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Curiosity Across the Lifespan:

General Shifts and Influences on Memory and Metacognition

A dissertation submitted in partial satisfaction of the

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by

Mary Carolyn Whatley

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ABSTRACT OF THE DISSERTATION

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Doctor of Philosophy in Psychology

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Professor Alan Dan Castel, Chair

Curiosity motivates many of our everyday behaviors, including learning, hobbies, and goal pursuit. Theories of cognitive aging (e.g., Baltes & Baltes, 1990; Carstensen, 1999; Hess, 2014) suggest that knowledge-based goals may decline as we age in favor of social-emotional goals, and thus, maintaining curiosity to learn may not fit with our goals as we get older. However, curiosity in older age is associated with a variety of positive outcomes (Sakaki et al., 2018) and can improve learning and memory performance (Galli et al., 2018; Kang et al., 2009; McGillivray et al., 2015). The current dissertation examines how different forms of curiosity may shift across the adult lifespan (Chapter 2) as well as how curiosity works to influence learning, memory, and metacognition in both younger adults and older adults (Chapters 3 and 4).

Though some work suggests that curiosity declines with age (e.g., Chu et al., 2020), this dissertation (Study 1) reports evidence that different types of curiosity may show differential relationships with age. Specifically, one's general tendency to be curious may decrease with increasing age, but one's curiosity in response to interesting material, like trivia questions, may increase as we age, suggesting we may be more selective about when and why we experience curiosity in older age. Additionally, curiosity continues to be a motivator of learning and memory throughout the lifespan. Chapter 3 explores how this intrinsic motivation may interact with extrinsic motivation (i.e., value). Results suggest that both forms of motivation may independently influence both younger and older adults' memory, but show different patterns on more detailed associative memory (i.e., memory for the binding of two or more pieces of information). Finally, Chapter 4 examines whether curiosity can influence memory for true and false information. The evidence suggests that curiosity may also improve memory for whether information is true or false, but that these effects may depend on the time course of curiosity (e.g., when curiosity is elicited vs. when curiosity is quenched). The current dissertation adds to our knowledge about how curiosity motivates learning and memory across the adult lifespan.

The dissertation of Mary Carolyn Whatley is approved.

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DEDICATION

To my grandparents, thank you for being examples of successful aging.

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1. **Whatley, M. C.,** Schwartz, S. T., Block, J. B., & Castel, A. D. (2023). Memory, metamemory, and false memory for features of familiar logos: A misinformation effect for the Apple logo. *Applied Cognitive Psychology, 37*(5), 904–918.
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SELECTED PRESENTATIONS

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CHAPTER 1: INTRODUCTION

Curiosity is a construct we are all familiar with. It has been present throughout societies since ancient times (Goodale, 2003), appearing in texts ranging from the Bible, writings from Greek philosophers, all the way to current representations in media and books (Livio, 2017). Researchers in psychology have been studying curiosity and how it motivates behavior for decades (Berlyne, 1966; Spielberger & Starr, 1994). Curiosity has even been proposed to be an evolutionarily adaptive trait (Kidd & Hayden, 2015; Lau et al., 2020). Curiosity is thought to be at least a partial a motivator of a variety of everyday behaviors (Kashdan & Steger, 2007; Silvia, 2012). Hobbies, such as learning how to play an instrument, travelling, gardening, and others can all be driven by a sense of curiosity.

Although we can easily recognize curiosity when we see or feel it, curiosity can be difficult to define. Researchers have struggled to agree on a singular definition of curiosity that is parsimonious. For example, it has been defined as a drive to satiate basic needs (Schmitt & Lahroodi, 2008), a pleasant experience of seeking novelty (Spielberger & Starr, 1994), and a way to satisfy a knowledge gap (Loewenstein, 1994). However, none of these definitions fully capture all of the ways one can be curious (Kashdan et al., 2018). For example, those who enjoy birdwatching and are driven by curiosity to learn more about different types of birds, their eating behaviors, mating behaviors, etc. may not be attempting to satisfy a basic need. Additionally, those who travel to see and learn about new parts of the world are not necessarily aiming to satisfy a knowledge gap but may be more driven by the joy of learning and experiencing new things. Thus, curiosity can present itself and motivate behavior in a variety of ways and through potentially different mechanisms.

Recently, curiosity has been defined as "the recognition, pursuit and desire to explore novel, uncertain, complex, and ambiguous events" (Kashdan et al., 2018) or "the desire for new knowledge, information, experiences, or stimulation to resolve gaps or experience the unknown" (Grossnickle, 2016). Both of these definitions highlight the breadth of curiosity, from gaining knowledge to coping with ambiguity and taking risks. In general, curiosity tends to be defined broadly to encompass thoughts, behaviors, and internal drives, all of which may motivate the way we think and behave.

In defining curiosity, it is also important to distinguish it from interest. Some have treated curiosity and interest as essentially synonymous (e.g., Schmidt & Rotgans, 2021), while others argue they should be considered distinct concepts (e.g., Grossnickle, 2016; Tang et al., 2022). Curiosity is often considered to be a personality trait (Kashdan et al., 2018; Litman & Spielberger, 2003) or a psychological state (Loewenstein, 1994), while interest has largely been viewed as a motivational construct (Renninger & Hidi, 2015). For example, one may be curious to learn some specific information in a moment (i.e., a state of curiosity), or be a generally curious person (i.e., trait curiosity), and/or be generally interested in a specific topic (e.g., birdwatching), which motivates their learning more about that topic (i.e., interest). Distinguishing the two constructs also becomes difficult, as many scales that are designed to assess each construct have highly overlapping terminology (see Tang et al., 2022). However, a recent study (Tang et al., 2022) showed an asymmetrical relationship between curiosity and interest, such that interest often occurs with curiosity, whereas curiosity does not occur with feelings of interest as often. The authors argue that curiosity may foster interest, which is a longer sustained motivator of behavior, and this argument also fits with typical models of information seeking (Murayama, 2022). Thus, although curiosity and interest are similar and likely highly overlapping, there may be some important differences in terms of how and when they motivate behavior.

Curiosity has been shown to be correlated with a variety of positive traits in everyday settings. For example, in educational settings, greater curiosity is related to student question asking (Peters, 1978) and academic performance (von Stumm et al., 2011). Beyond educational settings, curiosity is also a predictor of job performance and learning at work (Reio & Wiswell, 2000). In addition, those who show higher levels of trait curiosity report more meaningful moments in their life (Kashdan & Steger, 2007), partially resulting from greater pursuit of meaningful goals (Sheldon et al., 2015). Thus, curiosity can motivate learning and goal pursuit in a variety of settings across the lifespan.

Curiosity may be especially important to maintain in older age (see Sakaki et al., 2018). Curiosity is often a primary motivator for older adults' engagement in formal learning (Hachem, 2023; Kim & Merriam, 2004; Xiong & Zuo, 2019), and engagement in these types of stimulating cognitive activities has shown to protect against some age-related declines in cognitive abilities (Ferreira et al., 2015; Leanos et al., 2023; Park et al., 2014). In one study, older adults who were more curious at a baseline measurement were shown to have a greater survival rate over a five-year period than those who were less curious (Swan & Carmelli, 1996). These benefits led Sakaki et al. (2018) to argue that curiosity may be a key predictor of successful aging.

Although it is possible to be curious in a variety of ways, cognitive psychologists typically tend to be concerned with curiosity as it relates to learning and thinking. Specifically, in this dissertation, I view curiosity as a motivator of knowledge acquisition, generally known as *epistemic curiosity*, or the desire to obtain new knowledge in order to fill a knowledge gap or to stimulate intellectual interest (Litman, 2008; Lowenstein, 1994). However, I acknowledge that curiosity is a multi-dimensional construct (Kashdan et al., 2018) that scientific domains within and outside of psychology continue to examine from different perspectives.

Theories of Motivation Across the Adult Lifespan

To understand how curiosity, which is a motivator of behavior, may change across the lifespan, it is important to first discuss theories of motivation across the lifespan. There are a few well-known theories proposing motivational and goal shifts that occur in older age. The theories described here are by no means a comprehensive list, but they have been influential in our understanding of changes that occur in healthy aging, and they highlight the important role of goals and motivation. Although these theories differ in their views regarding how and why these changes occur, they all highlight the role of shifting goals and prioritization due to less availability of resources like time, cognitive capacity, or physical resources.

Socioemotional Selectivity Theory

Socioemotional selectivity theory (SST; Carstensen et al., 1999, 2003) is a domain-general theory describing motivational shifts in terms of emotional and social goals. SST proposes that normal aging is associated with a limited future time perspective, or knowledge that time is limited, which leads older adults to prioritize activities that satisfy goals enhancing their emotional experiences in the present. The theory also posits that older adults focus more on emotional well-being and building close relationships, which can satisfy more immediate goals. Younger adults, on the other hand, may choose to expand their social relationships and prioritize knowledge acquisition, which can help them acquire knowledge and experience to be used in the future, thus satisfying more long-term goals. These shifts in goals can influence the way we interact with others (Fredrickson & Carstensen, 1990; Fung et al., 1999), learn and remember

(Charles et al., 2003; Mather & Carstensen, 2003), and make decisions (Löckenhoff & Carstensen, 2004; Mikels et al., 2010).

There is an abundance of evidence supporting SST. For example, older adults show a preference for advertisements that highlight "special moments" compared to those highlighting exploration, while younger adults show the opposite pattern (Fung & Carstensen, 2003). Older adults also tend to prefer to interact with familiar people over new people (Fredrickson & Carstensen, 1990) and have smaller social networks than do younger adults (Wrzus et al., 2013). SST has further been supported by research examining the "positivity effect," or older adults' preference for more positive and/or less negative information in comparison to younger adults (Isaacowitz et al., 2006; Mather & Carstensen, 2005; Reed et al., 2014). These social and emotional preference differences are proposed to be driven primarily by a limited time perspective. Indeed, when time perspective is manipulated by having participants think about either more expansive or more limited futures, older adults show behavior more like that of younger adults in terms of social preferences (Fung & Carstensen, 2003), memory performance (Barber et al., 2016), and emotion perception (Kellough & Knight, 2012), although some work has failed to find these effects (see Barber et al., 2020). It is also worth noting that more recent work has highlighted the importance of personal and cultural relevance, which may, in some cases, override the effects of future time perspective (Fung et al., 2018; Gong & Fung, 2020).

In terms of how SST may predict changes in curiosity across the lifespan, SST suggests that older adults are less likely to learn new information for the sake of learning, as this would satisfy longer-term, knowledge-based goals. Thus, according to this theory, curiosity should decline across the lifespan, as would constructs that are similar to curiosity, such as openness to experience, novelty seeking, and sensation seeking. Indeed, research has examined how these constructs change across the lifespan and generally found declines. For example, the desire to travel and seek new experiences tends to decline as we age (Roth et al., 2007; Schwaba et al., 2018; Zuckerman & Neeb, 1980), and older adults have been shown to engage in less variety and novelty seeking, or the tendency to try new things for the sake of novelty (McAllister & Pessemier, 1982; Novak & Mather, 2007; Reio & Choi, 2004). Need for cognition, which generally encompasses one's desire for and enjoyment of effortful thinking (Petty et al., 2009), has also been shown to decrease in older age compared to young adulthood and middle age (Bruinsma & Crutzen, 2018). Some research has examined epistemic curiosity in older adulthood and shown that epistemic curiosity is lower in older adults than younger adults (Dellenbach & Zimprich, 2008; Zimprich et al., 2009), and that this is potentially driven by a more limited future time perspective (Chu et al., 2020) or emotion regulation strategies (Hertwig et al., 2021).

However, some research has begun examining the reasons that some older adults do learn new things later in life, for example by taking online courses, taking up new hobbies, or even wanting to learn facts in a cognitive task in a lab setting. As will be discussed in more detail in Chapter 2, many older adults report learning new things for the sake of learning (Xiong & Zuo, 2019). There seem to be some cases in which older adults are motivated to learn, such as when they are curious or when there are social implications like the ability to share the information or avoid social embarrassment (Gorlick & Maddox, 2015; Hess et al., 2001; Smith & Hess, 2015). Thus, older adults do engage in new learning, often motivated by epistemic curiosity, suggesting that curiosity toward specific information may show a different relationship with age compared to a more stable, trait level curiosity.

Selective Optimization with Compensation

The selective optimization with compensation (SOC) model (Baltes, 1997; Baltes & Baltes, 1990) suggests that as we get older, we have fewer available resources, which leads us to adapt our goals from focusing on gains to compensating for declines and minimizing losses. In this model, older adults are able to maintain everyday functioning in light of declines by shifting goals (Freund, 2008). For example, older adults have been shown to make similarly optimal decisions as younger adults, even though they search less information, process information longer, and use less effortful strategies when making decisions (Mata et al., 2007).

According to the SOC model, older adults may also be differentially motivated to prioritize gains or to minimize losses, depending on resource availability, and this can affect cognition. When engaging in a cognitive task in which participants were given the option to end the task or keep going, older adults were more motivated to continue when the task was focused on compensating for losses, whereas younger adults were most motivated to continue when the task was framed in terms of maximizing gains (Freund, 2006). Another study either allowed participants to gain rewards when they correctly remembered items (gain framed) or lose rewards from an initial amount when they forgot items (loss framed). The study showed that younger adults performed better when the task was framed in terms of gains than losses, whereas older adults showed the opposite pattern of results (Horn & Freund, 2020). Thus, priorities may shift with age, such that older adults focus on maintenance or minimizing losses rather than maximizing gains.

Given the emphasis on minimizing losses as we age, we can make predictions from SOC about expected changes in curiosity across the adult lifespan. SOC would likely predict that curiosity declines across the lifespan, because learning for the sake of learning is more in line with maximizing gains, rather than minimizing losses. Specifically, learning driven by eliminating knowledge gaps or to stimulate interest would aid in gaining information that might be useful later but does not prevent the loss of information currently in memory. However, SOC may support the idea that curiosity can serve as a motivator of learning and memory in older adulthood, depending on goals. Specifically, if one may be able to share new information with a friend or use it to engage in a hobby, then acquiring the new information may serve loss prevention goals, like maintaining relationships or current activity levels (see Spaniol & Swirsky, 2023). Research has also shown that older adults are better at later remembering information that they were initially curious about (Galli et al., 2018; McGillivray et al., 2015).

Selective Engagement Hypothesis

Similar to the SOC model, Hess (2014) has proposed the selective engagement hypothesis (SEH), which argues that older adults perceive the cognitive costs (e.g., effort, fatigue) of engaging in a task as higher than younger adults because of declining resources and, as a result, are more selective about what they choose to use limited cognitive resources for. According to the SEH, not only are costs perceived as higher, but the benefits of engaging in a task become more salient as we age, and older adults may be less willing to engage in difficult cognitive tasks unless the self-relevant benefits are great enough.

Motivational factors like interest in the task or information importance (indicated by either extrinsic or intrinsic value) are influential in older adults' cognition, according to the SEH. Findings have supported this claim, showing that motivation helps to explain the relationship between cognitive declines from typical aging and later cognitive abilities such as working memory (Hess et al., 2012). Additionally, age-related differences in task performance can be reduced when older adults are sufficiently motivated by reward or extrinsic incentives (Castel, 2008; Spaniol et al., 2011; Touron et al., 2007) or personally relevant materials (Tomaszczyk et al., 2008).

Motivational factors that are social in nature also seem to be salient for older adults, in line with both SEH and SST. For example, when older adults were told that their performance would be evaluated by another participant, they performed as well as younger adults on a cognitive task, even though they performed worse than younger adults without this motivator (Hess et al., 2001; Smith & Hess, 2015). In addition, when older adults completing a prospective memory task thought they were doing the experimenter a favor, they performed better than when no mention of a favor was given (Altgassen et al., 2010). Therefore, older adults can be sufficiently motivated through social and reward-based motivational factors to engage in cognitively effortful tasks, which supports SEH's claim that increasing the self-relevance of a task encourages greater use of cognitive resources.

Like the SOC model and SST, the SEH would likely predict a general decline in curiosity with increasing age, as learning and exploring new information requires greater cognitive costs, like time, effort, attention, and memory processes. However, using the SEH framework, we can also predict that older adults' memory may benefit from curiosity, which may be an indicator of self-relevance. For example, recent research suggests that older adults show higher levels of curiosity about information for which there is greater perceived self-relevance (Chu & Fung, 2022). Thus, curiosity may encourage older adults to engage in cognitive effort due to perceived self-relevance. Some work has also suggested that high states of curiosity may actually reduce the cognitive effort required to encode information (e.g., Gruber et al., 2014), which suggests that the costs of learning information when curious may not be as high as when we are not curious, which further supports the notion that, according to SEH, older adults may be more likely to engage with new learning when in a state of curiosity.

Socioemotional Selectivity Theory, the Selective Optimization with Compensation model, and the Selective Engagement Theory all propose motivational and goal shifts that occur across the lifespan. In general, they argue that, as we age, we are faced with declines in physical and cognitive abilities, as well as external resources like time. However, healthy aging is associated with shifts that prioritize emotion regulation, maintaining functioning and minimizing losses, and using resources sparingly. As a result, these broad and domain-general theories of motivational shifts with age can predict that curiosity may decline across the lifespan. However, they also support the idea that curiosity can act as a motivator of learning and memory processes and may serve to accomplish some social-emotional or self-relevant goals (see Whatley et al., 2021).

Curiosity as a Motivator of Learning and Memory

Just as curiosity can be a motivator of behavior and goals, it can also motivate cognition. A few studies have begun to examine how curiosity can influence memory for to-be-learned information. Kang et al. (2009) showed people trivia questions, and asked them how curious they were to learn the answer. Then they were shown the answer and a surprise recall test was given 11 to 16 days later. They found that participants better remembered the answers to trivia questions they were initially curious about than those they were less curious about on the final test. McGillivray et al. (2015) conducted a similar set of experiments and found that interest in the answer was predictive of later memory (one week later) in both younger and older adults. Additionally, Fastrich et al. (2018) found that curiosity to learn the answer to a trivia question is predictive of later interest in the answer itself, which is also more strongly associated with later memory performance. Thus, initial curiosity may influence later interest in the information, and both of these states of curiosity are related to memory performance.

Although curiosity has been shown to improve memory for semantic knowledge, like trivia questions and magic tricks (Ozono et al., 2020), there are many ways curiosity may influence cognitive performance. For example, states of high curiosity can influence memory for both target and non-target information (Gruber et al., 2014). One study used the trivia question task described earlier to test how states of curiosity can influence memory for information participants were not trying to encode. Gruber et al (2014) showed participants trivia questions (without answers) and asked them to rate their curiosity about each question during a screening phase. In the next phase, participants were shown each question followed by the answer, but a face was also presented in between the presentation of the trivia question and the answer. When memory for the faces was tested, the researchers found that participants better remembered the answers to the questions they were more initially curious about. Interestingly, however, participants also more accurately recognized the faces that were presented during the trials in which participants were more curious. Galli et al (2018) replicated this finding in older adults, showing that older and younger adults do not differ in the extent to which heightened curiosity improves memory for task-relevant (i.e., trivia questions) and task-irrelevant (i.e., faces) information. Thus, curiosity may improve memory more broadly for information encountered during this state.

There is also neural evidence to support the claim that states of curiosity can enhance memory more broadly, and that this occurs by heightening attention. One recently-proposed model – the Prediction, Appraisal, Curiosity, and Exploration (PACE) framework – proposes a neural mechanism for how curiosity enhances memory (Gruber & Ranganath, 2019). The framework suggests that prediction errors, in either the environment or one's knowledge, lead to an appraisal process wherein one assesses whether there is a threat or one has the ability to resolve the uncertainty. If there is no threat and the person can resolve the uncertainty, then a state of curiosity arises (as opposed to anxiety, as would arise if a threat was detected). Then, that state of curiosity activates dopaminergic neuromodulation, which leads to enhanced attention and hippocampal activity, which leads to better encoding and consolidation. Thus, this framework suggests that curiosity is triggered by a prediction error (often a knowledge gap), and then enhances memory via heightened attention and hippocampal activity. Each part of the framework and evidence will be discussed in more detail subsequently.

To first discuss what drives curiosity, the PACE framework proposes that curiosity arises when the hippocampus or anterior cingulate cortex (ACC) encounters a prediction error or information gap. When one experiences a prediction error in their knowledge (e.g., an event violates expectations about their knowledge on a particular topic), the anterior cingulate cortex (ACC) is often activated, which can recruit prefrontal areas that, in turn, direct actions to resolve the conflict (Lau et al., 2020). For example, participants show increased ACC activity when they are highly curious and choose to explore new information, even when there is a negative consequence (such as receiving an electric shock or seeing negative information; Lau et al., 2020; Oosterwijk et al., 2020). Thus, the ACC is implicated when participants choose to expose themselves to information they are curious about, even when it is risky or negative. This finding suggests that the ACC directs the prefrontal cortex (PFC) to act on curiosity that is stimulated by a prediction error. In line with the PACE framework, a gap in knowledge, or knowing that you don't know something, can be considered a type of prediction error that has been shown to drive feelings of curiosity and learning (Brooks et al., 2021; Marvin & Shohamy, 2016; Metcalfe et al., 2020).

Next discussing how curiosity may improve learning and memory, the PACE framework posits that states of curiosity influence memory due to heightened attention and dopaminergic modulation of the hippocampus (Gruber & Ranganath, 2019). For example, one study showed that when participants were more curious about the answer to a trivia question, they moved their eyes to where they knew the answer would appear in anticipation (Baranes et al., 2015). As mentioned previously, memory has also been shown to be enhanced for faces that were presented incidentally during the presentation of trivia questions (Gruber et al., 2014). This study also examined neural activation during states of curiosity and found that individual differences in dopaminergic projections of midbrain areas to the hippocampus predicted the extent to which curiosity enhanced memory for task-irrelevant information (Gruber et al., 2014). Interestingly, some work has shown that the beneficial effects of curiosity on memory persist after delays, but do not depend on sleep, suggesting that curiosity may have a greater effect on the initial encoding processes and less effect on later consolidation processes (Stare et al., 2018). Taken as a whole, the PACE model suggests that at least one mechanism for curiosity's influence on memory performance is through dopamine-modulated attentional and hippocampal activity.

It is clear that curiosity can be a motivational driver of learning behaviors by leading people to pursue more knowledge acquisition as a result of knowledge gaps (Goupil & Proust, 2023; e.g., Loewenstein, 1994; Metcalfe et al., 2020), as well as the general desire to learn for the sake of learning (Kashdan et al., 2018; Xiong & Zuo, 2019). In addition, states of curiosity can create conditions for better learning and memory performance, likely through attentional mechanisms (Gruber et al., 2014; Gruber & Ranganath, 2019). In this dissertation, I examine changes in curiosity across the adult lifespan as well as how curiosity may affect learning and memory in the presence of external motivating influences and when information is true or false. Chapter 2 broadly examines curiosity across the lifespan by assessing both trait measures of curiosity as well as state curiosity and constructs that may be related to these types of curiosity, like boredom proneness and subjective age. Chapter 3 examines how curiosity may (or may not) interact with external motivational influences, like point value, under intentional learning conditions, as well as what how these two motivational factors contribute to associative memory in younger and older adults. Finally, Chapter 4 focuses on how curiosity may influence item and associative memory for true and false information. The aim of this dissertation is to examine curiosity as a motivational factor that changes with age (Chapter 2) and can influence memory processes as we age in the presence of information of varying value (Chapter 3) and of varying truth (Chapter 4). Together, this dissertation attempts to address general shifts in curiosity across the adult lifespan, as well as explore predictions from two potential explanations (through attentional mechanisms and value mechanisms) for how curiosity affects memory across the lifespan.

CHAPTER 2: STATE AND TRAIT CURIOSITY ACROSS THE LIFESPAN

Curiosity is a motivating influence that can drive us to participate in hobbies, pursue education, and travel to experience new things, and curiosity can be especially important to maintain in older age (see Sakaki et al., 2018). Although it has been established that maintaining curiosity throughout the lifespan can be beneficial for a variety of outcomes, including learning and well-being (Kashdan & Steger, 2007; Reio & Wiswell, 2000; Sakaki et al., 2018; Sheldon et al., 2015), some evidence seems to suggest that curiosity may decline with age (Chu et al., 2020; Hertwig et al., 2021). Drawing from theories described previously (e.g., SST, SOC, SEH), maintaining high curiosity in later life may not be an adaptive use of resources, given that older adults are adapting to a loss of resources and may need to prioritize more immediate goals and use cognitive resources sparingly.

However, some work has suggested that certain forms of curiosity may actually increase as we get older (Chu & Fung, 2022; Mascherek & Zimprich, 2012). One important difference between these findings and those that show declines in curiosity (e.g., Chu et al., 2020) is the distinction between state and trait curiosity. Researchers have largely failed to distinguish between state and trait curiosity, viewing trait curiosity as simply the accumulation of many instances of state curiosity (Boyle, 1989; Fleeson, 2001). While people who are often state curious may likely be more trait curious overall, there may be instances in which people's general tendency (i.e., trait curiosity) can be overridden by a situational trigger of curiosity (i.e., state curiosity). Thus, it is possible that trait curiosity and state curiosity show different relationships with age.

As people age, they generally develop rich and wide semantic knowledge (Rönnlund et al., 2005), and thus, when people are exposed to concrete learning materials, older adults may be able to find more connections between the learning materials and their knowledge, resulting in increased curiosity to know the information (Murayama, 2022). In fact, people tend to be more curious about information they have some knowledge about (Metcalfe et al., 2017, 2020; Wade & Kidd, 2019). Additionally, older adults are better able to learn information that is consistent with semantic knowledge (Castel, 2005; Umanath & Marsh, 2014; Whatley & Castel, 2022), as well as if they have some expertise in a specific domain (Castel, 2007; Krampe & Charness, 2018), leading older adults to experience less difficulty in learning new information that expands on their prior knowledge. Chapter 2 examines the relationship between age and both state and trait curiosity, as well as how these constructs relate to scam susceptibility and boredom.

Boredom is generally defined as the aversive feeling associated with being cognitively unengaged (Eastwood et al., 2012) and, more specifically, wishing to be cognitively engaged (Danckert et al., 2018). Prior research has shown that being more prone to boredom is associated with negative outcomes, such as lower affect and mood (Isacescu et al., 2017; Lee & Zelman, 2019), self-control (Struk et al., 2016), greater risk-taking (Kılıç et al., 2020), and problematic or addictive behaviors (Elhai et al., 2018; Mercer & Eastwood, 2010). However, some work has shown a positive correlation between boredom and some types of curiosity (Hunter et al., 2016), suggesting that while boredom may often be a negative influence on behavior, it has the potential to have positive influences as well. Thus, in the current study, we expect to find a positive relationship between boredom proneness and curiosity, but boredom may also positively be related to scam susceptibility (i.e., a problem behavior).

Prior work suggests that boredom proneness is likely to decrease as we get older due to increases in self-control (Danckert et al., 2018; Essed et al., 2006). However, this relationship has not been directly assessed across the adult lifespan. Other work suggests that scam susceptibility may actually decrease as we age (Mueller et al., 2020; Nolte et al., 2021), although this depends on various demographic factors, like education and income (Shang et al., 2022). However, many people still believe that older adults are more susceptible to scams (Williams, 2023). It remains unclear whether or how boredom proneness and scam susceptibility may be related, and how these constructs relate to age. Chapter 2 attempts to establish relationships among these variables to gain a better understanding of how different forms of curiosity, as well as boredom and scam susceptibility may change across the adult lifespan.

Study 1

Method

The method and analysis plan are described in a preregistration, which is available at https://osf.io/a3f78.

Participants. An *a priori* power analysis was conducted based on the effect size of the correlation between age and state curiosity in Fastrich et al. (2018). We conducted a power analysis using G*Power (Faul et al., 2007) with .95 power and alpha of .05 to detect a small effect size of $r = 0.10$ in a correlational model. The power analysis revealed that we needed a sample size of 1,289 participants. Based on our pilot study, we estimated that 25% of participants would be excluded according to our preregistered criteria to ensure data quality (see below). As such, we over-sampled; we planned and collected data from 2,000 participants from Amazon's Mechanical Turk (MTurk).

Participants' data were excluded if they (1) reported looking up the answers to most of the questions as this would affect curiosity ratings ($n = 69$), (2) were determined to be bots based on their responses to open-ended questions ($n = 147$), (3) were discovered to be a duplicate ($n = 82$), (4) had significant missing data from skipping data ($n = 12$) or from completing only one part of the study (e.g., completing the survey portion but not the trivia portion (*n* = 123), (5) had significant problems with the task or their internet that affected their data (*n* = 156), (6) reported having completed a task with the same questions before (*n* = 53), or (7) their reported birthday being more than one year off from their reported age (*n* = 140), indicating they lied about their age (an important variable in the current study). After the exclusion, the final sample of participants consisted of 1,218 adults aged 20-84 years (*M* = 44.4, *SD* = 15.5). Participant demographics are displayed in Table 1. All participants resided in the United States and were compensated $7.25 per hour of their participation.

Stimuli and Measures. To assess state curiosity, trivia questions were taken from a database normed by Fastrich et al. (2018). To ensure the generalizability of the findings, all 244 trivia question-answer pairs from the database were used in the task, with a random 63 items selected for each participant. Each of the trivia questions was presented on the screen for 20 s along with a text box in a random order. Participants were told that they could make a guess, but if they did not think of a guess within 20 s, the page would automatically advance. Participants rated their curiosity to learn the answer to the question on a 1 (*not at all curious*) to 10 (*very curious*) scale, and then rated their confidence that they knew the correct answer on a 1 (*not at all confident*) to 10 (*very confident*) scale. Participants were then shown the answer to the question, and this process repeated for all 63 items. Each trial was separated by a page saying "the task will continue in a couple of seconds" which lasted 2 s. We included a trial at the halfway point that indicated to participants they were about halfway through the task and could take a short break to drink water, use the restroom, etc. if needed.

To assess trait curiosity, we used two scales. The first was the Epistemic Curiosity Scale (ECS; Litman, 2008; Litman & Spielberger, 2003), which contains 10 items rated on a 1 (*almost* *never*) to 4 (*always*) scale. Items are statements such as, “I enjoy exploring new ideas” and “I spend hours on a problem because I can’t rest without the answer.” The second measure of trait curiosity that we preregistered was the intellectual curiosity (IC) facet from the openness to experience subscale of the larger Five Factor Inventory (Costa & McCrae, 1992; Saucier, 1998). This scale includes three items, such as, “I have a lot of intellectual curiosity,” which are all rated on a scale from 1 (*strongly disagree*) to 5 (*strongly agree*). However, this three-item scale showed very low reliability ($\alpha = .12$) and thus we omitted the scale from analyses.

Participants also completed the short version of the Boredom Proneness Scale (BPS; Struk et al., 2017; Vodanovich & Kass, 1990), which contains 8 items, including “I find it hard to entertain myself” and “much of the time, I just sit around doing nothing,” rated on a 1 (*strongly disagree*) to 7 (*strongly agree*) scale, as well as the Scam Susceptibility Scale (SSS; James et al., 2014), which asks participants to rate five items (e.g., “If a telemarketer calls me, I usually listen to what they have to say”) rated on a 1 (*strongly disagree*) to 7 (*strongly agree*) scale. We also included a single question, “Have you ever been the victim of a scam?” with answer choices *Yes*, *No*, or *I’m not sure*.

Participants then completed an open-ended question: “What do you think are the THREE most important words in life? Please list them below in any order.” Aside from allowing us to explore what participants entered for qualitative analyses, this question also allowed us to check for bots by assuring that responses made sense and were not random phrases.

Finally, participants completed a subjective age measure, which asked them to move a sliding bar to a point on a line that corresponded to how old they felt at that moment. The line ranged from 0 to 120, with a midpoint marker at age 60. When participants selected a point on the line, they were not shown the value corresponding to that point, so that they could base their response on its relation to 0, 60, and 120 without trying to select a specific age.

Procedure. All procedures were approved by the University of California, Los Angeles (UCLA) institutional review board (IRB). Participants first answered demographic questions, including reporting their age, gender, race, education, income level, English fluency, and state of residence. Participants consented to participate in the study by checking a box. Then, half of the participants completed the survey portion of the task first, and the other half completed the trivia task first. For the trivia task, participants were first told that they would be studying trivia questions and answering questions about them, and they proceeded to the task after general instructions. For the survey portion of the task, participants simply responded to survey questions including the ECS, IC, BPS, SSS, scam history question, subjective age, and bot check item.

Results

First, any items for which participants correctly guessed the answer were removed from analyses, as we were interested only in curiosity to learn new information[1]. The correlation matrix of the primary variables is presented in Table 1.1. State curiosity scores were computed by averaging curiosity ratings across the 63 trivia question items for each participant (reliability = .988, based on generalizability theory). We also computed average confidence scores in a similar manner. One notable observation is that state curiosity and trait curiosity were positively correlated, $r = .23$, $t(1216) = 8.37$, $p < .001$ (Figure 2.1), indicating that those who report higher levels of trait curiosity are likely to feel higher state curiosity when exposed to trivia questions.

[1] We analyzed the number of items participants correctly guessed and found that age was negatively related to number of items guessed correctly ($r = -.12$, $p < .001$), suggesting older adults correctly guessed fewer answers compared to younger adults. Also, participants who guessed more answers correctly reported higher trait ($r = .10$, $p < .001$) and state curiosity ($r = .07$, $p = .021$). We also found that neither ECS scores, $t(1216) = 1.54$, $p = .123$, nor average curiosity ratings, $t(1216) = 0.96$, $p = .335$, significantly differed by order (i.e., completing the survey questions or the trivia task first).

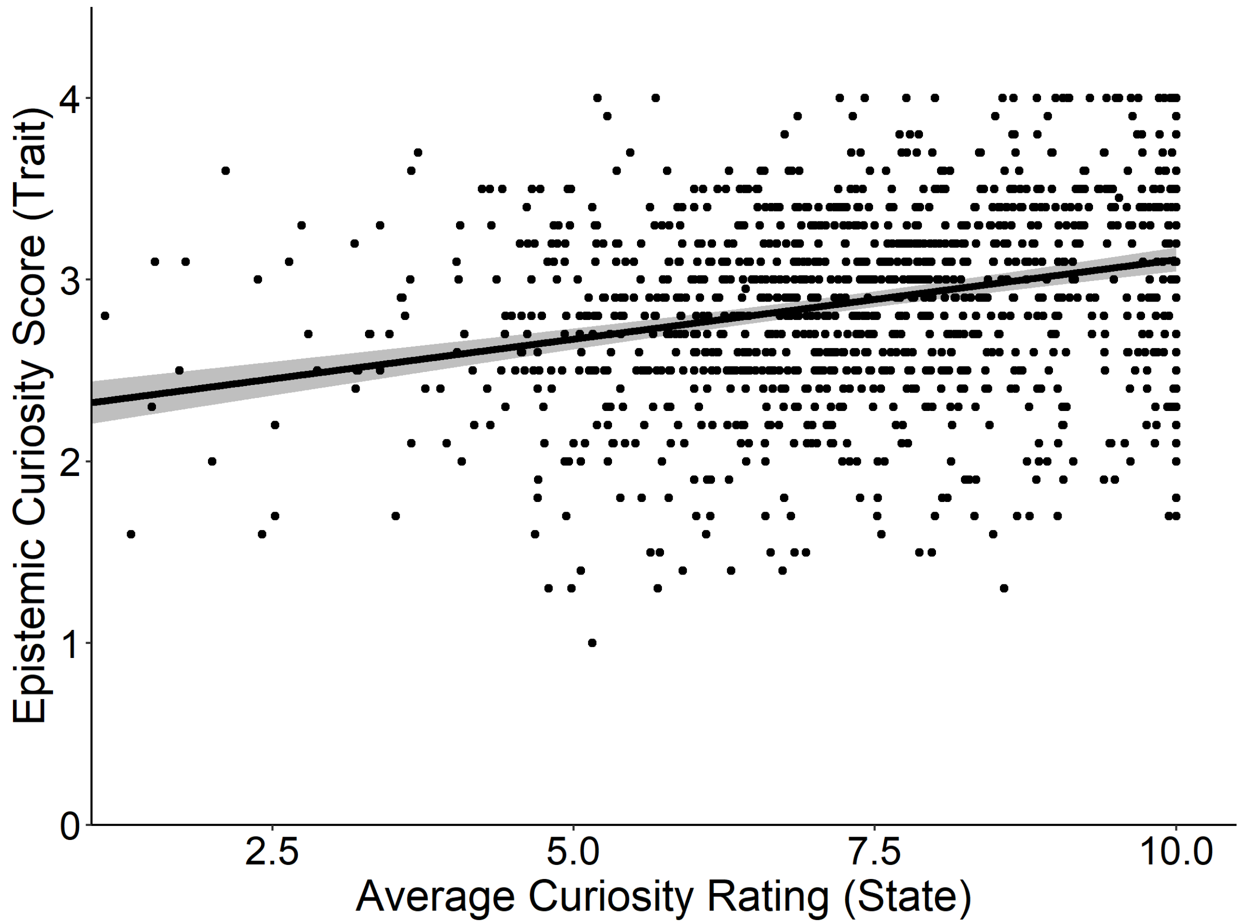

Figure 2.1. The relationship between state curiosity (measured as participants' average curiosity rating towards trivia questions) and trait curiosity (measured by scores on the Epistemic Curiosity Scale; ECS). Dots represent individuals, and the line represents the regression slope from the single level linear regression. The shaded area represents 95% confidence intervals.

Trait Curiosity. Age and trait curiosity were *negatively* correlated, $r = -.18$, $t(1211) = 6.54$, $p < .001$ (Figure 2.2). To further examine the robustness of this association, we conducted a linear regression analysis predicting trait curiosity from age with gender (dummy coded, anchored on male), race (dummy coded, anchored on White), education (centered), and income (centered) as covariates. The model revealed that age was a significant negative predictor of trait curiosity, *b* = -.006, *SE* = 0.001, *t*(1139) = 6.12, *p* < .001. Trait curiosity was also positively predicted by education, *b* = 0.02, *SE* = 0.008, *t*(1139) = 2.68, *p* = .007, and participants who identified as Black/African American were more curious than participants who identified as White, *b* = 0.13, *SE* = 0.057, *t*(1139) = 1.59, *p* = .023. Neither gender nor income were significant predictors of trait curiosity score (all *p*'s > .08).

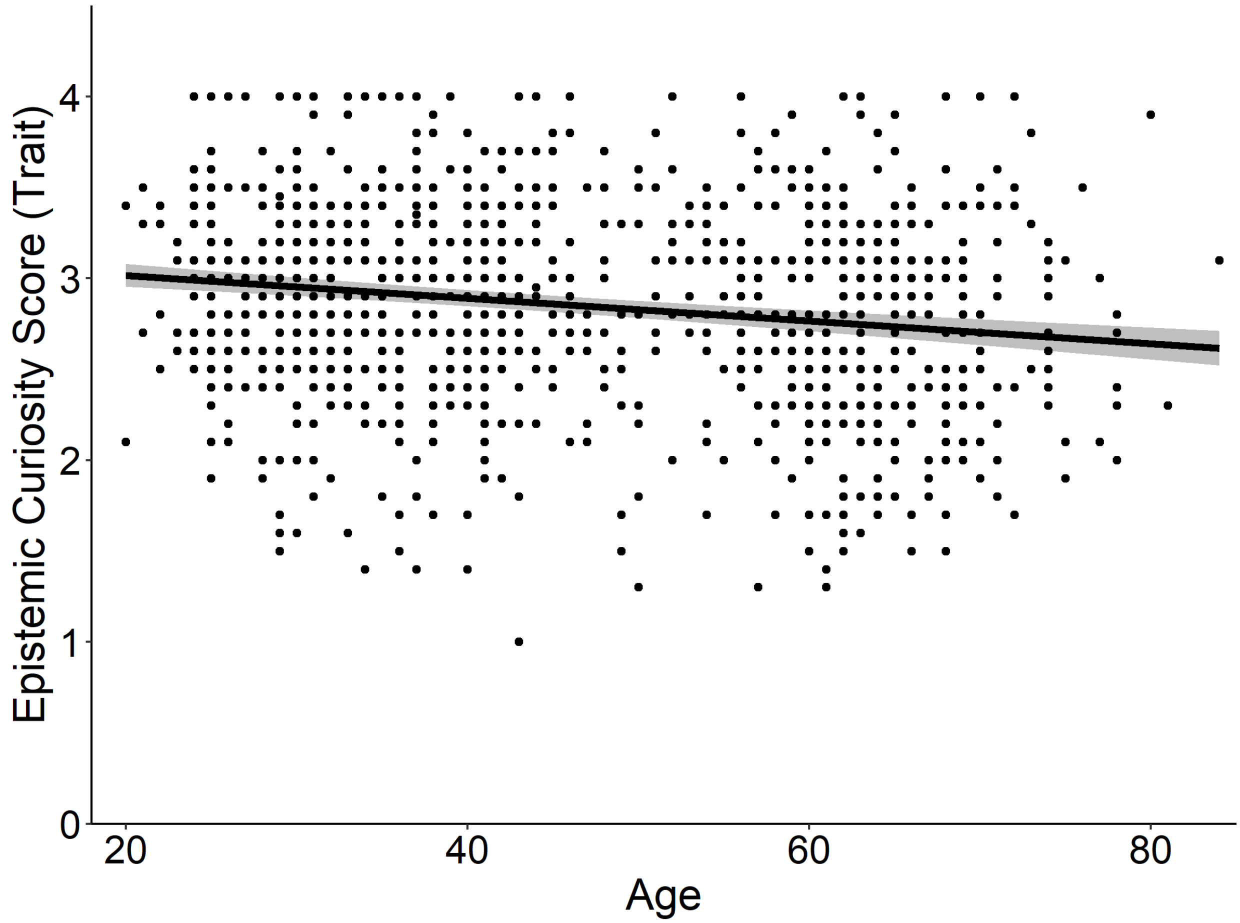

Figure 2.2. The relationship between chronological age and trait curiosity, as measured by the Epistemic Curiosity Scale. ECS scores ranged from 1-4, with 4 indicating higher curiosity. Dots represent individuals, and the line represents the regression slope from the single level linear regression. The shaded area represents 95% confidence intervals.

State Curiosity. Next looking at state curiosity, age and state curiosity were *positively* correlated, $r = .16$, $t(1211) = 5.72$, $p < .001$; Figure 2.3). To further examine the robustness of this association, we first conducted a single-level linear regression predicting state curiosity from age with gender (dummy coded, anchored on males), race (dummy coded, anchored on White), education (centered), and income (centered) as covariates. The model revealed that age was a significant positive predictor of state curiosity, $b = 0.02$, $SE = 0.003$, $t(1139) = 5.16$, $p < .001$. Females also reported higher state curiosity than males, $b = 0.21$, $SE = 0.10$, $t(1139) = 2.16$, $p = .03$. Additionally, participants identifying as Black/African American were more state curious than White participants, $b = 0.52$, $SE = 0.181$, $t(1139) = 2.87$, $p = .004$, and participants of more than one race were more curious than White participants, $b = 1.48$, $SE = 0.628$, $t(1139) = 2.35$, $p = .02$. No other predictors in the model significantly predicted state curiosity.

Next, to take into account the fact that participants saw different trivia questions, we conducted a mixed effects linear regression model using the lme4 package in R (Bates et al., 2015), with trial-level state curiosity ratings as the outcome variable and age, gender, race, education, and income as well as average confidence level as predictors. We included average confidence rating to control for a participant's general tendency to provide high or low ratings on Likert scales. We included random intercepts of participants and items, as well as random slopes of items for the age variable. Donnellan, Usami, and Murayama (2023) showed that this "random item slope regression" analysis ensures that the results are generalizable to the population of items and prevents the potential inflation of Type-I errors.

The results confirmed that age was a significant positive predictor of state curiosity, $b = .02$, $SE = 0.003$, $t(1143) = 7.25$, $p < .001$. Average confidence rating also significantly positively predicted state curiosity, $b = .16$, $SE = 0.023$, $t(1142) = 7.01$, $p < .001$, while education had a significant negative relationship with state curiosity, $b = -0.09$ $SE = .025$, $t(1139) = 3.82$, $p < .001$. Females were also significantly more curious than males, $b = 0.24$, $SE = 0.10$, $t(1142) = 2.47$, $p = .014$. Some racial differences emerged, such that African American participants were more curious than White participants, $b = 0.55$, $SE = 0.18$, $t(1140) = 3.08$, $p = .002$, and participants of more than one race were more curious than White participants, $b = 1.74$, $SE = 0.617$, $t(1135) = 2.82$, $p = .005$. No other predictors of state curiosity were significant.

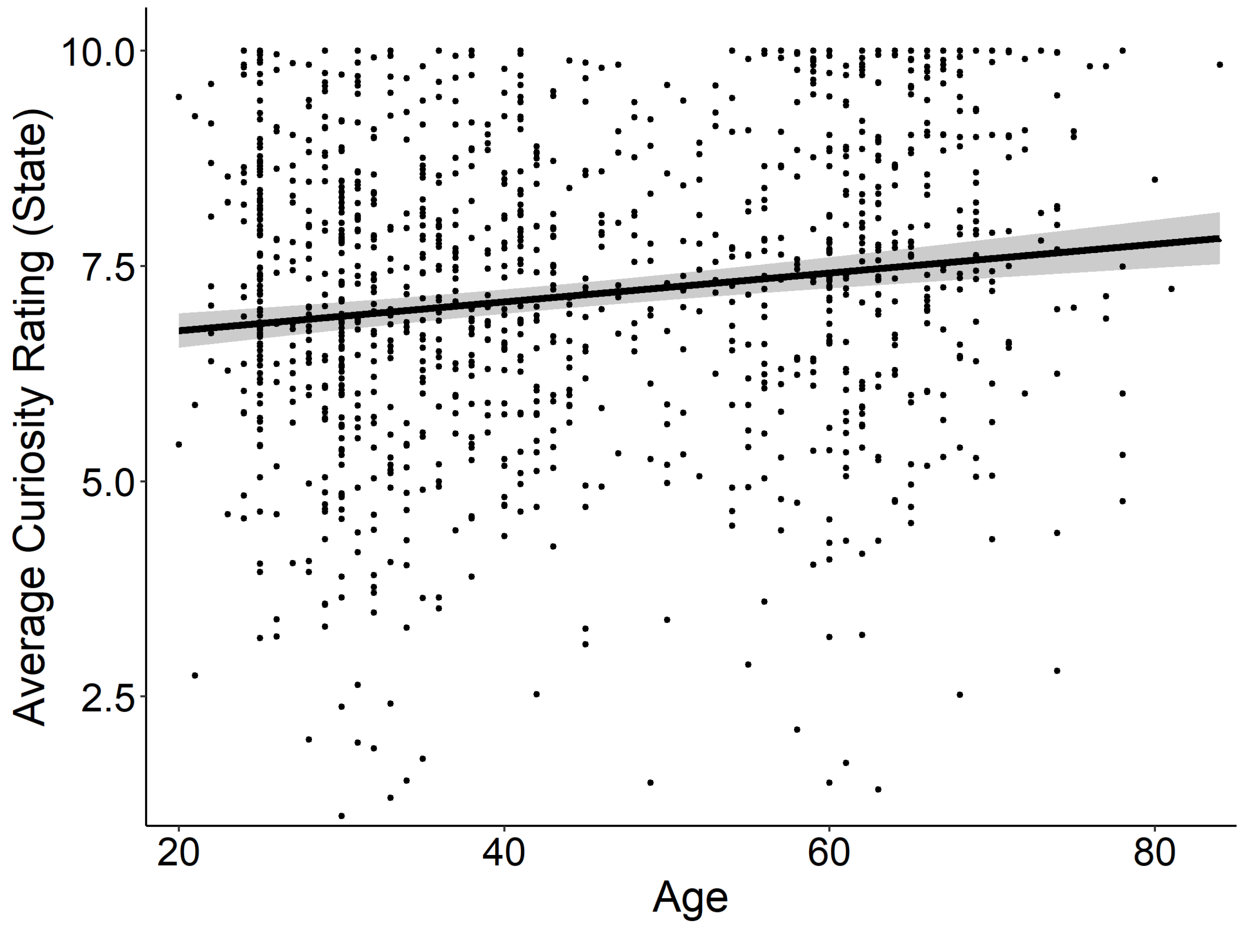

Figure 2.3. The relationship between chronological age and state curiosity (measured as the average of curiosity ratings toward trivia questions). Dots represent individuals, and the line represents the regression slope from the single level linear regression. The shaded area represents 95% confidence intervals.

Exploratory Analyses

We also explored the relationship between curiosity and boredom proneness, scam susceptibility, subjective age, and demographic factors. We first examined the relationship between curiosity and subjective age and found that ECS scores were negatively correlated with chronological age, $r = -.18$, $t(1211) = -6.54$, $p < .001$, but the relationship between ECS and subjective age was nonsignificant, $r = .02$, $t(1216) = 0.67$, $p = .502$. Thus subjective age was not significantly related to trait curiosity.

Boredom Proneness. We then examined factors related to boredom proneness. First looking at age, we found that boredom proneness showed an opposite relationship with chronological age ($r = -.37$, $p < .001$) than with subjective age ($r = .33$, $p < .001$). To further probe these relationships, we conducted regression models to control for covariates. We conducted a single-level regression model with boredom proneness predicted as a function of subjective age while controlling for chronological age (centered), education level (centered), income (centered), gender (dummy coded), and race (dummy coded). The results revealed a significant positive relationship between subjective age and boredom proneness, $b = 0.02$, $SE = 0.003$, $t(1138) = 14.56$, $p < .001$. There was also a unique *negative* relationship between chronological age and boredom proneness, $b = -0.04$, $SE = 0.003$, $t(1138) = 16.25$, $p < .001$. Education was also positively related to boredom proneness, $b = 0.13$, $SE = 0.019$, $t(1138) = 6.61$, $p < .001$, while higher income was negatively related to boredom proneness, $b = -0.03$, $SE = 0.012$, $t(1138) = 2.74$, $p = .006$. No other predictors in the model significantly predicted boredom proneness. These results suggest that we may be less prone to boredom as we get older, but that feeling older may be associated with greater boredom proneness.

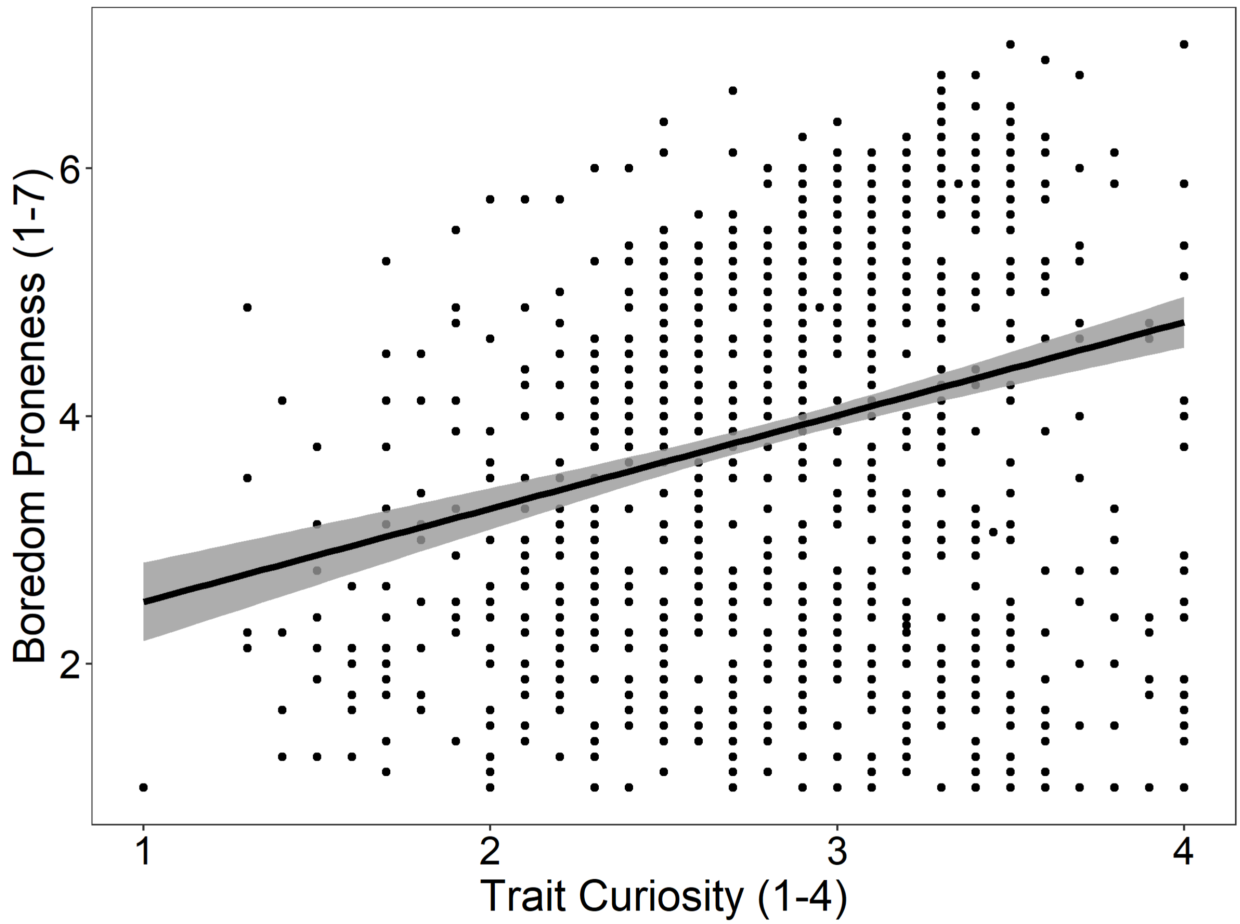

Figure 2.4. The relationship between trait curiosity (measured by the ECS) and boredom proneness (measured by the BPS). Dots represent individuals, and the line represents the regression slope from the single level linear regression. The shaded area represents 95% confidence intervals.

To next examine how boredom proneness was related to different types of curiosity, we conducted correlations, which showed that individuals with higher state curiosity were less prone to boredom (r = -.10, p < .001), while individuals with higher trait curiosity were more prone to boredom (r = .25, p < .001). To further examine these relationships, we conducted a regression with boredom proneness predicted by state curiosity (average curiosity rating on the trivia task), trait curiosity (ECS score), age (centered), education (centered), income (centered), gender (dummy coded), and race (dummy coded). The results showed that state curiosity was a significant negative predictor, $b = -0.08$, $SE = 0.026$, $t(1137) = 2.99$, $p = .003$, while trait curiosity was a significant positive predictor of boredom proneness, $b = 0.57$, $SE = 0.083$, $t(1137) = 6.81$, $p < .001$. As in previous models, education was a significant positive predictor of boredom proneness, while income and age were negative predictors. Interestingly, the results suggest that people who are more curious are more prone to boredom, but that people who experience greater state curiosity in response to trivia questions are less prone to boredom, although this relationship was much weaker.

Scam Susceptibility. In looking at the measures that were related to scam susceptibility in the current study, we first conducted correlation analyses. Looking first at subjective age, scam susceptibility showed an opposite relationship with chronological age ($r = -.42$, $p < .001$) and subjective age ($r = .23$, $p < .001$). Then, we ran a similar model as above predicting scam susceptibility from subjective age as well as chronological age (centered), education (centered), income (centered), gender (dummy coded), and race (dummy coded). Similar to boredom proneness, the results showed subjective age to be a significant positive predictor, $b = 0.01$, $SE = 0.001$, $t(1138) = 9.84$, $p < .001$, while chronological age was a significant negative predictor, $b = -0.03$, $SE = 0.002$, $t(1138) = 16.98$, $p < .001$, of scam susceptibility. Additionally, education was a positive predictor of scam susceptibility, $b = 0.13$, $SE = 0.015$, $t(1138) = 8.46$, $p < .001$. There were also a few gender and race differences. Those who reported their gender as other were less susceptible to scams than males, $b = -1.61$, $SE = 0.73$, $t(1138) = 2.21$, $p = .027$, and Asian participants reported lower scam susceptibility than White participants, $b = -0.74$, $SE = 0.19$, $t(1138) = 3.88$, $p < .001$. No other model predictors of scam susceptibility were significant.

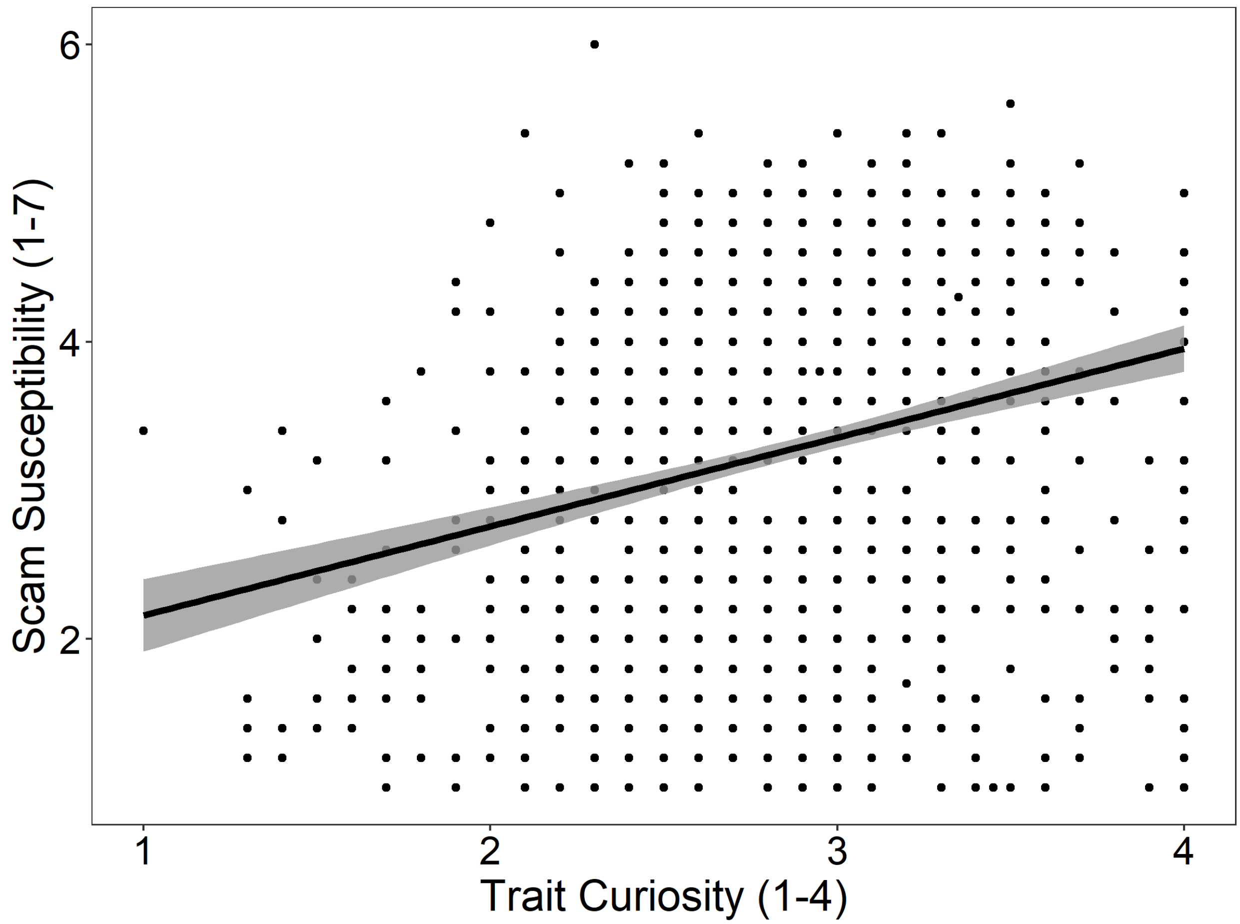

Figure 2.5. The relationship between trait curiosity (measured by the ECS) and scam susceptibility (measured by the SSS). Dots represent individuals, and the line represents the regression slope from the single level linear regression. The shaded area represents 95% confidence intervals.

Next, we examined the relationship between scam susceptibility and curiosity. As with boredom proneness, there was an opposite relationship between scam susceptibility and state and trait curiosity. Specifically, there was a negative relationship between state curiosity and scam susceptibility (r = -.07, p = .009), but a positive relationship with trait curiosity (r = .26, p < .001). Again, to examine the robustness of these associations, we conducted a multiple linear regression with scam susceptibility predicted by state curiosity (average curiosity rating), trait curiosity rating (ECS score), education (centered), income (centered), gender (dummy coded), and race (dummy coded). The model revealed a significant positive relationship between trait curiosity and scam susceptibility, $b = 0.37$, $SE = 0.062$, $t(1137) = 6.08$, $p < .001$, but the relationship between state curiosity and scam susceptibility was not significant, $b = -0.02$, $SE = 0.019$, $t(1137) = 1.13$, $p = .259$. Again, education was a positive predictor, $b = 0.14$, $SE = 0.015$, $t(1137) = 9.27$, $p < .001$, while age was a negative predictor of scam susceptibility, $b = -0.03$, $SE = 0.002$, $t(1137) = 13.38$, $p < .001$. Asian American participants were again less susceptible to scams than White participants, $b = -0.77$, $SE = 0.195$, $t(1137) = 3.96$, $p < .001$. Thus, those who were more curious overall also tended to be more susceptible to scams, but this was not true for those who reported higher state curiosity.

Lastly, we examined the relationship between boredom proneness and scam susceptibility. Correlations revealed that those who were more prone to boredom were also more susceptible to scams ($r = .67$, $p < .001$). Again, we further examined the robustness of the relationship by regressing scam susceptibility on boredom proneness, age (centered), education (centered), income (centered), gender (dummy coded), and race (dummy coded). In the model, boredom proneness was a significant positive predictor of scam susceptibility, $b = 0.43$, $SE = 0.018$, $t(1138) = 23.82$, $p < .001$. Again, age was a negative predictor, while education was a positive predictor of scam susceptibility.

Discussion

In the current study, we found a positive relationship between trait curiosity and state curiosity, indicating overlap of these constructs. Nevertheless, we found that the two types of curiosity are related to age in the opposite direction. Specifically, the results supported our preregistered hypothesis that state curiosity triggered by specific learning materials increases across age, while trait curiosity declines with age.

These findings indicate a nuanced relationship between aging and curiosity. Specifically, age does not have a uniform influence on curiosity; rather, we need to consider the multifaceted nature of this construct when discussing aging effects. In fact, there has been a growing number of studies indicating that developmental trajectories of curiosity, or information-seeking behavior, strongly depends on the type of curiosity researchers investigate (Giron et al., 2023; Schulz et al., 2019). This is because curiosity subsumes different levels of psychological processes (e.g., emotional processes, reinforcement, learning, attention, appraisal, etc.), each of which would be impacted differently by age (Murayama, 2022). Therefore, trait and state curiosity may be reflective of different psychological processes, which may have different patterns of change across the lifespan.

One limitation of our findings is that we assessed state curiosity only in the context of trivia questions. This was a deliberate choice, as our hypothesis is based on the previous findings that people tend to be more curious about information for which they have more prior knowledge (Fastrich & Murayama, 2020; Metcalfe et al., 2020; Wade & Kidd, 2019; Witherby & Carpenter, 2022). With the use of a wide range of trivia questions, participants likely had some prior knowledge about the domains of these questions. However, future studies should examine which types of state curiosity is positively associated with age. For example, a previous study has reported an age-related increase in curiosity toward other materials besides trivia questions (e.g., magic tricks; Ozono et al., 2020). Another related limitation is that we did not examine the exact mechanisms through which age is positively associated with state curiosity. We conjectured that increased prior knowledge for the learning materials not only increased the motivation to learn the information, but also reduced the cost to engage in the information, but further research is needed to investigate that possibility.

Additionally, while our sample size is large and our study is well-powered, there were significant data exclusions due to the online nature of the study. This issue highlights the need for better screenings for bots and poor quality data on online platforms, and the findings should be replicated using other platforms. We also used just one measure of trait curiosity due to the poor reliability of the IC scale. However, more dynamic, multi-faceted measures of trait curiosity have recently been developed (e.g., Kashdan et al., 2018) that may allow for a more nuanced examination of the relationship between age and curiosity.

This study also offers some exploratory evidence that there may be interesting relationships between one's curiosity and proneness to boredom as well as susceptibility to scams. Interestingly, scam susceptibility and boredom proneness were very highly correlated, suggesting that people who are more easily bored may be more likely to fall for scams. Prior work has shown that people who score highly on boredom proneness are also more likely to engage in problem gambling or smartphone use (Elhai et al., 2018; Mercer & Eastwood, 2010). Researchers have argued that boredom becomes problematic and encourages these behaviors when we search for maladaptive cures to the lack of satisfaction that arises from boredom (Danckert et al., 2018). Following this line of thinking, people more prone to boredom may find new conversations or opportunities stimulating, and thus be more likely to engage with scammers when they call or email. Future research will need to address potential mechanisms for these relationships.

There were also some interesting findings regarding age and both boredom and scam susceptibility. Chronological age was related to less boredom proneness and lower scam susceptibility, which confirms and extends some prior work (Essed et al., 2006; Nolte et al., 2021; Shang et al., 2022). Interestingly, however, subjective age showed opposite relationships with both boredom proneness and scam susceptibility, suggesting that individuals who feel older are likely to be more prone to boredom and susceptible to scams. It is important to note that subjective age was measured by a single item, and participants did not see the age they selected, which could have affected the results. Nonetheless, this finding is worth replicating in addition to exploring potential mechanisms for these relationships.

Finally, trait curiosity was a positive predictor of both boredom proneness and scam susceptibility, suggesting that one's general tendency to be curious may play into the relationship between both boredom and scam susceptibility. Prior work has shown that greater proneness to boredom is related to the deprivation-type curiosity, but not the interest-type curiosity (Hunter et al., 2016). In the current study, we did not examine these factors separately, but we did examine state curiosity in response to specific learning materials, which can be argued to be a closer measure to the deprivation-type curiosity, as it assesses curiosity to learn an unknown answer to a question. We found that state curiosity actually showed a small negative relationship with boredom proneness. While this finding should be replicated, it suggests that the relationship between boredom and curiosity may depend on situational factors and how both constructs are measured. Higher trait curiosity was also related to greater scam susceptibility, but we did not find a significant relationship between state curiosity and scam susceptibility while controlling for other measures. Thus, those who are more curious overall may be more likely to fall for scams, which highlights a potential downside to curiosity and offers a potential mechanism by which people may fall for scams.

Chapter 2 Conclusions

Chapter 2 examined the relationship between chronological age and two types of curiosity: trait-level curiosity, measured using surveys, and state-level curiosity, measured using ratings in response to trivia questions, as well as how age and curiosity relate to problem behaviors, like scam susceptibility. This work revealed a negative relationship between age and trait curiosity, but a positive relationship between age and state curiosity. It also showed that curiosity is related to both boredom proneness and scam susceptibility, suggesting that curiosity may motivate some positive and negative behaviors as we age, and it is important for future work to examine these relationships further.

Chapter 2 presents work that suggests it is important to consider some of the ways that older adults may maintain curiosity other than via trait curiosity measures. Specifically, older adults may be selectively curious about things that have greater self-relevance (Chu & Fung, 2022; Hess, 2014) or which are relevant to their prior knowledge, which may benefit them in specific contexts. Thus, it may be important to recognize and encourage specific domains of curiosity for older adults, rather than simply focusing on measures of trait curiosity.

Table 2.1

Participant Demographics in Study 1

	Mean (SD)	**N**	**% of total**
Age	44.4 (15.5)	--	--
Not Reported	--	5	0.4%
Gender			
Men	--	621	51.0%
Women	--	582	47.8%
Other	--	3	0.2%
Not Reported	--	12	1.0%
Race/Ethnicity			
American Indian/Alaska Native	--	10	0.8%
Asian or Pacific Islander	--	32	2.6%
Black/African American	--	94	7.7%
Hispanic or Latino/a/x	--	26	2.1%
White	--	1040	85.4%
More than one race	--	7	0.6%
Not reported	--	9	0.7%
Education	16 years (2.11)	--	--
Household Income	$60,656 ($30,375)	--	--

Table 2.2

Correlations Among Variables in Study 1

	Gender	Age	Education	Income	Average Curiosity Rating	Average Confidence Rating	Subjective Age	ECS	BPS	SSS
Gender	--									
Age	0.19***	--								
Education	-0.03	-0.11***	--							
Income	0.03	-0.04	0.29***	--						
Average Curiosity Rating	0.09**	0.16***	-0.06*	0.03	--					
Average Confidence Rating	-0.10***	-0.33***	0.32***	0.09**	0.12***	--				
Subjective Age	-0.02	0.14***	0.14***	-0.02	0.03	0.34***	--			
ECS	-0.06*	-0.18***	0.10***	0.06*	0.23***	0.28***	0.02	--		
BPS	-0.10***	-0.37***	0.25***	-0.004	-0.11***	0.67***	0.33***	0.25***	--	
SSS	-0.12***	-0.42***	0.30***	0.06*	-0.08**	0.68***	0.23***	0.26***	0.67***	--

Note. * p < .05, ** p < .01, *** p < .001

CHAPTER 3:

CURIOSITY AND VALUE AS INTRINSIC AND EXTRINSIC MOTIVATORS OF MEMORY

In our everyday lives, memory is influenced by a variety of factors, including both extrinsic motivators and intrinsic motivators. For example, some facts may be remembered because someone tells you it is important to remember them (i.e., an extrinsic factor). Others may be remembered because they naturally sparked your curiosity or because you found the information important and therefore tried to remember it (i.e., intrinsic factors).

A growing body of research shows that we are better able to remember information that we are more curious about (Fastrich et al., 2018; Gruber et al., 2014; Kang et al., 2009). In addition, research has shown that curiosity about to-be-learned information benefits memory in older age, often to the same extent as younger adults (Galli et al., 2018; McGillivray et al., 2015). Many of these tasks have used trivia questions to elicit curiosity, wherein trivia questions are presented to participants and curiosity ratings are collected. Typically, recall of trivia answers is tested after a delay of a few days to one week, and results show that the items participants were initially curious about are remembered at higher rates than those participants were less curious about (Fastrich et al., 2018; Kang et al., 2009; Marvin & Shohamy, 2016; McGillivray et al., 2015).

Although there are a few proposed mechanisms for how curiosity may improve memory (e.g., Goupil & Proust, 2023; Gruber & Ranganath, 2019; Metcalfe et al., 2020), one explanation focuses on curiosity as being reflective of information's intrinsic value (Dubey et al., 2022; Murayama, 2022; Murayama et al., 2019). Specifically, as Murayama et al. (2019) explains (and updated with Murayama, 2022), typical reward learning models of learning posit that experiencing a knowledge gap (which may present itself in many ways, including as uncertainty, novelty, or conflict) leads individuals to compute an expected reward value of the missing information. Thus, the more reward an individual expects to receive with new information, the more likely they are to seek that information. Then, when the information is acquired, individuals should experience the reward, leading to greater information seeking for similar information later. In applying these reward learning models to curiosity and information seeking, Murayama (2019) argues that knowledge acquisition leads to awareness of additional knowledge gaps, and an increase in expected value of new information. This process can perpetuate longer-term sustainment of interest and continued learning (Murayama, 2022).

Recent work has supported the idea that curiosity may motivate learning in a similar fashion to external rewards, showing that curiosity ratings were higher for facts that were rated as being more useful (i.e., greater utility value) in the future (Dubey et al., 2022), suggesting that expected utility can drive curiosity and information seeking. Other work has shown a link between states of curiosity and activation in brain regions associated with reward anticipation, including within the dopamine system (e.g., nucleus accumbens, ventral tegmental area; FitzGibbon et al., 2020; Gruber et al., 2014; Jauhar et al., 2021; Kang et al., 2009). There has also been some evidence that satisfying curiosity activates brain regions associated with reward delivery (Jepma et al., 2012; Ligneul et al., 2018; Rüterbories et al., 2024; but see Kidd & Hayden, 2015). The idea that reward-motivated information seeking and intrinsically-motivated information seeking share an underlying neural code is known as the *common currency* view (Bromberg-Martin & Hikosaka, 2009) and has influenced a growing theory in the curiosity literature which involves reward mechanisms (Cervera et al., 2020). This and other evidence has thus motivated the proposal that information itself can function like a reward (FitzGibbon et al., 2020; Marvin & Shohamy, 2016).

Intrinsic and Extrinsic Reward Learning

Although reward learning and curiosity mechanisms may overlap, it is currently not understood how the two motivating influences on learning may work together or interact. Just as curiosity has been shown to improve memory, there is ample evidence that information that is more valuable is more likely to be remembered later (see Castel, 2008; Knowlton & Castel, 2022 for reviews). This phenomenon, known as *value-directed remembering* (VDR), has been studied through a paradigm in which participants study one or more lists of items that are each paired with a point value (typically ranging from 1 to 12). The point value indicates the number of points participants will earn if they correctly remember the corresponding item. The reward-learning view of curiosity is interesting to examine using an aging approach, as older adults have been shown to have intact memory for high value information even when their overall memory performance tends to be lower than that of younger adults (Ariel et al., 2015; Castel et al., 2002; Hennessee et al., 2017; Siegel & Castel, 2018; Spaniol et al., 2014). Thus, both external reward and intrinsic curiosity seem to improve older adults' memory performance.

Some research has begun to examine the overlap or potential competition between learning high-value information and information one is curious about. In younger adults, rewarding information that one is curious about or interested in has been shown to diminish the influence of curiosity on later memory performance (Murayama et al., 2010; Murayama & Kuhbandner, 2011), suggesting that the presence of an extrinsic reward can undermine the influence of intrinsic motivation on memory performance, known as the *undermining effect*. A recent study further found that older adults show this undermining effect, such that extrinsic reward (e.g., monetary value) may be more motivating than intrinsic curiosity (Swirsky et al., 2021). This finding suggests that curiosity may rely on similar mechanisms as reward learning, leading to some competition between the two motivational influences on learning.

However, another study examined the interaction between curiosity and external reward in younger adults under intentional learning conditions (Halamish et al., 2019). In this task, participants were told that some questions were “bonus questions,” meaning that they would be rewarded with extra monetary incentive if they correctly remembered those items at the test one week later. The results showed that curiosity and reward had an *additive* effect under experimenter-paced study time, and only curiosity had an effect on later memory under self-paced study conditions. Duan et al. (2020) also demonstrated the lack of an undermining effect, and that curiosity was more influential for memory performance than external reward under intentional learning conditions after a one-day delay. Further, this study showed some neural differentiation between curiosity and reward, demonstrating that the neural basis of learning trivia questions may activate regions associated with “semantic control,” or the activation and manipulation of stored semantic knowledge (Davey et al., 2015; Whitney et al., 2011), as well as areas associated with processing outcome uncertainty (Lieshout et al., 2018), whereas rewarded items were associated with activation in areas implicated in reward anticipation (Adcock et al., 2006; Wittmann et al., 2005).

There are a few reasons why there may be differences between the results found in Halamish et al. (2019) and Duan et al. (2020) and those found in both Murayama and Kuhbandner (2011) and Swirsky et al. (2021). First, it could have to do with what is being rewarded. In the latter studies, participants in the reward condition were told that they would be rewarded for correctly guessing the answer to the trivia question (Murayama & Kuhbandner, 2011), or they earned a bonus of $0.25 for each correct guess (Swirsky et al., 2021). In other words, the participants were rewarded for items for which they already knew the answer, and participants were aware of the reward structure when viewing the question (i.e., in a state of high or low curiosity). In this way, reward was manipulated between-subjects, and participants were not rewarded for learning. However, Halamish et al. (2019) and Duan et al. (2020) rewarded participants for correctly remembering the answer to each trivia question on the later test. Thus, participants were rewarded for *learning* rather than already knowing the answers.

Another potential reason for differences across studies involves whether learning is intentional or incidental. In general, information that is encoded intentionally with the expectation of a later test tends to be better remembered than incidentally encountered information where there is no knowledge of a later test (e.g., Craik & Tulving, 1975). Thus, it is possible that strategic or effortful processes differentially impact the undermining effect compared to more passive viewing of information, which may reflect more automatic memory processes (cf. Meliss et al., 2024).

The Current Study

In the present experiments, we examined whether there would be an undermining effect or an additive effect of value and curiosity under intentional learning conditions using a value-directed remembering approach. We were also interested in whether any effects would be similar in older adults, as older adults' memory benefits from both high value information (Castel, 2008; Knowlton & Castel, 2022) and curiosity (Galli et al., 2018; McGillivray et al., 2015). However, older adults have more limited cognitive resources, which could lead to greater competition between motivating influences if the motivators rely on effortful processing (see Knowlton & Castel, 2022 for discussion of strategic and automatic influences of value on memory).

In the current study, participants were rewarded for their learning of new information, similar to Halamish et al. (2019). However, rather than using monetary incentives, participants were rewarded with point values ranging from 1 to 10. By using point values that lie on the same scale as curiosity ratings, there was more likely to be a direct tradeoff between curiosity and external value from a participant's perspective. Additionally, this way of manipulating value allows *all* items to be rewarded to some extent, but it is up to participants to weigh the magnitude of each reward. This may allow for a more nuanced understanding of a potential undermining effect.

In the present experiments, we also included two retention intervals to assess whether the effects of either curiosity or value would potentially change across delays. Very little research has explicitly examined how the effects of value on memory may change across delays. A recent study examined the impact of value-directed remembering on associative memory at an immediate test and on a surprise 24-hour delay test (Yin et al., 2021). The results showed that value was a significant predictor of associative memory at both the immediate and 24-hour test, but the effect of value did not change across retention interval. However, some other work has suggested that some effects of reward or value may not appear until 24 hours after initial encoding (Braun et al., 2018; Murayama & Kitagami, 2014; Spaniol et al., 2014). In terms of the effects of curiosity on memory after delays, McGillivray et al. (2015) examined the role of curiosity to learn the answer to trivia questions, as well as interest in the answers, on incidental memory at two test time points: a 60-min delay and a 1-week delay. They found that the relationship between interest in the trivia answers and memory increased for older adults from the short delay to the long delay, whereas this relationship decreased for younger adults across retention intervals. However, it is unclear whether this relationship is present for curiosity to learn the answer (rather than interest in the answer once learned) or whether it may differ under intentional learning conditions.

Chapter 3 explores the influence of curiosity to learn the answers to trivia questions and point values associated with correctly learning each item on later memory for trivia question-answer pairs. We also explore how curiosity and point value may influence memory for more specific or associated information: namely, the point value itself. This allows us to examine whether curiosity and/or value have different influences on item and associative or gist memory, which can reveal potential mechanisms underlying motivated learning. Chapter 3 examines metacognitive awareness at both the global and local levels. We were interested in participants' overall accuracy in predicting their future memory performance, as well as their confidence in their memory performance (in Experiment 2 only).

Experiment 1

In Experiment 1, we investigated whether trivia answers worth more points would be better remembered than those worth fewer points, as well as whether participants would remember the answers to trivia questions they were more initially curious about after a shorter (two-day) and longer (seven-day) delay. In addition, we were interested in whether the presence of higher point values would override the influence of curiosity on memory performance. In other words, if external value undermines intrinsic motivation, we would expect a reduced effect of curiosity on memory for high-value items, but a stronger effect for low-value items. We also examined memory for the point value itself, as well as global JOLs assessing participants' predictions for their overall memory performance across delays.

Method

Participants. The final sample of participants were 126 Amazon Mechanical Turk (MTurk) workers, who were paid $10 per hour for their participation. Younger adults (n = 57) had an average age of 25.65 (SD = 2.30, range: 19-30), and older adults (n = 69) had an average age of 66.20 (SD = 4.30, range: 60-80). At the beginning of the task, participants were asked, "What is your favorite animal, and why?" to ensure participants were reading the instructions and to check for bots. A total of 11 participants were excluded for this reason. We also excluded participants who reported looking up the answers to the trivia questions during the task (n = 6). Fourteen participants were also excluded for reporting their age as between 30 and 60.

Stimuli. Trivia questions were taken from Fastrich et al. (2018). Specifically, we selected 60 trivia questions from the freely available database that was created from Fastrich et al. (2018) that all had an average normed guess rate of less than 20% to prevent significant data loss, as trivia answers participants guessed correctly at initial study were excluded in all analyses. All trivia questions were randomly paired with a point value between 1 and 10. Trivia questions were presented in the center of a computer screen on a plain, white background in 24-pt black text.

Procedure. All procedures were approved by the UCLA IRB. Participants first provided demographic information, such as age, gender, race, income, state of residence, and English fluency, and indicated informed consent by checking a box. Participants were then instructed that they would study trivia questions and answers, and that they should try to remember the answers, as they would be tested again after two days and one week. After seeing one example trial, participants began the study phase. Figure 3.1 shows the general procedure.

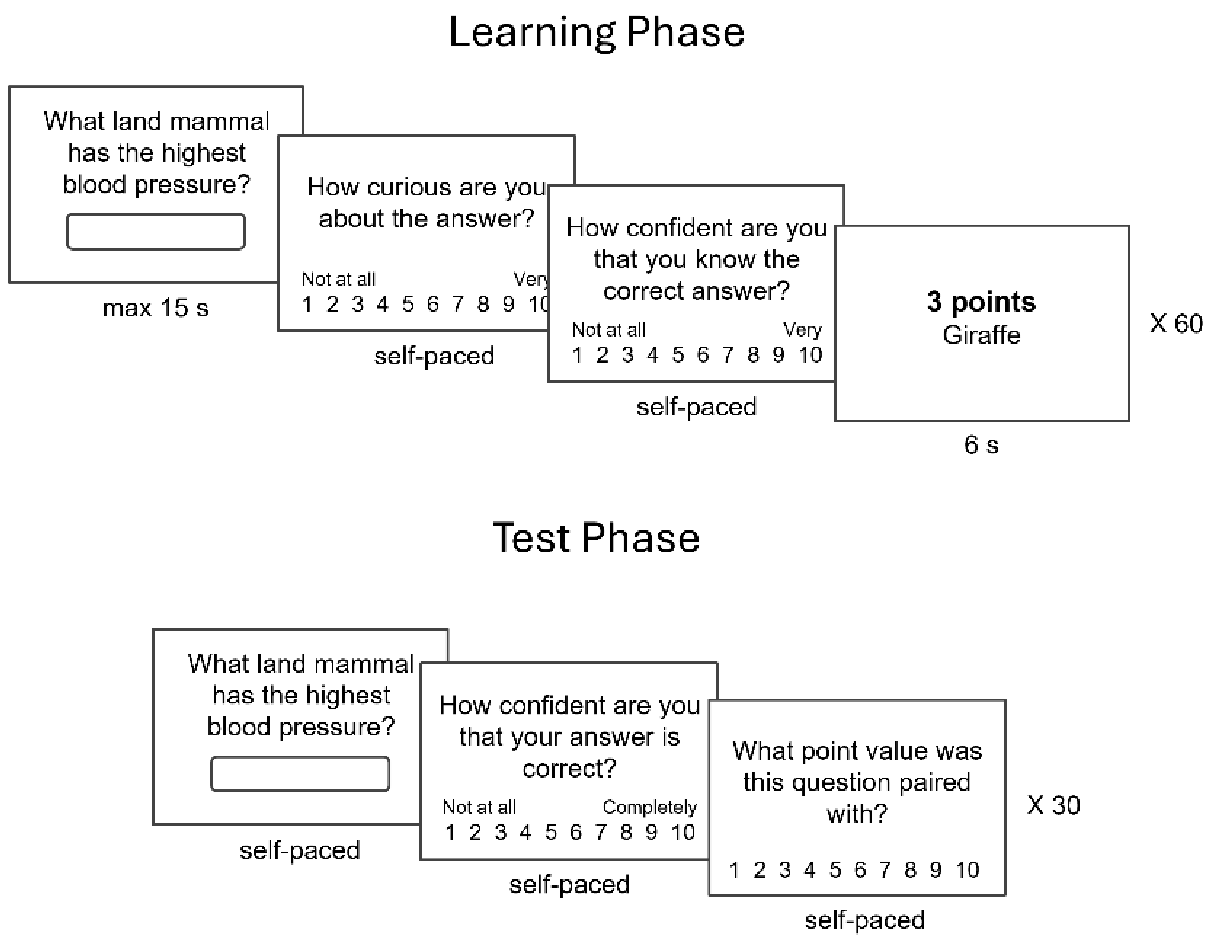

Figure 3.1. The trivia learning procedure in Experiment 1. During the Learning Phase, participants studied all 60 trivia items (shown in the top panel). There were two test time points: two days and one week after learning, which both followed the procedure shown in the Test Phase (bottom panel). At each test time point, participants were tested on half of the items.

Each trivia question was presented on the screen for 15 s, along with a text box for participants to enter a guess. If they did not provide a guess within the 15 s, the page advanced automatically. Next, participants rated their curiosity to learn the answer on a scale of 1 (*not at all curious*) to 10 (*very curious*), and then their confidence that they already know the answer on a scale of 1 (*not at all confident*) to 10 (*very confident*). Ratings were self-paced. Next, the answer to the trivia question appeared on the screen, with the point value shown above in bold in 26-pt font, for 8 s. This process repeated for all 60 trivia questions, which were presented in a random order for each participant. After studying all 60 trivia items, participants provided a global JOL for both test time points by answering first, out of 30, how many answers they thought they would remember after two days and then how many answers out of 30 they thought they would remember after one week. They were then asked to report if they looked up the answer to any questions during the task. Finally, participants answered some questions about whether they experienced any internet problems or problems with the task loading.

The short delay test opened on MTurk after two days, and participants completed it an average of 2.01 days (*SD* = 0.19 days) after the study phase. Participants were told their memory for the answers they had studied would be tested. First, the question was presented on the screen with a textbox, and participants were asked to enter the answer to the question. There was no time limit for this recall response. Next, participants were asked to rate their confidence in their answer on a scale of 1 (*not at all confident*) to 10 (*completely confident*). Participants were then asked what point value the question was paired with from 1 to 10. After completing that process for half of the items, participants reported a global JOL for the final time point by answering, out of 30, how many items they thought they would remember after five days.

The long delay test became available on MTurk 5 days after the short delay, and participants completed it an average of 7.06 days (*SD* = 0.31 days) after the study phase. As with the short delay, participants were shown each trivia question and asked to enter their answer into a textbox (self-paced). Then, they reported what point value they thought the question was paired with, from 1 to 10. After repeating this process for the 30 questions that were not tested at the short delay time point, they answered questions about looking up the answers, being distracted, and whether they had issues with the task or their internet.

Results

Analysis Plan. In both experiments, we use mixed effects models to examine the influence of curiosity and value on our outcomes of interest. These models have the benefit of treating the data as nested within both individuals and within items, which allows us to separate within- and between-person variance, as well as within-item and between-item variance, as some items may elicit more curiosity or be easier to recall than others. Curiosity ratings are centered around each participant's mean curiosity rating in all mixed effects models, known as *cluster based centering*, which accounts for participants having different average levels of curiosity and interpreting Likert scales in different ways. For example, one participant may rate their curiosity toward all items between a 4 and 8 and another participant may rate their curiosity toward all items between a 6 and 10. In the current analyses, each item's curiosity rating is compared to *each participant's* mean rather than the overall mean across all participants. This approach allows us to examine item-by-item influences of curiosity and value on memory performance. Cluster centering also allows for full isolation of level-1 (or item-level) effects, which is especially important when including interactions in models (see Enders & Tofighi, 2007 for discussion).

In the current analyses, all categorical predictors are coded using simple effect coding. This coding is similar to dummy coding, in that each level of the variable is compared to the reference level. However, simple coding allows for other predictors in a model to be interpreted at the mean of each categorical predictor, rather than at a single reference level. In this way, the interpretation of predictors when using simple coding is more similar to that of an ANOVA. In all experiments, age is coded such that the reference is younger adults, value (when categorical) is coded such that low value items are the reference level, and retention interval is coded such that the short delay test is the reference level.

For all binary outcomes (e.g., memory performance; 1=correct, 0=incorrect), we use logistic mixed effects models, whereas for any continuous predictors (e.g., confidence), we use linear mixed effects models. For logistic models, the outcome is transformed to a log odds ratio, or the log odds of being correct compared to the log odds of being incorrect. For all logistic models, we report odds ratios (*OR*), which are the change in the odds of being correct divided by the odds of being incorrect across increasing values of the predictor. An *OR* of 1 would indicate the odds of being correct are equal to the odds of being incorrect, whereas an *OR* of 2 would indicate that, given a one-unit increase in the value of the predictor, we would expect the odds of being correct to increase by 2 compared to the odds of being incorrect. For linear models, we report the unstandardized estimate (*b*).

Finally, for all analyses, items that participants correctly guessed during the study phase were removed, as these items do not reflect new learning and therefore are qualitatively different from items that do reflect new learning.

Recall. Figure 3.2 shows participants' predicted probability of correct recall as a function of curiosity, point value, and age. To examine participants' accuracy at each timepoint across value and curiosity, we conducted a mixed effects (i.e., multilevel) logistic regression analysis. The model assessed item-level recall accuracy as a function of age group, retention interval, value (centered around the grand mean), and curiosity (cluster centered), as well as the interactions between all of these predictors.

The model revealed no significant effect of age group (*OR* = 0.81, *SE* = 0.20, 95% CI: 0.55 – 1.18, $z = 1.10$, $p = .27$) on recall accuracy. Participants remembered more at the 2-day delay test compared to the 7-day delay test (*OR* = 0.45, *SE* = 0.20, 95% CI: 0.31 – 0.67, $z = 3.98$, $p < .001$). There was also a significant effect of curiosity (*OR* = 1.13, *SE* = 0.02, 95% CI: 1.09 – 1.17, $z = 7.33$, $p < .001$), wherein higher curiosity was associated with greater likelihood of correct recall. In addition, curiosity interacted with age group (*OR* = 0.92, *SE* = 0.03, 95% CI: 0.86 – 0.99, $z = 2.39$, $p = .02$), such that curiosity positively predicted recall accuracy for both younger adults (*OR* = 1.18, *SE* = 0.03, 95% CI: 1.12 – 1.24, $z = 6.22$, $p < .001$) and for older adults (*OR* = 1.09, *SE* = 0.02, 95% CI: 1.04 – 1.13, $z = 3.97$, $p < .001$), but the effect was stronger for younger adults.

There was no effect of point value on recall performance (*OR* = 1.04, *SE* = 0.03, 95% CI: 0.97 – 1.11, $z = 1.11$, $p = .27$), and value did not interact with age group (*OR* = 1.02, *SE* = 0.02, 95% CI: 0.98 – 1.07, $z = 1.10$, $p = .27$), nor with retention interval (*OR* = 0.93, *SE* = 0.07, 95% CI: 0.81 – 1.06, $z = 1.10$, $p = .27$).

Of most interest, we did not find a significant interaction between point value and curiosity (*OR* = 1.00, *SE* = 0.004, 95% CI: 0.99 – 1.01, $p = .52$). No other predictors in the model were significant (all *p*s > .13). These findings suggest that, in the current study, the effect of curiosity did not change with different point values, and that relationship was not significantly different across age groups or retention intervals.

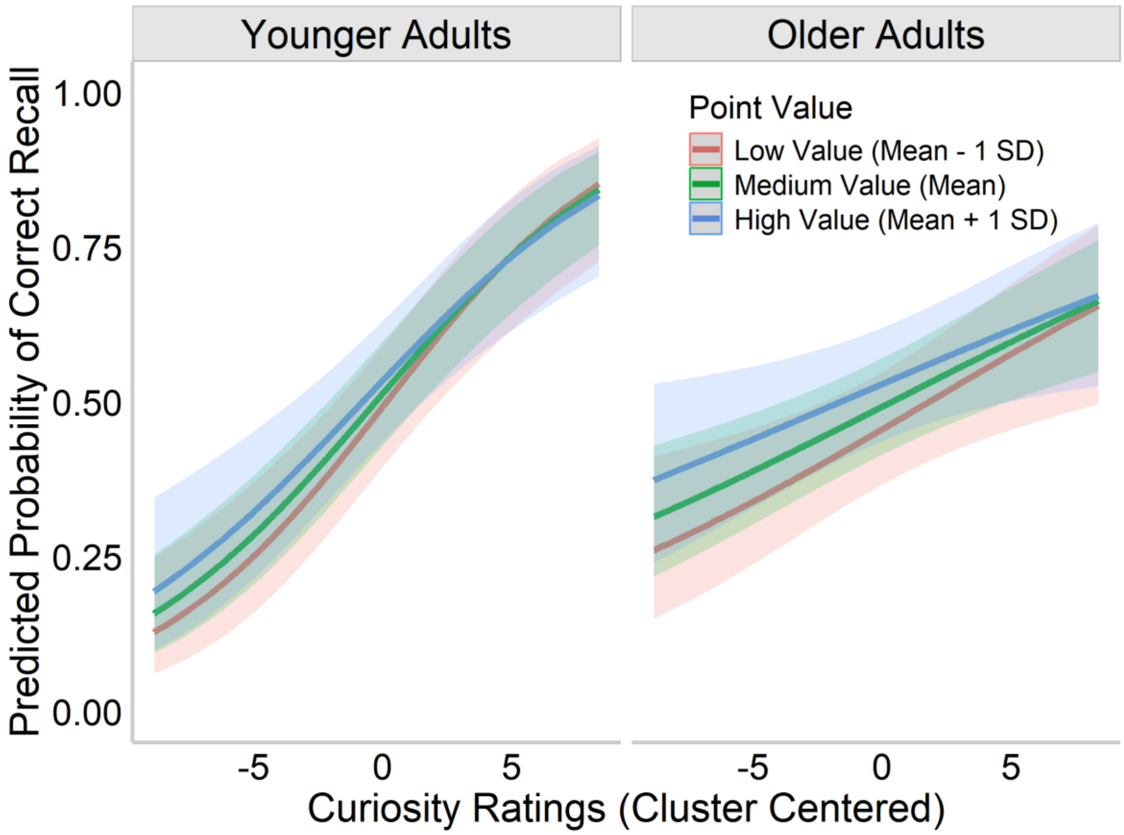

Figure 3.2. Probability of correct recall as a function of curiosity rating, point value, and age group in Experiment 1. Curiosity ratings are shown centered around each participant's mean. Point values are shown at one standard deviation below the mean (i.e., low value), the mean (i.e., medium value), and one standard deviation above the mean (i.e., high value). Shaded areas represent 95% confidence intervals.

Value Memory. We planned to analyze participants' accuracy in remembering the point value each item was paired with, but performance was at floor for this measure ($M < 0.001$ correct), so we could not run analyses with this outcome. However, we calculated a categorical measure to assess participants' value memory. For this outcome, if participants' memory of the value was in the same category (e.g., low: 1-3, medium: 4-7, high: 8-10), they would receive a 1, and if not, they would receive a 0. We then ran the same model as for previous categorical outcomes on accuracy of remembering the value within the correct category as a function of point value (centered), curiosity (cluster centered), age group, and retention interval, as well as their interactions. The only predictor that emerged as significant in the model was the interaction between value and curiosity (OR = 1.02, SE = 0.01, 95% CI: 1.00 – 1.03, z = 2.54, p = .01), such that curiosity *negatively* predicted value memory for low value items (OR = 0.94, SE = .03, 95% CI: 0.90 – 0.99, z = 2.24, p = .03), but not for medium value items (OR = 0.99, SE = 0.02, 95% CI: 0.96 – 1.02, z = 0.64, p = .52) or high value items (OR = 1.04, SE = 0.02, 95% CI: 0.99 – 1.09, z = 1.46, p = .14). This result suggests that higher curiosity may actually impair memory for more detailed associative information, but only for less important items.

There were a few predictors that were marginally significant, including the value by age interaction (OR = 0.96, SE = 0.02, 95% CI: 0.93 – 1.00, z = 1.79, p = .07) and the curiosity by retention interval interaction (OR = 0.94, SE = 0.03, 95% CI: 0.87 – 1.00, z = 1.91, p = .06). However, these were further qualified by a marginally significant interaction between value, curiosity, and retention interval (OR = 1.02, SE = 0.01, 95% CI: 1.00 – 1.05, z = 1.89, p = .06). Follow-up simple effects tests showed that at the 2-day delay test, curiosity was not a significant predictor of remembering the correct value category for low value items (OR = 1.01, SE = 0.04, 95% CI: 0.94 – 1.08, z = 0.28, p = .78), medium value items (OR = 1.02, SE = 0.02, 95% CI: 0.97 – 1.07, z = 0.91, p = .36), or for high value items (OR = 1.03, SE = 0.04, 95% CI: 0.96 – 1.11, z = 0.95, p = .34). However, at the 7-day delay test, curiosity was a negative predictor of correctly remembering the value category of items for low value items (OR = 0.88, SE = 0.04, 95% CI: 0.82 – 0.95, z = 3.34, $p < .001$), but not for medium (OR = 0.96, SE = 0.02, 95% CI: 0.91 – 1.00, z = 1.79, p = .07) or high value items (OR = 1.04, SE = 0.03, 95% CI: 0.97 – 1.11, z

= 1.12, p = .26). Thus, the negative effect of curiosity on value memory for low value items seemed to be mostly present at the longer delay. These effects are shown in Figure 3.3.

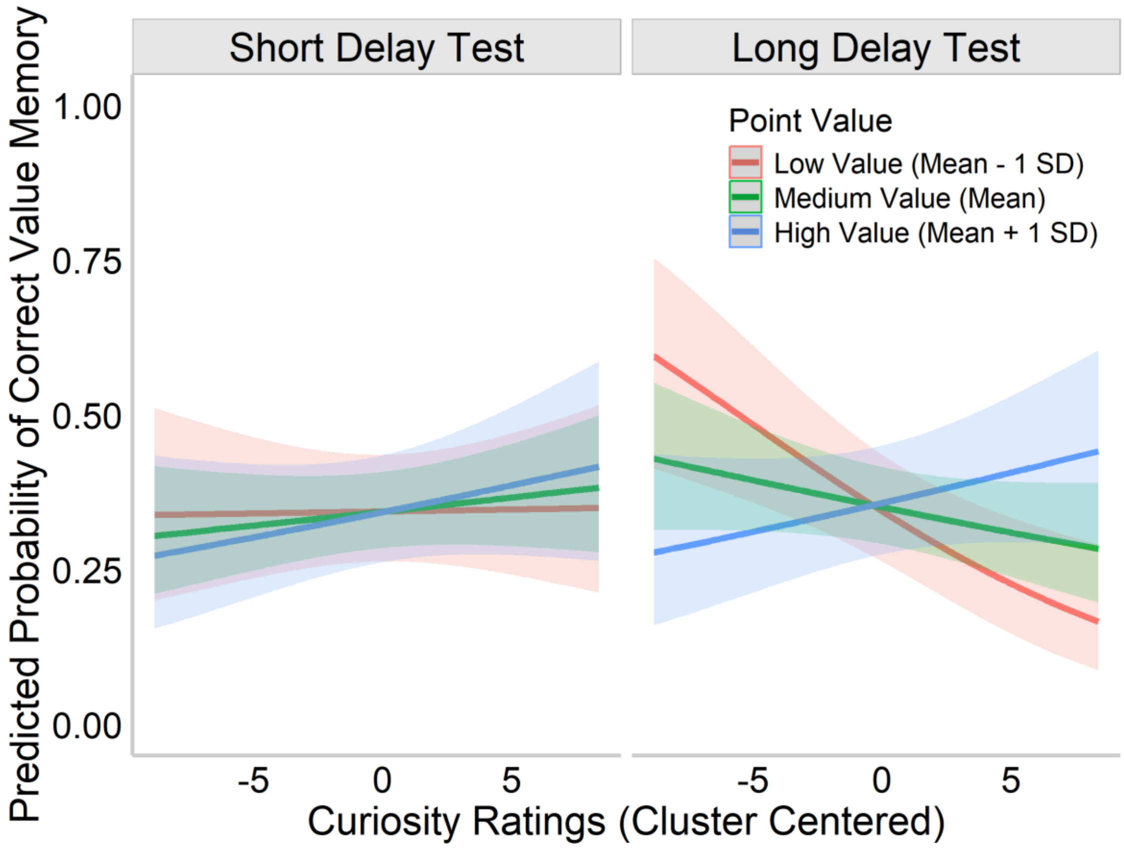

Figure 3.3. Predicted probability of correctly remembering the value category of each item as a function of curiosity, point value, and retention interval in Experiment 1. Curiosity ratings shown are centered around each participant's mean. Point value is shown at one standard deviation below the mean, the mean, and one standard deviation above the mean. Shaded areas represent 95% confidence intervals.

Global JOLs. Average global JOLs are represented in Figure 3.4. To examine participants' global JOLs, we conducted a 2 (Age Group: young, old) X 3 (Time) repeated measures ANOVA. The three time points include two predictions made at the end of learning:

one for the 2-day delay and one for the 7-day delay test. Participants made a third prediction after the 2-day delay test about their predicted performance on the 7-day delay test. The analysis revealed a main effect of time, $F(2, 246) = 4.83$, $p = .009$, such that, at the study phase, participants predicted they would remember fewer answers at the long delay than the short delay, $t(123) = 5.33$, $p < .001$. However, predictions made after taking the first test (2-day delay test) were not significantly different from initial predictions made for either the 2-day delay, $t(123) = 0.54$, $p > .99$, or the 7-day delay test, $t(123) = 2.03$, $p = .13$.

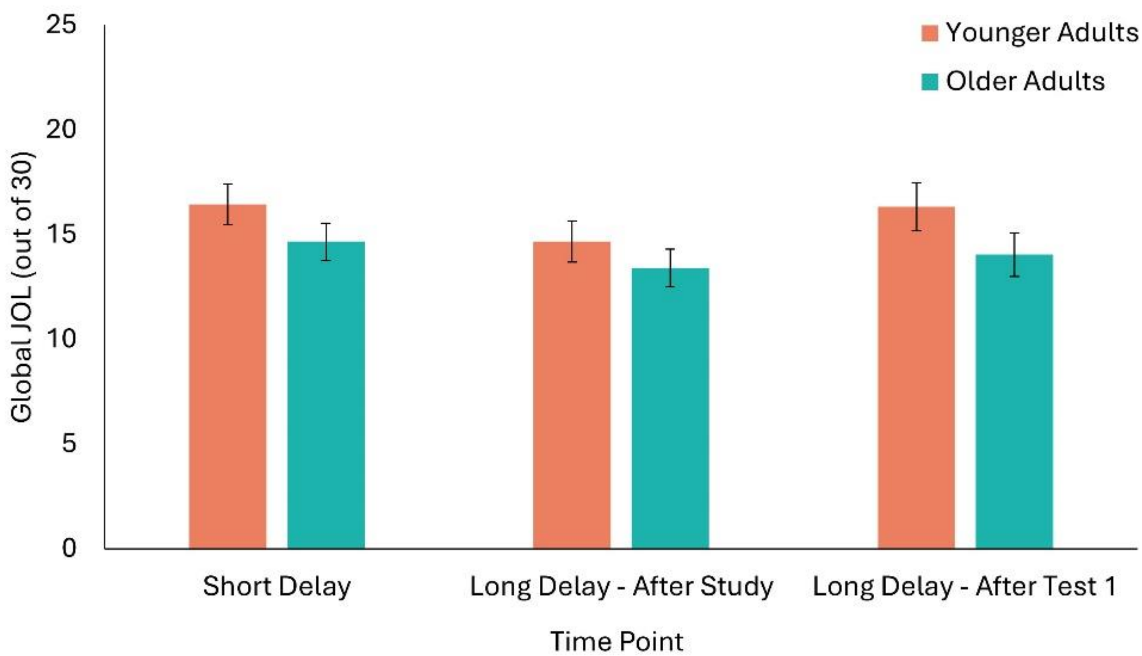

Figure 3.4. Global JOLs for each time point and age group in Experiment 1. The Short Delay JOL was a prediction made about the 2-day delay test after the study phase. The Long Delay-After Study JOL was a prediction made about the 7-day delay test after the study phase. The Long Delay-After Test 1 JOL was made about the 7-day delay test after completing the 2-day delay test. Error bars represent standard error of the mean.

There was no significant effect of age group on predictions overall, $F(1, 123) = 1.84$, $p = .18$, and age did not interact with the time point, $F(2, 246) = 0.72$, $p = .49$. These results suggest that, after learning, participants (both younger and older adults) predicted they would remember fewer answers after a longer delay than a shorter delay, and after testing, these predictions did not significantly change.

Discussion

Experiment 1 replicated findings showing that curiosity is a positive predictor of memory performance over long delays (Kang et al., 2009; McGillivray et al., 2015) and that external value does not undermine the influence of curiosity on memory performance in younger or older adults (Duan et al., 2020; Halamish et al., 2019). These findings suggest that, when learning is intentional and memory is rewarded, curiosity remains a strong predictor of memory performance for both younger and older adults, even in the presence of external reward. However, point value was surprisingly not a significant predictor of recall of trivia answers in Experiment 1. There are a few potential reasons for this lack of effect. First, it is possible that the way value was manipulated in the current experiments was not salient enough for participants to be sensitive to value, and thus, they were more motivated by curiosity. The continuous nature of the value manipulation may have made it harder to focus on value information or to create categories of important and unimportant information. Second, in typical VDR tasks, participants are often given multiple study-test lists, which allows them to gain task experience and adjust their strategy to focus on higher-value information in subsequent lists. However, in the current experiments, participants only saw one list. Another possibility for the lack of effect of value is due to the retention intervals. In typical VDR experiments, the test occurs immediately or after a brief delay (e.g., 5 min.) after learning. However, in the current study, we tested participants' memory after 2 days and 7 days, which could have reduced the influence of value on memory.

The results also showed that, although there was no undermining effect on recall of trivia answers, we did find a significant interaction between curiosity and value on memory for the point value (i.e., whether participants' memory was within the correct category). Specifically, when the point value was low, higher curiosity actually seemed to reduce memory accuracy for the point value category, whereas curiosity did not influence value memory for higher point value items. This finding is different from what would be expected according to accounts suggesting that curiosity can improve memory for irrelevant information presented in states of curiosity (e.g., Gruber & Ranganath, 2019). However, in Experiment 1, the value was not presented during the presumed state of curiosity, but rather when learning the answer (i.e., when curiosity is quenched). Thus, experiencing greater curiosity could lead one to focus more on the answer (to quench their curiosity) and focus less on the value itself.

Lastly, we found that participants' global JOLs did reflect knowledge that they would remember less information after a longer delay than a shorter delay. However, after taking the first test, their predictions for the upcoming test did not change. Typically, delayed JOLs, or JOLs made at the test time point, tend to be lower than JOLs made at the time of study (Dunlosky & Nelson, 1992). However, these JOLs are typically made on an item-by-item basis, so it is possible that global JOLs are less impacted by a delay.

There were a few limitations in Experiment 1. First, as noted previously, we used a continuous scale of point values (1-10), and this could have made it harder for participants to create a clear strategy to focus on "high value" items compared to low value items. Second, participants learned the point value associated with each item at the time at which curiosity is quenched. This design allows for the interpretation that value could still undermine curiosity if it were to be presented while in a state of curiosity. Thus, in Experiment 2, we addressed these limitations using a categorical value manipulation to further differentiate high and low values. Additionally, we manipulated the time at which the value was shown to participants. For half the participants, the value was presented with the question, while for the other half, it was presented with the answer.

Experiment 2

In Experiment 2, younger and older adult participants first saw trivia questions and rated their curiosity to learn the answer. After they had rated all items, participants studied the trivia questions and answers, which were each paired with a point value of either 3 points (low value) or 12 points (high value). For half the participants, the point value was presented when they saw the question (i.e., when participants were in a state of curiosity), and for the other half of participants, the point value was presented when they learned the answer (i.e., when curiosity was satisfied). We examined participants' recall of trivia answers after 2 days and 7 days, as well as confidence in recall responses at each time point. We also assessed participants' memory for the point value to examine associative memory in addition to item memory.

Method

Participants. Participants were 88 younger adults (aged 20-30 years; M = 25.86, SD = 2.88) and 98 older adults (aged 65-78 years; M = 69.15, SD = 3.61) recruited from Prolific and compensated $10 per hour of their participation. Participants were excluded if they did not pass bot checks (n = 3), reported being distracted or off task (n = 8), reported looking up the answers to most or all of the questions (n = 9), failed the attention check items (see below; n = 11), or reported their age as between 30 and 60 (n = 5).

Stimuli and Procedure. Stimuli were the same as those used in Experiment 1. After providing informed consent by checking a box and reporting age, gender, education level, and race/ethnicity, participants were instructed that they would be studying trivia questions and would be asked to remember them for a later test. The general procedure was similar to that of Experiment 1, but the study portion of the task was broken into a ratings phase and a learning phase. During the ratings phase, participants viewed each trivia question in a random order and were able to make a guess as to the answer. If participants had not made a guess after 15 s had passed, the page automatically advanced. Then, participants rated their curiosity to learn the answer and their confidence they knew the answer, both on a 1 (*not at all*) to 10 (*very*) Likert scale. This process repeated for all 60 questions. The goal of the ratings phase was to acquire curiosity ratings before learning took place so that we could regulate the amount of time participants viewed questions and answers to equalize the presentation time of point values.

Once participants completed the ratings phase, they advanced to the learning phase. At the beginning of the learning phase, participants were told that each question would earn them a certain number of points if correctly remembered it, and that their goal should be to maximize their point score. During the learning phase, each question participants had rated previously was presented on a blank screen for 6 s, followed by the answer for 6 s. Questions were presented again in a random order. Importantly, for half the participants, a point value of either 3 points or 12 points was shown in bold text above the question, and for the other half of the participants, the point value was shown (also in bold) above the answer. Half of the items were paired with a low point value (3 points) and half with a high point value (12 points), and this pairing was randomized for each participant. Figure 3.5 shows an example of this general procedure.

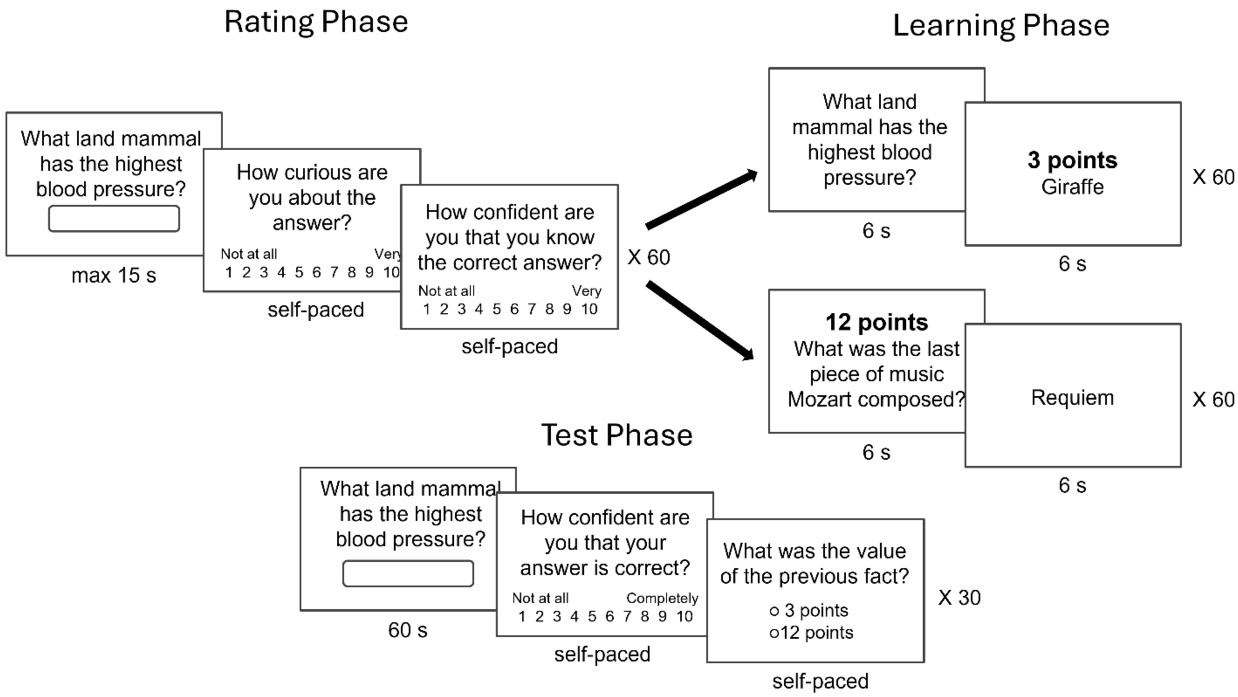

Figure 3.5. The trivia learning procedure in Experiment 2. During the Rating Phase, participants rated all 60 items. During the Learning Phase, participants either saw the value paired with the answer (top row) or with the question (bottom row). There were two test phases: two days and one week after learning. During each Test Phase, participants' memory was tested for half the items.

There were three attention check items included throughout the learning phase. After one fourth of the questions had been presented, an extra question was presented, followed by a multiple-choice question asking, "What was the value of the previous trivia fact?" Participants were excluded if they missed two or three of the attention check items. After learning all 60 trivia question-answer pairs, participants were asked to predict the number of answers (out of 30) they would remember after two days and after one week. Then, they answered questions about whether they were doing anything else during the task, had issues, or looked up any of the answers.

The test phases were again completed approximately two days (*M* = 2.02, *SD* = 0.21) and one week (*M* = 7.81, *SD* = 0.39) after the study phase. Participants were tested on half of the items at each testing time point, and this was counterbalanced across participants. During the test, participants were shown 30 of the trivia questions they had studied in a random order and were asked to recall the answers they were paired with. Participants were given 60 s to enter their answer in order to prevent them looking up the answers to the questions. Once they had entered their response or the 60 s had passed, participants rated their confidence in their answer on a 1 (*not at all confident*) to 10 (*very confident*) scale. Then, they were asked what point value the item was paired with, with the options "3 points" and "12 points." At the end of the short delay test, participants were asked again to predict how many answers (out of 30) they would remember after another five days. At the end of both the 2-day and 7-day delay test, participants answered questions about whether they were doing anything else during the task, looked up the answers to the questions, or had problems with their internet or the task.

Results

Analyses follow the analysis plan discussed in Experiment 1. The only differences are that in Experiment 2, value is categorical and is coded using simple effect coding (reference level being low value items). Additionally, we add condition to our models (i.e., value paired with question vs. value paired with answer). The condition variable was also coded using simple effect coding, and the reference level is always the value paired with the question.

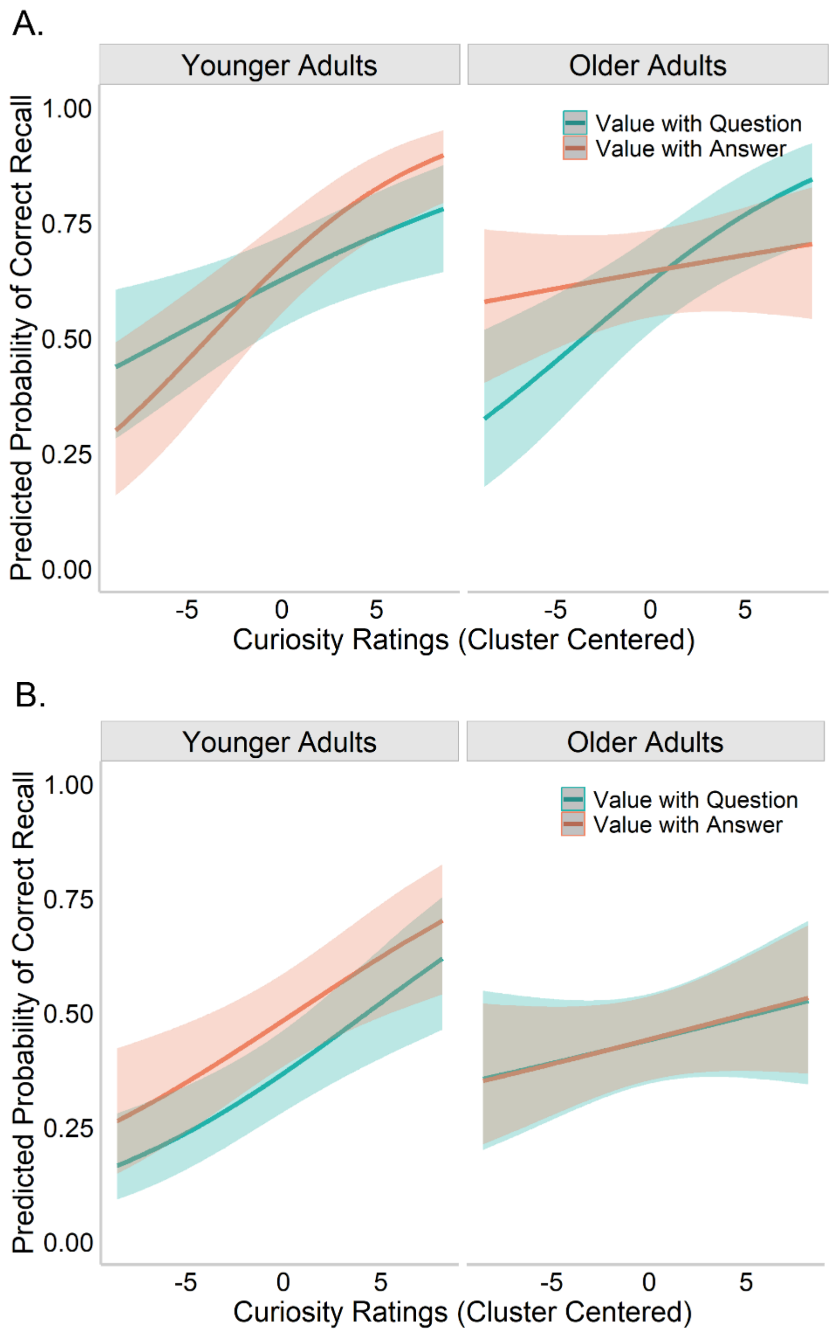

Figure 3.6. Probability of correct recall of trivia answers as a function of curiosity ratings, condition, age group, and retention interval in Experiment 2. A. shows the effects of curiosity, age, and point value at the two-day delay test, while B. shows the same effects at the seven-day delay test. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

Recall. We first examined participants' accuracy in recalling the answers to the trivia questions they had studied. We conducted a logistic mixed effects regression model (described in the analysis plan). The model revealed an overall significant positive effect of curiosity on recall accuracy (*OR* = 1.09, *SE* = 0.16, 95% CI: 1.06 – 1.12, $z = 6.86$, $p < .001$), as well as a significant effect of value (*OR* = 1.10, *SE* = 0.05, 95% CI: 1.01 – 1.21, $z = 2.09$, $p = .04$), such that high value items were better recalled than low value items. Replicating our finding from Experiment 1, point value did not interact with any other predictors, including curiosity (*OR* = 0.99, *SE* = 0.02, 95% CI: 0.94 – 1.04, $z = 0.52$, $p = .61$). There was also a significant effect of retention interval (*OR* = 0.44, *SE* = 0.05, 95% CI: 0.40 – 0.48, $z = 17.14$, $p < .001$), such that participants were more likely to recall the answers to items on the 2-day delay test than the 7-day delay test. Age was overall not a significant predictor of recall accuracy (*OR* = 1.03, *SE* = 0.16, 95% CI: 0.75 – 1.42, $z = 0.18$, $p = .86$), nor was condition (*OR* = 1.17, *SE* = 0.16, 95% CI: 0.85 – 1.62, $z = 0.98$, $p = .33$).

There were several interactions, but lower order interactions are influenced by the pattern of higher order interactions, so we describe the highest interaction here. First, the five-way interaction was marginally significant (*OR* = 0.68, *SE* = 0.20, 95% CI: 0.46 – 1.00, $z = 1.96$, $p = .05$). However, because there are many predictors in the model and we did not account for Type I error, and because the interaction is likely too complex to be meaningful, we do not explore it here. There was, however, a significant interaction between age, condition, retention interval, and curiosity (*OR* = 1.22, *SE* = 0.10, 95% CI: 1.00 – 1.49, $z = 2.01$, $p = .045$), which is represented in Figure 3.6. To explore the nature of this four-way interaction, we separated the data by each retention interval to examine the three-way interaction between age, condition, and curiosity at each test interval. At the first delay test (2 days), the three-way interaction between age, condition, and curiosity was significant (*OR* = 0.83, *SE* = 0.07, 95% CI: 0.72 – 0.95, z = 2.67, p = .008). In exploring this interaction, we examined the effect of curiosity on recall for younger and older adults in each condition. For younger adults, curiosity was a significant positive predictor of recall accuracy when the value was shown with the question (*OR* = 1.10, *SE* = 0.03, 95% CI: 1.03 – 1.17, z = 2.93, p = .003), as well as when the value was shown with the answer (*OR* = 1.19, *SE* = 0.04, 95% CI: 1.10 – 1.23, z = 4.46, $p < .001$). However, for older adults, curiosity significantly and positively predicted recall accuracy when the value was paired with the question (*OR* = 1.15, *SE* = 0.04, 95% CI: 1.06 – 1.24, z = 3.51, $p < .001$), but did not show a significant relationship with recall accuracy when it was paired with the answer (*OR* = 1.03, *SE* = 0.03, 95% CI: 0.97 – 1.10, z = 0.92, p = .36).

At the second delay test (7 days), the three-way interaction between age, condition, and curiosity was not significant (*OR* = 1.01, *SE* = 0.07, 95% CI: 0.88 – 1.16, z = 0.15, p = .88). To compare the results to those from the short delay test, we describe the pattern of results for these three variables. For younger adults, curiosity was a significant positive predictor of recall accuracy both when the value was paired with the question (*OR* = 1.13, *SE* = 0.03, 95% CI: 1.06 – 1.21, z = 3.81, $p < .001$) and when the value was paired with the answer (*OR* = 1.11, *SE* = 0.04, 95% CI: 1.04 – 1.20, z = 3.17, p = .002). However, for older adults, curiosity did not show a significant relationship with recall accuracy in either condition (paired with question: *OR* = 1.04, *SE* = 0.04, 95% CI: 0.96 – 1.13, z = 1.04, p = .30; paired with answer: *OR* = 1.04, *SE* = 0.04, 95% CI: 0.97 – 1.12, z = 1.19, p = .24). Thus, it seems that curiosity was generally a positive predictor of recall accuracy for younger adults across both conditions and retention intervals. However, for older adults, curiosity only predicted accuracy at the short delay test and only when the value had been paired with the question (not the answer). In other words, older adults may have benefitted from seeing the value when experiencing curiosity, but not once curiosity was quenched, and this effect was not long lasting.

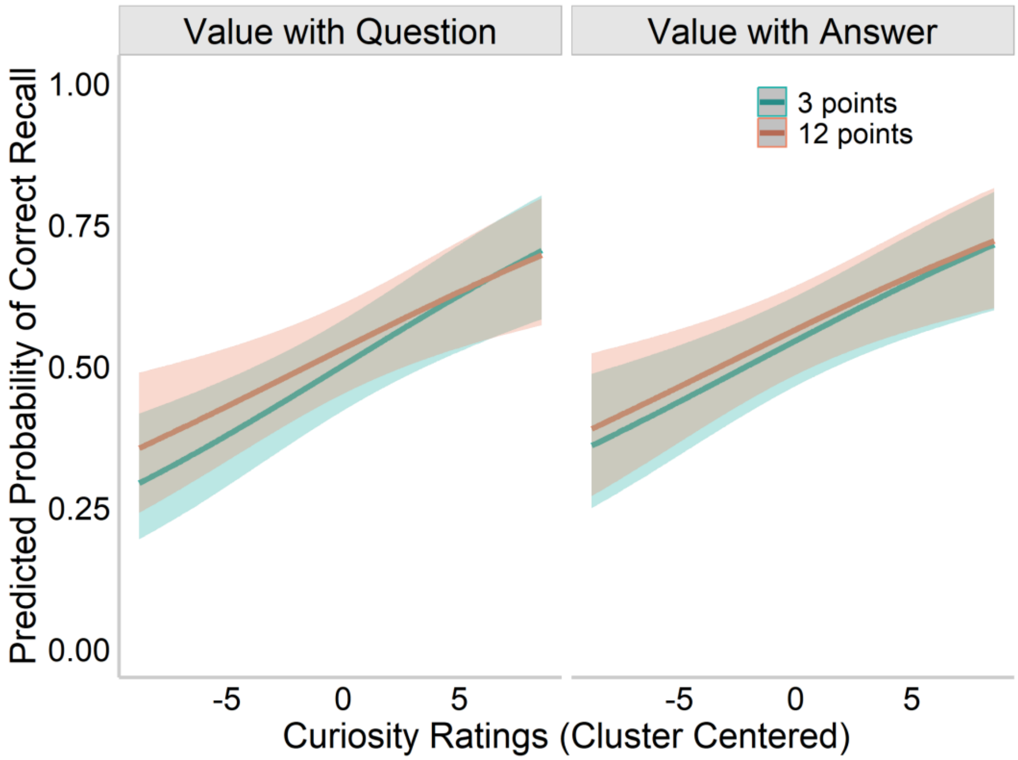

Figure 3.7. Probability of correct recall of trivia answers as a function of curiosity ratings, condition, and point value in Experiment 2. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

Additionally, the two-way interaction between value and curiosity was not significant (*OR* = 0.99, *SE* = 0.02, 95% CI: 0.94 – 1.04, *z* = 0.52, *p* = .61), nor was the interaction between value, curiosity, and age (*OR* = 1.03, *SE* = 0.05, 95% CI: 0.94 – 1.14, *z* = 0.61, *p* = .54), between value, curiosity, and condition (*OR* = 1.01, *SE* = 0.05, 95% CI: 0.92 – 1.12, *z* = 0.24, *p* = .81), or between value, curiosity, and retention interval (*OR* = 0.99, *SE* = 0.05, 95% CI: 0.90 – 1.09, *z* = 0.20, *p* = .84). Thus, we again found no significant interaction between value and curiosity, and this did not vary across age group, condition, or retention interval. The effects of value, curiosity, and condition on recall performance is depicted in Figure 3.7.

Recall Confidence. We next examined participants' confidence in their recall responses at the item level. We conducted a linear mixed effects model with confidence ratings modeled as a function of curiosity (cluster centered), value, condition, age group, and retention interval. First, retention interval was a significant predictor of confidence, such that participants were more confident in their recall responses at the short delay test than the long delay test, $b = -1.38$, $SE = 0.06$, $t(9852) = 22.68$, $p < .001$. Older adults were overall more confident in their memory than younger adults, $b = 0.56$, $SE = 0.25$, $t(182) = 2.30$, $p = .02$, and curiosity was a significant positive predictor of confidence, $b = 0.14$, $SE = 0.02$, $t(9895) = 8.85$, $p < .001$. However, value overall did not predict confidence, $b = 0.06$, $SE = 0.06$, $t(9849) = 0.97$, $p = .33$.

As in the previous model, there were several interactions. The five-way interaction was significant, $b = -0.50$, $SE = 0.25$, $t(9867) = 1.98$, $p = .048$, but again, we do not explore this interaction because of the lack of control over Type I error and the complexity of interpreting a five-way interaction. There was a significant interaction between age, condition, and retention interval, $b = -0.62$, $SE = 0.25$, $t(9896) = 2.49$, $p = .01$. In exploring simple effects, we found that at the short delay test, there were no age differences in confidence when the value had been paired with the question, $b = 0.68$, $SE = 0.36$, $t(205) = 1.91$, $p = .06$, nor with the answer, $b = 0.44$, $SE = 0.36$, $t(205) = 1.24$, $p = .22$. However, at the long delay test, older adults were more confident than younger adults when the value had been paired with the question, $b = 0.99$, $SE = 0.36$, $t(206) = 2.78$, $p = .006$, but not when the value was paired with the answer, $b = 0.14$, $SE = 0.36$, $t(206) = 0.38$, $p = .71$. In other words, older adults were more confident in their recall than younger adults when the value had been displayed while in a state of curiosity, but this effect was most pronounced after a longer delay.

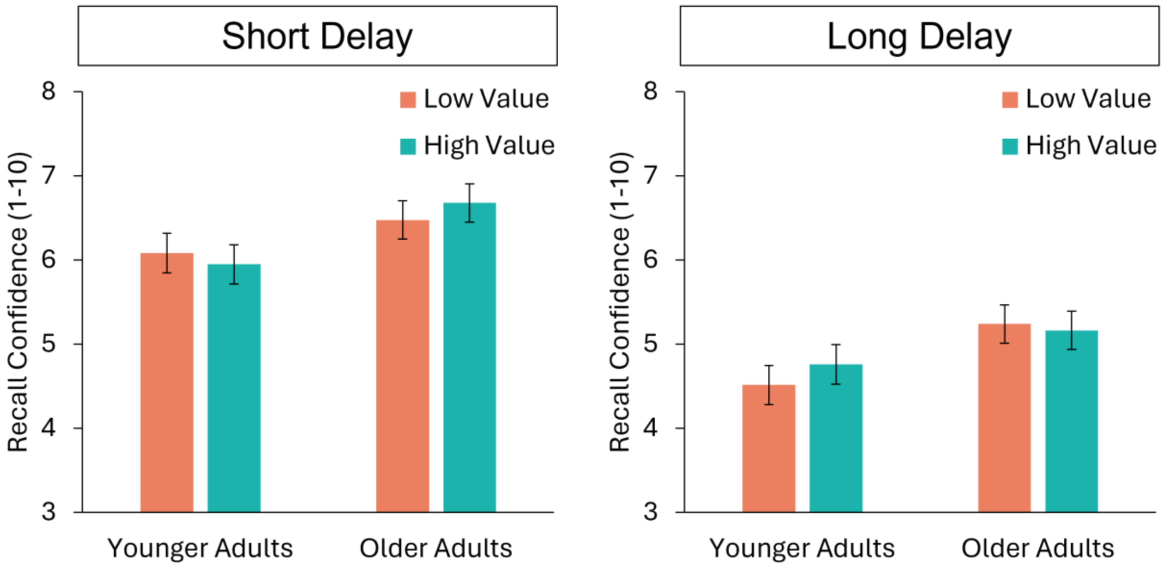

Figure 3.8. Participants' average ratings of confidence in their recall of trivia answers as a function of age group, point value, and retention interval in Experiment 2. Confidence was rated on a 1-10 scale. Error bars represent standard error of the mean.

There was also a significant interaction between age, value, and retention interval, b = -0.66, SE = 0.24, $t(9869) = 2.68$, $p = .007$, which is presented in Figure 3.8. In looking at the short delay test, there were no age differences in confidence for low value items, b = 0.39, SE = 0.27, $t(255) = 1.48$, $p = .14$, but older adults were more confident in their memory for high value items, b = 0.73, SE = 0.27, $t(254) = 2.74$, $p = .007$. At the long delay test, however, there were no age differences in confidence for high value items, b = 0.40, SE = 0.27, $t(257) = 1.51$, $p = .13$, but older adults were more confident in their memory for low value items than younger adults, b = 0.72, SE = 0.27, $t(255) = 2.71$, $p = .007$. Thus, at the shorter delay point, older adults' confidence was more sensitive to value, but at the longer delay test, younger adults' confidence was more (accurately) sensitive to value.

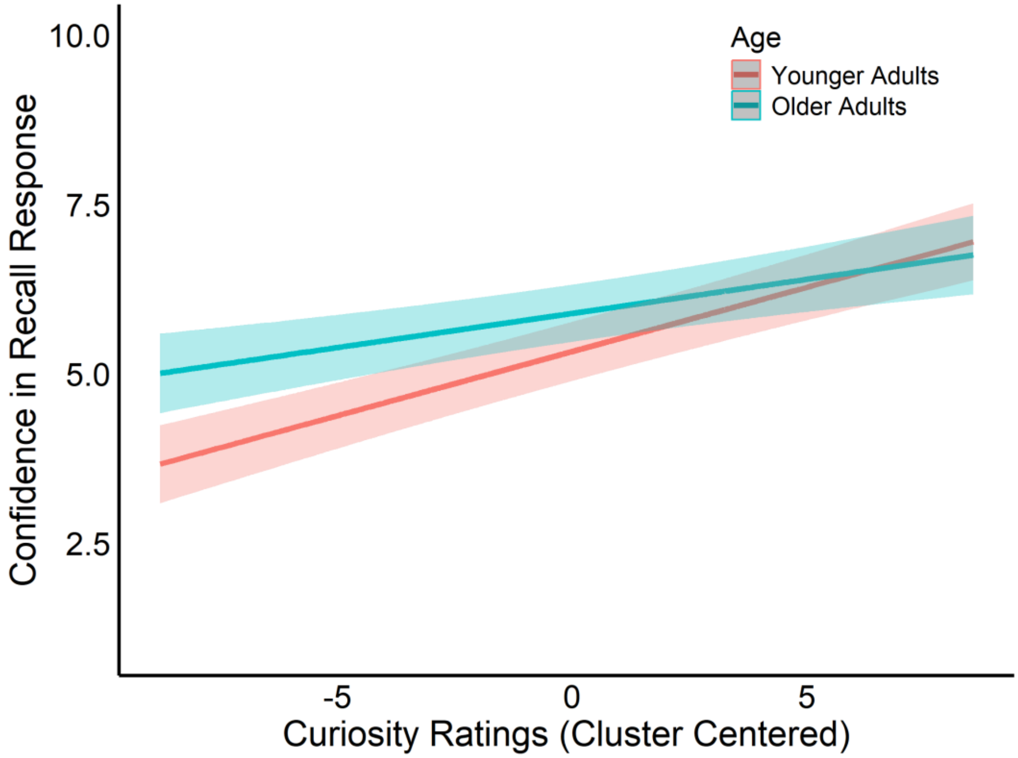

Figure 3.9. Participants' average confidence rating as a function of curiosity rating and age group in Experiment 2. Confidence was rated on a 1-10 scale. Shaded areas represent 95% confidence intervals.

Finally, there was an interaction between age and curiosity, b = -0.09, SE = 0.03, t(9848) = 2.82, p = .005, such that curiosity was a significant positive predictor of confidence for both younger adults, b = 0.19, SE = 0.02, t(9887) = 8.70, p < .001, and for older adults, b = 0.10, SE = 0.02, t(9871) = 4.25, p < .001, but the effect was stronger for younger adults. This interaction is shown in Figure 3.9. No other predictors in the model were significant (all ps > .05).

Value Memory. To examine participants' accuracy in remembering the point value each item had been paired with, we ran a logistic mixed effects model predicting value memory accuracy (1=correct, 0=incorrect) as a function of curiosity, point value, condition, retention interval, and age group. First, actual point value was a significant predictor of value memory, such that participants' memory for the value was more accurate for low value items than high value items (*OR* = 0.92, *SE* = 0.04, 95% CI: 0.85 – 0.99, *z* = 2.09, *p* = .04). However, there was no overall significant effect of age (*OR* = 1.09, *SE* = 0.05, 95% CI: 0.98 – 1.21, *z* = 1.53, *p* = .13), curiosity (*OR* = 1.00, *SE* = 0.01, 95% CI: 0.98 – 1.02, *z* = 0.09, *p* = .93), condition (*OR* = 1.06, *SE* = 0.05, 95% CI: 0.95 – 1.17, *z* = 0.98, *p* = .33), or retention interval (*OR* = 1.02, *SE* = 0.08, 95% CI: 0.94 – 1.10, *z* = 0.49, *p* = .62).

Again, there were a few significant interactions, so we focus on the highest order interaction here. There was a four-way interaction between age, condition, retention interval, and curiosity (*OR* = 0.76, *SE* = 0.09, 95% CI: 0.64 – 0.90, *z* = 3.23, *p* = .001), which is represented in Figure 3.10. To further examine the nature of this interaction, we split the dataset by testing time point. First, looking at the short delay test, we found that the three-way interaction between age, condition, and curiosity was significant (*OR* = 1.21, *SE* = 0.06, 95% CI: 1.08 – 1.36, *z* = 3.18, *p* = .001). Follow-up tests showed that for younger adults, curiosity did not significantly predict value memory accuracy when the value was paired with the question (*OR* = 1.04, *SE* = 0.03, 95% CI: 0.99 – 1.10, *z* = 1.45, *p* = .15), nor when paired with the answer (*OR* = 0.96, *SE* = 0.03, 95% CI: 0.90 – 1.02, *z* = 1.29, *p* = .20). However, for older adults, curiosity was a significant negative predictor of value memory when the point value was paired with the question (*OR* = 0.91, *SE* = 0.03, 95% CI: 0.85 – 0.97, *z* = 3.04, *p* = .002), but not when paired with the answer (*OR* = 1.01, *SE* = 0.03, 95% CI: 0.96 – 1.07, *z* = 0.46, *p* = .65).

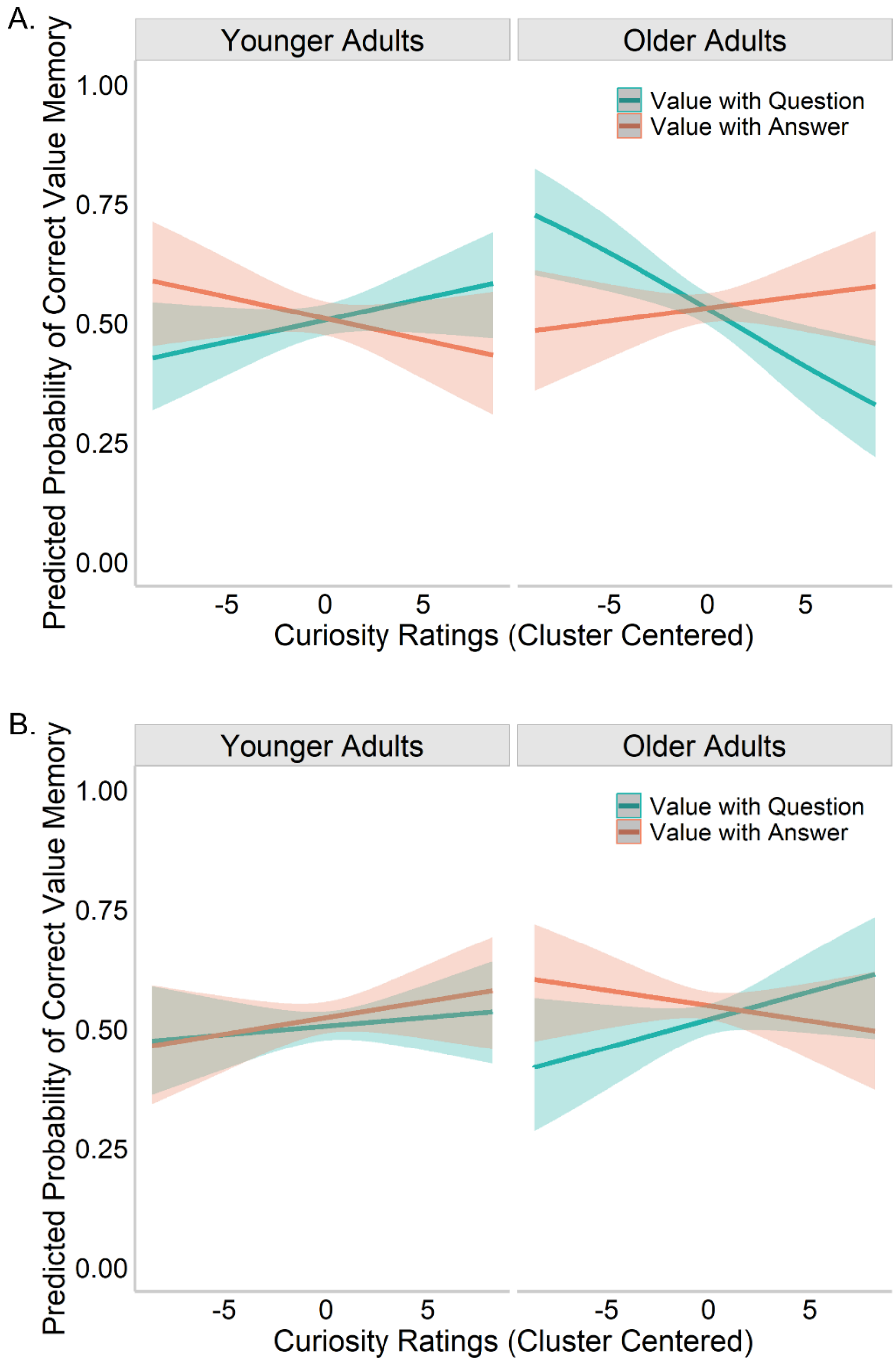

Figure 3.10. Predicted probability of correctly remembering the value of each item plotted as a function of curiosity ratings, condition, age group, and retention interval in Experiment 2. A. shows the two-day delay test, while B. shows the seven-day delay test. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

Then, looking at the long delay test, the three-way interaction between age, condition, and curiosity was not significant (*OR* = 0.92, *SE* = 0.06, 95% CI: 0.82 – 1.04, z = 1.36, p = .17). To compare to the results from the short delay test, curiosity did not significantly predict value memory accuracy for younger adults in either condition (paired with question: *OR* = 1.01, *SE* = 0.03, 95% CI: 0.96 – 1.07, z = 0.51, p = .61; paired with answer: (*OR* = 1.02, *SE* = 0.03, 95% CI: 0.97 – 1.09, z = 0.80, p = .43), nor for older adults (paired with question: *OR* = 1.06, *SE* = 0.03, 95% CI: 0.99 – 1.13, z = 1.65, p = .10; paired with answer: (*OR* = 0.98, *SE* = 0.03, 95% CI: 0.93 – 1.05, z = 0.54, p = .59). In other words, seeing the value when in a state of curiosity may have actually impaired older adults' memory for the value compared to seeing the value when curiosity was already quenched, but this effect was only present at the short delay test, and not the long delay test.

Additionally, the three-way interaction between age, value, and condition was significant (*OR* = 0.71, *SE* = 0.16, 95% CI: 0.52 – 0.98, z = 2.08, p = .04). Follow-up comparisons showed that younger adults were more accurate at remembering the value of low compared to high value items in both conditions (value paired with question: *OR* = 0.84, *SE* = 0.08, 95% CI: 0.72 – 0.98, z = 2.24, p = .03; value paired with answer: *OR* = 0.74, *SE* = 0.09, 95% CI: 0.63 – 0.88, z = 3.42, p < .001), whereas older adults also showed the same negative effect of value (more accurate for low than high value) when the value was paired with the answer (*OR* = 0.85, *SE* = 0.76, 95% CI: 0.73 – 0.99, z = 2.14, p = .03), but a positive effect of value when it was paired with the question (*OR* = 1.34, *SE* = 0.08, 95% CI: 1.14 – 1.58, z = 3.57, p < .001). These effects are depicted in Figure 3.11.

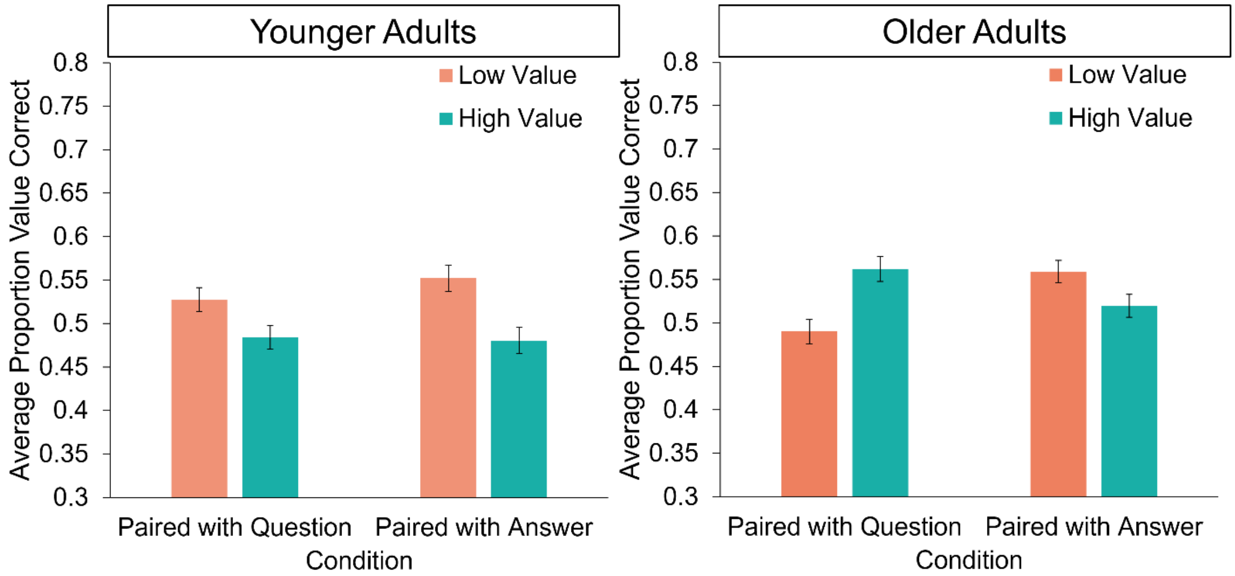

Figure 3.11. Average proportion correct memory for value of items as a function of condition, point value, and age group in Experiment 2. Error bars represent standard error of the mean.

Lastly, there was a two-way interaction between value and curiosity (*OR* = 1.07, *SE* = 0.02, 95% CI: 1.03 – 1.12, *z* = 3.21, *p* = .001), such that curiosity was a significant negative predictor of value memory for low value items (*OR* = 0.97, *SE* = 0.01, 95% CI: 0.94 – 0.99, *z* = 2.37, *p* = .02), but a significant positive predictor of value memory for high value items (*OR* = 1.03, *SE* = 0.02, 95% CI: 1.00 – 1.07, *z* = 2.17, *p* = .03).

Global JOLs. We were also interested in participants' judgments of how many answers they believed they would recall at each retention interval. At the end of the learning phase, participants judged how many items they would remember after two days and after one week. Then, they again judged how many items they would remember at the next test after completing the first test. We conducted a 2 (Age: young, old) X 2 (Condition: value paired with question, value paired with answer) X 3 (Timepoint) mixed ANOVA to analyze these predictions. The results revealed a significant effect of timepoint, $F(2, 364) = 27.83$, $p < .001$. Follow-up post-hoc tests showed that participants predicted they would remember fewer items at the long delay test (M = 13.48, SD = 7.10) than the short delay test (M = 15.66, SD = 6.63), $t(182) = 9.15$, $p < .001$. Participants also predicted they would remember fewer items on the long delay test after taking the first test (M = 12.67, SD = 6.70) compared to the short delay test, $t(182) = 6.37$, $p < .001$. However, initial judgments about the long delay test were not significantly different from judgments made about the long delay test after taking the first test, $t(182) = 1.40$, $p = .49$. Average JOLs across age and time point are represented in Figure 3.12.

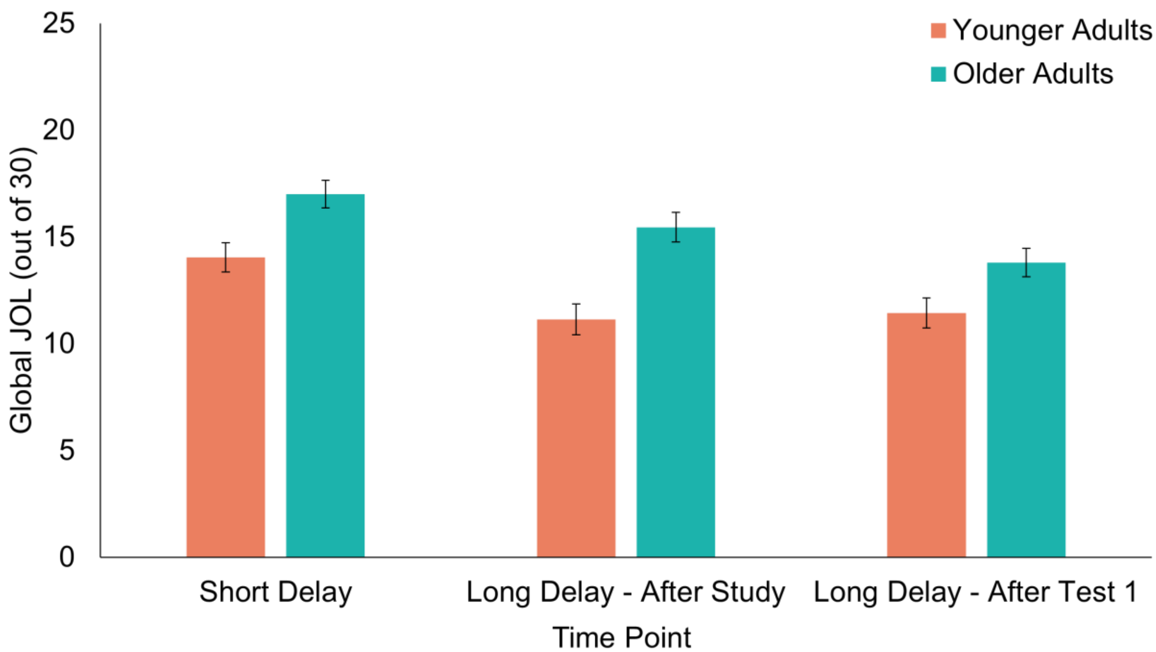

Figure 3.12. Average global JOLs at each time point and across age groups in Experiment 2. Error bars represent the standard error of the mean.

The interaction between age and time point was also significant, $F(2, 364) = 3.03$, p = .049. Bonferroni-corrected post hoc tests showed that younger adults initially estimated they would remember more words at the short delay test compared to the long delay test, $t(182)$ = 8.23, $p < .001$, and compared to after the first test, $t(182) = 3.94$, $p = .002$, but their estimates about the long delay test did not differ from those made after study and those made after testing, $t(182) = 0.44$, $p > .99$. Older adults, on the other hand, also initially estimated they would remember more words at the short delay than the long delay, $t(182) = 4.62$, $p < .001$, and than after the first test, $t(182) = 5.11$, $p < .001$. However, their estimates after the first test were slightly lower than those made about the same testing time point after learning, $t(182) = 2.50$, $p = .20$, although this did not reach significance when controlling for Type I error.

The effect of age was significant, $F(1, 182) = 14.29$, $p < .001$, such that older adults ($M = 15.43$, $SD = 0.59$) estimated they would remember more items overall than younger adults ($M = 12.21$, $SD = 0.62$). However, condition did not affect global JOLs, $F(1, 182) = 1.99$, $p = .16$, and condition did not interact with timepoint, $F(2, 364) = 1.47$, $p = .23$, or age, $F(1, 182) = 0.42$, $p = .52$. The three-way interaction was also not significant, $F(2, 364) = 2.75$, $p = .07$.

Discussion

In Experiment 2, we replicated the finding from Experiment 1 that value did not undermine the effects of curiosity on memory for trivia question-answer pairs. However, using a categorial value manipulation in Experiment 2, we did find a significant effect of value wherein high value items were more accurately recalled than low value items. The categorical manipulation of value likely allowed participants to focus more on prioritizing the high value items. We also found that younger adults showed a stronger influence of curiosity on recall performance than did older adults, similar to Experiment 1, suggesting that the presence of value information may have affected how much curiosity had an influence on older adults' memory.

Additionally, in Experiment 2, we manipulated the timing of the point value, such that for half of participants, the value appeared during the state of curiosity (with the question), and for the other half, it appeared during the satisfaction of curiosity (with the answer). We found that this manipulation did not affect the extent to which curiosity predicted recall at the long (7-day) delay, though curiosity positively predicted memory for younger adults, but not for older adults. However, at the shorter (2-day) delay, younger adults showed a positive effect of curiosity on recall, but older adults only saw this benefit of curiosity when the value was presented during the state of curiosity. Thus, viewing the value during a state of curiosity may have actually enhanced the influence of curiosity on memory for older adults, but this effect diminished after a longer delay. Importantly, condition did not interact with point value, suggesting that the timing of presentation of value may affect memory overall, but not the extent to which value affects memory.

In Experiment 2, we also replicated the interaction from Experiment 1 between value and curiosity on memory for the point value itself, or a more associative memory assessment. In both experiments, when point value was low, curiosity had a negative effect on later memory for the value itself. In Experiment 1, there was no effect of curiosity on value memory for high value items, but there was a positive effect in Experiment 2. Thus, there may be some form of undermining occurring for this associative, gist-based memory. We also found in Experiment 2 that the condition participants were assigned to affected their value memory, such that older adults' associative memory benefitted from high value items only when they saw the value with the question, whereas when the value was shown with the answer, both age groups were more accurate for low value items.

Lastly, we examined item-by-item confidence ratings in Experiment 2 in addition to global JOLs. Older adults were overall more confident in their recall responses than younger adults, despite recall accuracy being similar across age groups. Older adults also predicted they would remember more items at test in their global JOLs. Similar findings at both item-level and global levels have emerged in other work (e.g., Siegel & Castel, 2018). Further, younger adults' confidence ratings seemed to be more sensitive to the value of items at the long delay, as they reported higher confidence for high value than low value items, whereas older adults' confidence was more sensitive to value at the short delay, where they reported higher confidence for high than low value items. Thus, it is possible that retention interval can influence the accuracy of metacognitive judgments differentially across age groups.

General Discussion

In Chapter 3, we explored the combined influence of an intrinsic motivator (curiosity) and an extrinsic motivator (point value) on younger and older adults' item and associative memory, as well as their metacognitive judgments. Prior work has found mixed results regarding the competing or additive influence of curiosity and reward on memory formation. Some work (Murayama & Kuhbandner, 2011; Swirsky et al., 2021) has found evidence for an undermining effect, wherein the presence of external reward reduces the influence of intrinsic motivation on learning performance. In other words, external reward can overpower or undermine the influence of intrinsic motivation on learning. Other work has found an additive effect of curiosity and reward (Duan et al., 2020; Halamish et al., 2019), such that memory is better for both high curiosity and rewarded items, but reward does not interfere with the influence of curiosity on memory.

Across two experiments, we found support for curiosity and reward providing additive effects on memory, with no undermining effect. These results contribute to the literature in a few specific ways. First, while prior work has manipulated rewards by either offering a reward or not offering a reward, our research suggests that even when rewards are offered for all items, participants still show a benefit for high compared to low value information, and this presence of reward does not reduce the influence of curiosity on memory.

Secondly, our work helps to clarify the timing of reward presentation and its effects on memory. In some prior work (e.g., Murayama & Kuhbandner, 2011; Swirsky et al., 2021), participants have been rewarded for correctly guessing the answers to questions, or when curiosity is elicited. Duan et al. (2020) showed participants the reward associated with each item when the question appeared, but did not inform participants which of the items would actually be rewarded. Halamish et al. (2019) presented the reward information when learning the answers to trivia questions, as those were what was being rewarded. Thus, it was unclear whether the timing of the presentation of value – whether presented when curiosity was elicited or when curiosity was satisfied – would lead to different results. We manipulated the timing of reward presentation in Experiment 2 and found that this manipulation did not affect the relationship between curiosity and memory at a week-long delay. However, after a shorter delay of two days, the manipulation influenced the relationship between curiosity and recall for older adults, wherein presenting the value with the answer reduced the positive influence of curiosity on recall.

There are a few potential explanations for this finding. Older adults may have been focused on the value of the items, and presenting the value when learning the answer could have reduced their focus on the answers, thereby reducing the effects of curiosity. However, older adults' memory for the value was not influenced by the timing of presentation of value, showing that if older adults were strategically focused on the value instead of the answer, it did not improve their value memory. It is also possible that viewing the value while in a state of curiosity *enhanced* the influence of curiosity on memory, as curiosity was not a significant predictor of memory for older adults at the long delay test. Future work may address these possibilities more directly. Regardless, any influence that the timing of value presentation seemed to have on memory did not last through the long delay test.

Third, we examine not only item memory but also associative memory – or memory for the value itself. Interestingly, we found across both experiments an interesting relationship between value and curiosity on memory for the value. In Experiment 1, we found that curiosity was a negative predictor of memory for the value of items, but only for low value items – and this was most pronounced at the longer delay. In Experiment 2, we found a similar pattern: curiosity was a negative predictor of memory for low value items, but a positive predictor for high value items, but this did not significantly differ by retention interval. Thus, it seemed as if low value items actually reduced the effect of curiosity on memory for associative information. Some work has suggested that curiosity can improve memory for both target and irrelevant information (e.g., Gruber et al., 2014; Gruber & Ranganath, 2019), but this finding suggests curiosity may only improve memory for associated information if it is also important, indicating there may need to be some other motivating factor. Interestingly, recent work has shown that people's memory for value information may not be based on reliable cues (Filiz & Dobbins, 2024), suggesting that there may be other factors at work when examining memory for value.

The present research also examined confidence and global JOLs and found that older adults were generally overconfident, rating their confidence higher than that of younger adults in both local judgments (confidence) and global judgments. It is worth noting that there were no overall age differences in memory for the answers in either experiment, and this replicates prior work (Galli et al., 2018; McGillivray et al., 2015). Age differences in confidence ratings were also influenced by retention interval, such that older adults were more sensitive to value at the shorter delay, whereas this difference emerged for younger adults at the longer delay. Thus, it is possible that retention interval can influence the accuracy of metacognitive judgments differentially across age groups.

It is important to note some limitations and future directions to this work. First, because there were many variables of interest in the present experiments, the models we ran were fairly complex. Of course, there is always a balance between accounting for more variables in a design and simplicity, but future work may isolate some variables of most interest to examine these factors in more detail. Additionally, while we chose to reward all items but vary the amount of reward across items, it is possible that different effects would have emerged if only some items were rewarded or if the reward schedule was different (e.g., 75% low value, 25% high value). Lastly, as a metacognitive judgment, we collected participants' confidence ratings, but these are made after recall, leading them to be typically more accurate than predictions made at study. Thus, it could be informative for future research to compare participants' metacognitive predictions at the item level to their global judgments, as well as compare metacognitive judgments made at different times (e.g., study vs. test).

Chapter 3 Conclusions

Although it is established that greater curiosity can predict improved memory performance in both younger and older adults (Fastrich et al., 2018; Galli et al., 2018; Kang et al., 2009; McGillivray et al., 2015), it is less established whether curiosity may interact with external reward or value (Halamish et al., 2019; Murayama & Kuhbandner, 2011; Swirsky et al., 2021). Chapter 3, examined how external memory motivators, such as point value, and intrinsic memory motivators, like curiosity, may interact to influence intentional learning and memory. The results showed that the influence of curiosity on long-term memory performance does not seem to decrease with increases in external value information under intentional learning conditions. These findings suggest that participants are able to use curiosity to bolster memory performance over long retention intervals, even in the face of competing external value information.

However, Chapter 3 also revealed that curiosity and value may interact in interesting ways to affect associative gist memory (i.e., memory for the value itself). This result suggests that value and curiosity together may, in some cases, reduce memory for associative information, as it is possible that both value and curiosity increase the focus on items, and possibly away from associated information. Overall, both intrinsic motivation and extrinsic rewards work to improve item memory.

Table 3.1

Average Proportion Correct for Recall and Categorical Value Memory in Experiment 1

		Recall	Value Category
Two-Day Delay Test	Younger Adults	.58 (0.49)	.35 (0.48)
	Older Adults	.56 (0.50)	.36 (0.48)
Seven-Day Delay Test	Younger Adults	.43 (0.50)	.38 (0.49)
	Older Adults	.41 (0.49)	.36 (0.48)

Note. Means are shown in the cells, with standard deviation in parentheses. All means are collapsed across point value and curiosity ratings.

Table 3.2

Average Proportion Correct for Recall and Value Memory in Experiment 2

		Recall		Value Category	
		Younger Adults	Older Adults	Younger Adults	Older Adults
		Two-Day Delay Test			
Low Value	Paired with Question	.57 (0.50)	.57 (0.50)	.52 (0.50)	.49 (0.50)
	Paired with Answer	.60 (0.49)	.56 (0.50)	.55 (0.50)	.54 (0.50)
High Value	Paired with Question	.59 (0.49)	.59 (0.49)	.49 (0.50)	.57 (0.50)
	Paired with Answer	.61 (0.49)	.63 (0.48)	.47 (0.50)	.52 (0.50)
		Seven-Day Delay Test			
Low Value	Paired with Question	.37 (0.48)	.45 (0.50)	.53 (0.50)	.49 (0.50)
	Paired with Answer	.46 (0.50)	.44 (0.50)	.56 (0.50)	.58 (0.49)
High Value	Paired with Question	.41 (0.50)	.47 (0.49)	.48 (0.50)	.55 (0.50)
	Paired with Answer	.49 (0.50)	.44 (0.48)	.49 (0.50)	.52 (0.50)

Note. Means are shown in the cells, with standard deviation in parentheses. All means are collapsed across curiosity ratings.

CHAPTER 4:

CURIOSITY AND MEMORY FOR TRUE AND FALSE INFORMATION

We often encounter information in our everyday lives that may not be true, whether shared on social media or via word of mouth. The dawn of the internet and social media in the past few decades has changed the way we learn and share information in everyday life. Misinformation or inaccurate information (often, but not always, political in nature) has become a problem for maintaining trust in government and science and has contributed to a political divide in the U.S. (Lewandowsky et al., 2017). Additionally, monitoring truth of information that is shared online is becoming more difficult with the advancement of technology such as bots and deepfakes (Anderson & Rainie, 2017; Sample, 2020) and as we enter into an “infodemic,” where we are faced with overwhelming amounts of information intended to mislead us (Pehlivanoglu et al., 2022).

Misinformation is not only a problem because it is believed, but also because it is often shared. Research even shows that people are willing to share news headlines on social media without actually reading the article or knowing what it is about (Gabielkov et al., 2016). Unfortunately, older adults are more likely than younger adults to share misinformation online (Guess et al., 2019), and the oldest old adults may struggle the most with separating true from false information (Pehlivanoglu et al., 2022), suggesting older adults may be an especially vulnerable group to misinformation (Brashier, 2024). Although information can be fact checked or verified, we may still struggle to forget inaccurate information or misremember it as true. In lab settings, when false information (like news headlines) is presented and labeled as false, older adults are more likely than younger adults to later incorrectly remember it as true (Brashier & Schacter, 2020). This error has been attributed to deficits in source memory, or the binding of the source information to the information itself (Mitchell & Johnson, 2009). Older adults have demonstrated deficits when binding two or more pieces of information in memory but can often remember items as well as younger adults (Naveh-Benjamin, 2000; Schacter et al., 1991). Thus, in the case of corrected misinformation, the binding of the misinformation to the false label may be lost, but the misinformation itself may feel familiar, leading older adults to endorse a false statement as true (see Brashier & Schacter, 2020). However, some work has found that older adults can remember some types of gist-based source memory relating to truth (Rahhal et al., 2002), so it is possible that source deficits may be reduced in the presence of truth information.

News is a topic that many people may be interested in and somewhat knowledgeable about. Therefore, curiosity may play a role in how people interact with, learn about, and share news in real-life settings. As discussed in Chapter 1 of this dissertation, curiosity has been shown to lead to better memory for both target and irrelevant information in younger and older adults (Galli et al., 2018; Gruber et al., 2014), which suggests that curiosity may lead to a sort of expanding or spreading of attention to capture more information during that state (Gruber & Ranganath, 2019). This widening of attentional resources while in states of curiosity could be especially beneficial for older adults' source and associative memory deficits. In other work, variables like schematic support and value have shown to reduce effortful processing during learning (Knowlton & Castel, 2022; Whatley & Castel, 2022) and improve memory performance, especially in older adults. Thus, if curiosity works by reducing effort and making encoding happen more automatically, we may expect age-related source deficits to be reduced during states of curiosity.

There is also work that shows curiosity may benefit recognition accuracy in addition to recall. Recently, a study had younger and older adults learn trivia facts and then take a surprise test one day later (Swirsky & Spaniol, 2023). However, rather than the typical cued recall test that asks participants to report the answer to each question, they completed a recognition test wherein they were shown either the answer they studied or a new answer they had not studied and were asked whether each was the correct answer. They found greater false alarm rates for older adults when the false answers were semantically related to correct answers compared to when they were unrelated, but this effect was reduced for higher curiosity items. This work suggests that curiosity may improve older adults' recognition accuracy, helping them overcome typical age-related associative deficits.

The Current Study

Chapter 4 examines the influence of curiosity on younger and older adults' recall for true and false trivia question-answer pairs, as well as their memory for the truth of the items. In two experiments, participants were presented with trivia questions, rated their curiosity to learn the answer, and then were shown either a true or false answer. In Experiment 3A, the truth of each answer was presented when participants learned the answer, while in Experiment 4, the truth was withheld until after participants had learned the answer. In another experiment (Experiment 3B), we assessed the validity of the items, as well as whether participants' perceptions of truth relate to memory.

When examining the relationship between curiosity and memory for true and false information, there are competing hypotheses regarding younger and older adults' item and source memory performance. One possibility is that being curious about some information could make the information itself more salient or valuable, as suggested by prior research (Kang et al., 2009; Murayama et al., 2019), and this increased salience toward the item may reduce attention towards the associative information or source. In other words, participants may learn the answers to trivia questions more accurately when curious but may be less likely to remember the truth. This could lead to greater likelihood of endorsing false information as true, particularly for older adults compared to younger adults, who already show a source deficit (Mitchell & Johnson, 2009; Schacter et al., 1991). On the other hand, because curiosity has been shown to improve memory for task-irrelevant or incidental information, greater curiosity about some information could heighten attention more broadly during that state (Gruber et al., 2014; Gruber & Ranganath, 2019), leading to better source monitoring. If older adults also experience this attention widening (Galli et al., 2018), then their source memory may be particularly improved. Thus, curiosity may improve the ability to correctly distinguish between true and false information in memory. Understanding how curiosity influences memory for true and false information can help to elucidate either a potential mechanism for greater belief in or sharing of misinformation or a potential way to reduce belief in misinformation.

Experiment 3A

In Experiment 3A, we examined younger and older adults' memory for true and false information, as well as how curiosity may differentially relate to memory for true and false information. Participants studied trivia questions and provided curiosity ratings, but were shown answers that were either true or false. They were then asked to recall the answer they had studied, as well as whether it was true or false after one week, and memory for both of these measures of memory were assessed.

Method

Participants. Participants were 72 UCLA undergraduate students participating for partial fulfillment of course requirements (aged 18-30 years; *M* = 20.69, *SD* = 2.04). Seventy older adult participants (aged 60-78 years; *M* = 68.99, *SD* = 3.98) were recruited from Prolific and paid $10 per hour of their time. Five participants were excluded for being younger than 18 or between the ages of 30 and 60, and one participant was excluded for completing the test portion of the task well past the one-week point. We also planned to exclude participants for reporting that they looked up the answers to most or all of the questions and for reporting multi-tasking (e.g., listening to music, watching TV) during the task, but these criteria resulted in no exclusions.

Stimuli. Trivia questions were taken from the database created by Fastrich et al. (2018). Sixty trivia questions were selected that had a normed curiosity average rating of 6.76 out of 10 (*SD* = 0.33). False answers were generated that were similar to true answers. For example, for the question, "What ingredient is added to white sugar to make brown sugar?" the correct answer is "molasses," and the false answer was "maple syrup." See Table 4.1 for a full list of true and false answers. A random half of the items were presented as true and half as false, with these counterbalanced across participants.

Procedure. All procedures were approved by the UCLA IRB. After providing demographic information and informed consent, participants were instructed that they would be studying trivia questions and that they would need to remember the answers for a test one week later. They were told that some answers would be true and others would be false, and that they would need to remember whether each answer was true or false. Trivia questions were presented one at a time on a blank white screen for 15 s each, along with a textbox for participants to enter a guess. If they did not enter an answer within 15 s, the trial automatically advanced. Participants could not submit a guess until at least 2 s had passed to prevent participants from simply clicking through the task. Participants then rated their curiosity to learn the answer on a scale of 1 (*not at all curious*) to 10 (*extremely curious*) and then their confidence that they knew the correct answer from 1 (*not at all confident*) to 10 (*extremely confident*). Next, the answer was presented on the screen with a true or false label (i.e., "True Answer:" or "False Answer:") for 6 s. Figure 4.1 shows the procedure. This process repeated for all 60 questions, presented in a random order for each participant, and then participants reported whether they looked up the answers to any questions, were doing anything else while the study was going on, and whether they experienced issues with the task or their internet.

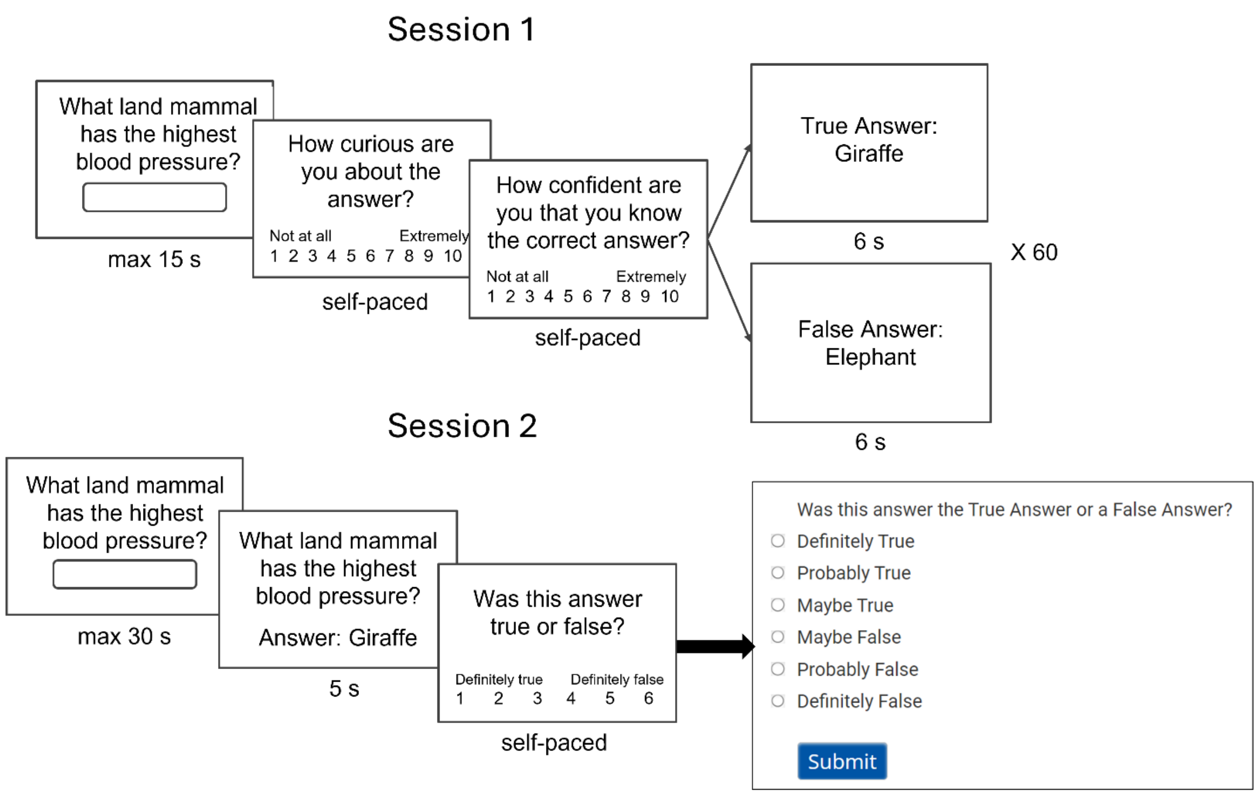

Figure 4.1. The trivia learning procedure for Experiment 3A. The top panel shows the procedure for the study phase, while the bottom panel shows the procedure for the test phase one week later. At the study phase, participants either saw the true answer or the false answer for a given question (not both). The right-most box in the bottom panel shows a zoomed in view of the true or false memory question.

The test phase of the task was completed, on average, 6.96 days (*SD* = 1.24 days) after the study phase. Participants were presented with each trivia question for 30 s and asked to enter the answer to prevent participants from being able to look up the answers. Then, participants were shown the answer they had studied without a true or false label for 6 s, after which they were asked to report whether that answer was true or false along with their confidence in their answer on a scale from 1 (*definitely true*) to 6 (*definitely false*), with values of 1-3 indicating true and 4-6 indicating false. This process repeated for all 60 questions, and then participants reported whether they looked up the answers to any questions, were doing anything else during the task, or experienced computer issues.

Results

Analysis Plan. In all experiments reported here, we conducted mixed effects models to examine memory performance and metamemory judgments. Similar to our approach in Chapter 3, these models allowed us to treat the data as nested within individuals and items to separate the within-person from the between-person (as well as within- vs. between-item) variance. In all mixed effects models, curiosity ratings were centered around each participant's average curiosity rating (cluster based centered) to account for differences in curiosity and use of Likert scales across participants, and to isolate item-level effects from person-level effects.

Also as in Chapter 3, all categorical predictors are coded using simple effect coding, wherein all levels are compared to a reference level. This allows the interpretation of categorical predictors and interactions to be more similar to that of ANOVA, as it holds the categorical variables at their mean (rather than the reference level) when examining the effects of other variables in the model. In subsequent analyses, age is coded such that younger adults are the reference level (i.e., -0.5 = younger adults, 0.5 = older adults), and truth of the answer is coded with true items as the reference level.

We again use logistic models for binary predictors, such as memory where the outcome (at the item level) is correct (1) or incorrect (0), whereas we use linear models for continuous predictors (e.g., metamemory). We report the results of logistic models as odds ratios (*OR*), where a value of 1 indicates the odds of being correct is the same as being incorrect (e.g., a null effect), values greater than 1 indicate a positive relationship, and values less than 1 indicate a negative relationship. For linear models, we report the results using the unstandardized estimate (*b*).

For all analyses, we removed items that participants correctly guessed the answers to during the study phase. Because these items do not reflect new learning, they are qualitatively different from items participants did not know the answers to. In addition, if participants already knew the true answer to a question, then participants may still report the true answer at test, even if they were shown a false answer to encode, thus confounding memory effects.

Recall. Figure 4.2 shows the relationship between curiosity and probability of correct recall for true and false answers for younger and older adults. To examine recall accuracy, we conducted a mixed effects logistic regression model predicting item-level accuracy as a function of curiosity rating, truth of the answer, age group, and the interaction of these variables. Both participant identifier and trivia question were entered as random intercept effects to allow for the data to be clustered within participants and for each trivia question.

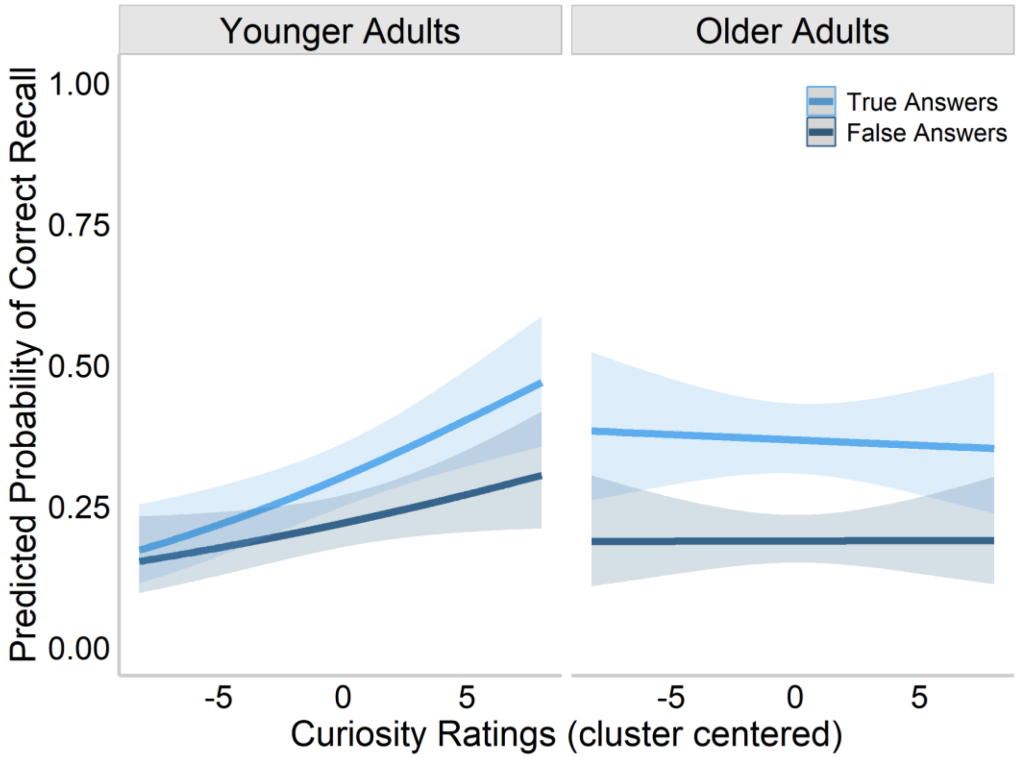

Figure 4.2. Predicted probability of correct recall plotted as a function of curiosity, truth of the answers, and age group in Experiment 3A. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

The analysis revealed that curiosity was a positive predictor of recall accuracy (*OR* = 1.03, *SE* = 0.02, 95% CI: 1.01 – 1.07, z = 2.22, p = .03), and that true answers were better recalled overall than false answers (*OR* = 0.51, *SE* = 0.06, 95% CI: 0.46 – 0.57, z = 11.72, p < .001). The effect of age group was not significant (*OR* = 1.04, *SE* = 0.13, 95% CI: 0.80 – 1.34, z = 0.29, p = .78). There was, however, a significant interaction between age group and curiosity (*OR* = 0.93, *SE* = 0.03, 95% CI: 0.87 – 0.98, z = 2.54, p = .01), such that for younger adults, higher curiosity significantly predicted more accurate recall (*OR* = 1.07, *SE* = 0.02, 95% CI: 1.04 – 1.11, z = 3.87, p < .001), but for older adults it did not (*OR* = 1.00, *SE* = 0.02, 95% CI: 0.95 – 1.04, z = 0.17, p = .87).

Additionally, the interaction between age group and truth of the answer was significant (*OR* = 0.62, *SE* = 0.11, 95% CI: 0.49 – 0.77, $z = 4.23$, $p < .001$). Bonferroni-corrected post hoc tests revealed that true answers were better recalled than false answers for both younger adults (*OR* = 1.54, *SE* = 0.12, $z = 5.52$, $p < .001$) and for older adults (*OR* = 2.49, *SE* = 0.21, $z = 10.93$, $p < .001$), but that this difference was larger for older adults. Neither the interaction between curiosity and truth of the answer (*OR* = 0.99, *SE* = 0.03, 95% CI: 0.93 – 1.05, $z = 0.45$, $p = .66$) nor the three-way interaction (*OR* = 1.04, *SE* = 0.06, 95% CI: 0.93 – 1.17, $z = 0.69$, $p = .49$) were significant.

Source Accuracy. Next, we examined the accuracy of source judgments, or correctly categorizing an answer as true or false, which is shown in Figure 4.3. We again conducted a mixed effects logistic regression model with items clustered within individuals, predicting source accuracy as a function of curiosity rating, whether the answer was true or false, age group, and the interaction of these variables. The results revealed no significant effect of curiosity on source accuracy (*OR* = 1.02, *SE* = 0.02, 95% CI: 0.99 – 1.05, $z = 1.31$, $p = .19$), and curiosity did not interact with age (*OR* = 0.98, *SE* = 0.03, 95% CI: 0.92 – 1.04, $z = 0.79$, $p = .43$), or truth of the answer (*OR* = 0.97, *SE* = 0.03, 95% CI: 0.91 – 1.03, $z = 1.12$, $p = .44$).

The effect of age group was also not significant (*OR* = 0.84, *SE* = 0.14, 95% CI: 0.65 – 1.11, $z = 1.26$, $p = .21$), but there was an overall difference in accuracy for true and false answers, such that true answers were more accurately categorized than false answers (*OR* = 0.13, *SE* = 0.06, 95% CI: 0.12 – 0.15, $z = 33.27$, $p < .001$). However, these effects were qualified by an interaction between age group and truth of the answer (*OR* = 0.25, *SE* = 0.12, 95% CI: 0.20 – 0.31, $z = 11.57$, $p < .001$). Bonferroni-corrected post hoc tests revealed that true answers were better recognized as true for both younger adults (*OR* = 3.81, *SE* = 0.29, $z = 17.33$, $p < .001$) and for older adults (*OR* = 15.34, *SE* = 1.43, *z* = 29.20, $p < .001$), but this difference was larger for older adults. The three-way interaction (*OR* = 1.05, *SE* = 0.06, 95% CI: 0.93 – 1.19, *z* = 0.78, *p* = .44) was not significant.

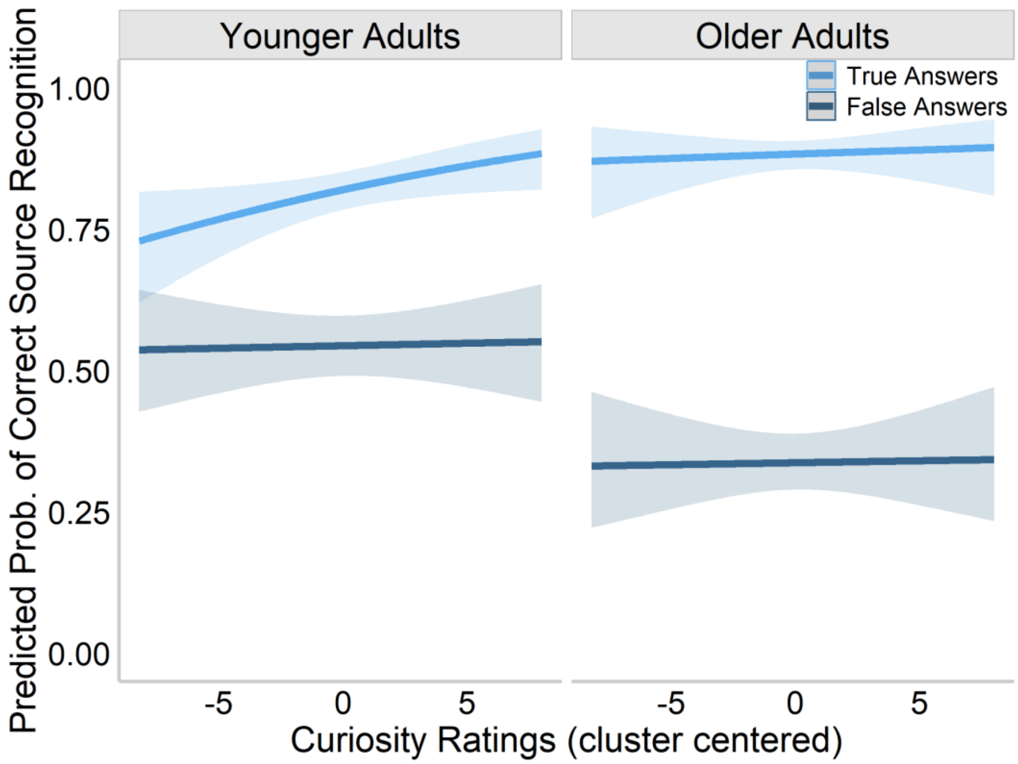

Figure 4.3. Predicted probability of correct source recognition plotted as a function of curiosity truth of the items, and age group in Experiment 3A. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

Source Confidence. We then examined participants' confidence in their source judgments. We calculated source accuracy by recoding any response with a "maybe" as a 1, any response with a "probably" as a 2, and any response with a "definitely" as a 3, regardless of accuracy. We then ran a mixed effects linear regression with source confidence as a function of curiosity ratings, truth of the answer, age group, and the interaction between these variables. The model revealed a significant effect of curiosity, such that higher curiosity was associated with greater confidence in source judgments, *b* = 0.01, *SE* = 0.004, *t*(7155) = 2.55, *p* = .01. True answers were also given higher confidence ratings than false answers, *b* = -0.16, *SE* = 0.016, *t*(7105) = 9.93, *p* < .001, but age group did not significantly predict confidence ratings, *b* = 0.07, *SE* = 0.059, *t*(139) = 1.11, *p* = .27. There was, however, a significant interaction between age and curiosity ratings, *b* = -0.02, *SE* = 0.009, *t*(7128) = 2.31, *p* = .02, such that for younger adults, curiosity was a significant predictor of confidence in one's source memory, *b* = 0.02, *SE* = 0.005, *t*(7156) = 3.92, *p* < .001, whereas for older adults it was not, *b* = 0.001, *SE* = 0.007, *t*(7148) = 0.18, *p* = .86.

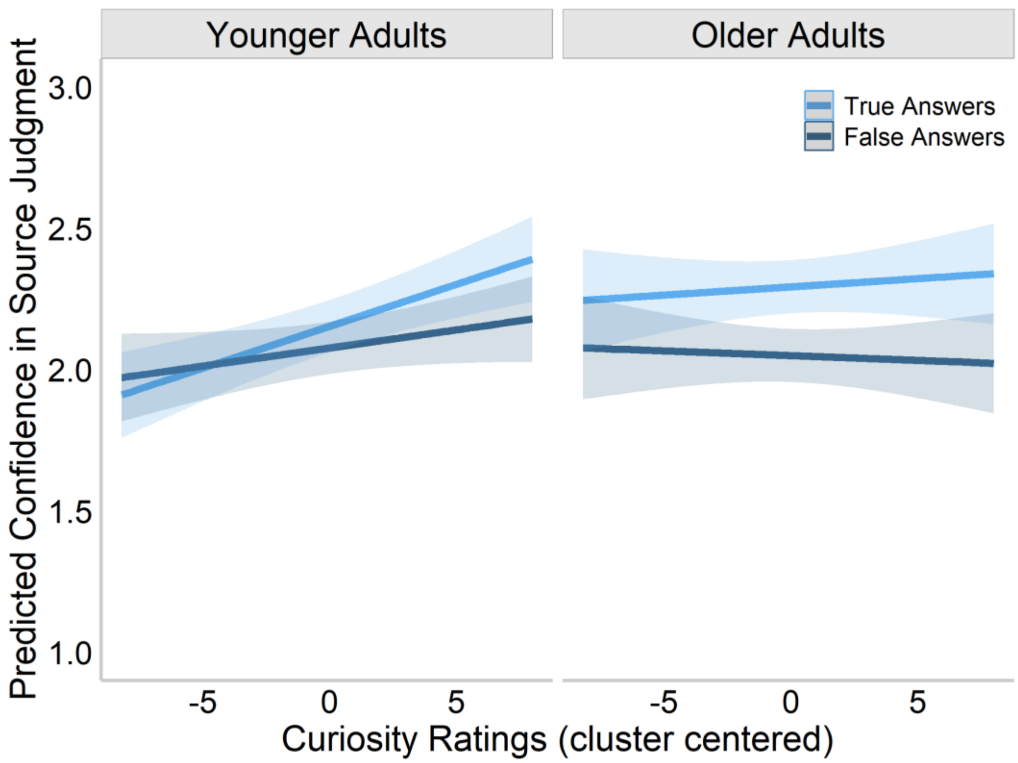

Figure 4.4. Predicted confidence in source responses plotted as a function of curiosity ratings, truth of the items, and age group in Experiment 3A. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

There was also a significant interaction between age group and truth of the answer, b = 0.17, SE = 0.032, t(7105) = 5.20, p < .001. Bonferroni-corrected post hoc tests showed that confidence was higher for true than false answers for both younger adults, b = 0.08, SE = 0.02, t(7102) = 3.45, p = .003, and older adults, b = 0.25, SE = 0.024, t(7109) = 10.39, p < .001, but this difference was larger in older adults. Neither the interaction between curiosity and truth of the answers, b = -0.01, SE = 0.009, t(7137) = 1.50, p = .13, nor the three-way interaction, b = 0.01, SE = 0.017, t(7141) = 0.44, p = .66, were significant.

Discussion

In Experiment 3A, we found that curiosity did significantly predict memory for trivia answers, but only for younger adults and not for older adults. This finding was somewhat surprising given that curiosity has consistently been shown to improve memory for both age groups in prior work (Galli et al., 2018; McGillivray et al., 2015). However, older adults showed a stronger effect of truth on their memory than younger adults. Together, these findings suggest truth may have been a more salient memory cue than curiosity in the present experiment – particularly for older adults.

We also found that curiosity did not influence the accuracy of younger or older adults' source memory (i.e., whether the items were true or false). Instead, both age groups' source memory was much more accurate for true answers than false answers. However, this difference in accuracy was likely driven by a response bias to respond true more often than false (younger adults: 69.72%, older adults: 76%). This response bias supports prior work that shows that when participants are unsure, they are more likely to default to a response of true in a memory test (Nadarevic & Erdfelder, 2013), and further provides evidence that older adults also show this truth bias, even to a greater extent. Interestingly, confidence in source responses was influenced by initial curiosity to learn the answer, but only for younger adults. Both age groups did seem to be aware that their memory was more accurate for true than false items.

Taken together, these results suggest that curiosity may not support greater memory for older adults in the presence of truth information. This could be because true information is deemed more memorable, especially by older adults, and thus overrides the effects of curiosity. However, it is also possible that true answers were simply easier to remember because the false answers that were created for this study were not believable. Therefore, in Experiment 3B, we explored this possibility to validate the materials in terms of believability and memory, and to explore how participants' perceptions of truth may affect their memory after a delay.

Experiment 3B

Given the limitations of Experiment 3A, Experiment 3B was designed to assess whether the false answers were deemed to be believable by a separate group of participants, as well as whether participants' curiosity ratings influenced their perceptions of truth. We were also interested in whether perceptions of truth could influence memory without knowing whether the answers were true or false.

Method

Participants. Participants were 110 UCLA undergraduate students (aged 18-43, M = 20.54, SD = 3.29) participating for partial fulfillment of course requirements.

Stimuli and Procedure. The stimuli were the same as those used in Experiment 3A. The procedure was similar to that of Experiment 3A, in that participants were told they would be studying trivia questions and answers and would need to remember them for a later test, and that some of the answers would be true and some would be false. Each trivia question was presented in the center of a blank screen with a textbox below for participants to enter a guess. Once participants submitted their guess, or 15 s had passed, participants provided a curiosity rating and a confidence rating, each on a 1 (*not at all*) to 10 (*very*) Likert scale. Next, participants saw the trivia question again with the answer below. However, unlike in Experiment 3A, there was no indication of whether the answer was true or false. After the answer was shown for 6 s, participants were shown a multiple-choice question asking whether they thought the answer presented was true or false. Once they had made their guess, the task proceeded to the next question, and this process repeated for all 60 questions.

Approximately one week later (M = 6.81 days, SD = 0.66), participants were shown each question again with a textbox below for them to enter the answer they had studied. They then rated their confidence in their memory for each question, and this process repeated for all 60 questions. Finally, participants answered the same questions as in Experiment 3A about whether they were distracted, looked up questions, or had issues with the task.

Results

Truth Ratings. Overall, participants rated 67.05% of the answers as true, which was significantly more than 50%, $X^2(1) = 688.10$, $p < .001$. However, participants were 50.47% accurate at identifying which answers were true and which were false, which was not significantly different from 50%, or chance, $X^2(1) = 0.53$, $p = .47$. Thus, participants tended to guess most answers were true, but were at chance at guessing the truth of the answers. The proportion of items guessed as true and false as a function of their actual truth is shown in Figure 4.5.

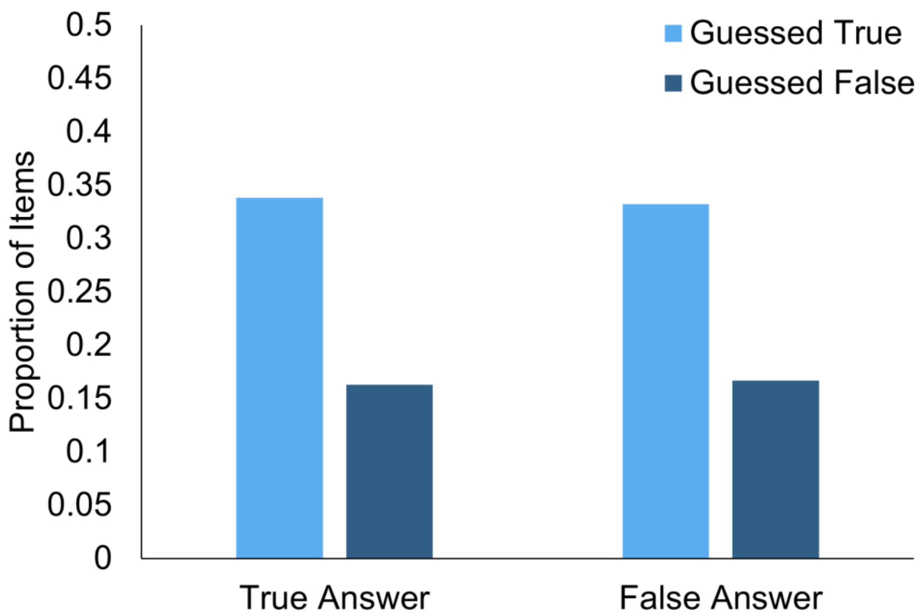

Figure 4.5. Proportion out of the total 60 items guessed to be true as a function of their actual truth in Experiment 3B. Actual truth is shown on the X-axis, and participants' guesses are represented in the legend.

We also examined whether curiosity was related to participants' guesses about the truth. To examine this, we conducted a mixed effects logistic regression model with likelihood of guessing the answer to be false (1=guessed false, 0=guessed true) modeled as a function of curiosity (cluster centered), the actual truth of the answers, and the interaction of these two variables. The model revealed no significant effect of curiosity (*OR* = 1.00, *SE* = 0.02, 95% CI: 0.97 – 1.03, $z = 0.22$, $p = .83$), and no significant effect of truth of the answers (*OR* = 1.04, *SE* = 0.06, 95% CI: 0.92 – 1.16, $z = 0.58$, $p = .56$). Additionally, there was no significant interaction (*OR* = 1.04, *SE* = 0.03, 95% CI: 0.98 – 1.10, $z = 1.20$, $p = .23$). In other words, being more curious did not lead to participants being more likely to guess the answer was true or false, and truth guesses did not vary depending on actual truth of the answers. These results are shown in Figure 4.6.

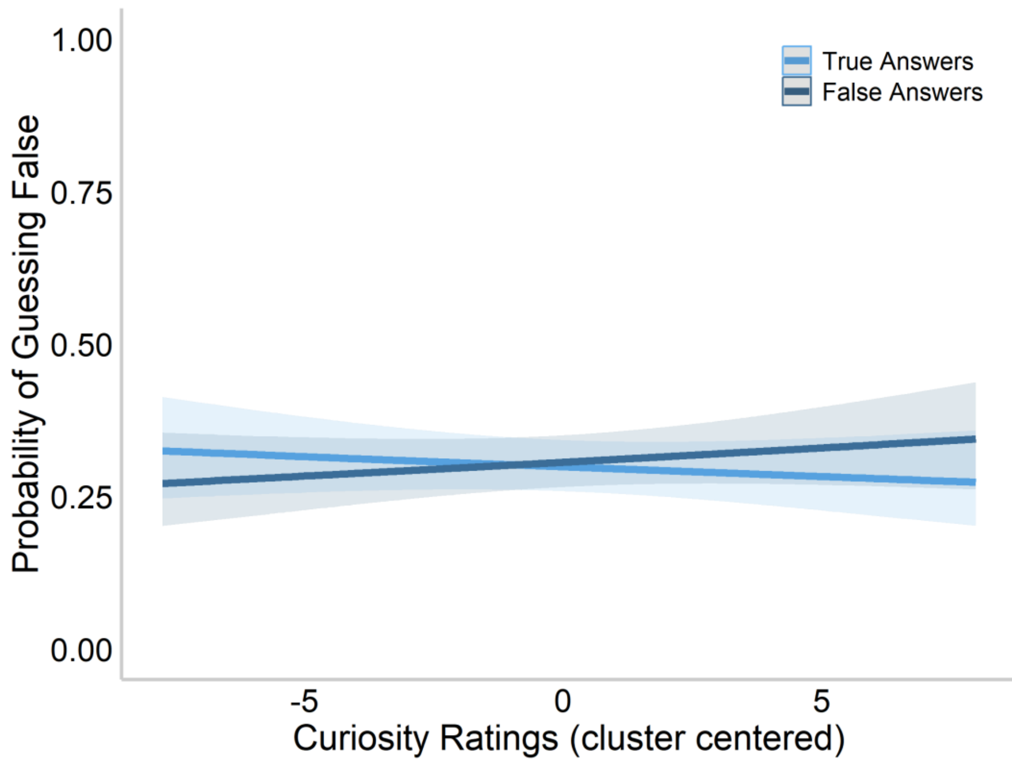

Figure 4.6. Predicted probability of guessing the answer to be false (1=false guess, 0=true guess) as a function of curiosity ratings and actual truth of the answer in Experiment 3B. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

Recall. We next examined participants' recall accuracy using a logistic mixed effects model as a function of curiosity ratings (cluster centered), participants' truth guess (simple effect coded; anchored on true), and actual truth of the answers, as well as the interactions between these variables. The analysis showed a significant effect of curiosity (*OR* = 1.04, *SE* = 0.02, 95% CI: 1.01 – 1.08, $z = 2.42$, $p = .02$), such that higher curiosity was associated with greater likelihood of correct recall. Participants also better recalled the answers to items they thought were true than those they thought were false (*OR* = 0.48, *SE* = 0.07, 95% CI: 0.42 – 0.55, *z* = 10.22, *p* < .001). However, participants' recall was more accurate when the answer was actually false than when it was true (*OR* = 1.54, *SE* = 0.07, 95% CI: 1.35 – 1.76, *z* = 6.36, *p* < .001). There were no significant interactions in the model (all *p*s > .12). Together, these results suggest that believing something to be true can improve memory, but that false answers were also more memorable than true answers.

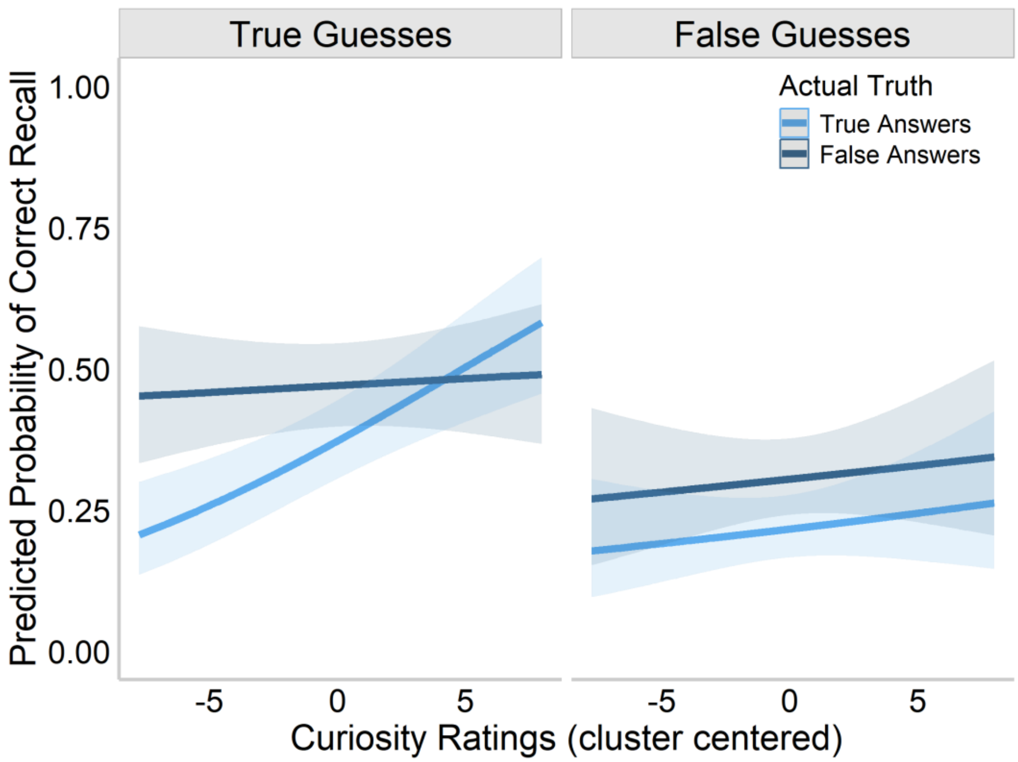

Figure 4.7. Predicted probability of correct recall of trivia answers plotted as a function of curiosity ratings, participants' truth guesses, and actual truth in Experiment 3B. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

Discussion

In Experiment 3B, we found that younger adult participants were not able to guess above chance which items were true and which were false, but that they defaulted to guess that approximately two thirds of items were true. This result is supported by a vast literature on the truth bias (Dechêne et al., 2010; Levine et al., 1999; Nadarevic & Erdfelder, 2013; Pantazi et al., 2018), suggesting that without additional contextual information, people tend to think information to be true by default. Indeed, much of the information we encounter in daily life is true, so this bias is adaptive in most cases. Importantly, this experiment validated that our stimuli were believable, with false answers guessed as true at similar rates as true answers.

In terms of recall performance, we found that participants' recall was positively predicted by curiosity ratings. Participants also better remembered items that they believed to be true than those they believed to be false. However, answers that were actually false were better remembered than answers that were true. This suggests that the false answers created for this study were not less memorable, but actually *more* memorable. However, participants' beliefs about truth likely overrode this difference. Thus, participants' improved memory toward true information likely was not influenced by the stimuli themselves, but by knowledge of truth.

General Discussion for Experiments 3A and 3B

The results from Experiments 3A and 3B reveal that the presence of truth information may override the influence of curiosity on recall for older adults. Experiment 3A showed that participants' recall accuracy was influenced by how curious they were about the information, but that this was only true for younger adults. Older adults' memory, on the other hand, was influenced largely by the truth of the information they learned. Experiment 3B further revealed that false answers were actually more memorable than true answers, but that younger adult participants' memory was improved by believing answers to be true. Thus, it is likely that the stimuli did not differentially affect older adults' memory or the effects of curiosity, but rather seeing that information was true influenced older adults' memory.

We also found in Experiment 3B that guesses about whether the answer was true or false did not seem to be influenced by curiosity. One possibility was that participants may be more likely to think something is true if they are more curious about it. However, participants' truth ratings did not seem to be influenced by their curiosity. Instead, truth ratings seemed to be highly biased (i.e., a 2:1 ratio) toward true responses. This result is not particularly surprising given research about a truth bias (Dechêne et al., 2010; Gilbert et al., 1990; Levine et al., 1999). The truth bias describes people's tendencies to believe new information unless told otherwise. Thus, when there is ambiguity about whether information being presented is true, participants may default to believing it is true over false (Nadarevic & Erdfelder, 2013).

Given that in Experiment 3A, neither older adults' item or source memory was influenced by curiosity, but was influenced strongly by truth of information, they may have been strategically focusing on true information over false information, as it may have been more meaningful. This could have led them to ignore or not attempt to encode false answers. However, if they do not learn the truth of the answers until after they have encoded them, it is possible curiosity will show a different relationship with memory. Thus, we showed the true and false label after encoding the answers to trivia questions in Experiment 4.

Experiment 4

Experiment 4 assessed whether curiosity to learn trivia and truth of the trivia answers affected younger and older adults' item and source memory when the truth label was not presented until after participants had encoded the answers. First, this design removes the possibility that participants actively ignore or fail to encode the answers to trivia questions. Secondly, in everyday settings, true and false labels may not always be present when we initially learn information, so understanding how curiosity may affect memory when the true/false label comes after the information is useful for applying this knowledge to more realistic settings.

Method

Participants. After exclusions, participants were 83 younger adults (aged 19-30, M = 24.76, SD = 3.20) and 84 older adults (aged 62-85 years, M = 68.60, SD = 3.90) recruited from Prolific and compensated $10 per hour of their time. Participants were excluded if they did not pass bot checks (n = 0), reported looking up the answers to trivia questions (n = 3), or failed attention checks (n = 3). Two participants were also excluded for reporting their age as between 30 and 60 years.

Stimuli and Procedure. Stimuli were the same as those used in Experiments 3A and 3B. Sixty trivia questions were taken from the database created from Fastrich et al. (2018). All questions had a pre-knowledge rate of 20% or less to prevent too much data loss during analysis (as items that participants correctly guess at study were removed from all analyses). The procedure was the same as that used in Experiment 3A with one main difference: instead of learning the truth of each answer along with the answer, the truth label was presented after the answer. During learning, participants were shown each trivia question and entered a guess (max 15 s), then rated their curiosity and confidence. Next, the answer to the trivia question on the screen for 6 s. After the answer disappeared, they were shown whether the answer was true or false for 3 s, with a page that said, “This answer is: TRUE” or “This answer is: FALSE.” This process repeated for all 60 items. Then, participants answered general questions about whether they were doing anything during the task, whether they looked up the answers to any questions, and whether they experienced any issues with the task or their internet.

Also different from Experiment 3A, in addition to the 60 questions, there were four items used as attention checks. After each attention check item was presented, participants were asked, "was the previous answer true or false?" These items were dispersed evenly throughout the task, and participants were excluded if they responded incorrectly to 3 or more of the items.

Approximately one week later, participants' memory was tested for both the answers to the trivia questions they studied, as well as the true or false label associated with each answer. The test took place on average 6.91 days after learning (*SD* = 0.35). This process was the same as that of Experiment 3A, except that participants had 60 s rather than 30 s to enter their response. The goal was to limit their response time in order to prevent them from looking up the answers, but to allow enough time to recall and type their responses. Once participants completed this process for all 60 questions, they answered some final questions about the task, whether they looked up answers or were distracted, and whether they experienced any problems with the task or their internet.

Results

Recall. Recall performance as a function of age, curiosity, and truth is presented in Figure 4.8. To assess participants' memory accuracy for the answers to the trivia questions, we conducted a mixed effects logistic regression analysis predicting recall accuracy as a function of curiosity (cluster centered), age group, whether the item was true or false, and the interaction of these variables. The model revealed that curiosity was a significant positive predictor of recall accuracy overall (*OR* = 1.03, *SE* = 0.01, 95% CI: 1.00 – 1.06, $z = 2.13$, $p = .03$). There was also a significant effect of truth of the item, such that true answers were better recalled than false answers (*OR* = 0.83, *SE* = 0.05, 95% CI: 0.75 – 0.92, *z* = 3.65, *p* < .001). Age was not a significant predictor of recall (*OR* = 0.92, *SE* = 0.13, 95% CI: 0.71 – 1.18, *z* = 0.68, *p* = .50). However, these effects were qualified by an interaction between age and truth of the answer, (*OR* = 0.76, *SE* = 0.10, 95% CI: 0.62 – 0.92, *z* = 2.75, *p* = .006). Bonferroni-corrected post hoc tests revealed that for younger adults, there was no significant difference in recall accuracy for true and false answers (*OR* = 1.05, *SE* = 0.07, *z* = 0.64, *p* > .99), but for older adults, true answers were better recalled than false answers (*OR* = 1.38, *SE* = 0.10, *z* = 4.50, *p* < .001).

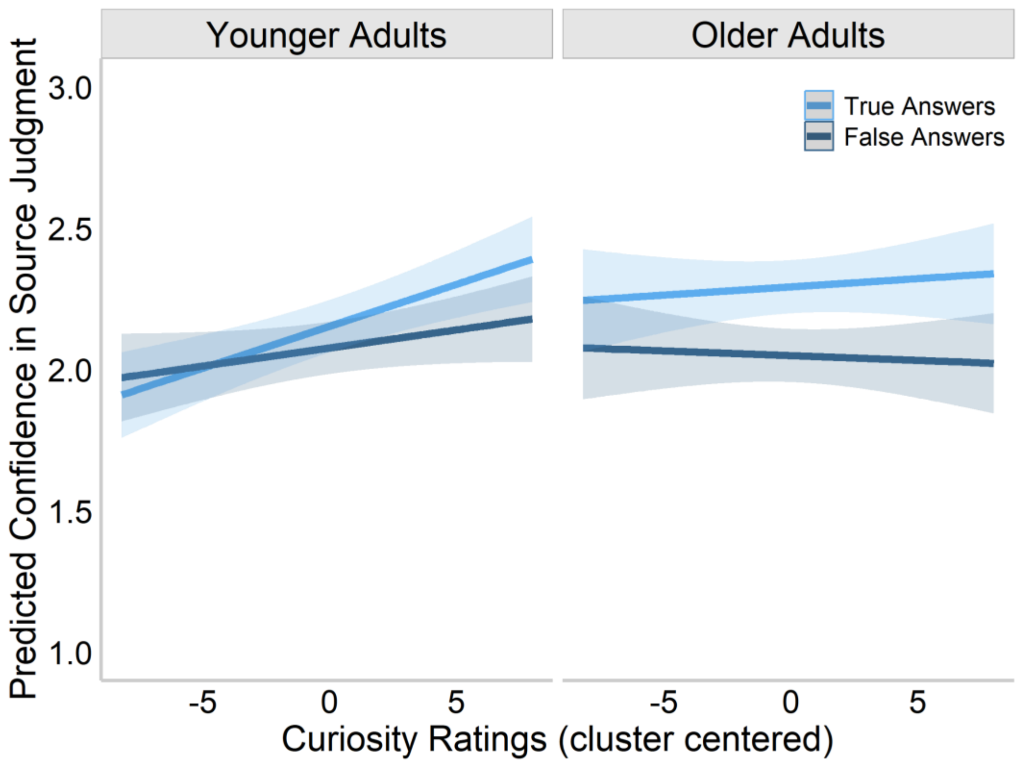

Figure 4.8. Predicted probability of correct recall of trivia answers as a function of curiosity ratings, truth of the answers, and age group in Experiment 4. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

The interaction between curiosity and the truth of the answers did not reach statistical significance (*OR* = 0.95, *SE* = 0.03, 95% CI: 0.90 – 1.01, *z* = 1.73, *p* = .084). However, we explored this marginally significant interaction and found that for true answers, curiosity significantly and positively predicted recall accuracy (*OR* = 1.06, *SE* = 0.02, 95% CI: 1.02 – 1.10, *z* = 2.78, *p* = .006), but not for false answers (*OR* = 1.01, *SE* = 0.02, 95% CI: 0.97 – 1.05, *z* = 0.30, *p* = .77). Neither the interaction between age and curiosity (*OR* = 1.00, *SE* = 0.03, 95% CI: 0.95 – 1.05, *z* = 0.14, *p* = .89), nor the three-way interaction were significant (*OR* = 1.05, *SE* = 0.06, 95% CI: 0.94 – 1.18, *z* = .86, *p* = .39). Thus, curiosity positively predicted recall for both older and younger adults, but older adults also better remembered true than false answers.

Source Memory. Source accuracy is shown in Figure 4.9. We examined participants' source memory accuracy by conducting a mixed effects logistic regression model, which was the same as that for recall, except that the dependent variable was whether participants correctly recognized each answer as true or false. The model revealed that curiosity was a significant positive predictor of source accuracy (*OR* = 1.05, *SE* = 0.02, 95% CI: 1.02 – 1.08, *z* = 3.12, *p* = .002), and that true answers were more accurately recognized as true than false answers as false (*OR* = 0.10, *SE* = 0.06, 95% CI: 0.09 – 0.11, *z* = 41.17, *p* < .001). However, there was no significant age difference in source accuracy (*OR* = 0.87, *SE* = 0.10, 95% CI: 0.72 – 1.05, *z* = 1.48, *p* = .14). There was also a significant interaction between age and truth of the answer (*OR* = 0.49, *SE* = 0.11, 95% CI: 0.39 – 0.60, *z* = 6.62, *p* < .001). Bonferroni post-hoc tests showed that true answers were better remembered than false answers for both younger adults (*OR* = 7.05, *SE* = 0.53, *z* = 26.05, *p* < .001) and for older adults (*OR* = 14.47, *SE* = 1.18, *z* = 32.89, *p* < .001), but this difference was larger for older adults. Curiosity did not interact with any other variables in the model, and the three-way interaction was not significant (all *p*s > .22).

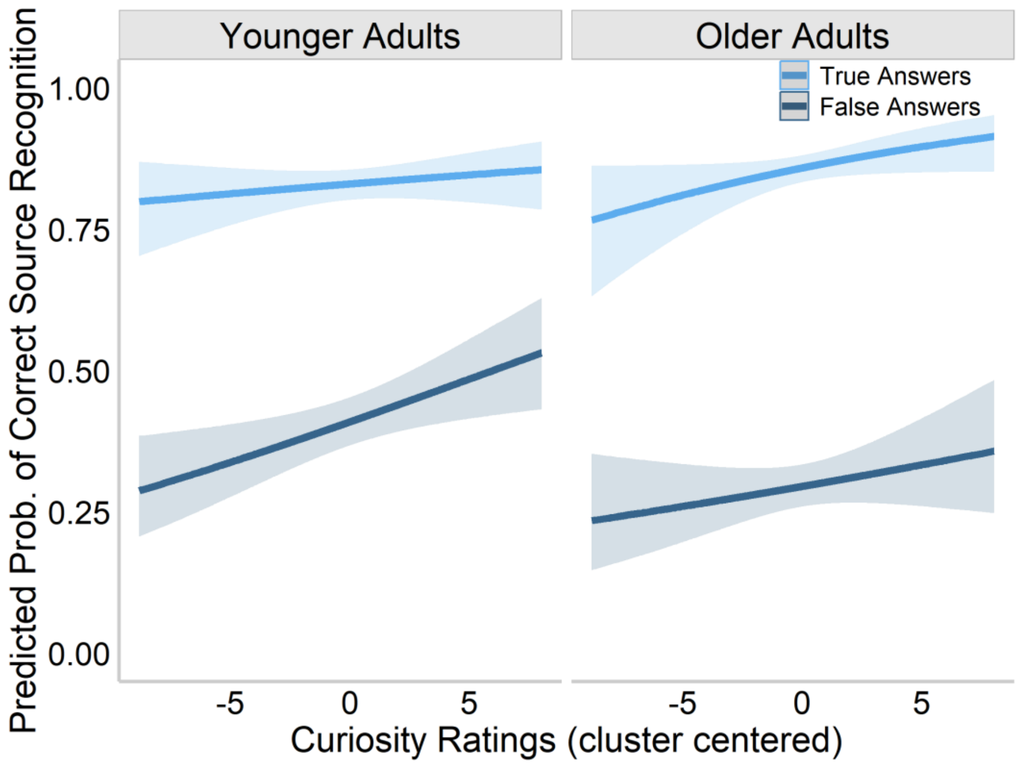

Figure 4.9. Predicted probability of correct source judgments in Experiment 4 plotted as a function of curiosity ratings, truth of answers, and age group. Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

Source Confidence. We then examined participants' confidence in their source judgment in the same way as in Experiment 3A, using a mixed effects regression model with age, curiosity, and truth of the answer, as well as the interaction of these variables as predictors. The model revealed that curiosity was significantly positively related to confidence in source judgments, b = 0.01, SE = 0.004, $t(8288) = 2.30$, $p = .02$. Additionally, participants were more confident in their judgments for true than false answers, b = -0.09, SE = 0.014, $t(8242) = 6.35$, $p < .001$, and older adults were more confident in their responses than younger adults, b = 0.21, SE = 0.066, $t(164) = 3.22$, $p = .002$. There was also a significant interaction between age and truth of the answer, b = -0.10, SE = 0.029, $t(8240) = 3.58$, $p < .001$, such that older adults were more confident than younger adults for true answers, $b = -0.26$, $SE = 0.07$, $t(180) = 3.91$, $p < .001$, but not for false answers, $b = -0.16$, $SE = 0.07$, $t(180) = 2.39$, $p = .11$. Curiosity did not interact with either age or answer truth, and the three-way interaction was not significant (all *p*s > .14). Source confidence ratings are displayed in Figure 4.10.

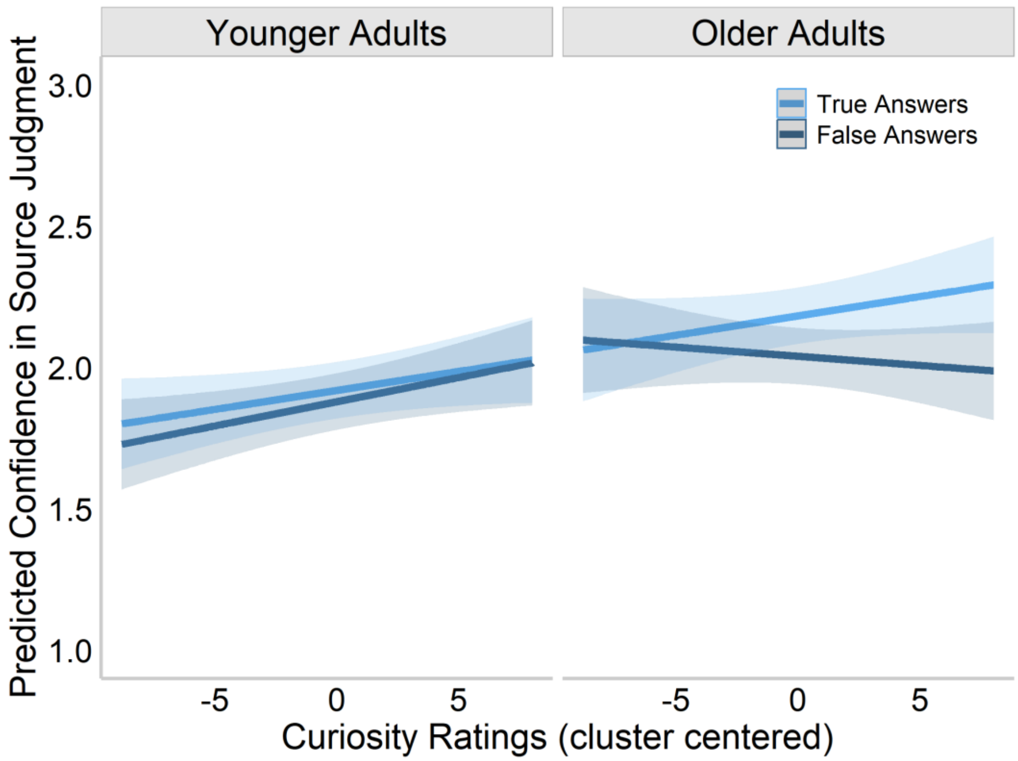

Figure 4.10. Predicted ratings of confidence in source response in Experiment 4 plotted as a function of curiosity ratings, truth of answers, and age group. Confidence ratings ranged from 1 (maybe) to 3 (definitely). Curiosity ratings shown are centered around each participant's mean. Shaded areas represent 95% confidence intervals.

Discussion

In Experiment 4, we found that curiosity was predictive of both younger and older adults' item memory performance. Curiosity was a slightly stronger predictor of memory for true items than false items, but this difference did not reach statistical significance. Older adults also better remembered true than false items, whereas younger adults did not show this effect. This finding supports the possibility that older adults may have still been more motivated to remember true over false information, even when they did not learn the truth of information until after encoding. We also showed in Experiment 4 a slight positive effect of curiosity on source accuracy, suggesting that when participants do not learn the truth until after encoding, curiosity may aid in binding the truth of information in memory. Confidence in source judgments was again influenced by curiosity, and curiosity particularly increased confidence for true answers for older adults.

General Discussion

In the present research, we examined whether younger and older adults' item and source memory was influenced by curiosity and truth of information. In Experiment 3A, we found that curiosity significantly predicted item memory for younger adults, but this effect was not found for older adults, whose memory was more strongly influenced by the truth of information. Experiment 3B showed that this effect was not due to false answers being less believable or more difficult to remember. Instead, we speculated that older adults may not have been motivated to remember answers that were false. Therefore, in Experiment 4, participants did not learn whether the answers to trivia questions were true or false until after the answer had been presented, making it more difficult to simply ignore false answers. In Experiment 4, both younger and older adults' item memory was influenced by curiosity, although older adults' memory was still more influenced by item truth than younger adults' memory.

These findings suggest that both curiosity and truth can aid memory in younger and older adults, but that truth may be a stronger predictor of memory for older adults than younger adults. It is unclear from the current research whether this effect of truth is more strategic or automatic, as participants were instructed to remember all items, regardless of truth. However, future research could examine whether presenting a truth label leads older adults to engage in more strategic processing (e.g., due to motivational factors) or whether presenting a false label may have acted as a sort of directed forgetting cue in the current study. Interestingly, recent work has shown that younger adults' item and context memory are more influenced by truth than external value information and that truth may make prioritization easier (Ford & Nieznański, 2024), suggesting that knowing information is true could lead to similar effects as value on memory. Our results support this finding, and further suggest these effects could be stronger in older adults.

In the present research, we were also interested in whether curiosity would influence participants' source accuracy, or their memory for the truth of the items. Because older adults have shown a deficit in source memory in prior work (Mitchell & Johnson, 2009; Schacter et al., 1991), but older adults have been shown to be able to remember gist information about truth (Rahhal et al., 2002), we were interested in whether curiosity could influence source memory when information varied in truth. In Experiment 3A, we found that curiosity did not predict source accuracy, and, again, older adults especially were influenced by the truth of items. However, in Experiment 3B, curiosity did predict source accuracy, and older adults' source memory was again more accurate for true information. One possibility for why this effect emerged in Experiment 4 and not Experiment 3A is because by splitting the answer and truth label into separate phases, there was less information present to encode at once, which could have made it easier to bind the information in memory. However, it is also possible that, as mentioned earlier, participants (especially older adults) may have given less effort toward false answers overall in Experiment 3A, and this also affected their source judgments. Either way, the finding that older adults' source memory was less accurate for false items supports literature showing that older adults may forget source information and misremember false information as true (Brashier & Schacter, 2020). Overall, curiosity may improve source memory in some cases, but not in others (e.g., when the truth of information is especially salient), and its effects do not seem to differ by age groups.

One difference between the present experiments and other prior work that has found improved memory for incidental information during states of curiosity is that the information being encoded in the present research is not incidental. Specifically, truth information is intrinsically related to the information itself and affects its meaning, which may influenced its perceived value. Truth is also an interesting concept, as there is a default assumption that information we encounter is true (Dechêne et al., 2010), and truth can be influenced by feelings of familiarity or fluency in both younger and older adults (Parks & Toth, 2006; Reber & Schwarz, 1999; Unkelbach, 2007). Additionally, prior work has shown a bias in remembering the truth of information, such that when participants are unable to remember the truth of information, they tend to guess that it was true (Nadarevic & Erdfelder, 2013). We may also use more gist-based heuristics to learn truth information (Rahhal et al., 2002). Thus, the design of the current research with an even distribution of true and false answers may have led to a general tendency to remember more information as true. However, the current work suggests that, at least in some cases, the finding that curiosity may improve associative information extends to intentionally learned information.

It is also worth noting that the presence of truth information created an interesting situation in the present research wherein when participants learned false answers, their curiosity was not truly satisfied (as they never learned the true answer). Thus, it is possible that participants were still experiencing curiosity after learning false answers, rather than typical encoding processes that occur at the resolution of curiosity (Davey et al., 2015; Ligneul et al., 2018; Rüterbories et al., 2024). It is also possible that participants were experiencing frustration or a negative emotion in response to not learning the true answer, which could also have affected memory in interesting ways. Thus, future research may examine participants' curiosity after learning a false answer, and how this may influence memory independently.

Another difference between our research and prior work is the timing of the presentation of associative information. Specifically, in work that has found improvement of memory during states of curiosity, incidental information has been presented between the presentation of the question and the answer, during which participants are experiencing a state of curiosity. In our work, the truth of information was presented when learning the answer, or when curiosity is presumably satisfied. More recent work has further shown that incidental memory benefits from curiosity only when presented in close proximity (approx. 1-2 sec) from the elicitation of curiosity (Murphy et al., 2021). Thus, it is possible that if the truth information had been presented immediately after the presentation of the trivia question, source memory could have been further strengthened by curiosity.

A third difference between our research and prior work is the type of stimuli used. Faces are a type of stimuli that may be particularly memorable (Rapcsak, 2003; Sato & Yoshikawa, 2013), as recognizing faces is an important evolutionary ability for humans. Interestingly, prior work has used a similar paradigm as Gruber et al. (2014) but varied the emotional valence of the faces (e.g., negative expression vs. positive expression) and found that curiosity enhances memory for faces irrespective of their emotional valence (Padulo et al., 2022), which suggests that the valence of faces may not affect the extent to which curiosity benefits memory for incidental information. However, this work has yet to be replicated using other types of stimuli, so it remains to be seen whether it may be limited to faces or is more universal for other types of stimuli. In fact, Keller et al. (2024) used a similar paradigm to that of Gruber et al. (2014) but presented scholastic facts rather than faces either immediately after rating curiosity about each question or immediately before learning the answer (a few seconds later). Interestingly, they found that high curiosity actually impaired memory for the incidental facts compared to low curiosity. It is possible that with text materials, there is some interference in learning, suggesting faces or other visual information may be more likely to elicit the effect. The present research suggests that curiosity may enhance memory for other types of associated information, but only in some cases.

Chapter 4 Conclusions

While it is known that curiosity can improve memory performance, it is not known how curiosity may differentially strengthen memory for information that is true or false. Chapter 4 presents evidence that the way in which curiosity contributes to memory may change depending on whether the information we are learning is true or false, and this may differ between younger and older adults. Curiosity seems to work to improve memory for both true and false information, even when we know that the information is false, but knowing the information is true or false may override these effects in older adults.

Prior work has also demonstrated that curiosity can improve memory for incidentally presented information during states of high curiosity (Gruber et al., 2014; Murphy et al., 2021; Padulo et al., 2022), but not for some types of information, including facts (Keller et al., 2024). Our results suggest that curiosity may improve memory for intentionally encoded associated information (i.e., truth) in some cases. However, truth information is unique, as it influences meaning, and older adults seem to be influenced more by truth than curiosity.

Importantly, we also find that both younger and older adults were more accurate at remembering true information as true, but more often misremembered false information as true, and this was especially true for older adults. Thus, although curiosity did have a positive relationship with source accuracy in Experiment 4, both younger and older adults were more likely to remember false information as true than vice versa, and this was especially true for older adults. Finally, we assessed participants' confidence in their source memory, which was influenced by curiosity and truth in both experiments, suggesting participants have some awareness that both curiosity and truth can influence source memory.

Table 4.1

True and False Answers for Trivia Items

Question	True Answer	False Answer
What is a baby oyster called?	Spat	Larva
What is the side of a hammer called?	Cheek	Face
What is a group of goats called?	Trip	Drove
73% of what country is covered by forest?	Finland	Brazil
Who is the Greek God of music?	Apollo	Dionysus
Which country has a national anthem that consists of only 32 syllables?	Japan	China
Which planet in the solar system is the only one that rotates clockwise?	Venus	Uranus
What is the only cat in the world that cannot retract its claws completely?	Cheetah	Leopard
Which country has the world's only non-quadrilateral national flag?	Nepal	Hungary
Which fish can produce more eggs than any other known vertebrate?	Sunfish	Seahorse
What disability did Thomas Edison suffer from?	Deafness	Dyslexia
What Beatles song remained the longest on the music charts?	Hey Jude	Here Comes the Sun
What breed of dog is the only animal whose evidence is admissible in some USA courts?	Bloodhound	German Shepherd
What is the only lizard that has a voice?	Gecko	Komodo Dragon
What food did the Aztecs reckon was the food of the Gods?	Chocolate	Papaya
Which chemical element belongs in the Halogen Family with fluorine, chlorine, bromine and astatine?	Iodine	Krypton
What island country lies off the south-east coast of India?	Sri Lanka	Indonesia
What is Spain's national flower?	Carnation	Geranium
Which land mammal has the highest blood pressure?	Giraffe	Elephant
What is the largest freshwater lake in the world by surface area?	Lake Superior	Lake Victoria

What color are cranberries before they turn red?	White	Purple
Which company is the largest manufacturer of tires?	Lego	Good Year
What insulates the ice cream to prevent it from melting in the hot dish "Baked Alaska"?	Meringue	Cake
What is measured with an ombrometer?	Rainfall	Humidity
What is the only country to have won at least one gold in every Olympic Games?	Great Britain	Italy
Christopher Columbus introduced what animal to North America?	Pig	Cow
On what vegetable did an ancient Egyptian place his right hand when taking an oath?	Onion	Garlic
What was the name of the first chimpanzee sent into space by America?	Ham	Dave
What is added to white sugar to make brown sugar?	Molasses	Maple Syrup
The Gold Coast is now known as what country?	Ghana	South Africa
Which country has the longest coastline?	Canada	United States
What does an ichthyologist study?	Fish	Insects
What type of fruit would you pick from a Mirabelle tree?	Plum	Fig
Who was the first winner of the Fifa World Cup?	Uruguay	Argentina
What is the name of the company that produces "Baby Ruth" candy bars?	Nestle	Hershey
In what ancient city were the "Hanging Gardens" located?	Babylon	Constantinople
What is the capital city of Australia?	Canberra	Sydney
In which city is Michelangelo's statue of David located?	Florence	Rome
Of which country is Nairobi the capital?	Kenya	Nigeria
What is the last name of the first person to complete a solo flight across the Atlantic Ocean?	Lindbergh	Earhart
What was the first nation to give women the right to vote?	New Zealand	Denmark
What was the last piece of music Mozart composed?	Requiem	Jupiter
What did Joseph Priestley discover in 1774?	Oxygen	Hydrogen
What was the name of the Apollo lunar module that landed the first man on the moon?	Eagle	Falcon

What was the name of the goldfish in the story of Pinocchio?	Cleo	Claude
Who was the first ruler of the Holy Roman Empire?	Charlemagne	Constantine
What is the name of the brightest star in the sky, excluding the sun?	Sirius	Polaris
What is the name of the mountain range that separates Asia from Europe?	Ural	Himalayas
What is the name of the instrument used to measure wind speed?	Anemometer	Windometer
Which sport uses the terms "stones" and "brooms"?	Curling	Cricket
What is the name of the unit of measure that refers to a six-foot depth of water?	Fathom	League
Who is known as "the father of geometry"?	Euclid	Newton
What is the name of the largest desert on earth?	Antarctica	Sahara
Which is the only continent without a desert?	Europe	South America
What animal's milk does not curdle?	Camel	Horse
What wild animal in Africa has killed the most people?	Hippo	Rhinoceros
Which bird is the international symbol of happiness?	Bluebird	Dove
Which is the largest joint in the body?	Knee	Hip
What was once called brimstone?	Sulfur	Granite
What is the name of the largest island in the world?	Greenland	Australia

Table 4.2

Average proportion correct for recall of trivia answers in Experiment 3A

		Recall Accuracy	Source Accuracy
Younger Adults	True Answers	.42 (.49)	.79 (.41)
	False Answers	.34 (.47)	.52 (.50)
Older Adults	True Answers	.41 (.49)	.86 (.35)
	False Answers	.25 (.43)	.34 (.47)

Note. Means are shown in the cells, and standard deviations are presented in parentheses.

Table 4.3

Average proportion correct for recall of trivia answers in Experiment 4

		Recall Accuracy	Source Accuracy
Younger Adults	True Answers	.37 (.48)	.81 (.40)
	False Answers	.36 (.48)	.41 (.49)
Older Adults	True Answers	.37 (.48)	.84 (.37)
	False Answers	.32 (.46)	.31 (.46)

Note. Means are shown in the cells, and standard deviations are presented in parentheses.

CHAPTER 5: CONCLUSIONS

Overview of Findings

Curiosity is a state that has been known to drive human behavior for centuries. However, cognitive psychology still has much to learn about how curiosity operates in our daily lives. Curiosity may drive many everyday behaviors throughout the lifespan, and maintaining curiosity across the lifespan is a predictor of learning (Xiong & Zuo, 2019), goal pursuit (Kashdan & Steger, 2007; Sheldon et al., 2015), and even survival rates (Swan & Carmelli, 1996). Clearly, curiosity remains a powerful motivator and important part of wellbeing into older adulthood (Sakaki et al., 2018). However, theories of aging typically argue that curiosity declines as we age (Carstensen et al., 1999, 2003), and research has largely supported this view (e.g., Chu et al., 2020; Dellenbach & Zimprich, 2008; Hertwig et al., 2021), suggesting that as we age, we are less interested in learning for the sake of learning. On the other hand, some theories of aging (Baltes & Baltes, 1990; Hess, 2014) make room for the idea that curiosity may be a motivator of learning and memory behavior, despite possible declines. The research reported in Chapters 2, 3, and 4 seeks to understand how different types of curiosity may change differentially across the lifespan, as well as how and when curiosity motivates learning and memory as we age.

Age-related changes in curiosity

In Chapter 2, we assessed how measures of trait curiosity (i.e., a general, more stable type of curiosity) and state curiosity (i.e., curiosity experienced in response to specific information or situations) may differentially shift across the lifespan using a large cross-sectional survey design. Adult participants (aged 20-84) completed surveys regarding their general level of curiosity and completed a trivia task in which they viewed trivia questions and rated their curiosity to learn the answer before learning the answer. We examined the relationship between age and survey scores as a measure of trait curiosity, as well as average curiosity ratings in the trivia task as a measure of state curiosity. Age showed a negative relationship with trait curiosity, but a positive relationship with state curiosity, suggesting a differentiation between these two forms of curiosity and their relationship with age.

In addition to their curiosity, participants rated constructs including scam susceptibility, boredom proneness, and subjective age. Trait curiosity was positively related to both boredom proneness and scam susceptibility, such that people who were more curious were more prone to boredom and more susceptible to scams. Furthermore, while age was negatively related to both boredom proneness and scam susceptibility, subjective age showed an opposite relationship. In other words, people who felt older were more prone to boredom and susceptible to scams.

Taken together, Chapter 2 provides evidence that not all forms of curiosity decline with age, and that curiosity is a multifaceted construct that can motivate behavior in different ways, depending on the type of curiosity being measured, which has implications for theories of learning and goal pursuit across the lifespan (as will be discussed further in the next section). As curiosity research has grown substantially in recent years in various field, including cognitive psychology, personality research, and motivation science, it is especially important to differentiate curiosity from other constructs (e.g., interest) and ensure that claims are specific to the type of curiosity being measured. This work also provides a starting point for future research to further examine how different types of curiosity may motivate learning and behavior in various ways, as well as how these different types of curiosity can be harnessed as we age.

Relatedly, the finding that curiosity is related to both boredom proneness and scam susceptibility suggests curiosity may play a role in problem behaviors that arise from boredom (e.g., problem gambling or internet use) and the likelihood of falling for scams. These results are correlational, but again provide an interesting avenue for future work. For example, people who are more curious may be more likely to engage with a scammer due to the cognitive stimulation that arises from new interactions and relief of boredom.

Overall, Chapter 2 of this dissertation finds support that older adults may be less curious overall but more interested in learning new facts. This finding lends support for the idea that older adults may be selectively curious, meaning that they do not tend to experience curiosity as much as younger adults (as this may use cognitive resources unnecessarily), but they are curious about information that may either have some personal relevance, satisfy goals (e.g., social-emotional goals), or about which they have greater prior knowledge.

Influence of Curiosity and Reward on Memory and Metacognition

Chapter 2 focused on how curiosity may change across the adult lifespan, while Chapters 3 and 4 focused on how curiosity influences memory and metacognition. Prior research shows that older adults can rely on curiosity to bolster learning and memory. For example, when we are curious to learn information, we are more likely to remember that information later, and this is true for both younger and older adults (Fastrich et al., 2018; Galli et al., 2018; Kang et al., 2009).

One potential explanation for this effect is that curiosity shares some mechanistic traits with value (FitzGibbon et al., 2020; Murayama et al., 2019). Specifically, curiosity may be dependent on the intrinsic value of the information to an individual, and we may experience greater reward when learning information that we are curious about. If curiosity and reward share similar underlying processes (neural and/or cognitive), there may be a competition for cognitive resources when there is a mismatch. There have been mixed results in the literature about whether curiosity and reward work together to improve memory (e.g., have additive effects) or the two motivational processes interfere with one another.

Chapter 3 examined the influence of curiosity and value on item memory and associative gist-based memory at two long-term delays: two days and one week. Chapter 3 also assessed whether participants' metacognitive judgments are sensitive to curiosity, value, and different retention intervals. In Experiment 1, younger and older adults were presented with trivia questions, after which they rated their curiosity to learn the answer. Then, they learned an answer that was paired with a point value ranging from 1-10 points, indicating the number of points they would earn if they correctly remembered the answer at a later test. Then, participants' memory was tested for the answer and its value for half the items after two days and the other half after one week. Participants also made judgments about how many items they would remember at each time point. Recall was positively influenced by curiosity, but not point value, and the two did not interact, offering more support for the additive explanation of intrinsic and extrinsic reward. However, curiosity was negatively related to accurate associative memory for low but not higher value items.

In Experiment 1, curiosity seemed to support item memory but impair associative memory (for low value information), while value did not improve item memory as was expected. However, it was possible that value lying on a continuum led to greater difficulty in making decisions about which values to strategically focus on, and participants did not get multiple opportunities to adjust their study strategies, as there was one list only. Additionally, the value of items was presented when participants learned the answer to the questions, meaning that value may not have been presented when participants were actually in a state of curiosity, but rather when curiosity was quenched or satisfied.

In Experiment 2, participants completed the same task as in Experiment 1, but we manipulated the timing of when value was presented: either when the question was presented (elicitation of curiosity) or when the answer was presented (satisfaction of curiosity). We also used a categorical value measure so that it was easier for participants to distinguish between high and low values. In Experiment 2, both older and younger adults better remembered items associated with high values, but the timing of the presentation of value did not affect value's influence on memory. Curiosity also predicted younger adults' memory for trivia answers across conditions, but older adults' memory benefitted from curiosity only when the value was presented with the question, suggesting that the presentation of value when learning the answer may have overridden effects of curiosity on memory. Again, curiosity had a negative influence on associative memory for low value items but only for older adults, and this influence dissipated after a longer delay. Taken together, we find that curiosity and value do not compete for influence on memory performance, but rather seem to have independent influences on item memory. Additionally, there may be some cases where curiosity may actually reduce detailed memory accuracy, perhaps when the information is deemed unimportant to remember, but this should be explored further in future work.

In both experiments in Chapter 3, we found that participants' metacognitive judgments mapped onto their memory performance for the most part. In Experiment 1, younger and older adults predicted they would remember less information after a longer delay than a shorter delay. In Experiment 2, we replicated this finding and showed that older adults reduced their predictions further after experiencing the first test, supporting the idea that older adults may correct overconfidence after being given feedback. Older adults were overconfident in their item-by-item responses as well, but their judgments were sensitive to value at the shorter delay, while younger adults' judgments were more sensitive to value at the longer delay. Both age groups' confidence judgments were sensitive to curiosity, suggesting people are generally aware of the effects of curiosity on memory.

In sum, Chapter 3 demonstrates the influence of an intrinsic and extrinsic motivator on memory in younger and older adults, and importantly shows that both influences can work to improve memory independently. However, associative memory performance may show a different pattern of influence of value and curiosity, which warrants further research.

Influence of Curiosity on Item and Source Memory

While Chapter 3 focused on how curiosity interacts with another memory motivator (i.e., value) to affect item and associative information, Chapter 4 focuses on how curiosity affects memory for item and source memory, or specifically, truth information. Curiosity is not only elicited for true, neutral information encountered in lab settings. Instead, in our everyday lives, we often see information that may pique our interest, but this information may not necessarily be reliable. Chapter 4 examined how curiosity was related to memory for true and false information as well as memory for the truth itself. There were competing hypotheses, which suggested that curiosity could benefit both item and source memory due to an attentional widening, or curiosity could heighten focus on the item itself, drawing cognitive resources away from the associated information.

In Experiment 3A, younger and older adults studied trivia questions and then learned an answer that was either true or false. Their memory was tested after one week for both the answer and whether it was true or false. Recall was positively predicted by curiosity for younger adults, but not for older adults. Further, curiosity did not predict source memory (i.e., memory for truth), but did predict confidence in source judgments. Both age groups' recall and source memory, however, were strongly influenced by the truth of information – and this was even more true for older adults. One explanation for this result was that the presentation of the true/false label led older adults to focus almost entirely on the truth of the information and even potentially ignore the false information, as it could have been viewed as less meaningful, acting almost like a directed forgetting task. Additionally, we had not validated the false answers to ensure they were believable and not less memorable than true answers.

To rule out these explanations, Experiment 3B used a similar design to that of Experiment 3A, except that participants were not informed which items were true and false, and instead were asked to guess whether each item was true or false. Participants (younger adults only) were biased towards guessing that items were true overall but were not more accurate at guessing the truth of true over false answers, suggesting that the false answers were equally believable. True answers were also remembered less accurately overall than false answers, suggesting true answers were not simply more memorable. However, participants better remembered items they guessed to be true, suggesting perceptions of truth may influence memory in the absence of knowledge of truth.

After establishing that true items were not more memorable and that false answers were believable, it was still possible that participants – and especially older adults – found the information labeled as true to be more meaningful, which could have led to differences in strategic processing of the trivia answers. Experiment 4 again used a similar design to Experiment 3A, except that the truth label was presented after encoding to prevent participants from simply ignoring the answers that were false. In Experiment 4, curiosity was a significant predictor of recall (i.e., item memory) for both younger and older adults, and was a marginally stronger predictor of recall for true items than false items. Curiosity also significantly predicted source memory and confidence, but, again, truth was a stronger predictor of source accuracy, especially for older adults, and metacognitive judgments largely mapped onto memory results.

Taken together, Chapter 4 showed that curiosity may influence item and source memory in some cases, but not others. Specifically, when truth information is presented when learning answers to trivia, it may override any effects of curiosity on both item and source memory for older adults. However, when participants encode the information prior to learning its truth, curiosity may be effective at improving item and source memory. This work highlights the importance of considering the temporal dynamics of curiosity and the type of associated information that is presented when examining curiosity and memory, as will be discussed further in the next section. Chapter 4 also showed that, again, both younger and older adults' metacognitive judgments tend to be overall in line with performance, such that participants' judgments were sensitive to truth of information and curiosity.

In sum, Chapter 4 shows that curiosity may influence both item and source memory across age groups under certain conditions, suggesting that curiosity could be a potential mechanism by which to improve associative or source memory, which has implications for understanding learning in the real world. In an age of misinformation, where older adults are especially vulnerable, fostering greater curiosity or interest may be a positive way to improve memory.

Implications for Theory

Theories of Goal Pursuit Across the Adult Lifespan

In Chapter 2 of this dissertation, trait curiosity and state curiosity were shown to have opposite relationships with age. Trait curiosity showed a negative relationship with age, which was largely predicted by prior work (e.g., Chu et al., 2020; Robinson et al., 2017). This finding is also in line with what would be predicted by theories of aging. Specifically, socioemotional selectivity theory (SST) suggests that as we age, our time perspectives become more limited, and we shift from more long-term goals to more short-term goals (Carstensen et al., 1999, 2003). Gaining knowledge for the sake of learning, including because one is interested, can be argued to serve long-term goals, as the more knowledge one acquires, the more suited they may be to deal with novel situations or environments in the future. Knowledge acquisition does not seem to serve shorter-term goals, unless the information has a specific use for the individual at the present time. Thus, our findings present a potential exception to the lack of desire for new learning in older age. Importantly, our results are not entirely contrary to those predicted by SST, as we did find a negative relationship between age and trait curiosity. Rather, our results suggest that older adults do maintain curiosity to learn new information in response to specific materials (i.e., trivia questions), which updates our understanding of goal shifts with age. Specifically, curiosity may reflect a focus on selectivity, wherein older adults are less likely to be curious in general, but may be curious in specific situations, including when information is easily attainable, when the information draws on prior knowledge, or when they see some use for the information (e.g., to share with a friend or loved one). The reasoning behind increases in state curiosity can be further explored by future work but may provide greater nuance to our understanding of goal pursuit and learning across the lifespan.

The results from Chapter 2 also contribute to theories of learning across the lifespan. As discussed in Chapter 1 of this dissertation, theories of learning and aging, including the Selective Optimization with Compensation (SOC) model (Baltes & Baltes, 1990) and the Selective Engagement Hypothesis (SEH; Hess, 2014), suggest that older adults conserve resources to focus on maintenance and selectivity. Knowledge acquisition can generally be considered a gain-focused behavior (i.e., acquiring as much knowledge as possible), and, thus, would likely decline with age. On the other hand, maintenance goals may include learning within domains for which one already has prior knowledge or in order to accomplish more immediate goals. Thus, these theories may generally predict a decline in curiosity with age, similar to SST. Again, the finding that older adults do show lower trait curiosity fits with these theories, while the finding that older adults show higher state curiosity may present an exception. However, there is still much to be learned about the mechanisms through which curiosity affects learning and goals. Therefore, it is possible that more general levels of curiosity are lower in older age, while learning about trivia specifically draws on some selective or maintenance goals or reduces the effort required to engage in new learning. Again, these possibilities will need to be further explored in future work but may allow for a greater understanding of when and why older adults are motivated to learn seemingly useless information.

It is important to note that none of the theories discussed here make specific predictions or claims about curiosity, so the predictions drawn from these theories are based on the more fundamental aspects of the theories' claims about goal pursuit and the variables that are suggested to motivate older adults' learning. There also may be aspects of these theories that have not yet been explored but that account for the complex relationships between age and curiosity. For example, we have shown that older adults maintain curiosity to learn about trivia questions, but we can only speculate about their reasoning for wanting to learn trivia. It is possible that socioemotional goals (e.g., the desire to share the information) underly this motivation, which would support the general claims made by SST. It is also possible that curiosity drives learning through a reduction of effortful processing (e.g., through schematic support or more automatic neural processes) or that curiosity is reflective of greater self-relevance of information, in which case both SOC and SEH could explain the lack of more general trait level curiosity in older age but increased state curiosity in response to trivia. Thus, our work provides new avenues to expand theories of goal pursuit and learning across the adult lifespan.

Reward Learning Frameworks of Curiosity

While research on curiosity is relatively new and theories are still being developed, some frameworks have been proposed to explain how curiosity influences learning and memory processes. One such framework suggests that curiosity relies on reward mechanisms to influence memory. Specifically, curiosity-driven learning may work similarly to reward-driven learning and information seeking (Murayama, 2022; Murayama et al., 2019), and these two forms of motivation may rely on similar neural and cognitive processes (FitzGibbon et al., 2020; Kang et al., 2009; Rüterbories et al., 2024).

In Chapter 3 of this dissertation, we examined the extent to which curiosity and reward (in the form of point values) interfere with one another during intentional learning and whether this potential interference was dependent on the temporal dynamics of curiosity. The results from Chapter 3 suggest that curiosity and reward may have separate and unique influences on memory in both younger and older adults. Importantly, this finding challenges the idea that curiosity and reward rely on overlapping neural and cognitive processes and instead suggests that they may work through separate processes. The present findings do not rule out the possibility that curiosity and reward may work in similar ways (e.g., through a valuation process), or that they may rely on similar resources when under other conditions (e.g., incidental learning, how reward is manipulated). However, overall, we show that curiosity and point value have additive influences on memory, suggesting they do not interfere with one another.

However, we also found that the presence of value (regardless of whether the value was high or low) may compete with curiosity mechanisms depending on the time course of when it is presented, specifically in older adults. Experiment 2 showed that when value information was presented during the time at which curiosity was activated (i.e., when the question was presented), curiosity had a positive relationship with later recall of trivia answers. However, when value information was presented during the time at which curiosity was satisfied (i.e., when learning the answer), there was no relationship between curiosity and later memory for trivia answers in older adults. This finding suggests that the presence of value does not interfere with processes occurring during the activation of curiosity but may interfere with processes occurring during the satisfaction of curiosity. Thus, curiosity may rely on similar mechanisms as reward during encoding, especially in older adults.

It is important to consider alternative reasons why presenting reward information (i.e., a point value, regardless of its magnitude) could interfere with curiosity's influence on memory. For example, prior work has shown that interest in the answers to trivia questions has a unique influence on later recall of answers over and above that of initial curiosity to learn the answer (Fastrich et al., 2018), so it is possible that the presentation of value during satisfaction of curiosity interferes with interest-driven learning. Additionally, this finding was only present for older adults. Older adults may have fewer resources available to process and encode value information, which may lead to an interference with curiosity mechanisms, whereas younger adults may have greater resources available to process and encode value information in the presence of curiosity. Future work will need to assess these different possibilities.

Temporal Dynamics of Curiosity

Another framework that has been proposed to explain how curiosity may influence memory is the Prediction, Appraisal, Curiosity, and Exploration (PACE) framework, which posits that curiosity triggers a dopaminergic modulation process that can enhance attention and consolidation (Gruber & Ranganath, 2019). This framework has been used to explain how curiosity may enhance memory for not only target information but also incidental information that has been presented during states of curiosity (Gruber et al., 2014), suggesting that attention may be enhanced during states of curiosity, which can lead to improved memory more broadly.

In Chapter 4, we examined whether curiosity was related to memory for target and source information – specifically, whether answers to trivia questions were true or false. Given that curiosity has been shown to enhance memory more broadly for incidental information, we were interested in whether curiosity would improve memory for associated information that is intentionally learned in both younger and older adults. Results from Chapter 4 revealed that curiosity's relationship with memory was dependent on when truth information was presented. Source memory was improved by higher curiosity when truth was not shown until after learning the answers to trivia questions, suggesting that curiosity can improve source memory. However, in the presence of truth information, truth can override effects of curiosity, especially for older adults.

This finding suggests that the effects of curiosity on both item and source information can be overridden by the presence of meaningful information, especially in older age. The results from Chapter 3 also support this finding, wherein the presence of value information overrode the effects of curiosity on item and associative memory in older adults. Taken together, these findings indicate that the time course of curiosity may be important to consider when understanding how curiosity interacts with meaningful information to affect memory. Specifically, when meaningful information (e.g., truth or value) is presented before encoding is required or after information has already been encoded, curiosity has a positive influence on memory. However, when presented during encoding, the meaningful information may override effects of curiosity. One possibility is that processing both interesting and meaningful information may require effort and cognitive resources, leading to a tradeoff for older adults, or interesting and meaningful information may be processed in a similar manner. Alternatively, it is possible that presenting two pieces of information places a higher demand on working memory in older age, causing meaning to have a greater impact on memory. Truth may even have acted as a directed forgetting cue for older adults, leading to a lack of encoding of false information. As mentioned previously, there are other possibilities for this interaction between meaning and curiosity in older age, and future research can continue to sort through these possibilities, as is further discussed in the next section.

Future Directions

Age-Related Changes in Curiosity

Chapter 2 of this dissertation established relationships that had not yet been established (i.e., between age and different types of curiosity, as well as between curiosity and scam susceptibility). To build on the findings from Chapter 2, future work can explore these relationships further to better understand what types of curiosity may change with age and in what ways. For example, are increases in state curiosity specific to trivia questions? Some work suggests that older adults may show greater state curiosity toward magic tricks (Ozono et al., 2020) and assistive care technology (Chu & Fung, 2022), but it is worth exploring other types of materials that may (or may not) elicit greater feelings of curiosity in older adults. It would also be useful to explore whether older adults may be more *selectively* curious, meaning that they may be more state curiosity in response to some types of information over others, and this could vary depending on personal relevance and importance of the information.

To further explore the relationship between age and state curiosity, it would also be useful to take experimental or causal approaches. Specifically, some work has begun to examine the factors that may lead to greater curiosity (e.g., social cues; Dubey et al., 2021, 2022; Spaniol & Swirsky, 2023), but these have yet to be explored in older adults. Understanding whether certain factors differentially produce greater rates of curiosity among younger and older adults will allow for a more mechanistic understanding of changes in curiosity across the adult lifespan. Similarly, a more limited future time perspective is proposed to be a potential mechanism underlying lower trait curiosity in older age, in line with socioemotional selectivity theory, but it has yet to be tested whether manipulating time perspective has causal effects on either trait or state curiosity.

Aside from exploring age differences in state curiosity further, most research that has examined age and trait curiosity uses typical measures of curiosity, some of which differentiate between an information type (i.e., desire to seek learning for pleasure) and a deprivational type (i.e., desire to seek learning to eliminate knowledge gaps). However, there are many other ways to be curious and ways that curiosity can influence behaviors, such as by seeking new experiences (e.g., travel, food) or through social activities. Thus, it will be informative to understand how age-related changes in curiosity may differ for various types of trait curiosity and how these may influence behavior as we age. Specifically, future work may examine more behavioral measures of state curiosity, beyond trivia questions and surveys.

Chapter 2 also highlighted relationships between curiosity, boredom proneness, and susceptibility to scams. While the relationships established were correlational, these findings provide a foundation on which to explore how curiosity may have more causal influences on problem behaviors. It is well known that curiosity can motivate negative behaviors (e.g., opening Pandora's box), but it is important to examine these influences in older adults, especially in the time of technology, when misinformation and scams seem to be ever-present.

Mechanisms for Curiosity and Memory

In both Chapters 3 and 4, we found that presenting information (either value or truth) during the presentation of answers to trivia questions led to a reduced effect of curiosity on memory for older adults specifically. In other words, when associated information was presented along with to-be-learned information and when curiosity was "quenched" (i.e., participants were learning the answers to the questions that had elicited their curiosity), curiosity did not influence memory. There are a few potential explanations for this finding. One is that the presentation of associative information was distracting or required additional cognitive resources for older adults, leading them to focus more on the associated information, which could have reduced the effects of curiosity on learning. Another explanation for this finding is that older adults were more motivated to learn the associated information (e.g., value or truth in the present research), or even that the information itself could have sparked some independent feeling of curiosity. Future work can assess these possibilities by using information that is not tied to the meaning of the presented information, but may act to test perceptual associative memory (e.g., the color of the answer) or distractions (e.g., a shape presented on the screen). These manipulations can help differentiate the influence of meaningful information from unrelated information on curiosity and memory. To assess whether attentional mechanisms may contribute, divided attention paradigms may help to elucidate the role of attention. Additionally, if working memory is responsible for the effects, either increasing or decreasing working memory demands may reveal differences in the extent to which curiosity influences item and associative memory.

Chapters 3 and 4 highlighted the importance of considering the temporal dynamics of curiosity when presenting additional information during learning of information that evokes curiosity. Specifically, in Chapter 3, curiosity had different influences on memory, especially for older adults, when value information was presented during a state of curiosity compared to when curiosity was satisfied, and in Chapter 4, curiosity was overridden by truth information when the truth label was presented during satisfaction of curiosity, but not when it was presented afterwards. Some work has begun to explore the importance of timing the presentation of information during states of curiosity (e.g., Keller et al., 2024; Murphy et al., 2021), but understanding the temporal dynamics of curiosity can help to elucidate the cognitive mechanisms underlying curiosity-enhanced memory.

In all present experiments reported in this dissertation, trivia questions were used to evoke feelings of curiosity. These stimuli are convenient for use in cognitive psychology experimental designs, as they are designed to be unlikely to already be known (allowing for tests of new learning), evoke various levels of curiosity, and involve learning of semantic information. However, we experience curiosity in everyday life in response to many materials, many of which are semantic or factual, but which also vary in importance (e.g., news vs. trivia), how we intend to use the information (e.g., to share with a friend vs. to make a decision), and how the information is presented (e.g., through social media vs. books). Thus, it will be important to expand this work to understand how curiosity may influence learning with different materials or under different situational factors.

Finally, it may be useful to apply these findings to everyday settings. Specifically, education is often a breeding ground for curiosity, and there are many opportunities to improve the way educators harness curiosity to improve learning outcomes, and this can be applied across the lifespan in work settings and through cognitive interventions. In addition, we not only benefit from curiosity when learning in everyday life, but curiosity may motivate how we use the information we learn. For example, information one is more curious about may be more likely to be shared with others, and this can have implications for social well-being as well as the spread of information online. Thus, it is important to continue exploring everyday settings in which curiosity motivates learning and other behaviors.

Conclusions

The goals of the current dissertation were to gain a better understanding of how curiosity may shift across the adult lifespan, and to explore when and how curiosity relates to memory for information that also carries some other meaning (i.e., varies in truth or extrinsic value). Specifically, we sought to examine age-related differences in state and trait curiosity to expand the literature on age-related differences in curiosity, which has largely shown declines with age. In Chapter 2, we showed that while trait curiosity may decline with increasing age, state curiosity may actually increase, at least in response to trivia, suggesting that older adults may maintain curiosity in complex ways, and it is important to consider the different ways in which older adults can be curious when examining motivated learning and information seeking.

Chapters 3 and 4 aimed to examine the role of curiosity in younger and older adults' learning of trivia in the presence of meaningful information, including external value (Chapter 3) and truth (Chapter 4). The results revealed that in the presence of other meaningful information, curiosity may not be as influential on older adults' memory, but that timing of information presentation likely affects the extent to which curiosity is beneficial for learning as we age. This work suggests that curiosity may be overridden by the presence of other meaningful information, or that processing meaningful and interesting information may rely on similar cognitive and neural processes. Chapters 3 and 4 also provided initial evidence that curiosity may boost younger and older adults' associative memory in some cases, as discussed in Experiments 2 and 4. Overall, we find that curiosity may have different influences on memory if presented during activation of curiosity, satisfaction of curiosity, or after learning, and these differences are most pronounced in older age. In sum, the present dissertation provided evidence that curiosity can look different across the lifespan, and that curiosity may influence learning and memory in complex ways, which are dependent on the temporal dynamics of curiosity, meaning of information, and age.

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