in all conditions were equal in EF skills and attention-related problems at the outset. This eliminated the confounding effects of these variables. Finally, this study is the first to examine and show the negative effects of fantastical content on EFs with a sample other than English-speaking and Chinese preschoolers. Although it is demonstrated that EF has different patterns and correlates in different populations (e.g., Lewis et al., 2009), the results of this study indicated that all preschoolers from different cultures may face the same cognitive challenges in completing EF tasks demanding cognitive resources after watching fantastical cartoons.

Some limitations of the study should also be taken into consideration. This study measured working memory first, followed by inhibitory control, cognitive flexibility, and mental transformation. The observation of nonsignificant results for the last two tasks suggests that these null findings may be linked to the sequence effect. Although no such effect was reported in the previous studies, children might become reluctant to

immediately participate in a less exciting activity after watching an attractive and enjoyable cartoon and adapt to the situation in performing the third task. Latin Square design could be used to eliminate the possibility of sequence effect. Moreover, children's engagement during watching and testing sessions could be assessed to understand better that differences in task performance may be related to children's level of willingness and concentration.

After the pilot study, the present study was turned into a between-subjects design. However, pre-post-design would be better to examine the changes after watching the fantastical cartoon. On the other hand, previous screen exposure and socioeconomic level of children were not controlled in the current study. Considering the relationship between screen time, socioeconomic level, and EF skills in preschoolers (e.g., Kostyrka-Allchorne et al., 2017b; Lawson et al., 2018), previous screen experience and socioeconomic level could be assessed as covariate variables. Lastly, a single measure assessed each EF component and mental rotation skills. Given that some cognitive tasks cannot comprehensively represent all aspects of cognitive skills (e.g., Blakey et al., 2016), more than one task may be required to better understand the impact of fantastical content.

4.3 Future Directions

This study showed that the negative effects of fantastical content on EFs disappeared after 10 min. However, repeated short-term effects may lead to long-term disruption; thus, the impact of frequent exposure to fantastical content needs to be explored. Examining the long-term influence of television is challenging because parents may become reluctant to record their children's screen use habits over a significant period of time. Additionally, parents can make inaccurate reporting due to social desirability bias (e.g., Radesky et al., 2020). Further examinations should also be done on whether certain types of fantastical events lead to more cognitive depletion. For instance, processing

fantastical events that children are accustomed to viewing in cartoons (e.g., talking animals) may be easier than processing extremely novel fantastical events (e.g., a baby outing dozens of hands from his back).

In addition, we do not know yet whether making fantastical events familiar to children can eliminate the negative effects. Fantastical events require more cognitive resources to process in young children since children do not have any existing experience, schema, or established neural circuitry to make these unfamiliar events sense. Thus, viewing fantastical events more may make them less surprising, novel, and more familiar; eventually, they may be processed without any cognitive cost. Moreover, it can be tested whether cognitive taxation on EFs is alleviated by using simple and explanatory language in the cartoons because fantastical events can make more sense with words and be processed easily.

On the other hand, this study demonstrated that a 10 min break can eliminate the negative effects of watching fantastical content may be due to the recovery of cognitive resources. Previous studies indicated that recharging the resources effectively changed depending on the forms of breaks (Hunter & Wu, 2016). For instance, individuals filling their breaks with physical activity performed better on cognitive tasks (attention, problem-solving, and working memory tests) than those resting in a massage chair (Wollseiffen et al., 2016). In the next studies, the effects of different types of breaks after watching fantastical content can be examined. Finally, future researchers can make finer descriptions of EF components, measure them in diverse tasks and extend the investigation to other cognitive skills.

Chapter 5

CONCLUSION

Executive functions are important for children's educational, professional, social, and emotional success. Past studies provided empirical evidence that watching fantastical content immediately disrupted EF skills in young children. However, they did not investigate how long it took for the negative effects to wear off and whether the negative effects applied or extended to other cognitive skills. In addition to replicating the previous evidence, the current study addressed these issues. It first found that the disruptive impact of watching fantastical content disappeared in 10 minutes; secondly, the negative effects did not extend to the mental rotation task. Altogether, these results indicated that watching fantastical content may overload cognitive resources due to its unexpected and incomprehensible nature. This may result in insufficient resources for subsequent EF tasks. And the resources may need some time to be recovered. However, the negative impact of watching fantastical content did not extend to the 2-D mental transformation task. This suggests that specific tasks may be more susceptible to being affected by resource depletion stemming from watching fantastical content. Given the popularity of fantastical content among preschoolers, the present research is important to alert parents to regulate the content their children consume on the screens in addition to screen time.

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