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UNIVERSITY OF CALIFORNIA  
RIVERSIDE

Influence of Interactive Media on Episodic Memory Development  
During Middle Childhood

A Dissertation submitted in partial satisfaction  
of the requirements for the degree of

Doctor of Philosophy

in

Psychology

by

Ashley Ann Ricker

June 2016

Dissertation Committee:

Dr. Rebekah A. Richert, Chairperson

Dr. Chandra A. Reynolds

Dr. Elizabeth L. Davis

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2016

The Dissertation of Ashley Ann Ricker is approved:

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Committee Chairperson

University of California, Riverside

*This dissertation is dedicated to my father, Robert N. Ricker*

I would not be the woman I am today without your encouragement, love, and support

## ACKNOWLEDGEMENTS

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## ABSTRACT OF THE DISSERTATION

### Influence of Interactive Media on Episodic Memory Development During Middle Childhood

by

Ashley Ann Ricker

Doctor of Philosophy, Graduate Program in Psychology  
University of California, Riverside, June 2016  
Dr. Rebekah A. Richert, Chairperson

This dissertation evaluates the influence of exposure to interactive media and tablet-based gaming on metacognition and episodic memory development during middle childhood. Despite a growing body of literature demonstrating the impacts of exposure to interactive media on various aspects of cognitive development, the effects on episodic memory have been largely unexplored. This dissertation addresses this dearth by presenting a conceptual model that describes metacognition as mediating the effects of interactive media on episodic memory in middle childhood. This model allows for the production of multiple testable hypotheses and guides the four overarching research questions addressed in the dissertation. These research questions were investigated using multiple data sets, an experimental intervention, and a variety of statistical approaches across three manuscripts presented as chapters.

Findings suggest that the effects of interactive media are not uniform, but rather vary as a function of the child's age. That is, children's episodic memory encoding skills



are more susceptible to the influence of interactive gaming in middle childhood rather than early childhood, once metacognitive skills have come online. The impacts of interactive media also vary based on features of interactive devices or games and the environments they provide for children. Games high in adaptivity, control, and feedback provided children with more opportunities for metacognitive experiences. After a two-week intervention, manipulating the types of gaming environments children experience in the home, small but significant improvements in episodic memory encoding was observed.

This dissertation makes both theoretical and applied contributions to the field of cognitive development. Importantly, these findings provide insight into the mechanisms through which episodic memory is influenced by exposure to different types of interactive media. Additionally, they highlight the importance of considering specific features of interactive games or devices (e.g., adaptivity, control, and feedback) and the types of environments they provide for children in the design of future interactive media targeted at promoting learning environments. Finally, this dissertation provides readily translatable evidence-based research to a wide audience of consumers and policy makers regarding how exposure to different types of interactive media might enhance or inhibit children's metacognition and episodic memory development.

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## **Chapter 1: Introduction**

### **Overview**

This dissertation assesses models of episodic memory by examining contextual factors that may lead to adaptive and maladaptive changes in memory and learning. Specifically, this research evaluates the influences of exposure to interactive media on both metacognitive skills and encoding processes that influence the development of episodic memory during middle-childhood. By employing multiple methodological approaches including cognitive testing, experimental manipulations, naturalistic exposure sessions, and both parent and child questionnaires with a sample of diverse elementary school children, the present study captures findings that are generalizable to families in the United States.

Guided by the dual systems approach to explaining human memory set forth by Endel Tulving (1972), this dissertation differentiates between episodic and semantic memories. Additionally, this research differentiates encoding processes from those of consolidation and retrieval, consistent with an information-processing perspective on memory development. The present line of research takes a socio-cultural approach to understanding children's cognitive development. Socio-cultural theories describe children as active agents in their own cognitive development and emphasize the importance of understanding that development occurs in a specific cultural context (Gauvain, 2001; Vygotsky, 1978). These theories discuss the prominence of cultural tools in children's learning environments and how these tools may benefit cognitive processes (Gauvain, 2001). As such, this dissertation evaluates interactive media as a cultural tool that may

have a profound influence on the development of metacognitive skills and awareness necessary to utilize effective encoding strategies for episodic memory.

### **Episodic Memory**

Memory is generally defined as the process by which humans remember information. There are many types of memory that are studied in the field of psychology. Tulving (1972) differentiated between two stores in long-term memory, one that contains information about general knowledge (semantic memory) and one that contains memory traces of information for personal experience (episodic memory). Episodic memory is a form of declarative memory in which individuals have a capacity for consciously recalling facts and events (i.e., times, places, and occurrences) that they experience personally (Squire, 2004; Tulving, 2002). This type of memory allows both children and adults to navigate their world in an efficient manner and translates into learning as it provides children with context-based remembering used to build their knowledge base. When studied empirically, episodic memory performance is often measured via performance on free recall tasks, recognition tasks, or paired association tasks whereby information is presented to an individual and memory performance for these tasks is dependent on the individual's ability to encode, consolidate, and eventually retrieve the presented information (Czernochowski, Mecklinger, & Johansson, 2009; Shing, Werkle-Bergner, Brehmer, Müller, Li, & Lindenberger, 2010).

The first step in forming new episodic memories is encoding, which involves perceiving the new information (e.g., seeing or hearing a stimuli) and forming a mental representation of the information in order to allow the perceived item of interest to be

converted into a construct that can be stored within the brain (Tulving, 1972). Once information has been encoded, it is stored in the short-term memory store. In order for information to be moved into long-term memory, consolidation (i.e., the cellular and systematic stabilization of a memory trace into a long term memory) needs to take place (Wixted & Squire, 2010). The last step in episodic memory is retrieval, which involves the process of pulling information out of memory in order to restate what one previously learned (Wixted & Squire, 2010). All three of these processes have been well defined in previous literature and studied at specific periods in the lifespan; however, over the course of the lifespan these three mechanisms mature and deteriorate at different rates, leading to differential influences by environmental contexts during different sensitive periods.

### *The Development of Episodic Memory*

The typical trajectory of change in episodic memory over the lifespan is roughly U-shaped, showing rapid increases in childhood as well as adolescence and decline later in life. Typically, by 2 to 3 years of age, children are able to organize and recall temporally accurate descriptions of events (Fivush, 1997), this skill acquisition coincides with the development of the hippocampus as well as general changes in language development early in life (Squire, 2004; Pathman, Samson, Dugas, Cabeza, & Bauer, 2011). In the preschool years, episodic memory has been theorized to come online as children's theory-of-mind abilities increase (Perner, Kloo, & Gornik, 2007). However, strategic behaviors and increased attention, which assists with the development of efficient encoding skills, are not practiced until ages 7 to 10 (Bjorklund & Douglas, 1997;

Schneider & Pressley, 2013; Trick & Enns, 1998); and episodic memory has been described as reaching peak performance sometime during late adolescence (i.e., between the ages of 15 and 20, Shing et al., 2010; Sprondel, Kipp, & Mecklinger, 2011). These changes coincide with increases in metacognitive skills (Kuhn, 2000), executive functioning (De Luca et al., 2003; Sabbagh, Moses, & Shiverick, 2006), and continuing development of and changes in the prefrontal cortex during this developmental period (Aine et al., 2011; Shing et al., 2010; Squire 2004). Additionally, findings from cross-sectional work suggest that changes in episodic memory performance, flattening out and the beginning of decline, can be seen as early as the third decade of life (Salthouse, 2009). Between the ages of 55 and 80, episodic memory, like most cognitive abilities, shows modest and gradual decline with much steeper decline after the age of 80 (Dixon, Wahlin, Maitland, Hultsch, Hertzog, & Bäckman, 2004).

A large body of literature in the field of cognitive psychology has examined episodic memory performance at one time point (e.g., Salthouse, 2009), however recent developmental work has focused on discussing changes in episodic memory over the lifespan. Based on a review of this literature, which has focused on maturational influences on episodic memory (e.g. development, organization, and deterioration in brain structures involved in encoding, consolidation and retrieval), Shing and colleagues (2010) posited that typical changes in episodic memory seen during specific developmental periods might be attributed to changes in these processes differentially. Specifically, changes seen to episodic memory during early life (i.e., before peak performance) are most likely due to changes in strategic and attention skills that affect



encoding, while changes to episodic memory experienced by older adults are most likely due to a combination of changes and deterioration in the brain regions that affect both encoding and consolidation (Shing et al., 2010). However, aside from biological maturation there are a number of aspects of development that influence episodic memory over the lifespan including environmental influences on contextual learning such as parenting practices, cultural focuses, exposure to technological advances, formal schooling, activity levels, stress and adversity. Because the maturational factors relevant to episodic memory differ across the lifespan, it is important to investigate how experiential and contextual factors interact with maturational factors in the development of episodic memory during specific developmental periods.

#### *Episodic Memory in Middle Childhood*

Middle childhood, typically referred to in the developmental literature as between the ages of 6 and 10, is a period of critical change in episodic memory because it is a period of increasing attention and control in the developing child's brain. Prior to middle childhood, memory performance and the formation of memories are qualitatively different than memory performance and the formation of memories in adulthood; however, during middle childhood memory performance begins to look more like that of an adolescent or adult. Infants in the first few months of life are able to remember information implicitly (i.e., without conscious awareness of remembering; Nelson, 1995). However, they are not able to remember lists or details about particular events (Bjorklund, 2012). During the preschool years, between the ages of 3 to 5, memory becomes more intentional (i.e., more explicit) and more strategic (Galotti, 2012); yet,

children at this age display production deficiencies with strategy usage for encoding information (Keeney, Cannizzo, & Flavell, 1967). A production deficiency exists when adults can prompt or guide children to use a specific encoding strategy successfully, however the child will not spontaneously employ these strategies on their own afterward. This deficiency has been demonstrated in multiple studies (Flavell, Beack, & Chinsky, 1966; Istomina, 1982) and discussed as a result of a lack of metacognitive skills in children between the ages of 3 and 5 (Galotti, 2012). Specifically, children in this age range lack the knowledge of how their cognitive processes work needed to be able to take the actions necessary to help them remember.

During middle childhood, children develop the metacognitive skills, strategic behaviors and increased attention needed to encode information effectively. Between the ages of 5 and 9, the ability to ignore irrelevant stimuli increases (Bartgis, Lilly, & Thomas, 2003); and between the ages of 5 and 7 there are dramatic brain developments with regard to attentional networks (Posner & Rothbart, 2007). As a result of these maturational changes, along with the influence of formal schooling during these years, changes in ability and strategy use take place. By the time children leave elementary school, they are typically able to describe an event they have experienced (or the context in which they learned new material) with great detail, and are capable of utilizing multiple encoding strategies successfully (Galotti, 2012).

### *Encoding Strategies in Middle Childhood*

An encoding strategy is a deliberate plan to enhance performance (Harnishfeger & Bjorklund, 1990) or form a memory trace (i.e., the act trying to remember something).

There are two main encoding strategies that children begin to utilize and typically master during middle childhood. One involves organization of items into categories in order to more easily remember them (Naus, & Ornstein, 1983). Most preschoolers do not use an organization strategy spontaneously, but can use one, with limited effectiveness, if prompted to do so (Schneider & Bjorklund, 1998). By age 6, children are effective at implementing this strategy and can utilize it almost implicitly (i.e., without conscious awareness). The other encoding strategy is maintenance rehearsal, which involves repeating the stimuli several times to one's self (Bjorklund, 2012). This is a more passive, low-effort, form of rehearsal, and children demonstrate the ability to effectively utilize this strategy between 6- to 10-years of age, with older children being more likely to rehearse information (Flavell, Beach & Chinsky, 1996). In order to master these strategies, and see direct benefits from them, children need to become familiar with the strategies through continued use, which leads to the efficient and more effective employment of these strategies (Miller, Seier, Barron, & Probert, 1994). However, before children can master encoding strategies, they need to recognize a need for them; which requires children to be aware of their cognitive processes.

### **Metacognition**

Flavell (1979) was the first researcher to describe metacognition, and he did so in the context of educational research. He referred to metacognition as the ability of individuals to think about their own thoughts, or to have cognitive awareness about cognitive objects. He noticed that young children did relatively little monitoring of their own comprehension and other cognitive activities, despite the importance of this

monitoring for successful completion of tasks and learning. Metacognition has been described as being divided in to two highly related components, metacognitive awareness (or knowledge) and metacognitive skills (Brown, 1987; Flavell, 1987; Schraw & Dennison, 1994; Sperling, Howard, Staley, & DuBois, 2004). Metacognitive awareness refers to knowledge about one's self and about learning strategies as well as knowledge about when, why, and how to use these strategies. Metacognitive skills refer to conscious regulation of cognition (i.e., comprehension monitoring and evaluation). According to Flavell (1979), these components are improved via metacognitive experiences (i.e., conscious thoughts and reflections on cognitive processes that occur in response to novel roles or situations that involve decisions and actions).

#### *Metacognition in Middle Childhood*

Typically, children between the ages of 3 and 4 years old begin to develop an understanding of how their beliefs, as well as other people's beliefs, about the world around them come to be and are revised through gained knowledge (Leslie, 1992; Wellman, 1992). Theory-of-mind and children's perspective-taking have been discussed as foundational for metacognition, as early awareness of the origin of knowledge is a critical first step in being able to build-up complex higher-order thoughts later in life (Ebert, 2015; Kuhn, 2000). However, less is known about the trajectory of metacognitive development, relative to that of theory-of-mind, throughout middle childhood and adolescence. Behavioral studies have observed children as young as 3 years of age engaging in metacognitive behaviors (e.g., displaying verbal knowledge of a strategy, monitoring their own progress, deliberating; Whitebread et al., 2009), and metacognition

has been found to be important for problem-based learning for children starting in the second grade (i.e., 7 to 8 years of age; Shamir, Zion, & Spector-Levi, 2008). However, even emerging adults have been able to improve their metacognitive skills with specific problem-based training (i.e., studying in tutorial groups attempting to understand, explain, and solve problems using seven problem-based learning steps, Downing et al., 2009).

### *Measurement of Metacognition*

Consensus does not exist regarding the best method for assessing or measuring metacognition. One common method is self-report, and the measurement most commonly used is the Metacognitive Awareness Inventory (MAI; Schraw & Dennison, 1994). The MAI is a 52-item instrument used to examine both metacognitive awareness (or knowledge) and metacognitive regulation in adolescents and adults. Self-reports of metacognition have also been collected with children between the ages of 8 and 11 using the Jr. MAI (Sperling, Howard, Miller, & Murphy, 2002), which contains developmentally-appropriate language allowing for verbal responses from children to questions such as “I know when I understand something” or “I think of several ways to solve a problem and then choose the best one.” Multi-method interviews have also been implemented using a combination of verbal reports, interviews, and teacher or parent reports of children’s metacognitive abilities (see Wilson, 2001; Wilson & Clark, 2004). Additionally, observational methods have been used in order to have teachers report on and allow researchers to code for both verbal and non-verbal indicators of metacognition in younger children ages 3 to 5 (Whitebread et al., 2009) and ages 5 to 7 (Bryce &

Whitebread, 2012). A verbal indicator would be a verbalization demonstrating explicit expression of one's knowledge (e.g., explains procedures in a particular task), whereas a non-verbal indicator would be a behavior that suggests reflective thought is taking place in a decision or selection (e.g., a child compares two objects before deciding which one to use for a task). The best approach to examining a child's metacognitive abilities is likely a multi-method approach that involves some combination of observational techniques and self-report. Further, it is important to separately assess children's metacognitive skills, metacognitive awareness, and metacognitive experiences, to fully capture the multiple facets of metacognition.

### **Metacognition and Episodic Memory**

The first challenge to effectively implementing encoding strategies for children during middle childhood is knowing when and how to use them (Galotti, 2012). In order for a child to implement an encoding strategy spontaneously, he or she must assess the challenge in front of them and recognize their own need for the strategy. Without metacognition, children are unable to make such assessments or adjustments, because children cannot think about their thinking and employ strategies for planning and controlling their own thought processes, resulting in production deficiencies.

Metacognitive skills that are being developed during middle childhood allow children not only to employ strategies but also to gain knowledge of how their memory works and when and how it fails them. Importantly, these metacognitive skills do not develop in a vacuum, but rather are developed within the context of the environments children find

themselves in. One environment children are increasingly finding themselves in is one in which they are being exposed to interactive media in one form or another.

### **Interactive Media**

Interactive media can refer to a number of different platforms and devices, including Internet exchanges, interactive books and toys, computer games, video games and smartphone/tablet based applications (Stewart & Pavlou, 2002). Young children are using increasing amounts of interactive media in their day-to-day lives, especially through recreational and educational video games (National Association for the Education of Young Children, 2012). More than 50% of game console owners are children between the ages of 2 and 17, and 88% of children ages 8 to 17 have played at least one video game (Blumberg & Altschuler, 2011; Gentile, 2011). According to a recent report by Common Sense Media (2013), roughly 85% of families with 0- to 8-year-olds have access to some type of mobile media device. Among children ages 5 to 8 years of age, 83% have used mobile applications for gaming (Common Sense Media, 2013). This increasing and prevalent exposure to interactive media occurs during a period in early development when children begin to show rapid increases in memory abilities imperative to learning. Furthermore, a number of educational video games and interactive media targeted at improving cognitive functions have been introduced in recent years (e.g., Lumosity and LearningRx). However, research examining the effectiveness of using these games as educational tools is lacking.

### *Elements of Interactivity*

A pre-requisite to estimating the effectiveness of interactive media on cognitive functioning is clearly defining what it means to be interactive. The first key to interactivity is that it is reciprocal, such that both the user and machine (for the purposes of the proposed research the child and the game) need to take an active role in the interaction (O’Keefe & Zehnder; 2004). Additionally, there are a number of elements of interactivity discussed in the literature of interactivity on which games can be rated, including adaptivity, control, feedback, creativity, and communication.

*Adaptivity.* Games can vary in both how flexible and how adaptive they are for the user (Magerko, 2008). Adaptivity in a game means that the experience changes for children to meet their specific need, interests, skill level or behaviors. A game rated as high in adaptivity can change what it is presenting to the child moment-to-moment, based on how the child is responding or performing, while a game rated as low in adaptivity might only be able to meet a child’s needs at the start of a gaming session (e.g., choosing a level; beginning, intermediate, or expert).

*Control.* Games can also vary in the amount of control that they maintain or relinquish to the child, which has also been discussed as a degree to which a device is interactive (McMillian & Hwang, 2002). That is, games vary in how much control the child has to choose her or his activity within the game. Games rated as having high control (i.e., child has high control), would be exploratory type games where the child can move back and forth between games without rules, whereas games rated as low



control (i.e., child has low control) might have structured lessons that must be followed in a particular order.

*Feedback.* Arguably the most imperative prerequisite to calling a medium or device interactive is whether it provides feedback (Rafaeli & Sudweeks, 1997). That is, whether the game provides the child with an indication of how he or she is doing. Games rated as having high feedback often provide instantaneous, real-time feedback, while those rated as having low feedback might offer some sort of delayed at the end of a challenge or task feedback.

*Creativity.* Another element of interactivity discussed in the literature is creativity, as a game can vary in the amount of creativity it encourages and allows for (Wartella, O'Keefe, Scantlin, 2000). Games rated high in creativity allow children to give multiple correct responses or take multiple paths to arrive at the same response, whereas a game rated low in creativity would be more rigid in response criteria.

*Communication.* Finally, games can allow the child or user to not feel alone, by communicating with her or him or offering support during an interaction (Rafaeli, 1988). More recently, technologies have advanced these elements of interactivity by increasing their sensitivity and capability for input and output. Games rated as having high communication would be able to engage in very supportive interactions for the child. By utilizing features such as voice recognition, they are able to receive input from the child and personalize the output (communications) sent. Alternatively, games that would be rated as having low communication would only allow for manual input of information (e.g., entering or typing in information about the user for the game to respond to).

It is important to clearly define these elements of interactivity, to allow researchers to appreciate the variability that exists in types of interactive media exposure. Different interactive media mediums (e.g., e-books, video games, mobile devices) as well as different specific games will vary in these elements of interactivity. These variations matter, as they could lead to differential impacts on the user. The focus of this dissertation is the influence of interactive media on memory development; in particular it was important to investigate elements of interactivity that might impact children's metacognitive experiences and episodic memory while gaming. Therefore, adaptivity, control and feedback were closely examined.

### *Interactive Media and Cognitive Development*

Previous research has suggested that exposure to interactive media, specifically to video games, may improve a number of cognitive abilities in adults, such as spatial ability, problem solving, cognitive flexibility, visual attention, and spatial relations (Bavelier, Green, Han, Renshaw, Merzenich, & Gentile, 2011; Feng, Spence, & Pratt, 2007; Green & Bavelier, 2003; Powers, Brooks, Aldrich, Palladino & Alfieri, 2013). Past work has been a combination of comparing gamers to non-gamers, along with controlled experiments bringing non-gamers into the lab and training them to look for benefits that could be linked to the training. However, despite this growing field, there has been much less empirical work examining the effects of video games on children's cognitive development (Green, Bavelier, & Dye, 2010; O'Keefe & Zehnder, 2004).

There has been limited research from developmental psychologists and educational researchers examining the impact of interactive media on some cognitive

domains. For instance, video gaming has been related to increased selective attention and visual perception, in children ages 7 to 11 years old, as this type of gaming requires the utilization of these cognitive skills (Blumberg, Altschuler, Almonte, & Mileaf, 2013). Also, relationships have been found between interactive media usage and problem solving and reasoning in adolescents (Blumberg 1998; Adachi & Willoughby, 2013). More recent work has examined interactive Wii fit video game play and the positive effects it has on executive functioning in middle childhood (Flynn, Richert, Staiano, Wartella, & Calvert, 2014).

Further exploration is needed on the influences of interactive media in middle-childhood, particularly both educational and recreational video gaming, and how they might interact with the successful development of metacognition as well as memory and learning. There has been only very limited research in the field addressing interactive media and memory. For example, Ricci and Beal (2002) examined differences in story memory performance for 6- to 7-year-olds when learning from interactive reading devices compared to television-based programs and found no advantage for reading through interactive media. One reason for their lack of finding could be methodological, along with comparing an Interactive Media condition to a Television control condition, it would have made sense to control for as many potential moderators of the effect as possible. Based on the previous discussion of metacognition, the proposed study posits metacognition as a key variable in understanding the relationship between interactive media and episodic memory.

### *Interactive Media and Metacognition*

Electronic gaming environments and mobile game applications present learning spaces for children in which their mental states can be challenged. Children are able to see both realistic and fantastical scenarios play out on screen, and have to learn patterns and rules about what will lead them to success as they navigate a new digital world. Successful navigation of the game and completion of tasks within a game require problem solving, discovery-based learning, and problem resolution in a safe environment. Within electronic gaming, children are able to work in an environment where theories and scenarios can be tested out immediately, which supports knowledge acquisition. For example, many games present tasks to challenge a player, and then provide feedback on performance. The feedback provided, whether explicit or not, can be integrated into the players' knowledge and utilized to make cognitive adjustments to their approach before reattempting to overcome the same task (Ko, 2002; Steinkuehler, 2006).

From a socio-cultural prospective of development, this type of interaction with a cultural tool can be thought of as supporting adjustment (Gauvain, 2001), as support from an electronic agent within the game is scaffolding the experience of the gamer. This pattern of the game providing adaptive feedback in response to novel and challenging tasks should support cognitive development, as long as the challenges presented to children are developmentally appropriate (i.e., fall within the Zone of Proximal Development; Vygotsky, 1978). Previous research has demonstrated 10- and 11-year-old children who are classified as frequent gamers (i.e., they have been gaming in this type of environment consistently for 3 to 5 years) display exceptional self-monitoring, principled

decision making, and qualitative thinking (VanDeventer & White, 2002). These findings suggest that with repeated exposure to gaming, and this unique learning environment, children might be able to build up their metacognitive knowledge and translate this into increased metacognitive skills.

### Summary

This dissertation examines the influence of exposure to different types of interactive media (i.e., those that vary in adaptivity, control and feedback) on metacognitive skills and encoding processes imperative to memory and learning. Gaming on multiple devices, including within tablet based applications, is examined as a cultural tool that promotes the development of metacognitive skills by providing children with opportunities for metacognitive experiences. The conceptual model put forth by this dissertation posits that interactive media and interactive gaming environments provide children with the opportunity for metacognitive experiences, which promote children's metacognitive awareness and skills. Further, it theorizes that this improvement in metacognitive skills promotes children's effective use of strategies for encoding information and enabling the formation of episodic memory (see Figure 1).

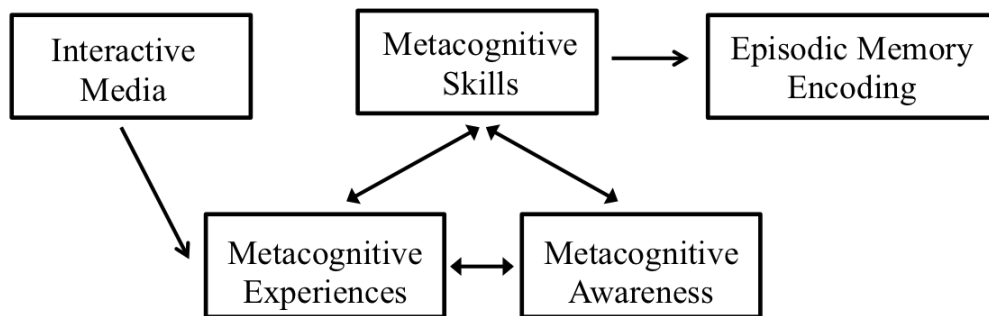


Figure 1. Conceptual Model: Interactive Media, Metacognition, and Episodic Memory Encoding

This dissertation includes a series of three manuscripts, organized into chapters, which examine this conceptual model. Chapter 2 describes secondary data-analysis of a one time-point study including children in early childhood between the ages and 4- to 6.5 years old along with a meta-analytic evaluation of current literature investigating the link between exposure to interactive media and memory across a wide range of ages. As a part of the meta-analytic work, age was evaluated as a moderator of this association, specifically in relation to children before and after preschool age. Chapter 3 evaluates parent report of children's previous exposure to interactive media as a predictor of episodic memory encoding in middle childhood between the ages of 6- to 10 years old, with metacognitive awareness evaluated as a potential mediator of this relationship. Finally, Chapter 4 presents an experimental examination of whether particular types of interactive media exposure can promote or inhibit episodic memory encoding performance and metacognitive skills in middle childhood between the ages of 6- to 10 years old.

This research contributes to the field of cognitive development by furthering the understanding of developmental processes involved in episodic memory development during early childhood. By elucidating the relationship between metacognition and the successful encoding of episodic memories in early development, as well as the impacts of interactive media exposure on this relationship, this dissertation has the potential to inform teaching interventions that involve interactive media usage designed to promote learning and memory. Furthermore, findings from this line of research will provide consumers of interactive media and video games with evidence-based information

regarding the ways in which exposure to these types of media might enhance or inhibit children's memory development.

### **Research Questions and Hypotheses**

**Research Question 1)** Is previous interactive media exposure related to episodic memory performance in early to middle childhood? Does the magnitude of association between previous interactive media and episodic memory vary as a function of age?

*Hypothesis 1a)* Previous exposure to interactive media will be positively related to episodic memory performance in middle childhood.

*Hypothesis 1b)* The magnitude of the effect of previous interactive media on episodic memory performance will be stronger in older children than in younger children.

**Research Question 2)** Does interactive media provide children with the opportunity for metacognitive experiences? And, do different types of gaming environments differentially influence children's metacognition in middle childhood?

*Hypothesis 2a)* Children will have opportunities for metacognitive experiences while playing interactive tablet games.

*Hypothesis 2b)* Exposure to games high in adaptivity, control, and feedback will provide children with more opportunities for metacognitive experience and subsequently have a positive influence children's metacognitive awareness. Alternatively, exposure to games low in adaptivity, and feedback will afford children fewer opportunities for metacognitive experiences, and will not be predictive of children's metacognitive experiences.

**Research Question 3)** Does metacognitive awareness mediate the relationship between previous interactive media and episodic memory performance?

*Hypothesis 3)* Metacognitive awareness will mediate the relationship between previous interactive media exposure and episodic memory performance.

**Research Question 4)** Can interactive media promote increased episodic memory encoding and/or increased metacognitive skills through exposure to games that provide children with the opportunity for metacognitive experiences?

*Hypothesis 4a)* Over the course of a two-week intervention, children exposed to games that provide greater opportunity for metacognitive experiences will show increased performance in episodic memory encoding compared to children exposed to games that provide less opportunity for metacognitive experiences.

*Hypothesis 4b)* Similarly, over the course of a two-week intervention, children exposed to games that provide greater opportunity for metacognitive experiences will show increased performance in metacognitive skills compared to children exposed to games that provide less opportunity for metacognitive experiences.



## **Chapter 2: Interactive Media and Memory Across Age**

**Citation:** Ricker, A. A., Richert, R. A., & Robb, M. (revise, resubmit). Age moderates the impact of interactive media on memory: Support for a Metacognitive Constraints Model. *Frontiers in Psychology*.

### **Abstract**

Previous research has demonstrated a relationship between use of interactive media (e.g., e-books, video games, touch-screen devices) and aspects of cognitive development, such as selective attention, problem solving, and executive functioning. However, minimal research has examined the impact of interactive media on episodic memory. A review of the limited literature on the influence of interactive media on memory related outcomes demonstrates mixed findings. In this Perspective Article, we present a conceptual model that highlights the importance of considering children's metacognition when investigating the impact of exposure to interactive media, including touch screen devices, and memory outcomes. Further, we discuss original findings from a cross-sectional study examining the effect of previous exposure to interactive media on children's episodic memory in 4- to 6-year-olds and a reanalysis of a meta-analytic study investigating the effects of interactivity on story comprehension. Both sets of findings demonstrate that age does significantly moderate the effects of interactive media on memory and story comprehension, such that as age increases the impact of interactive media on memory is greater. These findings not only elucidate periods of development that may be more or less susceptible to the impacts of interactive media exposure, but also provoke theoretical questions regarding the mechanisms at play. Taken together, these results offer

preliminary support for a Metacognitive Constraints Model, which predicts differential effects of interactive media on memory based on age-related constraints to metacognition.

*Keywords:* interactive media, interactivity, metacognition, memory, comprehension

### **Exposure to Interactive Media across Development**

Interactive media is increasingly a context in which children develop (Blumberg & Fisch, 2013). In the United States, parents have reported an increase in usage of mobile devices from 2011 to 2013; roughly 85% of families with 0- to 8-year-old children now have access to some type of mobile media device, and among children ages 5- to 8-years-old, 83% have used mobile applications for gaming (Common Sense Media, 2013). A large proportion of interactive media usage in the day-to-day lives of children takes the form of recreational and educational video games (National Association for the Education of Young Children, 2012). This increasing and prevalent exposure to interactive media occurs during a period in early development when children begin to show rapid increases in episodic memory abilities imperative to learning (Perner & Ruffman, 1995; Shing, Werkle-Bergner, Brehmer, Müller, Li, & Lindenberger, 2010). Episodic memory (i.e., explicitly remembering times, places, specific events and personal facts; Tulving, 2002) allows children to effectively navigate their world, and translates into learning as it provides children with context-based remembering used to build their knowledge base. Although previous research has demonstrated a relationship between interactive media use and various aspects of cognitive development, including selective attention, problem solving, and executive functioning (e.g., Blumberg & Randall, 2013; Flynn et al., 2014),

research directly examining the impact of interactive media use on episodic memory is limited.

Prior studies have examined the impact of interactivity on memory-related outcomes (e.g., story comprehension which relies on recall and recognition; Mandler & Johnson, 1977), as well as learning from interactive material. However, findings from this body of work are mixed. Research with 1- to 2-year-olds finds no increases in word learning following exposure to interactive DVDs (Robb, Richert, & Wartella, 2009; Richert, Robb, Fender, & Wartella, 2010). Similarly, work investigating the association between control of interactive devices and memory outcomes finds no relationship between the two in preschool-aged children (3- to 6-years-old; Calvert, Strong, & Gallagher, 2005). However, findings regarding the impact of interactive media on story comprehension indicate positive, negative, and non-significant relationships across a variety of ages (see for a review Takacs, Swart, & Buss, 2014). Incidentally, recall of specific facts and events as well as memory for new concepts, has been found to be positively influenced by computer-based training and video gaming in a wide age range from third-grade (7- to 8-years-old) to high school students (16- to 17-years-old; Chuang & Chen, 2009; Papastergiou, 2009). The effects of media exposure have been proposed to have differential effects based on children's dispositional and developmental susceptibility (Valkenberg & Peter, 2013). Of particular relevance to these mixed findings, children at different ages approach interactive devices with differential cognitive abilities that have the potential to alter the experience the child has with an interactive device.

## **The Metacognitive Constraints Model**

One cognitive process related to memory that undergoes change in early childhood is metacognition (i.e., one's ability to think about and control their own cognition; Flavell, 1979). Metacognition is of relevance to episodic memory, as it facilitates effective encoding strategies for children during middle-childhood, including knowing when and how to use them (Galotti, 2012). Further, both early episodic memory development and metacognition have been discussed in previous research as being related to theory-of-mind (Perner, Kloo, & Gornik, 2007; Kuhn, 2000). Episodic memory is thought to come online in the preschool years as theory-of-mind abilities increase (Perner, Kloo, & Gornik, 2007). Additionally, theory-of-mind and children's perspective taking abilities are discussed as the foundation of metacognition (Kuhn, 2000), as early awareness of the origin of knowledge is a critical first step in being able to build-up complex higher-order thoughts later in life (Ebert, 2015). Flavell (1979) described metacognitive skills as being enhanced over time as children respond to novel roles or situations that involve decisions or actions allowing them to engage in conscious reflections on their own cognitive processes (i.e., metacognitive experiences). An interactive environment is one potential context that affords children the opportunity for metacognitive experiences. In fact, previous findings suggest that children who are frequent gamers display exceptional metacognitive skills (VanDeventer & White, 2002).

In this perspective, we present the Metacognitive Constraints Model, a conceptual model for understanding how and when interactive media influences children's episodic memory development. Our model specifically posits that interactive media exposure and

gaming on touchscreen devices may influence children's episodic memory by providing opportunities for metacognitive experiences. According to this model, children and interactive devices engage in a dyadic interaction. In order for gaming on these types of devices to influence children's memory through this interaction, both the child and the game must not be constrained.

First, the child must have some level of metacognitive skills in order to demonstrate influences of interactive gaming on memory. Children with less developed metacognitive skills are limited in their ability to employ reflective cognition and monitoring. As such, there may be constraints on the extent to which interactivity will influence children's memory based on differential developmental susceptibilities related to metacognitive skills (Valkenberg & Peter, 2013). Thus, the Metacognitive Constraints Model posits that younger children, with metacognitive constraints, are limited in the memory benefits they glean from interactive gaming as their dyadic interactions with these devices and their features may be qualitatively different before they have begun to develop metacognitive awareness. Understanding the constraints related to young children's metacognitive abilities is especially relevant given that children as young as 6 months of age are using touchscreen, mobile devices (Kabali et al., 2015). In contrast, children who have begun to develop metacognitive awareness may begin to experience benefits from interactive gaming in terms of metacognition and therefore episodic memory.

Second, the game must not be constrained in the opportunities for metacognitive experience it can provide for the child. Previous research on various types of electronic

games suggests that not all interactive games incorporate the same degree or types of interactivity (see for example Hirsh-Pasek et al., 2015). Games differ both in terms of how they interact with the child (e.g., touch screen or computer based point and click) as well as the type of environment they provide. Some gaming environments present cognitively challenging learning spaces for children in which scenarios play out on screen, and children have to learn patterns and rules about what will lead to success as they navigate a new digital world. In these environments children can observe cause and effect can play out in real time, and track how their manipulation of the environment influences this process. Successful completion of these challenges can be beneficial for children, as engaging in reflective cognition and monitoring, allowing for metacognitive experiences (Flavell, 1979). As such, gaming environments (including touchscreen apps) that provide high levels of adaptivity, player control, and sensitive feedback may be expected to have the greatest degree of influence on children's metacognitive skills, and thereby memory.

As no current research has examined the relation between features of games and children's metacognitive skills or awareness, we examined the available literature for evidence supporting the cognitive developmental aspect of the model. Specifically, the Metacognitive Constraints Model posits that children with less developed metacognitive skills (e.g., younger children) should experience less impact of interactive media use on memory. We present results from two studies demonstrating that age moderates the effects of interactive media on memory, and examined these data to identify developmental periods (i.e., periods of differential metacognitive abilities before or after

6 years-of-age) in which children have increased susceptibility or reduced sensitivity to the effects of interactive media use on memory. In Study 1, cross-sectional methods were implemented to examine if the effect of prior interactive media exposure on children's episodic memory was moderated by age across the preschool years. Study 2 utilized meta-analytic techniques to examine age as a moderator of the effect of interactivity on story comprehension and memory in prior research.

### **Study 1: Cross-sectional Study on Exposure to Interactivity and Episodic Memory**

Study 1 examined age as a moderator of the relationship between children's previous exposure to interactive devices and their story memory. Families visited the laboratory individually, and parent report of children's prior exposure to interactive devices was examined as a predictor of children's memory performance. Seventy-seven English-speaking children ( $M_{age} = 4.89$  years,  $SD = 0.51$  years, range = [4 -6.5 years]; 46.75% female) were included; children with developmental delays or other disabilities that prevented them from participating fully were excluded from the study. To quantify previous exposure to interactive media (IM Exposure), parents responded to six questions, 3 on e-books and 3 on video game consoles (adapted from Rideout et al., 2010). First, parents were asked to report on the number of devices (e-books and game consoles) available to the child in the household ( $a$ ; parent's open-ended responses ranged from 0 to 6). [Note: These data were collected from 2009 to 2010, before touchscreens and smartphones were widely available in American homes.] Next, parents reported how often children played with each type of device ( $b$ ; 0 = never, 1 = less often, 2 = several times a year, 3 = several times a month, or 4 = every day). Finally, parents

reported the age at which their child first played with each type of device ( $c$ ; responses ranged from not yet [0] to as early as 6-months-old). Responses from these questions were used to calculate a variable representing quantity and duration of IM exposure<sup>1</sup> ( $M = 10.65$ ,  $SD = 4.49$ , range = 2-21). Children were assessed with the Peabody Picture Vocabulary Test, in order to examine variability in children's verbal ability (scaled scores:  $M = 105.81$ ,  $SD = 14.65$ , range = 62-135). To evaluate memory, children completed a story reading session of *Curious George Goes to a Chocolate Factory*, and free recall was immediately assessed. Children were prompted to recall the story (prompt: I'd like you to tell me about the story you just heard. Can you tell me everything that happened in the story? Start by telling me what happened at the beginning of the story.) Further, three additional systematic prompts were used encourage responses (i.e., Anything else?; Tell me some more from the story.; Think really hard and tell me something else from the story). Responses were coded for correctness and the number of individual correct details recalled was tallied ( $M = 3.56$ ,  $SD = 2.95$ , range = 0-12).

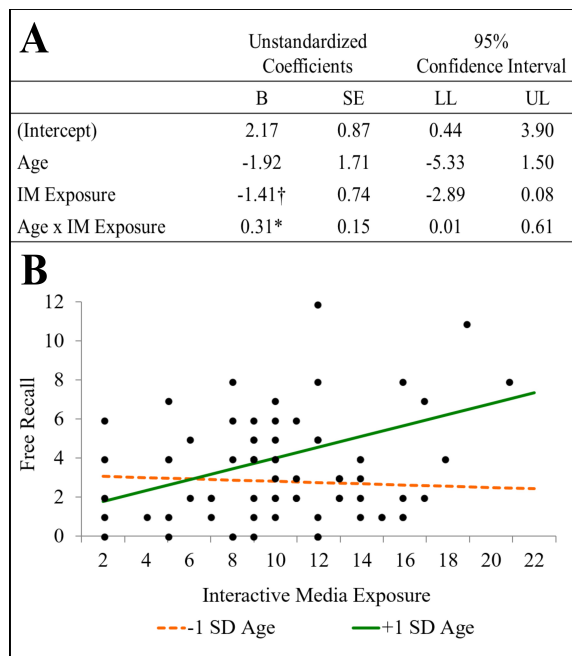
A Pearson product correlation coefficient examined the association between IM exposure and memory, and found a marginally significant moderate association,  $r = .22$ ,  $p = .060$ . In order to test if the association differed based on the child's age, hierarchical multiple regression examined age as a moderator of the association between IM exposure and memory. First, age and IM exposure were tested as predictors of memory performance; together they accounted for 7% of the variance in children's memory

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<sup>1</sup> Exposure =  $[(q_{e-books} \times d_{ebooks}) + (q_{videogames} \times d_{videogames})]$   
 where (q) quantity of specific device exposure =  $a \times b$ ;  
 and (d) duration of exposure = (child's age at visit to the lab -  $c$ ) where  $c \neq 0$ ;  $d = 0$  where  $c = 0$



performance,  $R^2 = .07$ ,  $F(2, 74) = 3.91$ ,  $p = .024$ . Verbal ability was included as a predictor but did not improve model fit,  $\Delta R^2 = .02$ ,  $\Delta F(1, 73) = 1.70$ ,  $p = .194$ . However, a model including the interaction between age and IM exposure significantly improved model fit,  $\Delta R^2 = .05$ ,  $\Delta F(1, 73) = 4.25$ ,  $p = .043$  (see Figure 2A for model parameters). This interaction demonstrates that as age increases the association between prior exposure and memory increases. More specifically, for children one standard deviation below the mean age, there was almost no association between prior exposure and memory. However, for children one standard deviation above the mean age, a positive association was observed, such that increased prior exposure to interactive media was related to increased memory performance (see B).



*Figure 2.* Chapter 2: Results from Study 1. **(A)** Parameters from regression model predicting Free Recall from Age and Interactive Media (IM) Exposure,  $\Delta R^2 = .05$ ,  $\Delta F(1, 73) = 4.25$ ,  $p = .043$ ; \*  $p < .05$ , †  $.05 < p < .10$ . **(B)** Scatter plot of children's Free Recall and Interactive Media Exposure. Lines of best fit, based on the model, at Age = 1 standard deviation below the mean (broken line) and 1 standard deviation above the mean (solid line). These lines demonstrate the age moderation of the association between Interactive Media Exposure and Free Recall.

These cross-sectional data suggest that the effect of exposure to interactive media on memory is not uniform across development. Instead, this effect varies as a function of age. The finding that the association between interactive media exposure and memory increases with age is in line with current views about children's differential susceptibility to media effects at different developmental periods (Valkenberg & Peter, 2013). Further, these findings demonstrate support for a Metacognitive Constraints Model, which suggests that developmental changes (i.e., increases in metacognitive skills) during this age window change the way children utilize or experience interactive media, leading to differential impacts on memory.

### **Study 2: Reanalyzing a Meta-analysis to Test for Age Moderation**

Study 2 examined whether age moderates the association between interactivity and memory in prior research. Takacs, Swart, and Bus (2015) conducted a meta-analysis evaluating the impact of interactive features on story comprehension across preschool and elementary school aged children. Takacs et al. (2015) found that compared to traditional books, reading devices with multimedia features (i.e., animations, music, and/or sound) had a significant positive effect on story comprehension ( $g+ = 0.39$ ), whereas those with both interactive and multimedia features or only interactive features (i.e., games, interactive questions, or hot spots) had no significant benefits over traditional books. The authors interpreted these differences in effects as evidence that interactive features have distracting or detrimental impacts on story comprehension. However, the studies included in Takacs et al.'s (2015) meta-analysis were heterogeneous in terms age (2-year to 9-years). Based on the findings from Study 1,

Study 2 tested age as a moderator of the association between interactive features and story comprehension in the Takacs et al.'s (2015) meta-analysis.

Of the 32 studies included in Takacs et al. (2015), 17 included analyses that examined comprehension and memory of stories delivered on reading devices with interactive features compared to traditional books (i.e., the contrast of interest relevant to our moderator analysis). For these 17 studies (see Table 1),  $g$  effect sizes were converted<sup>2</sup> to  $r$ . The effect size  $r$  acts much like a point biserial correlation coefficient, and represents the association between the level of interactivity (present vs. not-present) and story comprehension, but has the advantage of being more readily interpreted in terms of practical importance (Rosenthal & DiMatteo, 2001). Additionally, the average age of participants in the contrast of interest for each of the 17 studies was calculated. When necessary, authors of the original articles were contacted.

Across the 17 studies included, there was a very small and non-significant association between story comprehension and the presence of interactive features,  $r = .01$ ,  $t(16) = 0.20$ ,  $p = .841$ , consistent with the findings in Takacs et al. (2015). However these effect sizes were heterogeneous,  $\chi^2(16) = 29.13$ ,  $p = .023$ , range of  $r$  [-.38, .55]. Contrast tests were conducted to investigate age as a moderator of the association between interactive features and story comprehension. A significant difference was detected between studies that included a sample with an average age of under 6 years old ( $k = 12$ ) to those with an average age of 6 or over ( $k = 5$ ),  $t_{contrast}(15) = 4.20$ ,  $p = .0008$ ,  $r_{contrast} = .74$ . For studies with younger children, a negative association was observed between

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<sup>2</sup>  $r = \frac{g}{\sqrt{g^2+a}}$ , where  $n_1 = n_2$ ;  $a = 4$ , where  $n_1 \neq n_2$ ;  $a = \frac{(n_1+n_2)^2}{n_1n_2}$

interactive features and story comprehension, average  $r = -.11$ , 95% CI [-.20, -.01],  $k = 12$ ,  $n = 682$ . However, for studies with older children, a positive association was observed between interactive features and story comprehension, average  $r = .28$ , 95% CI [.12, .43],  $k = 5$ ,  $n = 155$ .

Table 1

*Chapter 2: Summary of articles included in meta-analytic moderator analysis*

First Author	Year	Average Age	Hedge's $g$	$r$
Caplovitz	2005	4.67	-0.24	-.11
Chiong	2012	4.35	0.17	.08
Chiong	2012	4.35	-0.81	-.38
de Jong	2002	5.36	-0.27	-.13
de Jong	2004	5.50	-0.53	-.26
Homer	2014	6.20	0.26	.13
Korat	2007c	5.81	-0.13	-.06
Okolo	1996a	7.98	0.64	.30
Okolo	1996b	7.98	0.53	.26
Parish-Morris	2013	3.51	-0.65	-.31
Ricci	2002	6.75	0.23	.11
Robb	2010a	4.94	0.21	.10
Robb	2010b	4.94	-0.06	-.03
Segers	2004a	5.83	-0.08	-.04
Segers	2004b	5.83	-0.41	-.20
Smeets	2014b	5.36	0.19	.09
Stine	1993	7.50	1.31	.55

Findings in Study 2 demonstrate that the presence or absence of interactive features differentially relate to story comprehension for preschool-aged children than for children over the age of 6. When samples include children across developmental periods, the effect of interactivity is muted and could potentially be missed. Taken together, Studies 1 and 2 suggest preschool-aged children demonstrate either no effect or potentially slight negative effects of interactivity on memory and comprehension. However, children over the age of 6 might see memory and comprehension benefits from interactive devices and features. The differential effects of interactivity on comprehension and memory outcomes for preschool-aged children compared to older children suggest that developmental changes across these ages might impact the way children are experiencing and using the interactive features of devices. Taken together, Studies 1 and 2 support the Metacognitive Constraints Model and suggest that interactive media and interactive features may begin to have a unique influence on memory around the age of 6, an age at which children first begin to demonstrate cognitive knowledge and metacognitive monitoring (Schraw & Moshman, 1995; Whitebread et al., 2009).

## **Conclusions**

In summary, the Metacognitive Constraints Model describes age-related constraints in children's metacognitive abilities as moderating the relationship between exposure to interactive media or interactive features and memory outcomes. The model also argues children's metacognitive experiences while gaming will mediate this relationship. This conceptual framework makes predictions based on the opportunity for metacognitive experiences in interactive environments, and can be applied to a variety of interactive

devices and platforms, including e-books, video game consoles, and touchscreen technology. The research presented in this perspective provides some support for the age-related child constraints predicted by the model. However, future work investigating the underlying mechanisms driving the effects of interactivity on memory and comprehension should both (a) take into account children's metacognitive skills and (b) investigate features of interactive devices that provide children with opportunities for metacognitive experiences. Research into these mechanisms is critical, as technological innovations (e.g., the nearly ubiquitous presence of touchscreen mobile devices in development) often out-pace the science needed to inform media creators, parents, and educators on the likely effects of the technologies on development. As we uncover the role of these mechanisms in the effects of interactive media and gaming on cognitive development, we can better predict the differential effects of future innovations in gaming (e.g., virtual reality immersion, 3D gaming) at different developmental periods. This kind of foresight will be critical for developmental scientists to be able to continue to offer recommendations on game creation and use. Our findings suggest it will be critical to understand the role of metacognition in the effects of gaming on cognitive development especially as interactive gaming environments evolve.

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### **Chapter 3: Interactive Gaming and Metacognition**

**Citation:** Ricker, A. A., & Richert, R. A. (under review). The effects of interactive media on metacognition: Different game play, different outcomes. *Journal of Cognition and Development*.

#### **Abstract**

Interactive game play is increasingly a popular activity of childhood; therefore, the current study examined the different types of digital games (i.e., tablet-based applications, console video games, and computer programs) to which children 6- to 10-years old are exposed for the opportunities for metacognitive experience they provide. We evaluated the impacts of metacognitive experiences in the context of interactive gaming on children's metacognitive awareness. Fifteen interactive digital games from five game genres (e.g., Sports, Puzzle, Action/Adventure) were coded for features of interactivity, including level-of-control, feedback, and adaptivity. Parents reported time spent by their child on each of these different games, and children completed a measure of metacognitive awareness. Results indicated that the frequency with which children played interactive games, specifically those that provided frequent opportunities for metacognitive reflection, positively predicted children's metacognitive awareness. However, the frequency with which children played interactive games with fewer metacognitive opportunities was unrelated to metacognitive awareness. These results support the hypothesis that different types of interactive digital games provide children with differential opportunities for metacognitive experience. These findings have

implications for future research investigating interactive media and metacognition, as well as their impacts on memory and learning.

*Keywords.* interactive media, interactivity, metacognition, metacognitive experiences

## **Introduction**

Electronic gaming environments and mobile game applications present learning spaces for children in which their cognition can be challenged. Children are able to see both realistic and fantastical scenarios play out on screen, and have to learn patterns and rules about what will lead them to success as they navigate the digital world. Successful navigation of games and completion of tasks within a game require problem solving, discovery-based learning, and problem resolution. Within electronic gaming, children are able to work in an environment in which theories and scenarios can be tested immediately, which supports knowledge acquisition. For example, many games present tasks to challenge a player, and then provide feedback on performance. The feedback provided, whether explicit or not, can be integrated into the players' knowledge and utilized to make cognitive adjustments to their approach before reattempting to solve the same task (Ko, 2002; Steinkuehler, 2004). The current study examined the relation between exposure to different types of interactive digital games and children's metacognition during middle childhood.

Flavell (1979) defined metacognition as the ability of individuals to think about their own thoughts, or to have cognitive awareness about cognitive objects. He noticed that young children did relatively little monitoring of their own comprehension and other cognitive activities, despite the importance of this monitoring for successful completion

of tasks and learning. Metacognition has been described as being divided into two highly related components: metacognitive awareness or knowledge and metacognitive skills (Brown, 1987; Flavell, 1987; Schraw & Dennison, 1994; Sperling, Howard, Staley, & DuBois, 2004). Metacognitive awareness refers to knowledge about one's self and about learning strategies as well as knowledge about when, why, and how to use these strategies. Metacognitive skills refer to conscious regulation of cognition (i.e., comprehension monitoring and evaluation). According to Flavell (1979), these components are improved via metacognitive experiences (i.e., conscious thoughts and reflections on cognitive processes that occur in response to novel roles or situations that involve decisions and actions).

Typically, children between the ages of 3 and 4 years begin to develop an understanding of how their beliefs, as well as other people's beliefs, about the world around them come to be and are revised through gained knowledge (Leslie, 1992; Premeck & Woodruff, 1978; Wellman, 1992). Theory-of-mind and children's perspective-taking have been discussed as foundational for metacognition, as early awareness of the origin of knowledge is a critical first step in being able to build-up complex higher-order thoughts later in life (Ebert, 2015; Kuhn, 2000). However, less is known about the trajectory of metacognitive development, relative to that of theory-of-mind, throughout middle childhood and adolescence. Behavioral studies have observed children as young as 3 years of age engaging in metacognitive behaviors (e.g., displaying verbal knowledge of a strategy, monitoring their own progress, deliberating; Whitebread et al., 2009), and metacognition has been found to be important for problem-based



learning for children starting in the second grade (i.e., 7 to 8 years of age; Shamir, Zion, & Spector-Levi, 2008). Even emerging adults have been able to improve their metacognitive skills with specific problem-based training (i.e., studying in tutorial groups attempting to understand, explain, and solve problems using seven problem-based learning steps, Downing et al., 2009).

From a socio-cultural perspective of development, the aspects of digital gaming described above can be conceptualized as a type of interaction with a cultural tool that promotes metacognitive awareness (Gauvain, 2001), as support from an electronic agent within the game scaffolds the experience of the gamer. Previous research has demonstrated 10- and 11-year-old children who are classified as frequent gamers (i.e., they have been gaming in this type of environment consistently for 3 to 5 years) display exceptional self-monitoring, principled decision-making, and qualitative thinking (VanDeventer & White, 2002). These findings suggest that with repeated exposure to the unique learning environment that digital interactive gaming provides, children might have increased metacognitive experiences promoting the development of metacognitive awareness and may translate into increased metacognitive skills.

When referring to gaming environments, the term *interactive* implies a reciprocal relationship, such that both the user and machine (i.e., the child and the game) are required to take an active role in the interaction (O’Keefe & Zehnder, 2004). However, as Hirsch-Pasek, Zosh, Golinkoff, Gray, Robb, and Kaufman (2015) noted, available interactive games vary in their degree of interactivity, and as such, can be expected to have differential effects on children’s cognition. Specifically, there are a number of

elements of this reciprocal interactivity on which games can vary. Critical to understanding the influence of digital gaming on metacognitive awareness is to delineate the dimensions of interactivity along which digital games vary, including adaptivity, control, and feedback.

*Adaptivity.* Games can vary in both how flexible and how adaptive they are for the user (Magerko, 2008). Adaptivity in a game means that the experience changes for children to meet their specific needs, interests, skill level or behaviors. Highly adaptive games can change what it is presented to the child moment-to-moment, based on how the child is responding or performing. Alternatively, games low in adaptivity might only be able to meet a child's needs at the start of a gaming session (e.g., choosing a level; beginning, intermediate, or expert).

*Control.* Games can also vary in the amount of control that they maintain or relinquish to the child, which has also been discussed as a degree to which a device is interactive (McMillan & Hwang, 2002). That is, games vary in how much control the child has to choose her or his activity within the game. Examples of games in which the child has high control might be exploratory types of games in which the child can move back and forth between activities without rules, whereas games in which the child has low control might have structured lessons that must be followed in a particular order.

*Feedback.* Finally, an arguably imperative prerequisite to calling a medium or device interactive is whether it provides feedback (Rafaeil & Sudweeks, 1997). That is, whether the game provides the child with an indication of how he or she is doing. Games that are high in feedback often provide instantaneous, real-time feedback, whereas those

that are low in feedback might offer some sort of delayed or standardized/scripted response at the end of a challenge or task.

### **The Current Studies**

We present a two-part study that aims to examine different types of digital games to which children are exposed for the opportunities for metacognitive experience those games provide, and to investigate if exposure to these different digital games differentially predicts children's metacognitive awareness. To examine these research questions, a preliminary study first selected 15 exemplar games that varied in their degree of (a) adaptivity of the game, (b) the child's level of control, and (c) level of feedback provided. These games were coded along these dimensions and categorized based on if they provided high or low frequency opportunities for metacognitive reflection. Second, in the primary study, parents rated the frequency of their child's play of each game type, and children were tested for their metacognitive awareness. We hypothesized that children's metacognitive awareness would be positively related to the playing of games high in opportunities for metacognitive experience (i.e., those high in adaptivity, control, and feedback) and would be either negatively or unrelated to their playing of games low in metacognitive opportunities.

#### **PRELIMINARY STUDY: GAME CATEGORIZATION**

The goals of the preliminary study were to rate the presence or absence of the three features of interactivity in commonly-played interactive games and to categorize these games as either High Opportunity or Low Opportunity Games. The categorization

of these games then was used in the primary study to examine whether the frequency with which children played each game type was related to their metacognitive awareness.

### **Method**

Fifteen interactive, digital games were examined for their levels of adaptivity, control, and feedback; as indicated by their rankings on relevant websites (e.g., Google Play, Apple iTunes Store, ING, Steam), the games were popular with children in the study age range (6- to 10-years old) at the time the data were collected (2014-2015) and were selected to cover five different game genres (i.e., Sport, Simulation, Puzzle, Action/Adventure, and Casual). Trained research assistants coded each game for interactive features that provide children with metacognitive opportunities while gaming. Screen capture software was used to record a three-minute clip of each game being played by a young adult who was not a coder. Research assistants watched the clips and rated the game on each of the following features: (a) adaptivity of the game, (b) the player's level of control, and (c) level of feedback provided. The descriptions of each category provided to research assistants are outlined in Table 2. Each game was watched and rated by three research assistants, and inter-rater reliability is described in the Results section.

Table 2

*Chapter 3: Game Feature Rating Scale*

	Low	High
a) Adaptivity	Game DOES NOT exhibit moment-to-moment adaptations based on player performance	Game DOES exhibit moment-to-moment adaptations based on player performance
	0	1
b) Control	The player's activity throughout the game is PRE-DETERMINED by a strict menu with little choice	The player is able to navigate the game and EXPLORE activities of their choice
	0	1
c) Feedback	Feedback given by the game is available to the player AFTER a substantial delay	Feedback give by the game is provided to the player INSTANTANEOUSLY
	0	1

**Results & Discussion**

Inter-Rater Reliability was assessed using a two-way mixed, consistency, average-measures ICC (intra-class correlation; McGraw & Wong, 1996) to assess the degree that coders provided consistency in their ratings of features across games. The resulting ICC was in the excellent range, ICC = 0.86 (Cicchetti, 1994), indicating that the three research assistants had a high degree of agreement and suggesting that game features were rated similarly across raters. Average feature ratings across the three research assistants were taken for each game in order to classify each game as High Opportunity or Low Opportunity (see Table 3). Games for which the average ratings were high (i.e., mean rating was above 0.50) on 2 of the 3 features were coded as High Opportunity games ( $n = 7$ ). Those for which the average rating was low (i.e., mean rating was below 0.50) on 2 of the 3 features were coded as Low Opportunity games ( $n = 8$ ).

Table 3

*Chapter 3: Categorization of Game Types – High vs. Low Opportunity*

<b>Game</b>	<b>Genre</b>	<b>Adaptivity</b>	<b>Control</b>	<b>Feedback</b>	<b>Categorization</b>
Wii Sports	Sport	<b>1.00</b>	0.00	<b>1.00</b>	High Opp
FIFA	Sport	<b>1.00</b>	0.33	<b>1.00</b>	High Opp
Sims	Simulation	<b>1.00</b>	<b>0.67</b>	<b>1.00</b>	High Opp
Virtual Families	Simulation	<b>1.00</b>	<b>0.67</b>	<b>1.00</b>	High Opp
Angry Birds	Puzzle	<b>1.00</b>	0.33	<b>1.00</b>	High Opp
Super Mario Brothers	Action/Adventure	<b>1.00</b>	0.00	<b>1.00</b>	High Opp
Lego City My City	Action/Adventure	<b>1.00</b>	<b>1.00</b>	0.33	High Opp
Just Dance	Sport	0.33	0.00	<b>0.67</b>	Low Opp
Farmville	Simulation	0.00	0.33	<b>0.67</b>	Low Opp
Tetris	Puzzle	<b>1.00</b>	0.00	0.33	Low Opp
Candy Crush	Puzzle	<b>0.67</b>	0.33	0.33	Low Opp
Bubble Shooter	Puzzle	0.33	0.00	<b>1.00</b>	Low Opp
Mario Kart 64	Action/Adventure	0.33	0.00	<b>1.00</b>	Low Opp
Cars Racer	Action/Adventure	<b>1.00</b>	0.00	0.33	Low Opp
Pop The Balloon	Casual	0.00	0.00	<b>1.00</b>	Low Opp

*Note.* **Bolded** values represent those that are high on average across the 3 raters (i.e., average rating > 0.50). Games rated high on at least 2 of the 3 features were categorized as High Opportunity games (High Opp) while those rated low on 2 or more of the 3 features were categorized as Low Opportunity Games (Low Opp).

In summary, the coding revealed that interactive digital games vary in how adaptive they are to a user's performance, in the level of control they afford the user while gaming, and in how feedback is provided to a user as she or he plays. These differences change the nature of gaming for the user, and subsequently alter the opportunities they have for metacognitive experiences within a game. The findings indicate that variability in features of interactivity can be reliably observed and coded from watching screen capture recordings of a game being played. Our findings demonstrate that variability in the features of interactivity exist even within the multiple genres of games examined, as both High Opportunity and Low Opportunity games were

identified within all four of the genres in which more than one specific game was examined.

Findings from the preliminary study suggest that broad labeling of interactive games based on their content or genre does not carry the range of relevant information about the types of experiences children have while gaming. Rather, features of interactivity should be considered when evaluating both the experiences children have while gaming and the effects of this game play on outcomes of interest. Thus, the primary study examined if children's metacognitive awareness is differentially related to how often children play games that vary in these features of interactivity.

## PRIMARY STUDY

The primary study examined if the frequency with which children played High Opportunity or Low Opportunity interactive digital games was differentially related to metacognitive awareness. To examine this question, parents reported the frequency of children's play of the 15 games categorized in the Preliminary Study and children were assessed for their metacognitive awareness.

### **Method**

#### **Participants**

One hundred and five children, along with their parents, were recruited for participation in this study. Two children were excluded due to failure to complete the full protocol. The final sample consisted of 103 participants (51 females) between the ages of 6 and 10.92 years ( $M_{\text{age}} = 8.42$  years;  $SD = 1.5$  years). The sample was diverse, and

representative of the demographics of the Southern Californian community from which the families were recruited through community events (see Table 4). All parents signed written consent, and children gave verbal assent.

Table 4

*Chapter 3: Summary of Descriptive Statistics for Study 2*

	N	%		N	%
<b>Gender</b>			<b>Ethnicity</b>		
Males	52	50.5%	White	38	36.9%
Females	51	49.5%	Hispanic/Latino	30	29.1%
			Black	9	8.7%
			Asian/Pacific Islander	7	6.8%
			Multi-Ethnic/Other	19	18.5%

**Materials & Measures**

*Interactive Gaming Exposure*

Parents were asked to report their child’s exposure to seven High Opportunity and eight Low Opportunity games (as classified in the Preliminary Study), although parents were not alerted to the researcher’s distinction between game types. For each game, parents were asked two questions: (1) “In a typical week, how many days does your child spend time playing \_\_\_\_\_” and (2) “On these days, how much time does your child generally spend playing \_\_\_\_\_.” For the first question, parents entered a number between 0 and 7. For the second question, parents chose from nine options reflecting 30-minute increments, ranging from “15 minutes” (coded as .25 hours) to “over and 4 hours and 15 minutes” (coded as 4.25 hours).



No parents in the sample endorsed the highest option. Number of days played per week was multiplied by hours played per day to create an indicator of hours-per-week. Hours-per-week (HPW) were then summed across the two different types of games to create two variables: High Opportunity HPW ( $M = 1.98$ ,  $SD = 3.90$ , range = 0-20.75) and Low Opportunity HPW ( $M = 1.56$ ,  $SD = 2.25$ , range = 0-9.75). The hours-per-week variables were positively skewed; therefore log transformations were applied to reduce any non-normality before including these variables in further analyses.

### *Metacognitive Awareness*

To assess children's metacognitive awareness, a researcher administered the Jr. Metacognitive Awareness Inventory (Jr. MAI; Sperling, Howard, Miller, & Murphy, 2002), which consists of 12 items that address children's cognitive monitoring and self-reflection (e.g., I can make myself learn when I need to; I know what the teacher expects me to learn; see Appendix for full list of items). Children were given the following prompt: "I am going to read you a short sentence and I want you to tell me if it describes you, or sounds like you (Never, Sometimes or Always). Think about the way you are when you are doing schoolwork or homework. Please answer as honestly as possible." Children responded to the researcher using the options Never (0), Sometimes (1), or Always (2). The responses were summed to create a Metacognitive Awareness Score ( $M = 15.77$ ,  $SD = 3.60$ , range = 6-22, Chronbach's  $\alpha = .76$ ).

### **Procedure**

Parents brought their children into a university research lab, which was staged to look like a comfortable hall and living room space, complete with carpet and couches.

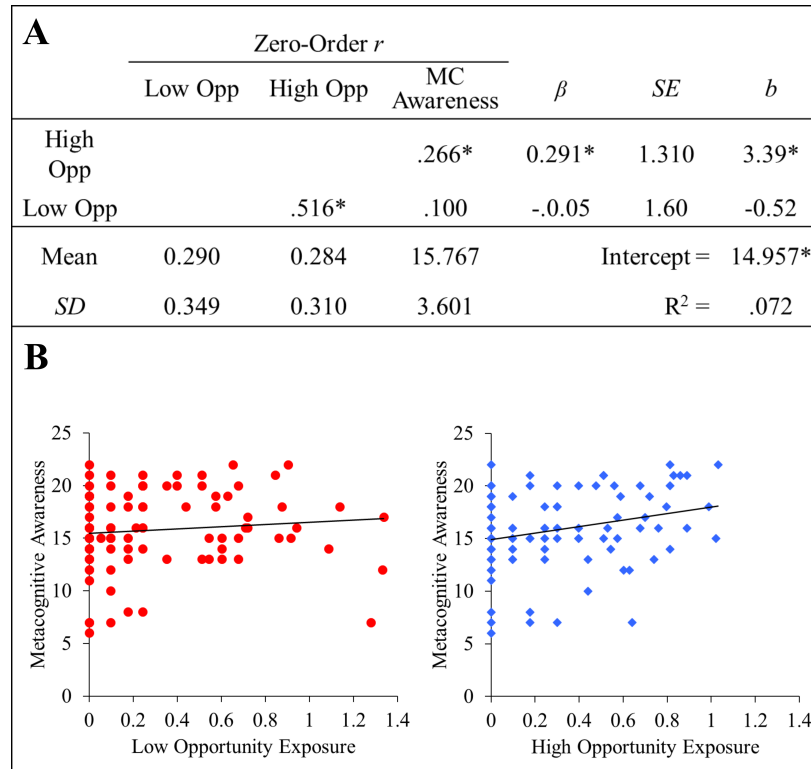
Parents worked at a small table in the hall to complete the parent questionnaire, which included child demographics and the children's interactive gaming exposure measure. The child was given the Jr. MAI, which was administered by the researcher who worked one-on-one with the child in the living room space.

## Results & Discussion

Preliminary analyses examined potential gender differences; an Independent-Samples t-test indicated no significant differences in amount of exposure between male and female children for either type of game (High Opportunity Games:  $t(101) = 1.07, p = .29, d = .21$ ; Low Opportunity Games:  $t(101) = 0.52, p = .61, d = .10$ ). Further, a Paired-Samples t-test indicated children did not play one type of game significantly more than the other,  $M_D = -.42, t(102) = 0.19, p = .85, d_D = .08$ . Pearson product-moment correlation coefficients demonstrated that age was not significantly related to metacognitive awareness ( $r = .11, p = .27$ ) or hours-per-week spent gaming either type of game (High Opportunity,  $r = -.03, p = .76$ ; Low Opportunity,  $r = .02, p = .83$ ).

Multiple regression analysis was utilized to test if exposure to both High Opportunity and Low Opportunity games significantly predicted children's metacognitive awareness (see Figure 3A). Together, the two predictors explained 7.2% of the variance in children's metacognitive awareness,  $R^2 = .072, F(2,100) = 3.91, p = .023, f^2 = .08$ . Frequency of exposure to High Opportunity games positively predicted greater metacognitive awareness ( $\beta = .29, p = .01$ ), whereas frequency of exposure to Low Opportunity was not a significant predictor ( $\beta = -.05, p = .66$ ). See Figure 3B for a

demonstration of the differential linear associations between metacognitive awareness and both High Opportunity and Low Opportunity Exposure.



*Figure 3.* Chapter 3: Predicting Metacognitive Awareness from Gaming Exposure. **A)** Results from multiple regression predicting metacognitive awareness from High Opportunity and Low Opportunity Gaming Exposure simultaneously, including zero-order correlations as well as means and standard deviations for all variables (High and Low Opportunity Exposure variables are log-transformed). Note: \*  $p < .05$  **B)** Scatter plots demonstrating the differential linear association between Metacognitive Awareness and the two exposure variables.

To further explore the extent to which different game play exposure might be related to children’s metacognitive awareness, ad hoc profiles of gamers were determined based on high and low exposure to both High Opportunity and Low Opportunity games. This allowed for the creation of four categorical groups that differentiated types of gamers based on both amount of exposure and preference for game type (i.e., Infrequent Gamers, Low Opportunity Gamers, High Opportunity Gamers, and Frequent Gamers, see

Table 5). Pearson's chi-squared test was used to examine group differences in gender, and one-way ANOVAs were used to examine group differences in age and total hours-per-week played. No significant differences were found between groups in terms of gender,  $\chi^2(3) = 3.39, p = .34, V_{\text{Cramer's}} = 0.10$ , or age,  $F(3, 99) = 1.070, p = .365, \eta^2 = .03$ . However, as expected, there was a very large and significant effect of gamer profile on hours-per-week spent gaming,  $F(3,99) = 32.49, p < .000, \eta^2 = .98$ . Tukey's HSD post-hoc analyses confirmed that Frequent Gamers played significantly more on average than all other gamers (all HSD's  $\geq 5.87$ , all  $p$ 's  $< .000$ ), but that there were no differences in time played between High Opportunity Gamers, Low Opportunity Gamers, and Infrequent Gamers (all HSD's  $\leq 2.59$ , all  $p$ 's  $\geq .14$ ).

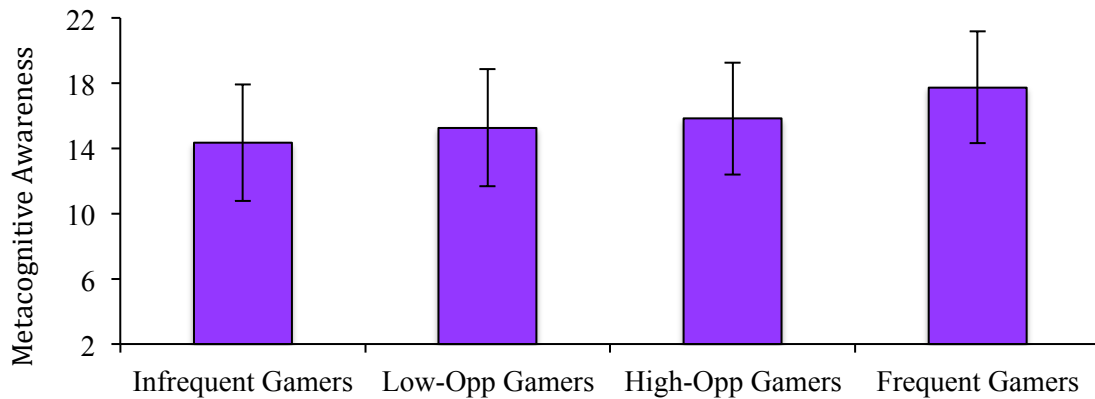
Table 5

*Chapter 3: Categorical Gaming Profiles*

		High Opportunity Games	
		Low Exposure	High Exposure
Low Opportunity Games	Low Exposure	Infrequent Gamers $n = 41, 58.5\% \text{ F}$ $M_{\text{age}} = 8.17$ $M_{\text{High Opp}} = 0.10$ $M_{\text{Low Opp}} = 0.09$	High-Opp Gamers $n = 13, 30.8\% \text{ F}$ $M_{\text{age}} = 8.78$ $M_{\text{High Opp}} = 2.02$ $M_{\text{Low Opp}} = 0.18$
	High Exposure	Low-Opp Gamers $n = 16, 43.8\% \text{ F}$ $M_{\text{age}} = 8.84$ $M_{\text{High Opp}} = 0.10$ $M_{\text{Low Opp}} = 2.68$	Frequent Gamers $n = 33, 48.5\% \text{ F}$ $M_{\text{age}} = 8.45$ $M_{\text{High Opp}} = 3.73$ $M_{\text{Low Opp}} = 4.91$

Analysis of Covariance (ANCOVA) was used to examine differences in metacognitive awareness based on gamer profile, controlling for hours-per-week spent gaming. Results indicated that after controlling for hours-per-week, there was a small but

significant omnibus effect of gaming profile on metacognitive awareness,  $F(3,98) = 2.99$ ,  $p = .035$ ,  $\eta_p^2 = .08$ . Tukey HSD post-hoc analyses, based on estimated marginal means, indicated that after adjusting for hours-per-week spent gaming the only significant difference in metacognitive awareness was between the Infrequent and Frequent Gamer Groups (HSD = 3.40,  $p = .022$ , 95% CI [0.32, 6.47]), such that Frequent Gamers had significantly higher metacognitive awareness than Infrequent Gamers (see Figure 4).



*Figure 4.* Chapter 3: Metacognitive Awareness by Gamer Group: Means are adjusted for hours-per-week spent gaming. Error bars represent standard deviations.

A final set of exploratory contrast analyses examined if children’s metacognitive awareness varied as a function of time spent gaming, type of games played, or a combination of both by applying hypothesis-driven contrast weights to the data (see Table 6). The first contrast examined the effect of type of game and revealed that gamers who preferred High Opportunity games or a combination of High and Low Opportunity games over just Low Opportunity games or neither had a non-significant trend toward higher metacognitive cognitive awareness,  $t_{\text{contrast}}(99) = 1.806$ ,  $p = .074$ ,  $r = .179$ . The

second contrast examined the effect of time spent gaming and revealed that participants who spent more time playing both types of games (High and Low Opportunity games) had higher metacognitive awareness than participants who spent less time in one type of game or essentially no time playing either type of game,  $t_{\text{contrast}}(99) = 2.210$ ,  $p = .029$ ,  $r = .217$ . Finally, the contrast weights that best fit the data indicated that children who spent more time gaming in total and who preferred High Opportunity games demonstrated significantly higher metacognitive awareness than other children,  $t_{\text{contrast}}(99) = 2.473$ ,  $p = .015$ ,  $r = .241$ .

Table 6

*Chapter 3: Contrast Weights and Summary of Analyses*

	Gamer Profiles and Contrast Weights				$t_{\text{contrast}}$	$p$	$r$
	Infrequent Gamers	Low Opp Gamers	High Opp Gamers	Frequent Gamers			
$\lambda_1$ Type of Game	-1	-1	1	1	1.81	.074	.179
$\lambda_2$ Time Gaming	-1	-1	-1	3	2.21	.029	.217
$\lambda_3$ Combined Theory	-2	-2	0	4	2.47	.015	.241

In summary, there were no gender differences in how frequently children played games that provided high or low metacognitive opportunities during middle childhood. On average, children play games that are high in adaptivity, control, and feedback with similar frequency to those that are low in those features. Overall, total hours-per-week spent gaming summed across high and low opportunity games were not significantly related to metacognitive awareness. However, examined separately the amount of time spent gaming in high opportunity games was positively predictive of children's

metacognitive awareness, whereas time spent gaming in low opportunity games was not predictive of metacognitive awareness. This pattern suggests that the experiences children have within these gaming environments have differential influence on their metacognition.

Findings from exploratory analyses identified four distinct gamer profiles based on the types of gaming environments children preferred as well as the number of hours they spent gaming per week. Gamer profiles were significantly predictive of children's metacognitive awareness; in particular, both how often children gamed, as well as the types of gaming environments in which they choose to spend that time (i.e., high opportunity vs. low opportunity games), influence their metacognitive awareness. These findings are in line with previous research finding that 10- and 11-year-old children classified as frequent gamers demonstrate excellent self-monitoring and decision-making skills (VanDeventer & White, 2002), and provide support for the hypothesis that when children spend more time in gaming environments that are high in adaptivity, control, and feedback, they are able to have more metacognitive experiences, which supports the development of metacognitive awareness.

### **General Discussion**

Interactive media and gaming during middle childhood are increasingly ubiquitous, and have become a part of the context in which children develop (Blumberg & Fisch, 2013). The current study examined exposure to interactive media as a cultural tool that may have a profound influence on the development of children's metacognition. Our findings demonstrate that previous exposure to interactive media was predictive of

metacognitive awareness in middle childhood; but not all types of interactive media were equally related to metacognitive awareness. The amount of time children spend gaming was differentially related to metacognitive awareness based on specific features of interactive games they choose to play, suggesting that these features of interactivity afford children differential opportunities for metacognitive experiences while they play.

In concert with recent reviews and theoretical approaches highlighting the differential effects of media exposure on development (Hirsch-Pasek et al., 2015; Valkenburg & Peter, 2013), these findings illustrate the importance of clearly defining elements of interactivity when developing hypotheses about the influences of interactive media exposure on cognitive development. Dimensions of interactivity vary across platforms (e.g., mobile devices, video games, e-books), genres (e.g., sports, puzzle, action/adventure), and individual games. As the current study demonstrated, different games and touch screen applications vary in how adaptive they are to the child's performance, how much control the child has over their exploration while playing the game, and the timing of feedback provided by the game. These variations matter, as they allow for different experiences within the gaming environment and lead to differential impacts on the user.

The different gaming environments examined in this study (i.e., high opportunity and low opportunity environments) are qualitatively different in terms of the types of challenges they present to children, how children approach those challenges, and the ways in which feedback are given. In high opportunity games, children can immediately test out cognitive theories and integrate the feedback they receive. These types of



experiences allow children to reflect on their own cognition in response to decisions they make or actions they take during game play. According to Flavell (1979), engaging in these metacognitive experiences allows children to build up their metacognitive awareness and improve their knowledge about when, why, and how to effectively use strategies over time. Indeed, exposure to these games positively predicted children's metacognitive awareness. Alternatively, in playing low opportunity games children are often engaging in highly repetitive behavior, with little freedom for decision making with regard to task engagement and with minimal or delayed feedback. These types of activities do not promote or require reflection of cognitive process or integration of feedback (when provided) for future decision-making, and exposure to these games was not related to children's metacognitive awareness.

### **Limitations**

Although the findings highlight the importance of considering not only the quantity, but also the quality and content of interactive game play, one limitation of the current study is the use of a small sample of exemplar games for parent response on the previous exposure measure. For the purpose of the current study, fifteen specific games across five genres of interactive devices were coded and examined. However, these fifteen games are only a tiny fraction of the interactive digital games available to children across the variety of platforms through which they game. For this reason, our hours-per-week variable cannot be used to describe the amount of time children spend gaming generally. Future work could develop a larger inventory of games and examine hours-per-week children spend in these environments to accurately estimate overall weekly

exposure. Nevertheless, the current study provides a refined examination of time spent in games with two distinct interactive environments, and explores how those distinct environments differentially impact metacognitive awareness.

## **Conclusions**

In conclusion, the findings from the current study highlight the importance of investigating not only the amount of time children play in interactive gaming environments but also the types of experiences children have while they game. They demonstrate that variability in experiences exist even within broad genres of games. These experiences can tell us more about the impacts of gaming than quantity of exposure alone. Further, our findings suggest that interactive gaming environments that are high in adaptivity, level-of-control, and feedback provide children with opportunities for metacognitive experience and that repeated exposure to these high opportunity interactive gaming environments demonstrate positive impacts on children's metacognitive awareness whereas games low in these features do not promote these metacognitive benefits. As such, these features should be further examined and considered when developing gaming for developmental or educational purposes.

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## **Chapter 4: Interactivity, Metacognitive Experiences, and Memory**

Ricker, A. A. (in preparation). Interactive gaming in middle childhood: Impacts on memory and metacognition.

### **Abstract**

Investigating the impact of exposure to mobile devices (e.g., phones and tablets) on children's cognitive development is imperative, as interactive media (IM) has become a part of the context in which children develop. A growing body of literature demonstrates the impacts of IM exposure and gaming on various aspects of cognitive development including reasoning and executive functioning. However, minimal work has directly examined the effect of IM exposure and gaming on episodic memory. We consider the influence of tablet-based gaming on episodic memory encoding during middle childhood, and propose that IM exposure provides children with the opportunity for metacognitive experiences to develop metacognitive skills necessary for episodic memory encoding processes. Parents and children participated in a two-week study designed to manipulate IM exposure with tablet-based games that provide either high or low opportunities for metacognitive experience in children between the ages of 6 and 10. As hypothesized, children's previous IM exposure positively predicted their episodic memory encoding, however previous IM exposure was not related to children's metacognitive awareness in this sample. We found that interactive games high in adaptivity, control, and feedback afford children greater opportunities for metacognitive experiences than games low in these features. Additionally, findings indicate that exposure to tablet applications high in opportunities for metacognitive experience promotes improved episodic memory

encoding, even after only a short period of time. Our results provide support for a model that describes opportunities for metacognitive experience mediating the effects of IM exposure on change in episodic memory.

*Keywords:* interactive media, memory, encoding, metacognition, middle childhood

### **Introduction**

Minimal research has examined the effect of mobile gaming on episodic memory (i.e., a person's ability to explicitly remember times, places, experienced information and events; Squire, 2004; Tulving, 2002). We propose that metacognition (i.e., conscious reflection on cognitive processes; Flavell, 1979) mediates a relationship between mobile gaming and memory encoding in middle childhood. Socio-cultural theories describe children as active agents in their own cognitive development and emphasize the importance of understanding that development occurs in a specific cultural context (Gauvain, 2001; Vygotsky, 1978). Additionally, these theories discuss the prominence of cultural tools in children's learning environments and how these tools may benefit cognitive development (Gauvain, 2001). As such, the present study evaluates interactive media and devices as cultural tools that may have a profound influence on the development of metacognitive skills necessary to utilize effective encoding strategies for episodic memory. By employing multiple methodological approaches including parent and child questionnaires, cognitive testing, experimental manipulations, and naturalistic exposure sessions with a sample of diverse elementary school children, this study was designed to capture findings that are easily generalizable to families in the United States.



Interactive media can refer to a number of different platforms and devices, including Internet exchanges, interactive books and toys, computer games, video games and smartphone or tablet based applications (Stewart & Pavlou, 2002). Young children are using increasing amounts of interactive media in their day-to-day lives, especially through recreational and educational video games (National Association for the Education of Young Children, 2012). More than 50% of game console owners are children between the ages of 2 and 17, and 88% of children ages 8 to 17 have played at least one video game (Blumberg & Altschuler, 2011; Gentile, 2011). According to a recent report by Common Sense Media (2013), approximately 85% of families with 0- to 8-year-olds have some type of mobile media devices in the home. Among children ages 5 to 8 years of age, 83% have used mobile applications for gaming (Common Sense Media, 2013). This exposure to interactive media occurs during the early development of episodic memory, when children's abilities are rapidly increasing (Perner & Ruffman, 1995; Shing, Werkle-Bergner, Brehmer, Müller, Li, & Lindenberger, 2010).

A growing body of research from developmental psychologists and educational researchers has examined the impact of interactive media on some cognitive domains. For instance, video gaming has been related to increased selective attention and visual perception, in children ages 7 to 11 years old, as this type of gaming requires the utilization of these cognitive skills (Blumberg, Altschuler, Almonte, & Mileaf, 2013). Also, associations have been found between interactive media usage and executive functioning in middle childhood (Flynn, Richert, Staiano, Wartella, & Calvert, 2014), as well as problem solving and reasoning in adolescence (Blumberg 1998; Adachi &

Willoughby, 2013). However, there has been little to no research in the field directly addressing the impacts of interactive media on children's metacognitive awareness and episodic memory. The limited research that has been done investigating the impacts of interactive media on children's memory has focused mainly on television shows or e-books (see for example Ricci & Beal, 2002). But, interactive media is quickly and constantly evolving; and by 2015, children were more likely to spend time on a tablet or mobile device than on an e-book (Common Sense Media, 2015), and interactive devices, games, and applications become irrelevant as quickly as they become popular.

As such, it is important to consider specific features of interactive media so that findings can be generalized and applied across platforms, games, or applications, as not all games are uniform in their degree of interactivity (Hirsch-Pasek, Zosh, Golinkoff, Gray, Robb, & Kaufman, 2015). In relation to metacognition, it is important to consider how differences in aspects such as adaptivity of the game, control the child has over the game, and feedback provided by a game might change the cognitive experiences children have while interacting with a device. Recent research suggests that games classified by features, as opposed to by content or genre, are differentially predictive of children's metacognitive awareness (Ricker & Richert, under review). Those findings suggested that games high in adaptivity, control, and feedback related positively to metacognition, therefore these games can be conceptualized as High Opportunity for metacognitive experiences, meaning that children will have more metacognitive experiences when they game with High Opportunity games.

Flavell (1979) was the first researcher to describe metacognition, and he did so in the context of educational research. He referred to metacognition as the ability of individuals to have cognitive awareness about cognitive objects or think about their own thoughts. Despite the importance of cognitive monitoring for successful completion of tasks and learning, children do relatively little monitoring of their own comprehension and other cognitive activities (Flavell, 1979). Metacognition is conceptualized as two highly related components, metacognitive awareness (or knowledge) and metacognitive skills (Brown, 1987; Flavell, 1987; Schraw & Dennison, 1994; Sperling, Howard, Staley, & DuBois, 2004). Metacognitive awareness refers to knowledge about one's self and about learning strategies as well as knowledge about when, why, and how to use these strategies. Metacognitive skills are the ability to monitor and evaluate one's cognition. According to Flavell (1979), these components are improved via metacognitive experiences (i.e., conscious thoughts and reflections on cognitive processes that occur in response to novel roles or situations that involve decisions and actions).

Typically, children between the ages of 3 and 4 years old begin to develop an understanding of how their beliefs, as well as other people's beliefs, about the world around them come to be and are revised through gained knowledge (Leslie, 1992; Wellman, 1992). Theory-of-mind and children's perspective-taking have been discussed as foundational for metacognition, as early awareness of the origin of knowledge is a critical first step in being able to build-up complex higher-order thoughts later in life (Kuhn, 2000). However, less is known about the trajectory of metacognitive development, relative to that of theory-of-mind, throughout middle childhood and

adolescence. Behavioral studies have observed children as young as 3 years of age engaging in metacognitive behaviors (e.g., displaying verbal knowledge of a strategy, monitoring their own progress, deliberating; Whitebread et al., 2009), and metacognition has been found to be important for problem-based learning for children starting in the second grade (i.e., 7- to 8-years of age; Shamir, Zion, & Spector-Levi, 2008). During middle childhood, commonly referred to in the developmental literature as between the ages of 6 and 10, children develop the metacognitive skills, strategic behaviors and increased attention needed to improve memory performance through improved encoding.

Very generally speaking, memory is the process by which humans remember information. There are many types of memory that are studied in the field of psychology. Tulving (1972) differentiated between two stores in long-term memory, one that contains information about general knowledge (semantic memory) and one that contains memory traces of information for personal experience (episodic memory). Episodic Memory (EM) is a form of declarative memory in which individuals have a capacity for consciously recalling facts and events (i.e., times, places, and occurrences) that they experience personally (Squire, 2004; Tulving, 2002). This type of memory allows both children and adults to navigate their world in an efficient manner. When studied empirically, EM performance is often measured via performance on free recall tasks, recognition tasks, or paired association tasks whereby information is presented to an individual and memory performance for these tasks is dependent on the individual's ability to encode, consolidate, and eventually retrieve the presented information (e.g., Czernochowski, Mecklinger, & Johansson, 2009; Shing, Werkle-Bergner, Brehmer, Müller, Li, &

Lindenberger, 2010). The first step in forming new episodic memories is encoding, which involves perceiving the new information (seeing or hearing it) and forming a mental representation of the information in order to allow the perceived item of interest to be converted into a construct that can be stored within the brain (Tulving, 1972). Once information has been encoded, it is stored in the short-term memory store.

Middle childhood is a period of critical change in episodic memory because it is a period of increasing attention and control in the developing child's brain. Prior to middle childhood, memory performance and the formation of memories are qualitatively different than memory performance and the formation of memories in adulthood; however, during middle childhood memory performance begins to look more like that of an adolescent or adult. Specifically, between the ages of 7 and 10, children begin to demonstrate strategic behaviors and increased attention, which help with the development of efficient encoding skills, (Bjorklund & Douglas, 1997; Schneider & Pressley, 2013; Trick & Enns, 1998). Encoding of episodic memory does not reach peak performance until sometime during late adolescence (i.e., between the ages of 15 and 20, Shing et al., 2010; Sprondel, Kipp, & Mecklinger, 2011). These changes coincide with increases in metacognitive skills (Kuhn, 2000), executive functioning (De Luca et al., 2003; Sabbagh, Moses, & Shiverick, 2006), and continuing development of and changes in the Prefrontal Cortex during this developmental period (Aine et al., 2011; Shing et al., 2010; Squire 2004). As a result of these maturational changes, along with the influence of formal schooling during these years, changes in ability and strategy use take place. By the time children leave elementary school, they typically are able to describe an event they have

experienced or the context in which they learned new material with great detail, and are capable of utilizing multiple encoding strategies successfully (Galotti, 2012).

Importantly, metacognition and episodic memory do not develop in a vacuum, but rather are developed within the context of the environments children find themselves in (Gauvain, 2001). There are a number of aspects of development, aside from biological maturation, that influence metacognition and episodic memory including environmental influences such as parenting practices, cultural focuses, formal schooling, activity levels, stress and adversity. Interactive media is a context in which children are increasingly choosing to find themselves; with the rate of technological advances children are being exposed to interactive media in one form or another. Further exploration is needed on the influence of interactive media in middle childhood and how it might interact with the successful development of metacognition as well as memory and learning.

### **Present Study**

The primary goal of this investigation is to explore the influence of interactive media exposure on episodic memory and metacognition during middle-childhood, between ages 6- to 10-years old. Children's metacognitive awareness is investigated as a potential mediator of the association between exposure to interactive devices and children's and memory performance. Additionally, we examine video game play on tablet devices as a cultural tool that promotes the development of metacognitive skills and episodic memory encoding by providing children with opportunities for metacognitive experiences. We hypothesize that children's previous interactive media exposure will be positively related to their episodic memory performance, and that the

association between these two variables will be partially explained by children's metacognitive awareness. Further, we hypothesize that following two weeks of exposure to interactive media that provides opportunities for metacognitive experiences, children will show differential performance in episodic memory encoding and metacognitive skills compared to children exposed to interactive media that does not provide them with opportunities for metacognitive experiences.

## **Method**

### **Participants**

The sample consisted of 58 children between the ages of 6 and 10 ( $M = 8.38$  years,  $SD = 1.42$ ). The participants were evenly split between female and male (29 each). Families were recruited from Southern California from a laboratory database as well as through community flyers, online postings, and community events. In order to participate, the primary language spoken in the home needed to be English, all parents signed written consent, and children gave verbal assent. As compensation for their time and travel costs, parents received \$20 and children received a small toy at the end of each visit. A university review board approved all procedures and materials.

The sample was diverse and representative of the area where they were collected: 38% Caucasian, 28% Hispanic/Latino, 14% Multi-Ethnic/Other, 12% Black/African American, 8% Asian/Pacific Islander. The majority of parents who completed the survey were mothers (91%), however 5 fathers did complete the survey (9%). Parents reported their level of education: 2% did not complete High School; 3% had a High School diploma or GED; 38% had some college; 12% had an Associates degree; 22% had

Bachelor's degrees; 21% had advanced degrees and 2 % declined to answer the question. In addition, parents reported their employment status: 40% of parents worked full-time outside of the home; 32% worked full-time in the home, 19% worked part-time outside of the home; 7% were full-time students, and 2% were unemployed. The participants were also diverse with respect to annual household income with the majority of families (22.4%) falling into the \$21,001 - \$35,000 income bracket [ $< \$21,000, > \$100,001$ ].

Families were randomly assigned into one of two conditions, and preliminary analyses explored differences in demographics by condition. An Independent Samples t-test revealed that there were no differences in age by condition,  $t(56) = 0.03, p = .98$ . Additionally, chi-square analyses revealed there were no significant differences in gender, ethnicity, parental education, parental employment, or annual household income by condition (see Table 7 for analyses and descriptive statistics).



Table 7

*Chapter 4: Means, Standard Deviations, and Percentages for Demographics by Condition*

	<b>Overall</b>	<b>High Opportunity</b>	<b>Low Opportunity</b>	<b>Statistical Test</b>
	<i>N</i> = 58	<i>N</i> = 29	<i>N</i> = 29	
Age	<i>M</i> = 8.38 <i>SD</i> = 1.42	<i>M</i> = 8.38 <i>SD</i> = 1.37	<i>M</i> = 8.39 <i>SD</i> = 1.50	<i>t</i> (56) = 0.03
% Female	50%	43%	57%	$\chi^2(1, N = 58) = 1.11$
Caucasian	38%	30%	46%	$\chi^2(4, N = 58) = 3.76$
Hispanic/Latino	28%	37%	18%	
Black/African American	14%	13%	11%	
Asian/Pacific Islander	12%	10%	7%	
Multi-Ethnic/Other	8%	10%	18%	
Some High School	2%	0%	4%	
High School Diploma	3%	4%	4%	
Some College	38%	50%	25%	
Associates Degree	12%	6%	18%	
Bachelor's Degree	22%	20%	25%	
Advanced Degree	21%	20%	20%	
Decline to Answer	2%	0%	4%	
Full Time Job	40%	41%	38%	$\chi^2(4, N = 58) = 2.12$
Full Time Home Maker	32%	34%	31%	
Part Time Job	19%	21%	17%	
Student	7%	4%	10%	
Unemployed	2%	0%	4%	

Note. † .05 < *p* < .10, \**p* < .05, \*\**p* < .01

## Materials

Children completed cognitive tasks in the lab using a Dell PC with a 15-inch monitor. To complete tablet-based gaming both in the lab and in home, children played on a D2 Android tablet (see Figure 5). The games did not require access to the Internet to play, and the tablet devices had Wi-Fi capabilities disabled for the duration of the study. Children’s game play was recorded using SCR Screen Recorder Pro, an Android based application developed for screen capture, pre-installed on the D2 Android Tablets. In the lab, children were asked to complete a 5-minute game play sessions in *LEGO City: My City*, a tablet based application rated by the Entertainment Software Rating Board as “E for Everyone,” recommended for children ages 4 and up. In the home, children were asked to game in up to four tablet-based applications (full list of games provided in Procedures, see Table 9).



*Figure 5.* Chapter 4: D2 Android Tablet. Children played on the D2 Android Tablet in the laboratory for a 5-minute play session during Visits 1 – 3, and checked out a D2 Android Tablet from the laboratory to play in-home throughout the duration of the 2-week study

## Measures

### *Previous Interactive Media Exposure Variable*

Parents completed an interactive media questionnaire regarding their child's previous exposure to interactive media. This questionnaire was based on, and expanded from, a commonly used media survey (Rideout et al., 2010). Parents were asked three questions regarding their child's exposure to six different types of devices: console video games, handheld video games, cell phone, tablets, computers, and e-books. First, parents were asked, "In a typical week, how many days does your child spend time playing \_\_\_\_\_" (*a*; parents entered a number between 0 and 7). Parents were then asked "On these days, how much time does your child generally spend playing \_\_\_\_\_", (*b*; parents chose from 9 options reflecting 30-minute increments, ranging from "15 minutes" [coded as .25 hours] to "over and 4 hours and 15 minutes" [coded as 4.25 hours]). Number of days played per week (*a*) was multiplied by hours played per day (*b*) to create (*q*), an index of quantity of device exposure (i.e., hours-per-week spent on each device). Finally, parents were asked to report the age at which their child first played with each device (*c*; responses ranged from not yet [coded as 0] to as early as 6 months of age). To calculate (*d*), an index of duration of device exposure across the lifespan, *c* was subtracted from the child's age at visit, except in cases where *c* = 0 for these cases *d* = 0 as the child had not yet been exposed to the device. Responses from these questions were used to calculate a variable representing quantity and duration of exposure across all six devices<sup>3</sup>, responses ranged from 0.94 to 212.54.

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<sup>3</sup> Exposure =  $\sum_{i=1}^6 q_i \times d_i$

### *Executive Functioning*

To evaluate executive functioning, children completed a computerized *Flanker Task*, a test of selective attention and inhibitory control (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009). For the purposes of this research, a Swimming Fish Task was programmed and run in MATLAB, which consisted of a modified version of the typical arrow based task, using friendly images of swimming fish. All instructions were presented on the computer screen and read out loud by the researcher. Children completed a practice session, to learn which keys to press and to be sure they understood the instructions, followed by the test session. The test session consisted of 4 test blocks with 30 trials per block, 120 trials total. The 120 trials included both congruent and incongruent trials in a 2:1 ratio. The incongruent trials ( $N = 40$ ) were examined for accuracy (i.e., percentage of trials correct) to evaluate children's executive functioning (see Appendix for full instructions and Figure A1 for example stimuli).

### *Episodic Memory Encoding*

Children's episodic memory encoding was assessed using a computerized *Paired Associates Task*, using pictures as stimuli (e.g., Dilley & Paivio, 1968). This task was programmed and run in PsychoPy, and named the Paired Pictures Tasks (PPT). Children were presented visually with two pictures on a computer screen; images were black line drawings on a white background. The two images (i.e., picture pairs) were not semantically related and were developmentally appropriate objects (e.g., canoe, robot; see Figure A2 for example stimuli). Children were first presented a Learning List (i.e., 36 images, 18 unrelated pairs, displayed for 5 second each), and were then immediately

presented with the Encoding Test List, which consists of 24 pairs of pictures, (12 intact pairs, 6 rearranged pairs, and 6 novel pairs). For each pair of pictures on the screen, children were asked whether or not the two pictures were presented together as a pair during their Learning List. Children could respond with yes (the items were shown together during the Learning List), or no (the items were not shown together during the Learning List). The Episodic Memory Encoding variable was computed by summing the number of correct responses (see Table A1), with a possible range of 0 to 24. Three versions of this task were created to use across the three visits, and counterbalanced to reduce the chance of an order effect. Children saw Versions 1, 2, and 3 in a seemingly random order, in one of six possible order combinations.

#### *Metacognitive Awareness*

To assess children's metacognitive awareness at baseline, a researcher administered the Jr. Metacognitive Awareness Inventory (Jr. MAI; Sperling, Howard, Miller, & Murphy, 2002), which consists of 12 items that address children's cognitive monitoring and self-reflection (e.g., I can make myself learn when I need to; I know what the teacher expects me to learn; see Appendix for full list of items). Children were given the following prompt: "I am going to read you a short sentence and I want you to tell me if it describes you, or sounds like you (Never, Sometimes or Always). Think about the way you are when you are doing schoolwork or homework. Please answer as honestly as possible." Children responded to the researcher using the options Never (0), Sometimes (1), or Always (2). The responses were summed (range = 0 to 24) to create a Metacognitive Awareness Score (Chronbach's  $\alpha = .73$ ).

### *Metacognitive Skills*

To assess children's metacognitive skills, a Metacognition Interview was completed following the interactive media exposure session for each of the three in-lab visits. This interview was adapted from the Multi Method Interview (MMI; Wilson 2001; Wilson & Clark; 2004), and was designed to assess how the child reflected on what she or he did and thought while the child gamed. The interview was adjusted in four ways to be appropriate for the 6- to 10-year-old age range. First, the previous tasks assigned to children ages 10 to 12 years old (i.e., Logic, Numeric, and Spatial) were replaced with an interactive challenge (LEGO City: My City; see Figure A3) on the tablet device. Second, two open-ended questions were added after task completion at the beginning of the interview to allow the child to warm up to the researcher conducting the interview and to put their cognitive monitoring abilities in their own words. Third, to accommodate differences in reading ability in this age range, the card sort task was replaced with a verbal rating of agreement with each question. Fourth, two items were dropped due to confusing (or irrelevant) language based on the task given to the children ("I thought about something I had done another time that had been helpful" and "I checked my work"). During questioning, children were shown a screenshot from each challenge they just completed, and responded to 12 questions about their specific cognitive processes throughout the game (e.g., "When you tried to jump over the plant... did you think 'is this right'?") for full protocol see Appendix). Responses were scored as Never (0), Sometimes (1), or Always (2); and the 12 items were summed (range = 0 to 24) to create

the Metacognitive Skills variable, which demonstrated high reliability at all three visits (all  $\alpha$ 's > .82).

#### *Opportunities for Metacognitive Experiences*

In home game play was continuously sampled using screen capture recording software during the two-week study. All in-home screen capture recordings were watched and coded for gaming start and stop times, in order to calculate amount of time played in the home and to number game play sessions within the continuous recordings (sessions were numbered in chronological order, 1 –  $i$ ). Each game play session included the child gaming within one application. When a game was exited and a new game entered, a new game play session was identified and numbered. For each participant, one 2.5-minute game play session from each week (5 minutes total) was time sampled and coded. To achieve this time sampling, a random number generator was used to determine the game play session to be included in the coding sample.

In order to index children's opportunities for Metacognitive Experiences, each time-sampled video clip was coded by one of two trained raters on three dimensions: (a) use of tools or help presented to the child by the game in real time, (b) purposeful navigation toward or away from an object, and (c) integration of game feedback that demonstrates learning or replication by the child (see Table 8 for the coding scheme used). The behaviors identified and coded for were chosen to reflect opportunities children had to test novel solutions, engage the game in order to witness cause and effect play out, and demonstrate integration of feedback while gaming (i.e., opportunities for

metacognitive experiences; Flavell, 1979). Specific behaviors were identified for each of the eight games used for in-home tablet game play.

Table 8

*Chapter 4: Coding Scheme for Metacognitive Experience Index*

	<b>Adaptivity</b>	<b>Control</b>	<b>Feedback</b>
	Use of Tools or Help Presented in Real Time	Navigation with Purpose Toward or Away	Integration Replication or Learning
<b>Coding Scheme</b>	0 = No 1 = Yes	Frequency Count [0 , i ]	Rating [0, 1, 2]

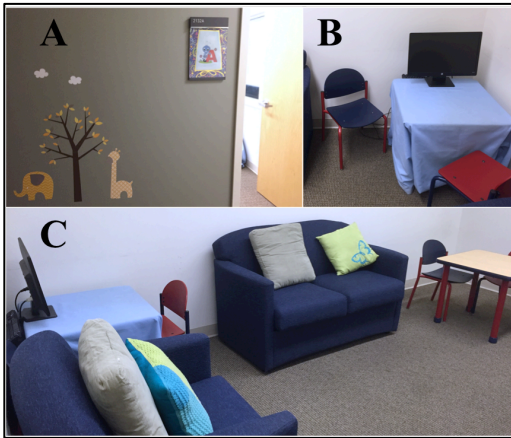
Responses from the three dimensions were summed across both weeks to create the Metacognitive Experience Index. Higher scores indicate greater opportunity for metacognitive experiences whereas a lower score indicates less opportunity for metacognitive experiences. Inter-Rater Reliability was assessed using a two-way mixed, consistency, average-measures ICC (intra-class correlation; McGraw & Wong, 1996) between the two trained raters and an expert rater on a subsample of  $n = 10$  (17.2% of total sample), which indicate that two trained raters demonstrated high degree of agreement with the expert rater  $ICC = .89$ .

**Procedure**

Parents brought their children in for three visits to a university laboratory; each visit lasted up to 90 minutes. Families were randomly assigned into one of two conditions that varied in the type of interactive media exposure in the home during the study (i.e., High Opportunity Games vs. Low Opportunity Games; see Table 9 for outline of full procedures). Researchers walked through the consent form with parents, and explained



that they would be participating in a two-week study with one week between visits. Parents and children checked out a tablet for the duration of the study, and children were assigned to play tablet-based games in-home that were pre-downloaded onto the tablets by the researchers. Parents signed informed consent and children gave verbal assent. During all visits, children spent the majority of the time with the researcher in the data collection room, which was set up to look like a comfortable living room space, containing carpet and a couch child-sized table and chair (see Figure 6), while parents sat in an adjacent hallway.



*Figure 6.* Chapter 4: Laboratory Data Collection Rooms: A) Adjacent hall for parents, B) child-sized table and chairs with 15-inch monitor for cognitive tasks, C) data collection room, or majority of visits, including the tablet play session

During Visit 1, children first completed the baseline Metacognition Awareness Inventory and baseline executive functioning Flanker Task. Next, children trained on the Picture Pairs Task Learning List, and were immediately tested for episodic memory encoding. Next, children were asked to complete a 5-minute game play session on the tablet device on, to complete the “Blue Cop Challenge”. Following the gaming session, children participated in the Metacognition Interview. While children participated in these

tasks, parents completed a parent survey that consisted of the interactive media questionnaire as well as demographic questions.

Upon the completion of the survey, a trained research assistant went through the tablet checkout procedure with the parent. Parents were provided with paperwork describing how to care for the tablet at home. They were not held liable for any damages to the tablet, but were asked to let the lab know immediately if the tablet was lost or stolen, and they were provided with documentation reminding them of the tablet's expected return date. Additionally, this checkout procedure also included the rules for tablet gameplay in the home for the duration of the two-week study. Parents were made aware of the four games their child was allowed to play (based on condition; see Table 9), they were told that the Google Play Store and Wi-Fi capabilities had been disabled, and parents were asked to have children play between 20 minutes to 2 hours a day, either in one sitting or across multiple sessions. Parents signed an additional Tablet Contract acknowledging and agreeing to these rules. At the end of the first visit, parents were compensated \$10 for their time and children were allowed to choose a small toy.

At Visit 2, the one-week follow-up, parents and children visited the lab and data from the in-home tablet play was downloaded and saved. Children completed a second version (order was counterbalanced) of the Picture Pair Task and were then invited to play the 5-minute game play session on the tablet device and complete the "Cargo Airplane Challenge." Again, children followed the tablet gaming with the Metacognition Interview to assess metacognitive skills. At the end of the second visit, parents were again compensated \$10 for their time and children were allowed to choose a small toy.

Table 9

*Chapter 4: Summary of In-Lab and In-Home Procedures*

<b>In Lab Measures and Materials by Visit</b>		
<b>Visit 1</b>	<b>Visit 2</b>	<b>Visit 3</b>
Parent Consent / Child Assent		
Parent Survey		
Tablet Check-Out	Download Tablet Data	Tablet Check-In
Metacognitive Awareness		
Executive Functioning		
Episodic Memory Encoding	Episodic Memory Encoding	Episodic Memory Encoding
5-minute Game Play LEGO City My City: Blue Cop Challenge	5-minute Game Play LEGO City My City: Cargo Airplane Challenge	5-minute Game Play LEGO City My City: Yellow Cop Challenge
Metacognitive Skills	Metacognitive Skills	Metacognitive Skills
<b>In Home Games by Condition</b>		
<b>High Opportunity</b>	<b>Low Opportunity</b>	
Lego Ninjago	Fruit Ninja	
Creator Island	Bubble Mania	
Lego Junior	100 Balls	
Lego Quest	Temple Run	

*Note:* In-lab procedures and tasks highlighted above were administered at all three visits

The third and final visit occurred one week after Visit 2. At Visit 3, the tablets were checked back into the lab and data from the in-home tablet play was downloaded and saved. Children completed the third version of the Picture Pair Task, the 5-minute game play session on the tablet device to complete the “Yellow Cop Challenge,” and the Metacognition Interview. For the final visit, as an incentive for completing all three visits, parents were compensated \$20 for their time, and children again were allowed to choose a small toy.

## Results

Results are divided into four subsections. First, descriptive statistics, associations between all study variables using Pearson product-moment correlations, and preliminary analyses are reported. Second, as a check for random assignment, differences between conditions (High Opportunity vs. Low Opportunity) in previous exposure to interactive media, executive functioning, memory, and metacognition at baseline were examined using Independent Samples t-tests. Third, metacognitive awareness was assessed as a mediator of the relationship between interactive media exposure and episodic memory encoding. However, as described below, Baron and Kenny's guidelines (1986) were not met, therefore, hierarchical regression was used to further investigate the relations between these three variables at baseline. Finally, the primary analysis of the experimental conditions was conducted. A manipulation check was conducted using Independent Samples t-tests to test for significant differences between conditions on children's in-home game play and the Metacognitive Experience Index, and two 2 x 3 Mixed Method Analyses of Variance (ANOVA) with condition as the between-subjects factor and visit as the within-subjects factor were applied to investigate differences between conditions in episodic memory encoding and metacognitive skills across the three in-lab visits.

### *Descriptive Statistics and Correlations*

Descriptive statistics for all study variables at each time point, for the entire sample and by condition, are presented in Table 10. Parents of children in the study reported a moderate amount of exposure to interactive devices; children played an

average of 3.43 hours-per-week on each device ( $SD = 2.00$  hours), and 76% of parents reported that their children had been exposed to at least 5 of the 6 devices. Results indicated that children had comparable previous exposure to interactive media in the High Opportunity condition ( $M = 87.49$ ,  $SD = 49.33$ ) and the Low Opportunity condition ( $M = 92.17$ ,  $SD = 50.63$ ;  $t(56) = 1.12$ ,  $p = .27$ ,  $r = .15$ ).

Table 10

*Chapter 4: Descriptive Statistics for all Study Variables*

<b><i>In-Home Variables</i></b>	<b><i>M</i></b>	<b><i>SD</i></b>				
<b>Hours-per-week Played</b>	<b>2.59</b>	<b>2.21</b>				
High Opportunity Condition	2.51	2.47				
Low Opportunity Condition	2.67	1.93				
<b>Metacognitive Experience Index</b>	<b>11.48</b>	<b>6.56</b>				
High Opportunity Condition	13.20	7.50				
Low Opportunity Condition	9.64	4.87				
<b><i>In Lab: Baseline Variables</i></b>	<b>Visit 1</b>					
<b>Previous IM Exposure</b>	<b>89.58</b>	<b>50.07</b>				
High Opportunity Condition	87.49	49.33				
Low Opportunity Condition	92.17	50.63				
<b>Executive Functioning</b>	<b>0.87</b>	<b>0.21</b>				
High Opportunity Condition	0.86	0.22				
Low Opportunity Condition	0.87	0.21				
<b>Metacognitive Awareness</b>	<b>15.88</b>	<b>3.41</b>				
High Opportunity Condition	16.17	3.57				
Low Opportunity Condition	15.57	3.26				
<b><i>In-Lab: All Three Visits</i></b>			<b>Visit 1</b>	<b>Visit 2</b>	<b>Visit 3</b>	
<b>Episodic Memory Encoding</b>	<b>17.98</b>	<b>3.77</b>	<b>18.79</b>	<b>3.50</b>	<b>19.33</b>	<b>3.42</b>
High Opportunity Condition	17.37	3.82	19.13	3.46	19.87	3.04
Low Opportunity Condition	18.64	3.67	18.43	3.56	18.75	3.75
<b>Metacognitive Skills</b>	<b>11.22</b>	<b>4.12</b>	<b>11.24</b>	<b>5.10</b>	<b>11.59</b>	<b>5.56</b>
High Opportunity Condition	10.57	4.60	11.40	5.22	12.60	5.92
Low Opportunity Condition	11.93	3.47	11.07	5.05	10.50	5.02

Table 11 shows the Pearson product-moment correlation coefficients between all study variables at Visit 1. The results from these correlational analyses demonstrate age was not significantly related to previous interactive media exposure, metacognitive awareness, or metacognitive skills (all  $p$ 's > .16). However, age was significantly and positively related to executive functioning ( $r = .41, p < .001$ ) and average hours-per-week of in-home game play during the study ( $r = .26, p = .03$ ). Additionally, age was marginally positively related to episodic memory encoding ( $r = .22, p = .09$ ).

Table 11

*Chapter 4: Correlations Between all Study Variables at Visit 1*

	1	2	3	4	5	6	7	8
1. Age	--							
2. Hours-per-week in home	.258*	--						
3. Metacognitive Experience Index	.043	.002	--					
4. Previous IM Exposure	-.027	.086	.113	--				
5. Executive Functioning	.412**	-.090	-.039	.073	--			
6. Metacognitive Awareness	.086	.228 <sup>†</sup>	.138	-.027	.217	--		
7. Episodic Memory Encoding	.220 <sup>†</sup>	.112	.076	.336**	.199	.428**	--	
8. Metacognitive Skills	.189	.161	.004	.135	-.037	.134	.159	--

Note. <sup>†</sup> .05 <  $p$  < .10, \* $p$  < .05, \*\* $p$  < .01

An assessment of within time-point associations at Visit 1 demonstrates that children's previous interactive media exposure was not significantly related to metacognitive awareness ( $r = .03, p = .84$ ), but was significantly and positively related to episodic memory encoding ( $r = .34, p = .01$ ). Additionally, metacognitive awareness and

episodic memory encoding were significantly related,  $r = .43, p < .01$ . Children's average hours-per-week of in-home game play was not significantly related to metacognitive skills ( $r = .16, p = .23$ ) or episodic memory encoding ( $r = .11, p = .40$ ). Further, executive functioning was not significantly correlated with memory ( $r = .20, p = .13$ ) or metacognitive skills ( $r = -.04, p = .78$ ). Therefore, neither average hours-per-week spent gaming in-home nor baseline executive functioning were considered as covariates in subsequent analyses.

An assessment of between time-point associations for episodic memory encoding and metacognitive skills demonstrates that both variables demonstrate associations with themselves over time. As anticipated, measurements of both variables that were closer to each other temporally and later in ontogeny were more strongly associated (see Table 12). However, episodic memory encoding and metacognitive skills were not significantly correlated significantly at any of the three visits (all  $p$ 's  $> .23$ ). These patterns of associations over time were also examined separately by condition, but no differences were found.

Table 12

*Chapter 4: Correlations Between Episodic Memory Encoding and Metacognitive Skills*

	<b>Visit 1</b>	<b>Visit 2</b>	<b>Visit 3</b>
<b>Episodic Memory Encoding</b>			
Visit 1	--	.367**	.390**
Visit 2		--	.653**
Visit 3			--
<b>Metacognitive Skills</b>			
Visit 1	--	.381**	.185†
Visit 2		--	.564**
Visit 3			--
<b>Memory x Metacognition</b>	<b>.159</b>	<b>.030</b>	<b>.092</b>

Note. †  $.05 < p < .10$ , \* $p < .05$ , \*\* $p < .01$

### *Examining Baseline Differences by Condition*

Independent Samples t-tests were used to examine differences in all cognitive variables at baseline (i.e., performance measured at Visit 1) between the two conditions. Results indicated that children had similar executive functioning skills in the High Opportunity condition ( $M = 0.86$ ,  $SD = 0.22$ ) as children in the Low Opportunity condition ( $M = 0.87$ ,  $SD = 0.21$ ;  $t(56) = 0.11$ ,  $p = .91$ ,  $r = .01$ ). Similarly, children had comparable metacognitive awareness in the High Opportunity condition ( $M = 16.17$ ,  $SD = 3.57$ ) as children in the Low Opportunity condition ( $M = 15.57$ ,  $SD = 3.26$ ;  $t(56) = 0.66$ ,  $p = .51$ ,  $r = .09$ ). Additionally, no condition differences were found between episodic memory encoding ( $M_{High\ Opp} = 17.37$ ,  $SD_{High\ Opp} = 3.82$ ,  $M_{Low\ Opp} = 18.64$ ,  $SD_{Low\ Opp} = 3.67$ ;  $t(56) = 1.30$ ,  $p = .20$ ,  $r = .17$ ) or metacognitive skills ( $M_{High\ Opp} = 10.57$ ,  $SD_{High\ Opp} = 4.60$ ,  $M_{Low\ Opp} = 11.93$ ,  $SD_{Low\ Opp} = 3.47$ ;  $t(56) = 1.27$ ,  $p = .21$ ,  $r = .17$ ).

### *Metacognitive Awareness*

Metacognitive awareness could not be tested as a mediator of the association between interactive media exposure and episodic memory encoding because there was no significant relation detected between previous interactive media exposure and metacognitive awareness in this sample. However, episodic memory encoding was significantly related to both previous interactive media exposure and metacognitive awareness. Given this pattern of associations, hierarchical regression analyses were run in order to verify the unique contribution of metacognitive awareness on episodic memory above and beyond the influence of previous interactive media exposure. At Step 1, age was entered as a control variable along with exposure. At Step 2, metacognitive



awareness at baseline was added to the model. This analysis showed that Step 1 explained 16.5% of the variance in episodic memory encoding,  $F(2, 55) = 5.45; p = .007$ . Step 2 significantly increased the model fit,  $\Delta R^2 = .18, \Delta F(1, 54) = 14.43, p < .001$ , with a significant contribution of metacognitive awareness ( $p < .001$ ; see Table 13), demonstrating that metacognitive awareness significantly predicts episodic memory encoding above and beyond age and exposure to interactive media.

Table 13

*Chapter 4: Predicting Episodic Memory Encoding from Age, Exposure, and Metacognition*

	<i>b</i>	SE	$\beta$	95 % CI
<i>Step 1</i>				
Age	.609	.327	.230†	[-.05, 1.7]
Exposure	.026	.009	.342**	[.01, .04]
<i>Step 2</i>				
Age	.513	.294	.193†	[-.08, 1.10]
Exposure	.027	.008	.353**	[.01, .04]
Metacognitive Awareness	.466	.123	.421**	[.22, .71]

Note. †  $.05 < p < .10$ , \* $p < .05$ , \*\* $p < .01$

*Metacognitive Experiences, Episodic Memory Encoding, and Metacognitive Skills*

On average, children in the study played on the tablet devices in-home 2.59 hours per week ( $SD = 2.21$ , range = [0, 12.40]), with an average gaming session of 17.04 minutes ( $SD = 8.86$ , range = [0, 48.98]). Results from an Independent Samples t-test indicated that children had similar amount of in-home game play in the High Opportunity condition ( $M = 2.51$  hours,  $SD = 2.47$ ) and in the Low Opportunity condition ( $M = 2.67$  hours,  $SD = 1.93$ ;  $t(56) = 0.28, p = .78, r = .001$ ). Additionally, Pearson product correlation coefficients demonstrated that hours per week gaming was not significantly associated to children’s episodic memory encoding during any of the three visits

(all  $p$ 's > .15) or children's metacognitive skills during any of the three visits (all  $p$ 's > .23). No differences were seen between the two conditions. To serve as a manipulation check, and investigate if the two conditions differed qualitatively in their in-home gaming throughout the duration of the two-week study, the Metacognitive Experience Index also was examined. Preliminary analyses indicated that this indicator of children's opportunities for metacognitive experiences while gaming was positively skewed and had a large standard deviation ( $M = 11.48$ ,  $SD = 6.56$ , range = [2, 32], skew = 1.16), therefore log transformations were applied to reduce any non-normality prior to further analyses (see Table 14 for descriptive statistics).

Table 14

*Chapter 4: Metacognitive Experience Index Descriptives Before and After Transformation*

	Overall			High Opportunity			Low Opportunity		
	<i>M</i>	<i>SD</i>	<i>Skew</i>	<i>M</i>	<i>SD</i>	<i>Skew</i>	<i>M</i>	<i>SD</i>	<i>Skew</i>
Raw Scores	11.48	6.56	1.16	13.20	7.50	1.00	9.64	4.87	0.62
Transformed Scores	2.29	0.57	-0.14	2.43	0.55	0.26	2.13	0.56	0.55

An Independent Samples t-test was used to examine if differences existed between the two conditions in the transformed Metacognitive Experience Index. Results demonstrate that children in the High Opportunity condition had a significantly higher Metacognitive Experience Index ( $M = 2.43$ ,  $SD = 0.55$ ) than children in the Low Opportunity condition ( $M = 2.13$ ,  $SD = 0.56$ ;  $t(56) = 2.10$ ,  $p = .04$ ,  $r = .07$ , see Figure 7), confirming the effect of the experimental manipulation on children's metacognitive experiences while gaming over the course of the experiment.

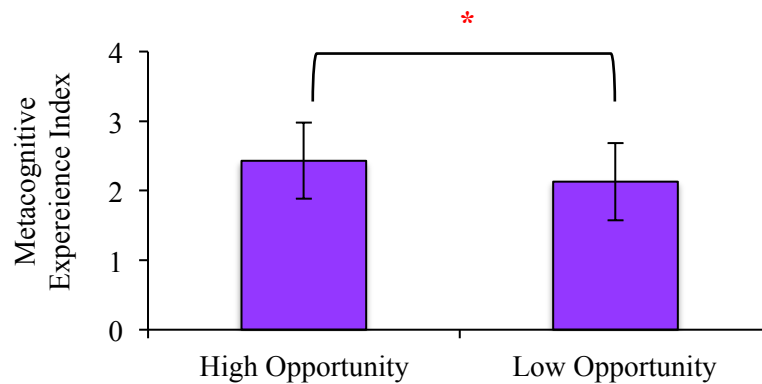


Figure 7. Chapter 4: Differences in Metacognitive Experience Index Scores by Condition: Average Metacognitive Experience Index across the two weeks by condition. This graph illustrates the significant difference in average Metacognitive Experience Index scores between the two groups (\*  $p < .05$ ). Error bars represent standard deviations.

Finally, to examine the impact of type of in-home games played on both episodic memory encoding and metacognitive skills, two 2 (condition: High Opportunity vs. Low Opportunity) x 3 (Visit 1, 2, and 3) Mixed Method ANOVAs were used. For episodic memory encoding, there was no main effect of condition,  $F(1,56) = 0.06$ ,  $p = .81$ ,  $\eta_p^2 = .001$ , however results did indicate a significant main effect of visit,  $F(2,112) = 3.82$ ,  $p = .03$ ,  $\eta_p^2 = .06$ . This result was qualified by a condition by visit interaction demonstrating that the effect of visit on episodic memory encoding differed based on condition,  $F(2,112) = 3.64$ ,  $p = .03$ ,  $\eta_p^2 = .06$ . Specifically, children in the High Opportunity condition showed a small but significant increase in episodic memory from Visit 1 ( $M = 17.37$ ,  $SD = 3.82$ ) to Visit 2 ( $M = 19.13$ ,  $SD = 3.46$ ),  $HSD = 1.78$ ,  $p = .033$ , 95% CI [0.15, 3.38], as well as from Visit 1 to Visit 3 ( $M = 19.87$ ,  $SD = 3.04$ ),  $HSD = 2.50$ ,  $p = .003$ , 95% CI [0.90, 4.10]. Alternatively, children in the Low Opportunity condition showed no change in encoding performance across visits, all  $p$ 's  $> .53$  (see Figure 8).

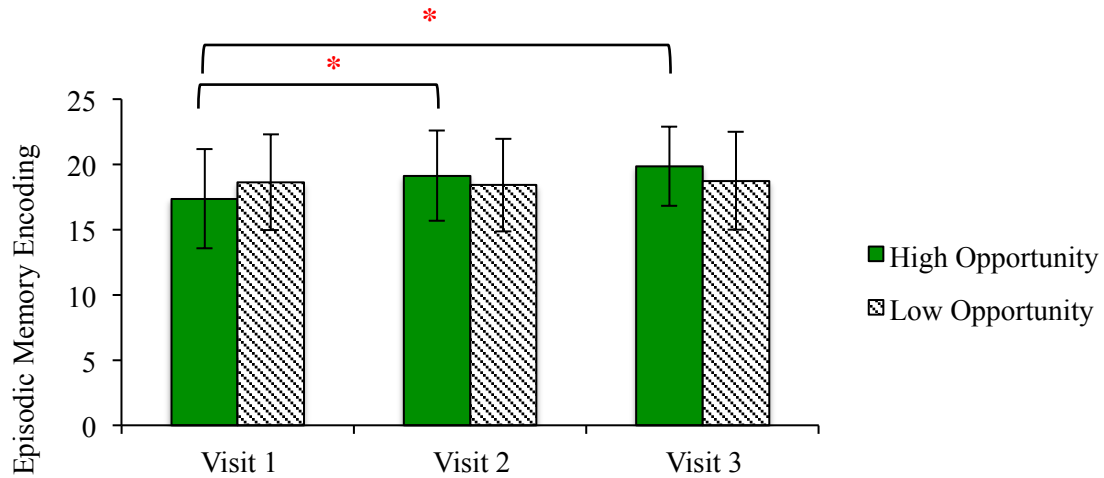


Figure 8. Chapter 4: Change in Episodic Memory Encoding across Visits 1-3 by Condition: For episodic memory encoding, a significant interaction was detected between condition and visit such that children in the High Opportunity condition (solid) showed change small but significant improvement from Visit 1 to Visit 2 and from Visit 1 to Visit 3 (\*  $p < .05$ ), whereas children in the Low Opportunity condition (striped) showed stability across the three visits. Error bars represent standard deviations.

For metacognitive skills, there was no main effect of condition,  $F(1,56) = 0.13, p = .73, \eta_p^2 = .002$ , and no main effect of visit within participants,  $F(2,112) = 0.13, p = .88, \eta_p^2 = .002$ . Additionally, for metacognitive skills the interaction between condition and visit was not statistically significant,  $F(2,112) = 2.95, p = .06, \eta_p^2 = .05$  (see Figure 9).

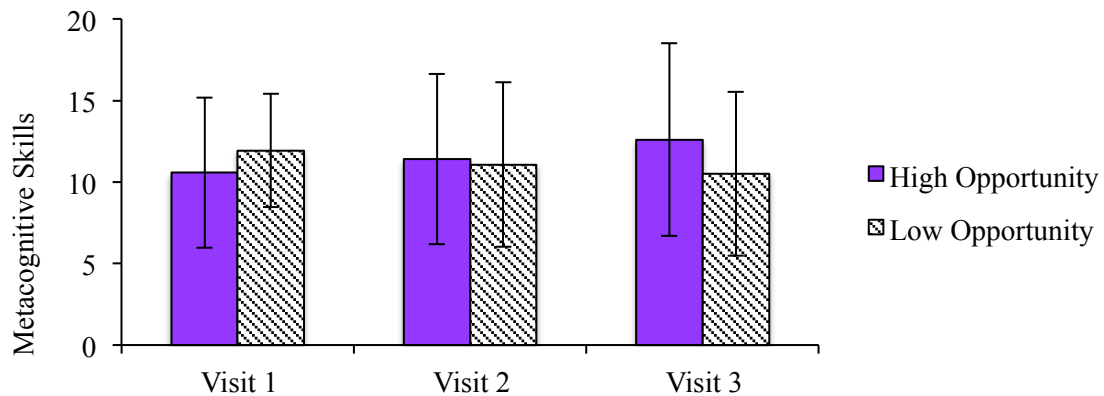


Figure 9. Chapter 4: Change in Metacognitive Skills across Visits 1-3 by Condition: For metacognitive skills, the interaction between condition and visit was not statistically significant ( $p = .06$ ). Error bars represent standard deviations.

## **Discussion**

Our findings speak to the prevalence of interactive media exposure and demonstrate the effects of interactive gaming on children's episodic memory in middle childhood. Specifically, the findings suggest that exposure to interactive media (i.e., duration of exposure across the lifespan and quantity of day-to-day exposure) is positively related to children's episodic memory encoding between ages 6 and 10. Moreover, our findings demonstrate that games high in interactive features such as adaptivity, control, and feedback afford children greater opportunity for metacognitive experiences while gaming. Finally, differential performance in episodic memory encoding over the course of two weeks was observed for children who were exposed to games that provided more metacognitive opportunities.

According to parent report and objective measures of gaming during the duration of the present study, children spent approximately three hours a day gaming in the home on a variety of interactive devices. However, children spent similar amounts of time gaming in-home on the tablets during the two-week study, which suggests that children in this age range do not show a strong preference for high opportunity games compared to low opportunity games. These findings are consistent with previous research in which parents report no differences in the hours-per-week children spend playing high opportunity and low opportunity games (Ricker & Richert, under review). Hours-per-week played on the tablet device in the home was positively related to age, suggesting that either parents allow older children to play longer or that older children prefer to play longer. These findings are in line with previous research demonstrating that older

children, specifically pre-teens and teenagers, tend to spend significantly more time with interactive media and electronic devices in general (Common Sense Media, 2015; Rideout, 2016).

Findings from the hierarchical linear regression demonstrate that metacognitive awareness significantly predicts episodic memory encoding above and beyond previous exposure to interactive media. Previous models of episodic memory acknowledge that in order to form episodic memories, children must be able to effectively encode presented information (Galotti, 2012; Tulving, 2002). Without metacognition children are unable to assess the challenge in front of them or recognize the need for the strategy, as they are unable to think about their thinking and controlling their own thought processes. However, previous research has not focused specifically on the relationship between metacognitive awareness and memory in middle childhood.

These findings highlight the important positive association between children's metacognition and encoding in middle childhood, and suggest that children who have a better knowledge about their cognition as well as when, why, and how to use cognitive strategies have better encoding skills. Which is consistent with findings that children start to use encoding strategies more efficiently between the ages of 7 and 10 (Bjorklund & Douglas, 1997; Schneider & Pressley, 2013; Trick & Enns, 1998). Further, increases in metacognitive awareness during middle childhood might partially explain the rapid increase in episodic memory performance observed from early childhood to adolescence.

Further, metacognitive awareness was not tested as a mediator in this sample as it was not significantly related to children's previous interactive media exposure. This finding was in contrast to past research with slightly older children (ages 10- to 12-years) demonstrating that children who are frequent gamers have higher self-monitoring, and principled decision-making (VanDeventer & White, 2002). One potential explanation for this finding is that the measure of interactive media used did not differentiate between high opportunity and low opportunity games. Previous research examining the relationship between features of interactive games and metacognition suggests that exposure to different types of games and applications differentially predict children's metacognitive awareness (Ricker & Richert, under review). This suggests that it would have been more appropriate to separately evaluate the influence of high and low opportunity games on metacognitive awareness. It is possible that there may be multiple pathways through which interactive media exposure might impact children's episodic memory encoding. Future research should test for moderated mediation to unpack the extent to which metacognitive awareness is one of the mechanisms through which exposure to interactive media that provides high opportunity for metacognitive experiences influences episodic memory encoding.

Sampling from the two-week period of game play demonstrated that children displayed different metacognitive experience index scores in response to high opportunity games versus low opportunity games. That is, games high in adaptivity, control, and feedback lead to significantly more situations where children are able to engage in activities that demonstrate the opportunity for cognitive reflection, and provide children

with a qualitatively different environment than games low in those interactive features. This finding demonstrates that different types of games provide children with differential cognitive experiences while gaming. Further, this is important to note methodologically, as it suggests that the manipulation of types of games played in the home across the two-week duration of the study actively changed the cognitive experiences children had while they gamed.

Despite children in the two conditions playing similar amounts of times (i.e., equally following instructions), when the types of games children regularly play are manipulated to be exclusively high opportunity games, changes in children's episodic memory encoding were observed. These changes were not observed in children who were assigned to play low opportunity games. Specifically, children who played high opportunity games in-home across the two weeks showed a small but significant increase in encoding across the three in-lab visits whereas children who played low opportunity games remained stable in their encoding performance.

Not only are these children getting better at the task when they come in to the lab for visits two and three, but they are getting significantly better compared to themselves, something their counterparts who were playing low opportunity games were not doing. These findings suggest that repeated exposure to high opportunity games positively influence children's memory performance in the lab and potentially change children's approach to encoding information to be remembered. The first challenge to effectively implementing encoding strategies for children during middle childhood is knowing when and how to use them (Galotti, 2012). Therefore, increases in metacognitive awareness



that allow children to monitor their cognitions as well as the need for strategies should lead to increase strategy use. Future work is needed to examine the actual encoding strategies children utilize at baseline, e.g., do children spontaneously engage in maintenance rehearsal (i.e., repeating stimuli to themselves either; Bjorklund, 2012), as well as how utilization of these strategies change across visits as a function of in-home gaming.

In contrast to findings regarding episodic memory encoding, type of game played in the home did not significantly impact children's metacognitive skills across the two weeks of the study. An interaction trending toward significance with a small effect size was observed, which indicated that children in the high opportunity condition trended toward improvement across the three visits in their metacognitive skills (i.e., monitoring and regulating of their cognitions while gaming), whereas children in the low condition showed a decrease in performance across the three visits. However, these results were non-significant and should not be over interpreted. Additionally, children's metacognitive skills, as measured by the metacognition interview, were not significantly related to memory at any of the three visits, despite the strong association between memory and baseline metacognitive awareness. Taken together, these results are suggestive of a larger measurement issue with the metacognition interview.

### **Limitations**

There are limitations to the present study that should be noted. First, throughout the duration of the study, the average hours-per-week spent gaming was only 2.59 hours. Parents were instructed to let children play between 20 minutes and 2 hours a day (i.e.,

between 2.33 hours to 14 hours-per-week), which means children played at the very low end of the allowed range. Children were asked to refrain from other interactive devices for the duration of the study, however the low hours-per-week observed might suggest some non-compliance. Alternatively, parents could have neglected the range and erred on the side of being more strict, as a result of over conformity, thereby only allowing their children to play 20 minutes a day. Either way, estimates of the effects of gaming in high opportunity games on memory and metacognitive skills are likely conservative as a result of less exposure time.

Second, the study was limited in that metacognitive skills were difficult to measure in a conceptually and ecologically valid way. Metacognitive awareness, as a construct, lent itself more readily to self-report measures, as articulating thoughts on one's cognition demonstrates awareness of those processes. However, metacognitive skills (i.e., monitoring and regulating of one's cognitions) were not as easily captured. The interview used in the present study was adapted for children in middle childhood, however responses to the specific questions were task dependent. The in-lab tablet challenge given immediately before the interview questions all came from one High Opportunity game (LEGO City: My City). It is possible that children in the high opportunity condition, who played high opportunity games in the home, may have been more comfortable playing this type of game due to familiarity, and therefore be more able to respond to questions regarding their cognitive experiences while game. Alternatively, children who played low opportunity games in the home may have been less familiar with this type of game in the lab, leading to a differential pattern of responses on the

metacognitive interview. As such, the findings of this research can make limited inferences regarding the impact of interactive gaming on specific metacognitive skills. Nonetheless, significant effects of interactive gaming on episodic memory were observed for games that provide children with high metacognitive opportunities. Future work should further explore valid ways of measuring metacognitive skills, and should identify direct pathways between those specific skills and the use of effective episodic memory encoding strategies.

## **Conclusions**

Interactive media has become a part of the context in which children develop (Blumberg & Fisch, 2013). Although the impacts of interactive media on cognitive development are documented in a growing body of research, little work has focused on children's episodic media. The present study contributes to the literature by being one of the first experimental studies to investigate the effects of interactive media exposure on metacognition and episodic memory. First, we identified both previous exposure to interactive media and metacognitive awareness as positive predictors of children's episodic memory encoding. Second, we found that not all interactive games afford children the same opportunities for metacognitive experiences. Finally, we demonstrate that exposure to tablet applications high in opportunities for metacognitive experience promotes improved episodic memory encoding, even after only a short period of time. Our findings suggest that interactive media and devices (e.g., mobile phones and tablets) are indeed cultural tools that influence the development of metacognitive skills necessary to utilize effective encoding strategies for episodic memory. Our work contributes

theoretically to the field of developmental psychology, by providing insight into the underlying mechanisms involved in the impacts of mobile technology on memory. Further, we present easily translatable research-based knowledge to inform both consumers of children's interactive media (e.g., teachers, parents, and children), as well as designers of games and applications for children.

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## **Chapter 5: General Discussion**

The primary goal of this dissertation was to assess models of episodic memory and examine interactive media exposure as a contextual factor that influences the development of children's episodic memory in middle childhood. This dissertation incorporated a series of studies utilizing multiple methodological approaches, including parent and child questionnaires, cognitive testing, naturalistic exposure sessions, and an experimental manipulation. Additionally, a variety of statistical approaches were utilized to test the conceptual model put forth by this dissertation, which described interactive media devices as cultural tools that afford children the opportunity for metacognitive experiences. These experiences were posited to promote children's metacognitive awareness, metacognitive skills, and episodic memory encoding.

The impact of interactive media on episodic memory was found to vary as a function of age, demonstrating positive impacts on children's encoding in middle childhood but little to no impact on children's free recall in early childhood. Exposure to interactive media (e.g., video game consoles, computers, mobile phones and tablets) was found to impact both children's metacognitive awareness and episodic memory. Specifically, exposure to games and applications high in certain features of interactivity (i.e., adaptivity, control, and feedback) positively predicted metacognitive awareness, and promoted episodic memory encoding in children ages 6- to 10-years of age. However, immediate impacts on children's metacognitive skills were not observed. Four overarching research questions were addressed across three manuscripts (i.e., Chapters 2-4; see Table 15).

Table 15

*Methodological Overview of Chapters 2, 3, and 4*

	<b>Chapter 2</b>	<b>Chapter 3</b>	<b>Chapter 4</b>
<b>Sample Size (Sex)</b>	N = 77 (36 Female)	N = 103 (51 Female)	N = 58 (29 Female)
<b>Age</b>	M = 4.89, SD = 0.51, range = [4, 6.5]	M = 8.42, SD = 1.50, range = [6, 10.9]	M = 8.38, SD = 1.42, range = [6, 10.9]
<b>Measures</b>			
<i>Interactive Media</i>			
<b>General IM Exposure</b>	✓	✗	✓
<b>Specific Game Exposure</b>	✗	✓	✗
<i>Metacognition</i>			
<b>MC Experiences</b>	✗	✗	✓ Coded Game Play
<b>MC Awareness</b>	✗	✓ Jr. MAI	✓ Jr. MAI
<b>MC Skills</b>	✗	✗	✓ MC Interview
<i>Episodic Memory</i>			
<b>Encoding</b>	✗	✗	✓ Picture Pairs Task
<b>Recall</b>	✓ Story Questionnaire	✗	✗
<b>Research Question(s) Addressed</b>	Research Question 1	Research Question 2	Research Question 1 Research Question 2 Research Question 3 Research Question 4

**Research Question 1**

The first research question asked if children's previous interactive media exposure was related to their episodic memory in early to middle childhood, that is, does interactive media use impact children's memory. The first hypothesis for this research question was that general exposure to interactive media would be positively related to children's episodic memory performance in middle childhood. Correlational findings from Chapter 2 examining the relationship between previous exposure to interactive

media and free recall in children ages 4- to 6.5-years old demonstrate that there is not a significant association between the quantity and duration of exposure to interactive devices and memory performance. However, findings from Chapter 4, examining correlation between previous interactive media exposure and episodic memory encoding in children ages of 6- to 10-years old suggest that these two variables are positively and significantly related. The positive association observed during middle childhood indicates that children in this age range who spend more time with interactive media devices and in interactive gaming environments tend to have better encoding skills (i.e., they are more likely to immediately recall or recognize experienced events or facts). These findings demonstrate support for the first hypothesis posited by the conceptual model for this research question that interactive media exposure and memory are positively related in middle childhood.

The second hypothesis for Research Question 1 posited that the magnitude of association between previous interactive media exposure and episodic memory performance would be stronger in older children than in younger children. The difference in correlational findings from Chapter 2 (no significant correlation in early childhood) and Chapter 4 (significant positive correlation in middle childhood) offer preliminary support for this hypothesis. Additionally, the multiple regression analysis in Chapter 2 predicting memory performance from age, interactive media, and the interaction between the age and exposure, identified age as a significant moderator of the association between exposure and memory performance in early childhood between the ages of 4- to 6.5-years. This interaction demonstrated that as age increased the effect of interactive media

exposure on memory also increased. Previous research, including a meta-analysis of research covering a wide range of developmental periods, estimated little to no association between memory performance and interactive media exposure on average (e.g., Takacs, Swart, & Bus 2015). However, the meta-analytic findings presented in Chapter 2 demonstrate that across 17 studies of children ages 2- to 9-years-old, age was a moderator of these effects. That is, on average the association between exposure and memory performance was non-significant for children younger than 6-years of age, but positive and significant for children over 6-years of age. These findings support the second hypothesis for this research question, and the notion that the impacts of interactive media exposure on episodic memory vary as a function of age.

### **Research Question 2**

The second research question addressed by this dissertation was do interactive games provide children with the opportunities for metacognitive experience and, do different types of gaming environments differentially influence children's metacognition in middle childhood. The first hypothesis for this research question was that children would have opportunities for metacognitive experiences while playing interactive tablet games. In Chapter 4, children's in-home game play was recorded via screen capture software and coded for the presence and quantity of specific behaviors and situations that afford children opportunities for metacognitive experiences (i.e., opportunities for conscious thoughts and reflections on cognitive processes). The behaviors and situations that were coded closely resembled those described by Flavell as eliciting metacognitive experiences (i.e., in response to novel roles or situations that involve decision making and



taking actions, 1979). Results of that coding demonstrate that children did experience novel challenges and tasks within the interactive gaming environment. These findings support the first hypothesis that children have metacognitive experiences while gaming.

The second hypothesis for Research Question 2 was that exposure to games high in adaptivity, control, and feedback would provide children with greater opportunities for metacognitive experience and subsequently have a positive influence on children's metacognitive awareness. In contrast, it was expected that exposure to games low in adaptivity, control, and feedback would afford children fewer opportunities for metacognitive experiences and would not be predictive of children's metacognitive awareness. Independent sample t-tests conducted in Chapter 4 to compare the number of opportunities for metacognitive experiences while gaming in-home between conditions indicated that children in the high opportunity condition engaged in significantly more of these novel challenges and tasks than children in the low opportunity condition. Children in the high opportunity condition were assigned to play four games rated as high in adaptivity, control, and feedback, whereas children in the low opportunity condition were assigned to play four games rated as low on these features. The differential metacognitive experiences observed based on condition suggest that different types of games provide children with differential cognitive experiences while gaming. Further, this is important to note methodologically, as it demonstrates that the experimental manipulation (i.e., changing the types of games children play in-home in order to influence metacognitive experiences) was successful.

Further, findings from Chapter 3, which examined parent reports of specific games their child plays, demonstrate that the quantity and duration of exposure to different types of interactive games (i.e., high opportunity compared to low opportunity as rated by levels of adaptivity, control, and feedback) differentially predict children's metacognitive awareness. For children between 6- to 10-years of age, more exposure to high opportunity games was predictive of greater metacognitive awareness, whereas the amount of exposure to low opportunity games was unrelated to metacognitive awareness. Taken together, the findings from Chapters 3 and 4 provide support for the second hypothesis of Research Question 2 that exposure to games high in adaptivity, control, and feedback would provide children with greater opportunities for metacognitive experience and subsequently have a positive influence on children's metacognitive awareness compared to exposure to games low in these features.

### **Research Question 3**

The third research question investigated if metacognitive awareness was a mediator of the association between previous interactive media and memory performance in middle childhood. It was hypothesized that metacognitive awareness would mediate the relationship between previous interactive media exposure and episodic memory encoding performance. Correlational results from Chapter 4 demonstrate that both exposure to interactive media and metacognitive awareness positively and significantly predict children's memory performance, but that general exposure to interactive media and metacognitive awareness were not significantly related. Therefore, mediation analyses could not be conducted. Hierarchical linear regression analyses that were

conducted as an alternative to further investigate the relationship between these three variables suggested that metacognitive awareness was predictive of episodic memory encoding above and beyond age and exposure to interactive media. Contrary to the hypothesis for Research Question 2, these findings suggest that both general interactive media exposure and children's metacognitive awareness predict unique variance in children's memory performance.

#### **Research Question 4**

The final research question this dissertation addressed is can interactive media promote increased episodic memory encoding and/or metacognitive skills through exposure to games that provide children with opportunities for metacognitive experiences. The first hypothesis was that following a two-week intervention, children exposed to games that provided more opportunities for metacognitive experience would show increased performance in episodic memory encoding compared to children exposed to games with fewer opportunities for metacognitive experience. The findings from Chapter 4 demonstrate that over the course of the two-week intervention, children that gamed in interactive environments with high opportunities for metacognitive experiences showed small but significant increases in episodic memory encoding, whereas children in the low opportunity condition showed no change in performance. These results show support for the first hypothesis for Research Question 4 that exposing children to games that provide greater opportunity for metacognitive experiences can promote increased episodic memory encoding.

The second hypothesis for this research question was that following the same two-week intervention, children exposed to games that provided more opportunities for metacognitive experience would demonstrate increased metacognitive skills compared to children exposed to games that provided fewer opportunities for metacognitive experience. The findings from Chapter 4 regarding metacognitive skills demonstrated a different pattern across the two-week intervention than that of episodic memory encoding. Children in the high opportunity condition demonstrated an increase in metacognitive skills over the two-weeks. In contrast, children in the low condition demonstrated a decrease in metacognitive skills. However, these changes were slight and not significant. Therefore, the second hypothesis that exposing children to games with greater opportunities for metacognitive experiences can promote improved metacognitive skills was not supported.

### **Theoretical Implications**

#### *Metacognition and Episodic Memory*

The findings that age moderates the relationship between exposure and memory performance are in line with current theoretical frameworks for understanding children's differential susceptibility to media effects at different developmental periods (Valkenberg & Peter, 2013), and suggest that interactive gaming does not impact all children identically. While there may be memory benefits for gaming in interactive environments, those benefits do not seem to come online until after the preschool years. Further, these findings indicate that middle childhood might be of particular saliency for considering the impacts of interactive media on episodic memory development. Importantly, this

moderation coincides with the development of children's metacognitive skills (Kuhn, 2000), which suggests that children who have not fully developed metacognitive awareness may not experience the full effects of interactive media exposure on episodic memory. These findings provide support for a model that suggests the impacts of interactive media may be at least partially mediated by metacognition and that these impact may be limited in early childhood by age-related cognitive constraints (Ricker, Robb, & Richert, under review).

Previous models of episodic memory acknowledge that in order to form episodic memories, children must be able to effectively encode presented information (Galotti, 2012; Tulving, 2002). However, without metacognition children are unable to assess the challenge in front of them or recognize the need for the strategy, as they are unable to think about their thinking and controlling their own thought processes. Despite literature focusing on the relationship between theory-of-mind and episodic memory in early childhood (Perner, Kloo, & Gornik, 2007), very little previous research has focused specifically on the relationship between metacognitive awareness and memory in middle childhood. This dissertation highlights the important positive association between children's metacognition and encoding in middle childhood, and suggests that children who have a better knowledge about their cognition as well as when, why, and how to use cognitive strategies have better encoding skills. These findings are consistent with findings that children start to use encoding strategies more efficiently between 7- to 10-years of age (Bjorklund & Douglas, 1997; Schneider & Pressley, 2013; Trick & Enns, 1998). Further, increases in metacognitive awareness during middle childhood might

partially explain the rapid increase in episodic memory performance observed from early childhood to adolescence.

Across the two-week intervention reported in this dissertation, children who were provided with more opportunities for metacognitive experience demonstrated improved episodic memory encoding. Providing support for the notion that that metacognitive experiences promote increased memory function in middle childhood. However, across a two-week intervention children's metacognitive skills, as measured by the metacognition interview, were not susceptible to the influence of interactive gaming. Theoretically, children's metacognitive skills and metacognitive experiences have a transactional relationship. That is, as children gain experience consciously reflecting on their own thoughts and cognitive processes in responses to novel challenges and tasks, they strengthen their ability to consciously monitor and regulate their own cognitions; in turn their future metacognitive experiences become more comprehensive and profound (Falvell, 1979; Efklides, 2009). With respect to interactive media exposure, as through gaming in environments children should have these types of experiences and in response would theoretically demonstrate micro-fluctuations in their metacognitive skills.

However, the findings of this dissertation suggest that increasing children's metacognitive experiences for a two-week period does not immediately enhance their self-reported metacognitive skills. These findings provide insight into the timeframe needed for integration of knowledge into skills, as previous research has discussed the feedback loop between these two facets of metacognition mostly theoretically (Brown, 1987; Efklides, 2009). These findings suggest that this integration is not immediate, but

rather that children may need substantial time to integrate the information gained through metacognitive experiences into their knowledge in order to explicitly report their ability to monitor their cognition.

*Environmental influences on Metacognition and Memory in Middle Childhood*

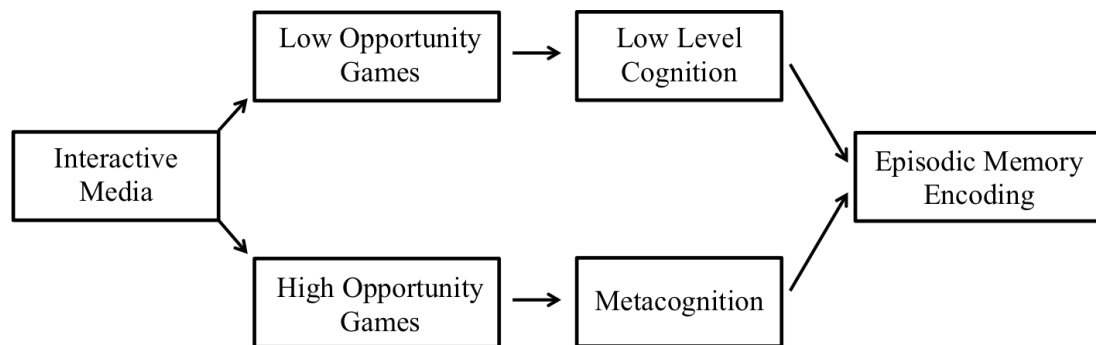
Previous research focusing on maturational etiology of the development of episodic memory encoding suggests that change in early life is mostly driven by changes to attentional networks (Shing et al., 2010). Little to no previous research work have thoroughly investigated the ways in which environmental influences (e.g., formal schooling, traditional play, and interactive gaming) impact children's episodic memory encoding. This dissertation provides evidence that previous interactive media exposure was more predictive of children's memory encoding skills than age. Which suggests that environmental influences can play a substantial role in episodic memory encoding during this developmental period, greater than maturation alone. What is unclear from these findings is whether gaming in middle childhood regardless of prior exposure to interactive media in the preschool years would still demonstrate these same positive benefits for episodic memory encoding. Additionally, findings from the impact of the two-week intervention suggest that children's episodic memory performance can be significantly promoted when the types of games children play in the home are manipulated.

From a developmental perspective, both of these findings are further evidence that children's metacognitive awareness and episodic memory are malleable in middle childhood and can be influenced by the cultural tools with which children interact. In

particular, interactive devices are able to influence children's metacognitive awareness, by providing an environment in which children are able to have metacognitive experiences. These experiences have been traditionally thought of as occurring in response to experiences gained in real world interactions; although interactive media and gaming seem to be qualitatively different environments compared to formal schooling or traditional play, these results demonstrate that simulated environments that can provide children with these same experiences and that these different environmental influences or environments may operate similarly in some ways. Specifically, interactive gaming environments provide children with the space to experience novel challenges and tasks, and in certain types of games support and feedback are offered that change in response to the child's needs. However, unlike formal schooling or traditional play, mistakes made in gaming environments are virtually consequence free. In this way interactive gaming environments might be more safe and flexible than other learning environments. Mediation analyses could not be conducted using the data from Chapter 4 and the findings did not support our hypothesis that metacognition would mediate the relationship between interactive media and memory; although it is worthwhile to note that these analyses investigated the impact of general interactive media exposure (i.e., combining high and low opportunity games). Alternatively, multiple regression conducted in Chapter 3 that considered the impacts of high and low opportunity games separately demonstrated that in 6- to 10-year olds metacognitive awareness was positively and significantly associated with exposure to high opportunity games, but not significantly associated with exposure to low opportunity games. This pattern of results



suggests that there may be multiple pathways through which interactive media exposure might impact children’s episodic memory encoding, as both high and low opportunity gaming demonstrates effects on memory, but only high opportunity gaming is related to metacognitive awareness. The results suggest that the pathway proposed in the conceptual model that guides this dissertation, i.e., metacognition mediating the effect of interactive media on episodic memory encoding, is a pathway through which high opportunity games enact change on children’s memory development. At least one alternative pathway likely exists, that is low opportunity games likely have a unique contribute to episodic memory encoding performance, not explained by metacognition (e.g., lower level cognitive functions). See Figure 10 for an applied path model that describes these differential pathways.



*Figure 10.* Path Model Describing Differential Effects By Type of Game: Note that here the three transactional facets of metacognition (i.e., metacognitive skills, metacognitive experiences, and metacognitive awareness) are collapsed into one box for simplicity of illustration.

The association between low opportunity games and episodic memory encoding could be mediated by factors other than metacognition. It is possible that features of low opportunity games engage lower level cognitive functions such as motor memory, working memory, or executive functioning, that may also lead to improvements in

episodic memory encoding. Although working memory and motor memory are conceptually very different constructs from episodic memory, they have been found in the memory literature to be positively correlated (see for example: Paradiso, Andreasen, O'Leary, Arndt, & Robinson, 1997; Tulving, 2002). Previous research has demonstrated benefits of general gaming exposure on episodic functioning (e.g., Flynn et al., 2014), which consists of general cognitive control and has the ability to influence episodic memory performance. This research however has not examined differential effects based on the opportunities afforded by specific games. The influence of lower level cognitive functioning might explain the positive association found between general interactive media exposure (i.e., low opportunity gaming in conjunction with high opportunity gaming) and children's episodic memory encoding performance in middle childhood, as well as why exposure to only low opportunity games across the two-week intervention did not have negative impacts on children's memory performance.

This applied model can be empirically tested in future research needed to confirm that the association between exposure to interactive games high in adaptivity, control, and feedback and metacognitive awareness is indeed significant, and if so how it mediates the relationship between that exposure and memory. Additionally, future studies along this line of research will examine quantity and duration of exposure to different types of games in relation to metacognitive awareness as well as other potential mediators, in order to test the applied path model presented in Figure 10. Taken together, the findings of this dissertation do provide some insight into the mechanisms through which exposure to interactive media can impact children's memory development. The results show

support for a model that describes gaming in interactive environments high in adaptivity, control, and feedback leading to increased metacognitive experiences and positively impacting episodic memory encoding. Additionally, these findings suggest that games with low opportunities for metacognitive experience may have a different impact on metacognitive skills than on episodic memory encoding.

### **Broader Implications**

The findings from this dissertation suggest that as children game they are given opportunities to challenge themselves cognitively, monitor their cognitions, and reflect on strategies used and choices made. Over time, these experiences allow children to integrate information into knowledge (Ko, 2002; Steinkuehler, 2006) and learn about their own cognitive processes, increasing their metacognitive awareness. However, the findings also demonstrate that not all games provide the same quality or quantity of these types of scenarios for children. Games that are low in adaptivity, feedback, or the control a child has over their activities within the game cannot challenge children in the same way, and therefore do not offer room for this same type of metacognitive growth. Previous exposure to games low in these features was unrelated to children's metacognitive awareness, and exposure to these games over the course of the two-week intervention did not promote positive change in encoding skills. These findings highlight the importance of investigating features of interactive games and how they shape the experiences children have within interactive environments, rather than focusing on the quantity of time children spend on devices or look at exposure to broad genres of games.

The findings from this dissertation suggest that these types of variables might not tell the whole story.

The experimental portion of this dissertation demonstrated that children's episodic memory encoding is susceptible to contextual influences in middle childhood. Specifically, manipulating the types of games children play on a regular basis can result in differential encoding performance. Exposure to the games that provided high opportunity for metacognitive experiences, even over a two-week period, resulted in positive changes in performance. These findings suggest that exposure to high opportunity games facilitates the utilization of more effective encoding strategies in the lab. Additionally, these findings demonstrate that even short term exposure to specific types of games can have positive effects on children's episodic memory, regardless of the quantity and duration of previous exposure to interactive media in the preschool years. Future research is needed to further investigate this finding by examining the specific encoding strategies children use in the lab to see how strategy use changes after exposure to high opportunity games.

The findings presented in this information which suggest that gaming environments that are adaptive, that allow the child to control their experience, and that give immediate feedback can provide children with similar opportunities as formal schooling or traditional play are should be of interest to consumers, creators, and researchers of interactive games alike. In the case of consumers (e.g., parents and teachers), knowledge of the types of game features that promote metacognition and memory can help with decisions regarding which types of games to have children game

on in the home or in the classroom. These findings are also of particular interest to game designers, who can apply this knowledge to manipulate interactive gaming environments and promote learning by choosing to include specific features in a game (i.e., adaptivity, control, and feedback). Programmers and game designers have much more control over manipulating interactive gaming environments than teachers do in formal schooling or parents do during traditional play. That is, programmers can create games that promote positive experiences by design, whereas teachers and parents have less control over the types of experiences children have while gaming. Finally, these findings have important implications at the intersection of consumers, creators, and researchers of interactive games and media for children. The conceptual model presented along with the identification of specific features of interactive media that promote metacognitive awareness and memory provide a framework for future research to evaluate the work of game designers and inform the decisions parents and educators make regarding what types of interactive media to introduce to children and at what developmental periods.

### **Limitations and Future Directions**

One limitation of the research conducted in Chapter 2, examining age as a moderator of the association between previous interactive media exposure and episodic memory is the lack of a metacognitive measure for children between 4- to 6.5-years-old. Without this, metacognitive skills cannot be examined as a potential explanation for the age moderation demonstrated. Future research on the influence of interactive media and gaming should examine children's metacognitive skills. However, this dissertation is one

of the first lines of research to examine the associations between exposure to interactive media, memory, and metacognition.

A second limitation is the survey-based data used to examine exposure to particular types of games in Chapter 3. Hours-per-week spent gaming was likely underestimated, as only a set of 15 specific games were examined and coded. Future research should have parents report on all of the games their children play along with hours per week. Trained raters could then code the list of games provided by parents for interactive features and opportunities for metacognition. This would allow for a more accurate estimation of total hours-per-week children play in both high and low opportunity games.

Additionally, the experimental portion of this dissertation presented in Chapter 4 was limited by time and funding. The small sample size, even with three time points, made it difficult to conduct complex analyses with multiple control variables (e.g., linear growth curves across the three visits controlling for amount of time played in the home). Future research along this line of inquiry will ideally be able to include a larger sample size and will allow for expansion of the research questions through the addition of more comparison and control groups (e.g., a true control group that refrains from gaming in the home across the two weeks). Research in this chapter assessed both memory and metacognition within a small window of time, and as separate outcomes influenced by two weeks of in-home gaming. Future research should utilize multilevel modeling to examine trajectories of memory performance and metacognitive skills over a longer period of time, one in which change in metacognitive skills can be captured. This would allow for an investigation of how high opportunity gaming exposure might dynamically influence

the two variables in a way that allows them to interact, potentially investigating metacognitive skills and episodic memory as a time-varying covariates.

Finally, the biggest limitation of this dissertation is the inadequate ability to directly assess the impacts of interactive gaming on metacognitive skills. Across the three visits discussed in Chapter 4, children's self-report of what they thought or did while they completed a task in the lab were collected using a metacognition interview designed to measure of metacognitive skills. However, while children's responses on this measure were correlated between visits, demonstrating reliability in their responses, children's response to this 12-item measure was not significantly correlated any other measures in the study, including age, exposure to interactive media, executive functioning, episodic memory encoding, and metacognitive awareness, as measured by a previous validated scale (i.e., the Jr. Metacognitive Awareness Inventory; Sperling et al., 2002). The lack of association between metacognitive skills and metacognitive awareness is particularly notable, and raises questions in regards to the validity of this measure as an indicator of change in children's metacognitive skills. Rather, performance on this measure might potentially provide us with information on the different types of metacognitive experiences children have when they game in an environment similar to or different from what they game in on a normal basis.

## **Conclusions**

Interactive media is ubiquitous in the lives of 6- to 10-year old children. Interactive devices such as tablets and computers are commonly used in the home and are increasingly being introduced into the classroom (Common Sense Media, 2015). These

tools are sometimes utilized in place of social interactions or outdoor play that children normally engage in. As such, this dissertation identifies interactive devices that allow for gaming as cultural tools that have the ability to promote the development of metacognitive awareness and episodic memory encoding. These findings suggest that the impacts of gaming or exposure to interactive media are not uniform, but rather vary as a function of the child's age as well as the features of the game. Specifically, children's episodic memory encoding is more susceptible to the influence of interactive gaming in middle childhood rather than early childhood, once metacognitive skills have come online. Also, games high in adaptivity, control, and feedback provide children with greater opportunity for metacognitive experiences, and positively promote encoding. However, games low in these features have a unique influence on memory that warrants future research. Technology is ever changing and updating, new games, applications, and devices are constantly being introduced to the market. As such, it is important to understand the specific features of interactive media how they impact cognition. Future research should classify games or devices by particular features, rather than focusing on one specific device/ game or even broad genres of games, in order to produce generalizable findings as the technology continues to develop or evolve.

The findings from this dissertation support the theory that specific features of interactive gaming environments provide children with opportunities for metacognitive experiences, which promote children's metacognitive awareness. After two-weeks of gaming in these types of environments, children showed small but significant improvement in episodic memory. These findings provide insight into the mechanisms



through which episodic memory is influenced by exposure to different types of interactive media (i.e., allowing children opportunities for metacognitive experiences, and promoting their metacognitive awareness). One major implication of this line of research is evidence that technology has the potential to intervene in the development of children's cognitive abilities. Specifically, the development of children's episodic memory encoding and metacognitive awareness is impacted by socio-cultural factors above and beyond developmental mechanisms. Importantly, these findings can provide input into the design of future interactive media targeted at promoting increased learning and memory. Further, this work is readily translatable to a wide audience of consumers and policy makers, providing them with evidence-based information regarding how exposure to these types of media might enhance or inhibit children's metacognition and episodic memory development.

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## Appendix

### Cognitive Measures

#### *Executive Functioning*

#### Flanker Swimming Fish Task: Programmed in MATLAB

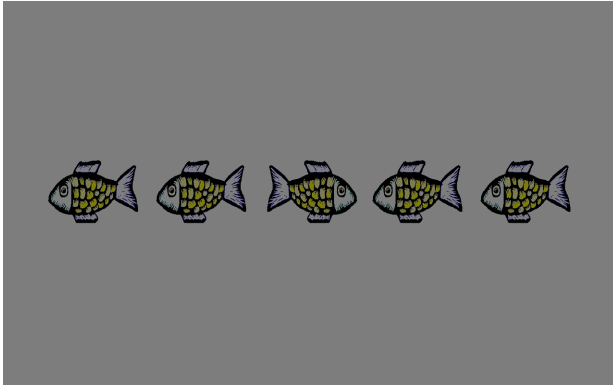


Figure A1. Flanker Swimming Fish Task: Example Stimuli – Incongruent Trial

#### **Instructions:**

This is the Swimming Fish Game, your job is to keep your eye on the middle fish and tell me which way he is swimming.

If he is swimming to the right and facing this way [**Research points to the right of the screen**], I want you to press the Right Arrow [**Research points at the Key, practically touching it**].

If he is swimming to the left and facing this way [**Research points to the left of the screen**],

I want you to press the Left Arrow [**Researcher points at the Key, practically touching it**].

Sometimes the middle fish might be swimming alone, and sometimes he might be swimming with friends. Sometimes they might all be swimming in the same direction, and sometimes they might be swimming in different directions. No matter how many fish are on the screen, I want you to **Keep your eye on the middle fish** and only tell me which way he is swimming.

I want you to respond as quickly and as correctly as you can each time. Any questions?

## Episodic Memory

### Paired Pictures Tasks: Programmed in PsychoPy

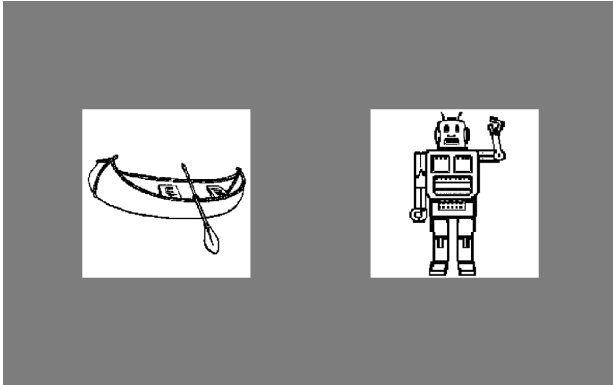


Figure A2. Paired Picture Task: Example stimuli

**First Instructions:** First we are going to show you your study list, you will be shown a set of picture pairs, two pictures together on the screen. Your task is to remember the two pictures together as a pair. We are going to ask you about the pairs later.

Do you have any questions? Okay, let's begin.

**Second Instructions:** During this section I am going to ask you about the picture pairs you just learned. You will be shown a pair of pictures on the screen and asked to decide whether those 2 pictures were or were not shown together, as a pair, during your study list.

First I will ask you, were these 2 pictures a pair? And you will tell me yes or no.

**Children were shown three types of pairs at test, intact pairs (correct pairs they saw during their study list), rearranged pairs (incorrectly paired images they were exposed to during their study list, and novel pairs (new images they had not yet seen before).**

Table A1

#### Calculating Episodic Memory Encoding Outcome

	Intact	Rearranged	Novel
Yes	Hit	False Alarm	False Alarm
No	Miss	Correct Reject	Correct Reject

Note. Encoding Outcome = Hits + Correct Rejections, [1, 24]

*Metacognitive Awareness*

Jr. MAI (Metacognitive Awareness Inventory): Verbal interview with responses directly entered into the tablet

**Verbal Instructions:** I am going to read you a short sentence and I want you to tell me if it describes you (Never, Sometimes or Always). Think about the way you are when you are doing school work or homework. Please answer as honestly as possible.

Responses: Never (0), Sometimes (1), Always (2)

1. I know when I understand something.
2. I can make myself learn when I need to.
3. I try to use ways of studying that have worked for me before.
4. I know what the teacher expects me to learn.
5. I learn best when I already know something about the topic.
6. I draw pictures or diagrams to help me understand while learning.
7. When I am done with my schoolwork, I ask myself if I learned what I wanted to learn.
8. I think of several ways to solve a problem and then choose the best one.
9. I think about what I need to learn before I start working.
10. I ask myself how well I am doing while I am learning something new.
11. I really pay attention to important information.
12. I learn more when I am interested in the topic.



### *Metacognitive Skills*

Metacognition Interview: Pen and paper interview, recorded and transcribed.

**Child completes tablet play challenge with Researcher 1 (the researcher administering the majority of the visit). At the end of the Tablet Play Session Researcher 1 will get up to leave the room:**

**Researcher 1:** Great job, I'll be right back I'm going to go upload your performance.

**Enter Researcher 2 (the researcher trained to administer the Metacognition Interview) with a clipboard. Note: Researcher 2 will have already met the child and parent at the start of the visit and said hello, so they will not be completely unfamiliar.**

**Researcher 2:** Hi, I've never played that Tablet Game you just played before, I want to ask you a few questions about it while we upload your scores...

1) Can you tell me everything you did during the game?

2) Can you tell me everything you thought about while you played the game?

Follow up prompt: Anything Else?

3) Okay great, I am going to show you a screen shot from the game and ask you some questions about what you were thinking or doing while you played. I want you to tell me if you did or thought these things (Never, Sometimes, or Always)"

**Researcher turns on the monitor and brings up an appropriate screenshot based on the game the child just played and their response to Question #1 above (see note below).**



Figure A3. Example Screen Shot: Cargo Airplane Challenge

**Specific Questions:** You said you tried to avoid bumping into other things in the air, like that other airplane over there [**Researcher points at specific feature of screenshot**], when you were trying to do that...

Responses: Never (0), Sometimes (1), Always (2)

Did you think about what you already knew about gaming?

Did you think ‘I know this sort of game’?

Did you try to remember if you had ever played a game like this before?

Did you think ‘I know what to do’?

Did you think about how you were going to avoid them?

Did you think about whether what you were doing was working?

Did you think ‘is this right?’

Did you think ‘I can’t do it’?

Did you make a plan to work it out?

Did you think about a different way to solve the problem?

Did you think about what you would do next?

Did you change the way you tried to fly your airplane?

Four screen shots were prepared for each visit, and each screenshot had a corresponding prompt like the one above along with adjusted questions. The version of questions administered was chosen by Researcher 2 based on the specific activities or tasks the child remembered engaging in (i.e., their response to Question #1). However, in the event that the child did not reference a specific task in the game, a designated *default* screenshot was used. For example, for the Cargo Airplane Challenge, avoiding obstacles (Figure A3 above) served as the default screenshot.

- 4) Thank you for answering all of my questions! Let me bring [**Researcher 1**] back in here so she/he can finish the rest of your visit.