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The Effect of Age, Syntax Complexity, and Cognitive Ability on the Rate of Semantic Illusions

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Approval of the Dissertation Committee

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Abstract

The Effect of Age, Syntax Complexity, and Cognitive Ability on the Occurrence of Semantic Illusions

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Semantic illusions are recognition errors that occur when an individual fails to notice that information contradicts their prior knowledge (Barton & Sanford, 1993; Erickson & Mattson, 1981). For example, after hearing the question, “If a plane crashes while flying over state lines, where should the survivors be buried?” many start to consider the legality or appropriateness of the scenario despite knowing “survivors” should not be buried. Having more knowledge does not necessarily prevent individuals from overlooking illusory information/misinformation. Older adults tend to have greater crystallized intelligence than young adults, yet these age groups appear to detect illusory information at equivalent rates (Umanath & Marsh, 2012; Umanath, 2014). However, there is also evidence that older adults experience more semantic illusions than young adults in general (Umanath et al., 2012). Previous research demonstrates that the rate of semantic illusions is sensitive to specific language structure manipulations, such as syntax structure or word placement that facilitate overlooking the illusory information (Bredart and Modolo, 1988; Büttner, 2007; Wang, Hagoort, & Yang, 2009). Furthermore, there is evidence that disrupting processing fluency by increasing the difficulty of reading enables more frequent detection of illusory information (Song, 2009). Although this effect has been demonstrated using easy- versus difficult-to-read font, increasing syntax complexity also increases reading difficulty

and requires more effort for comprehension (e.g., Kemtes & Kemper, 1997; Stromswold et al., 1996).

The current study used a combined experimental-correlational approach to investigate the effects of age, language structure, and cognitive ability on the rate of semantic illusions experienced in response to general knowledge questions. The experimental approach compared the rate of semantic illusions between young and older adult age groups for illusory information embedded in sentences with either simple or complex syntax structures. The correlational approach examined the best cognitive predictors of increased detection of illusory information among composite scores for crystallized intelligence, fluid intelligence, and rationality.

The sample of 203 participants, including 114 young adults (M = 24.98, SD = 4.06) and 89 older adults (M = 65.63; SD = 4.93), was administered a semantic illusion task, general knowledge check, and reading comprehension task, along with a battery of cognitive measures assessing fluid intelligence, crystallized intelligence, and rational thinking (Comprehensive Assessment of Rational Thinking [CART]; Stanovich, 2016). The semantic illusion task included general knowledge questions that either contained the correct information (target item), e.g., "How many animals of each kind did *Noah* bring on the ark?" or incorrect information (illusion item), e.g., How many animals of each kind did *Moses* bring on the ark?". The sentence structure of the general knowledge questions varied across syntax complexity condition, such that participants experienced target items and illusion items in both simple (right-branching) versus complex (left-branching, middle-branching) syntax structures. Scoring procedures assessed frequencies for: (a) correct responses on target items (target score), (b) successful detection of illusory information (detection score), and (c) failures to detect illusory information (illusion score).

The results of the experimental portion of the study confirmed an interaction of age and syntax for detection scores. Older adults detected illusory information more frequently than young adults, and complex versus simple syntax increased this advantage for the older adult age group. Alternatively, the pattern of results for illusion scores, or overlooking the illusory information, produced a main effect of age with older adults experiencing more semantic illusions than young adults regardless of syntax condition. Although counterintuitive, older adults had a higher baseline of prior knowledge, and therefore had more opportunities than young adults to detect *and* overlook the illusory information at higher rates.

The correlational portion was largely data-driven, and investigated which cognitive composites for fluid intelligence, crystallized intelligence, and rationality best predicted detection scores. Results demonstrated varying patterns between age groups, such that young adult detection scores were most accurately predicted by the rationality composite scores. However, older adult detection scores were best predicted by crystallized intelligence. Although both crystallized intelligence and rationality are positively associated with detection of illusory information (Hannon & Daneman, 2001; Mata et al., 2014), a mediation analysis revealed a potential underlying cause to the age-differences in the outcomes. A bootstrap mediation analysis indicated the effect of age group on detection scores was fully mediated by crystallized intelligence. More specifically, older adults had more prior knowledge than young adults to such a disparity, variation in detection scores between age groups can be fully accounted for by differences in crystallized intelligence between young and older adults. Overall, increased syntax complexity facilitates detection of illusory information compared to simple syntax. Furthermore, increased crystallized intelligence is associated with more frequent detection of illusory information. Yet, with less prior knowledge, performance on rational thinking problems is the better predictor of detecting illusory information.

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The Effect of Syntax Complexity, Age, and Cognitive Ability on Semantic Illusions

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Semantic illusions are recognition errors that occur when an individual fails to notice information that is incongruent with their prior knowledge (Barton & Sanford, 1993; Erickson & Mattson, 1981). These occurrences are also known as semantic distortions, or the *Moses Illusion,* based on the frequently cited example: "How many animals of each kind did *Moses* bring on the ark?". Many people respond with "two" despite having prior knowledge that *Noah* is the biblical character associated with the ark. The response indicates that some pre-existing knowledge has been retrieved (two animals of each kind on the ark) but the inconsistency between prior knowledge and new information (Noah vs. Moses) is not detected.

Much like visual illusions and false memories, semantic illusions provide a unique opportunity to investigate the mechanisms underlying complex cognitive behavior. For example, reducing processing fluency with a difficult font or syntax structure is associated with increased detection of the illusory/contradictory information (Song, 2009; Bredart and Modolo, 1988; Büttner, 2007).Furthermore, experimental effects, such as increased detection of illusions due to syntactic complexity, can be statistically associated with individual difference variables, such as age and cognitive ability (e.g., Umanath & Marsh, 2012; Hannon, 2014; Hannon & Daneman, 2001). Taken together, this implies that the cognitive mechanisms underlying memory and language, and the cognitive abilities associated with memory and language related task performance, can be explored together in a single study, from a unified psychological perspective (Cronbach, 1957).

The overarching purpose of the current study was to (a) investigate the cognitive mechanisms that give rise to semantic illusions by examining the influence of syntax complexity and age-related cognitive differences on performance; (b) better understand the nature of developmental and individual differences in related cognitive abilities and their role in detecting or overlooking illusory/contradictory information. The current study takes a combined experimental and correlational approach to address these two points, whereby the experimental approach corresponds to the first goal (a) and the correlational approach addresses the second goal (b). The experimental portion involved the manipulation of syntax complexity to determine the effect on detection of, or failure to detect, illusory information between young and older adults. Furthermore, these effects were examined after controlling for relevant variables that tend to reflect age-related differences, such as reading comprehension. This section was largely theory-driven and specific a priori predictions were tested. The correlational portion of this study was intended to take a more broad, exploratory approach to examining semantic illusions and is largely data driven. This section was intended to assess whether individual differences in cognitive abilities, such as composite scores for crystallized intelligence or fluid intelligence, can significantly predict the occurrence of semantic illusions or the avoidance of them.

To motivate the current study a comprehensive review of research on semantic illusions is provided, starting with experimental research on language-based influences on semantic illusions. Next, cognitive aging research on age-related differences in the ability to detect semantic illusions is reviewed. Following this section, semantic illusions are further discussed within the context of dual process theories of thinking and reasoning; this section illuminates the gaps in the literature and limitations in our current understanding of the cognitive mechanisms and abilities associated with semantic illusions. Finally, there is a review of individual differences in cognitive abilities that are expected to be relevant in the occurrence of semantic illusions or detecting illusory information.

Semantic Illusions: Language-based Influences

Several characteristics of the text containing contradictory or illusory information have been shown to affect the likelihood of detecting semantic illusions. Initial investigations established that semantic illusions occur when the target (correct) and illusory (incorrect) information replacing it have shared semantic features (Erickson & Mattson, 1981; Barton & Sanford, 1993; Reder & Kusbit, 1991; van Oostendorp & Kok, 1990). Erickson and Mattson (1981) conducted a series of experiments to test whether semantic similarity between the target word and the illusory word is necessary to produce the illusion effect (*semantic similarity hypothesis*). A response was considered a semantic illusion when the illusory information was overlooked in the initial reading of the item, but the correct information was provided in a subsequent knowledge check. Results confirmed that semantic illusions occurred for all incorrect names (e.g., Moses, Abraham, Adam) that had some degree of semantic overlap with the target word (i.e., Old Testament, male). This effect did not occur for dissimilar/unrelated names (e.g., Nixon). Additionally, this pattern of results was reproduced using stimuli across a variety of subject matter. Although this outcome provides support for the semantic similarity hypothesis (Erickson & Mattson, 1981), subsequent research has shown that illusion effects can occur for word pairings with shared phonology (*Armstrong illusion*; Shafto & MacKay, 2000; 1998a; 1998b) or a combination of shared features (*Mega-Moses illusion*, Shafto & Mackay, 2000; Davis & Abrams, 2016). Taken together, this initial line of research suggests that the occurrence of semantic illusions is facilitated by similarities between the illusory word and the target information.

While other shared features may cause similar errors, *semantic* similarity between the target word and illusory word is a prerequisite for eliciting *semantic* illusions. Moreover, the strength of the semantic association between the target word and the illusory word has an influence on the occurrence and detection of semantic illusions. For example, a strong semantic association between the target and illusory word has been shown to decrease the likelihood of detecting the inaccurate information (Van Oostendorp & De Mul, 1990; Van Oostendorp & Kok, 1990; Anderson, 1983; Anderson, 1980) and semantic illusions occur more often when the illusory word is strongly related to the target word (e.g., Erickson & Mattson, 1981; Barton & Sanford, 1993). For example, an incorrect name that has more semantic associations in common with a target name (e.g., Abraham or Moses *wrt.* Noah) will elicit illusions more frequently than a related name with fewer associations (e.g., Adam *wrt.* Noah; Van Oostendorp & Kok, 1990). Furthermore, the strength of the underlying semantic associations affects how often semantic illusions occur. Stronger associations between the target and illusory concepts increase the rate of semantic illusions, and this effect occurs for both pre-existing associations and associations created/strengthened in the lab (Anderson, 1983;Van Oostendorp & Kok, 1990;). For example, Anderson (1983) showed that the frequency of semantic illusions increased after conceptual links between Moses and Noah's story were strengthened using a paired-associate learning task (e.g., *Moses-ark*, *Moses-animals*; Van Oostendorp & Kok, 1990; Anderson, 1983). In sum, both the quantity and strength of semantic associations shared by the target/illusory stimuli influence the likelihood of illusions.

In addition to semantic similarity between the target and illusory word, the surrounding contextual detail included in the text also influences susceptibility to semantic illusions. Reder & Kusbit (1991) examined whether increasing the number of details in the text (that are semantically associated with the target) reduced detection of the illusory information. They evaluated the effect of increased contextual detail on questions with the correct information (undistorted) and questions with errors (distorted). The results indicated that, for distorted questions, including more detail was associated with a greater frequency of semantic illusions compared to items with less detail. For example, when the target word was “bishop”, the illusory word “cardinal” was detected less in a high-context version, “What board game includes cardinals, rooks, pawns, knights, kings, and queens?” compared to low-context version, “What game includes cardinals and pawns?”. In contrast, the amount of contextual detail did not impact accuracy on undistorted questions. In summary, compared to less detail, including more contextual detail related to the target information is associated with an increased frequency of semantic illusions.

Hannon and Daneman (2001) extended the work by Reder and Kusbit (1991), to determine if (a) adding more semantic details related to the target word—not including the actual target/illusory term, increased the rate of semantic illusions; and (b) whether the effect of contextual detail on the rate of semantic illusions is independent from-- or interactive with, the effects of semantic relatedness between the target and illusory word. The authors also explored the role of individual differences in the cognitive abilities underlying the text-based and knowledge-processes that facilitate the resolution of semantic illusions, however those results will be discussed in a later section. The findings confirmed that increasing the semantic overlap between the target and illusory words resulted in more semantic illusions. And semantic illusions were more likely to occur when there were more contextual details semantically related to the target word in the sentence. More importantly, the two language-based manipulations did not interact but produced independent, positive effects on the occurrence of illusions. Although both language-related manipulations elicited a similar pattern of increased semantic illusions, the authors speculated that the underlying cognitive mechanisms associated with each effect are distinct (Hannon and Daneman, 2001).

Similar to contextual detail, the detection of illusory information can be influenced by the syntactic structure of the language and how it shifts the focus of the sentence (see *information structure*; Halliday, 1967; Jackendoff, 2002). Per the results discussed in the previous paragraph, the increase in semantic illusions for items with more detail is attributed to increased contextual cohesion (Reder & Kusbit, 1991; Hannon & Daneman, 2001). However, another supposition is that incorporating more words/information in the sentence diminishes the focus on the incorrect information (see *focalization effect;* Bredart & Doquier 1989; Wang, Hagoort, & Yang, 2009; Ward & Sturt, 2007; Wang, et al., 2013; Hannon, 2014). In other words, manipulating the focus of the sentence using language structures, such as "it"-cleft sentences or subordination clauses, can impact the likelihood of noticing incorrect/illusory information (Sanford, 2002; Sanford & Sturt, 2002; Baker & Wagner, 1987). Bredart and Modolo (1988) compared sentence structures that de-emphasize the incorrect information and it-cleft clauses that focally-centered the illusory information. For example, the sentence *"It was the ark, that Moses filled with…*" was predicted to result in more semantic illusions than the clause, "*It was Moses, that filled the ark with*…" Indeed, comparing both conditions showed that directing focus away from the incorrect information increased the likelihood of overlooking the error. In this example, the placement of the word in the sentence was probably contributing to the effect. Language constructions with the incorrect information towards the middle of the phrase result in more semantic illusions compared to constructions with the information near the start/end (Hannon, 2014; Ward & Sturt, 2007). Overall, the results suggest that language structures that make the illusory information less conspicuous elicit more semantic illusions than structures that highlight the incorrect information.

However, the use of shadowing by Shafto and MacKay (2000) complicates this explanation. For the semantic illusion task, a partial shadowing procedure was used in which participants silently read each item presented on the screen. Certain critical words including the illusory-target terms and semantically related details were repeated out loud by the participants after a slight delay. This was conducted to ensure their attention was focused and maintained long enough for the illusory word and contradictory associations to register. Additionally, if speaking the illusory terms out loud did not increase detection, it would suggest that despite saying the illusory word, participants were comprehending it as the target term. Indeed, that is what occurred, and detection was not impacted between semantic or phonological illusions regardless of the shadowing paradigm. This suggests that the effect of syntax from the previous section is not solely due to making the illusory term conspicuous. Within the same paper, Shafto and MacKay compared rate of illusions for semantic pairings (Neil Armstrong/Alan Shepherd), phonological pairings (Neil Armstrong/Louie Armstrong), a known-unrelated person to the target (Neil Armstrong/Dizzie Gillespie), and an unknown-phonologically-related person to the target (Neil Armstrong /Rick Armstrong). It was expected that illusion effects would increase with the unknown phonological name due to participants having no other information stored for that construct to clash with target context sentence. Results confirmed this effect, and it was considered supporting evidence to the suggestion that detection of the error is due to *novelty detection* (MacKay, 1990). Thus, account suggest that the anomaly will only be noticed if the incoming novel information that contradicts with stored semantic information are both activated in mind at the same time. In sum, although some syntax manipulations appear to increase semantic illusions by “hiding” the incorrect term, a more likely explanation is that the novel contradictory information and the store semantic information are not active in mind at the same time/long enough to become aware of the discrepancy.

Relatedly the processing demands associated with specific forms of syntax are a relevant factor in the occurrence of semantic illusions (Graesser, McMahen, & Johnson, 1994; Levinson, 1983; Erickson & Mattson, 1981). For example, Büttner (2007) investigated the effect of syntactic structure on the detection of illusory information. Detection rates were compared for conditions with illusory information in a statement versus a question. The statement items were constructed to be responded to as “True” or “False”, e.g., “The famous ship Titanic tragically sank in the Pacific [Atlantic] Ocean after hitting an iceberg.” The question items were open-ended and required retrieval of a response from memory, but participants were warned that some questions may not make sense; e.g., “What famous ship tragically sank in the Pacific [Atlantic] Ocean after hitting an iceberg?”. As anticipated, incorrect/contradictory information was noticed less frequently in the questions compared to the statements. Questions place a greater demand on the reader than statements because of the expectation to produce a response (Graesser et al., 1994; Fiebach, Schlesewsky, & Friederici, 2004).

A follow-up study replicated the results using multiple-choice questions instead of open-ended questions. The purpose of the replication was to ensure the disparities between syntax conditions could not be attributed to the cognitive demands associated with retrieval of information for the open-ended questions. The authors reasoned that the cognitive resources used to process and respond to the question leave less attention available to monitor for errors in the text. Using multiple choice questions may reduce the disparity in the number of cognitive resources needed between the statement versus question items, however, these differences were not completely ruled out as contributors to any effects found. In summary, syntactic structures that place greater demand on the reader, such as questions compared to statements, increase the occurrence of semantic illusions.

Overall, language-based features associated with how the illusory information is presented, influences the probability of noticing contradictory/illusory information (e.g., Bredart & Doquier 1989; Büttner, 2007). Semantic illusions occur when there are shared semantic features between the target information and the illusory word (Erickson & Mattson, 1981; Barton & Sanford, 1993) and the likelihood of a semantic illusion increases the more strongly associated the target word and the illusory word (Reder and Kusbit, 1991). Furthermore, the contextual details included, and overall language structure, also contribute to the frequency of semantic illusions. The inclusion of more details that are semantically related to the target information leads to greater contextual cohesion and removes the focus from the illusory information (Wang, Hagoort, & Yang, 2009; Ward & Sturt, 2007). Indeed, factors that minimize focus on the contradictory information by requiring a response from reader, often lead to an increased frequency of semantic illusions (e.g., Büttner, 2007; Graesser et al, 1994).

The language-based features discussed in the previous section influence how often semantic illusions occur, yet the strength of these effects may be dependent on individual differences in cognitive ability. From a developmental perspective, it is necessary to determine how age-related cognitive changes influence the rate of semantic illusions across the lifespan. Therefore, in the next section, the occurrence of semantic illusions will be considered with respect to age-related differences between young and older adults.

Semantic Illusions: Cognitive Aging

According to dual-process theories of cognitive aging, automatic processes remain intact into older adulthood, while controlled processes are impacted by age-related declines (Hess, 2015; Craik, 1986; Light, 1991). For example, vocabulary, familiarity with language structures, and crystallized intelligence remain stable or increase with age (Craik & Salthouse, 2011; Salthouse, 2006; Baltes, 1997; Baltes, Stauding, & Lindenberger, 1999; Horn & Cattell, 1967). In fact, older adults show considerable advantages over young adults for vocabulary and tend to be more accurate when assessing their own skill level and performance (Kemper & Sumner, 2001; Kavé & Halamish, 2015; Ben-David, Erel, Goy, & Schneider, 2015). In addition, older adults compensate for declines in controlled processes (e.g., WMC) with a greater reliance on automatic processes associated with prior knowledge/experience (Gordon & Kindred, 2011; Craik & Bialystok, 2006; Bowles & Salthouse, 2008; Hess, 1990). For example, Badham and Maylor (2016) compared young and older adults' recognition performance for sentences that were either consistent or inconsistent with prior knowledge. Compared to inconsistent conditions, when the sentences were supported by prior knowledge, the benefits to older adults' recognition were greater than for young adults. Some evidence suggests that age-related differences in memory performance can be reduced/eliminated by using prior knowledge strategically to contribute conceptually to episodic memories, such as using semantic associations among constructs to facilitate recall/recognition (Naveh-Benjamin et al, 2007).

Given the relationship between working memory capacity (WMC) and semantic illusions (Hannon & Daneman, 2001), it might be assumed that older adults' reduced WMC would automatically render them more susceptible to semantic illusions. For example, older adults show reduced performance on reading comprehension tasks compared to young adults, especially on tasks with more difficult language structures (De Beni, Borella, & Carretti, 2007;

Norman, Kemper, & Kynette, 1992; Federmeier, & Kutas, 2005). However, the limited data available suggests that the likelihood of *detecting* semantic illusions does not necessarily change across the lifespan (Umanath & Marsh, 2012; Dechêne, Stahl, Hansen, & Wänke, 2010). For example, Umanath (2014) compared young and older adults on a semantic illusions task, and found that the two age-groups were essentially the same in their ability to detect illusory information embedded in general knowledge questions.

However, eye-tracking data recorded during semantic illusion tasks illuminate some of the less evident age-related differences. Burton (2011) found that older and young adults had equivalent rates for detecting semantic anomalies in text. However, eye-tracking data recorded during reading provided more insight into age-related differences. For internally coherent anomalies that were easier to detect (Burton, 2011; Barton & Stanford, 1993), older adults were more likely than the young adults to detect the anomaly on the first pass (i.e., initial fixation), rather than on a subsequent pass (i.e., regressive fixation). Yet, compared to the young adults, older adults required more time and processing resources overall, as determined by eye fixations. It should be noted that detection rates for the difficult anomalies were extremely low, suggesting a floor effect. Another problem with the paradigm in Burton (2014) is that detection was tested indirectly and inquired about after the passage had been removed from the screen. This design undoubtedly disadvantaged older adults with age-related declines in episodic memory (Craik & Jennings, 1992; Light, 1991; Naveh-Benjamin, Guez, & Shulman, 2004). In fact, eye-tracking data indicates that there were cases when older adults noticed anomalies that were then not reported. Burton (2011) speculated that this could be due to the older participants forgetting the initial occurrence or intentionally overlooking an assumed “human error”. Participants were not warned to be aware of potential anomalies before the task, as is typically done in this area of research. Taken together, these results suggest that older adults may be better than young adults at initially spotting illusory information, but other age-related deficits may prevent full awareness/resolution of the error.

Relatedly, young, and older adults may detect illusory information equally often, but there is evidence to suggest that older adults *fail* to detect semantic illusions more frequently than young adults. Umanath, et al. (2012) found that, although the age groups had equal detection rates, older adults failed to detect the contradictory information that contradicted their prior knowledge more frequently relative to young adults. Older adults experienced more semantic illusions than young adults, despite outperforming them on the knowledge check afterwards. At face value, it may seem contradictory that older adults could detect anomalies equally as often as young adults, but fail to detect more often than young adults. It should be noted that some research in this area may not include a knowledge check or may operationally define "detection" versus "semantic illusion" slightly differently. However, for the current study and other previous studies, to qualify as a "semantic illusion", the correct information must be provided on the knowledge check afterwards. Given this operational definition, having more knowledge compared to less, would increase the chances of detecting more anomalies, but also provides more opportunities to overlook the errors. Thus, it is quite possible to both detect and fail to detect anomalies more often than others, simultaneously, or even in conflicting directions. Interestingly, the authors also determined that older adults suffered fewer memorial effects from the semantic illusion task. These occur when a participant is exposed to illusory information, and later provide the incorrect information as a sincere response on a subsequent task (Umanath & Marsh, 2012). Older adults are less likely than young adults to repeat the contradictory information they encountered during a semantic illusion task as a response afterwards. In that sense, according to Umanath (2014; Umanath & Marsh, 2012) older adults' increased crystallized intelligence served as a protective factor against contamination from the contradictory information. Still, it is unclear why this effect does not similarly occur for preventing semantic illusions.

Another potential outcome is the effect age differentially impacts performance, depending on the difficulty of the text and the type of error being detected. Shafto (2015) compared young and older adults in their accuracy to find and correct proofreading errors in difficult, expository passages and easy, narrative passages. Errors included spelling errors, grammatical errors, or meaning errors. The results indicated that in general, the detection of errors within a passage was more difficult than correcting the error, accurately. Overall, older adults were equally accurate as young adults for detecting spelling errors, but were less accurate than young adults for correcting spelling errors. However, older adults performed less accurately than young adults for detecting and correcting both, grammatical errors and meaning errors, especially for difficult passages versus easy. The author attributed these results to the fact that detecting more surface-level details, like spelling errors, is mostly an automatic visual process (e.g., Stine-Morrow et al., 2004). However, assessing the accuracy for grammar and even more so, meaning, requires integration of the text and is a more deliberate, effortful process. Finally, these patterns remained consistent even after controlling for level of vocabulary, thus the results extend beyond just effects of word knowledge.

In sum, the evidence suggests that there are not necessarily age-related differences in the detection of anomalies/illusory information between young and older adults, yet there may be differences in how frequently older adults experience semantic illusions compared to young adults (Salthouse, 2006; Luo, & Craik, 2008; Hannon & Daneman, 2001; Umanath et al., 2014).

Additionally, older adults are differentially disadvantaged compared to young adults, in that they are less accurate at detecting and correcting grammatical and meaning errors in difficult passages. Additional research is needed to better understand the interplay between knowledge and the detection or failures to detect errors.

In addition to being less susceptible to contradictory information, there is some evidence that older adults are less likely to misattribute memory for unrelated details as evidence of familiarity with the target information. Parks and Toth (2006) found that for young adults, memory for details unrelated to a word's meaning (e.g., location of a word on the screen), increased the perceptions of familiarity with the target word. This effect was true even when young adults did not accurately classify the target word as "previously seen" in a recognition test. In other words, the perception of familiarity was a poor predictor of recognition accuracy because it was misattributed from other influences. Older adults on the other hand, had lower ratings of familiarity overall and their memory for non-critical details about the target word did not inflate feelings of familiarity to the point of inaccuracy. The illusion of familiarity is believed to be reduced in older adults due to reductions in episodic memory; older adults often do not have accessible memories for the recent events/misinformation enough to contaminate of their prior knowledge or perceptions of familiarity (Souchay, Isingrini, & Espagnet, 2000). Older adults are less likely than young adults to use information they read recently to answer associated questions; and instead rely on prior knowledge (Marsh, Balota, & Roediger, 2005; Parks & Toth, 2006). Likewise, older adults show less effects from reading misinformation compared to young adults during subsequent knowledge checks, especially if the questions could be answered using their superior crystallized intelligence (Marsh et al., 2005). Overall, older adults' reduced episodic memory and increased crystallized intelligence combine to reduce susceptibility to misinformation and to prevent contamination from outside influences on perceptions of familiarity with information. However, it seems increased crystallized intelligence could only facilitate preventing semantic illusions, if there was first a way to increase the odds of the individual first noticing the contradiction.

Perhaps understanding and comparing the process of detection between age groups could be understood better by examining the role of individual differences in other cognitive variables (e.g., fluid intelligence, reading comprehension) alongside experimental results for detection of semantic illusions For example, Burton (2011) found that when reading semantic anomalies, eye-tracking data showed that older adults often fixated on the anomaly sooner than young adults but required considerably more time and eye movements (i.e., processing demands) to achieve equivalent detection rates. This implies a potential cognitive trade-off or compensatory mechanism whereby older adults may be able to detect more semantic illusions than young adults if the context allows them to leverage their superior crystallized intelligence, and at the same time, minimizes the potential negative impact of age-related disadvantages. Individual differences in related cognitive variables will be revisited and discussed in a later section.

The following two sections introduce a theoretical framework and review relevant literature relating to those perspectives before returning to the discussion of semantic illusions. Although the study results will be described in more detail in later sections, motivations for the following portions were based on findings from Mata et al. (2014) that overcoming biases on reasoning problems (e.g., syllogism, base-rate problems) to produce the right answer was positively correlated with detecting anomalies on a semantic illusion task. First the theoretical framework will be described within the context it was developed, reasoning and decision-making. Next, semantic illusions will be revisited from that perspective, “Semantic Illusions Revisited: Dual-Process Theory and the Effect of Fluency” for more details about the study.

Dual Process Theory

A theoretical framework to help situate research on semantic illusions is *Dual-Process Theory* (Sloman, 1996; Kahneman, 2011; Stanovich & West, 2000). Dual-process theory was initially proposed to explain cognitive biases in reasoning and decision-making (Kahneman, 2000; Tversky & Kahneman, 1973; Kahneman, 2011; Stanovich & West, 1998). According to the theory, there are two cognitive systems underlying thinking and reasoning (fast and slow): (a) *Type 1*: automatic, easy, fast, heuristics-based; (b) *Type II,* deliberate, analytical, slow, resource-consuming (Stanovich & West, 2000; Evans, 2006; Kahneman, 2011). Stanovich and colleagues developed the *Comprehensive Assessment of Rational Thinking* (CART; Stanovitch, 2016) to test predictions of dual-process theory and measure people’s ability to override automatic biases/heuristics and engage in more deliberative thinking. Based on work with the CART, Stanovich (2013; 2016) suggests that a shift to Type II thinking requires engagement of WMC and “cognitive decoupling”, which allows for more careful, intentional thinking strategies to be employed when reasoning (Stanovich, & Toplak, 2012). Cognitive decoupling involves the suspension of real-world knowledge to engage with rules of a task, such as assessing a syllogism as logically valid even when it is not real-world believable. When a task becomes challenging or effortful, an automatic shift to Type II thinking is initiated to facilitate more effortful cognitive strategies that foster more methodical approaches to problem solving and decision-making.

It should be noted that for Type 1 and Type II thinking there is no inherent valence, such that Type II engagement guarantees a correct or good answer, nor that the intuitive Type 1 answer is always biased or incorrect (Oaksford & Chater, 2007; Stanovich, 2009). These cognitive paths describe two types of cognitive engagement when thinking (automatic versus deliberate) and both can produce correct and incorrect answers. Although, Type II engagement is often associated with a greater likelihood of accuracy due to the use of more effective strategies for problem solving (Kahneman, & Tversky, 1977; Kahneman, 2003); yet even the best thinking cannot retrieve a correct response if the information and/or previous experience is not available.

According to this perspective, reasoning problems are not toiled with long enough to trigger a shift into Type II thinking, and the initial response provided is typically rooted in automatic heuristics and biases (i.e., the intuitive response; Stanovich & West, 1998; Stanovich & West, 2000; Tversky & Kahneman, 1973). For example, from the heuristics and biases literature, the occurrence of semantic illusions is consistent with the characterization for "errors of application" (Kahneman & Tversky, 1996). These errors occur when the correct knowledge to solve a problem is available in long-term memory, but not applied to the problem at hand to resolve the issue. Further exploration into the shift to more deliberative thinking patterns that allow for application of prior knowledge is needed to understand the circumstances in which it is typically neglected.

Overall, dual-process theories describe two cognitive patterns of problem-solving that are characterized by different approaches to obtaining response, and often produce different outcomes as a result. The shift from Type I to Type II thinking not only facilitates more methodical thinking patterns but increases the likelihood of obtaining a correct response to challenging items (Sloman, 1996; Kahneman, 2011; Stanovich & West, 2000). The following section will explore the influences that enable the unconscious selection of either trajectory.

Feelings-as-Information Framework and Processing Fluency

Reasoning/rationality problems are designed to create a conflict between common heuristic-based resolutions (Type I) and more effortful, formulaic approaches (Tversky & Kahneman, 1973; Kahneman, 2011; Tversky & Kahneman, 1989).To understand why an intuitive answer is frequently provided, it is necessary to examine the subjective experiences that occur when retrieving a response. The *feelings-as-information* theory (Schwarz, 1989; Schwarz et al., 1991) posits that the subjective emotional experiences that coincide with processing are used as sources of information when making judgements about our thinking. Reliance on subjective experiences as a heuristic is associated with the ease with which the relevant information is processed or retrieved, also known as processing fluency (Schwarz, 2004; Alter & Oppenheimer, 2009). Stimuli that are processed or retrieved with greater fluency is often interpreted as an indicator of the accuracy or truthfulness for the information, even if uninterrogated for true legitimacy. In general, the subjective feelings that are experienced while processing information affect our assessment of that information, and this includes feelings of confidence in its accuracy or truthfulness.

Relatedly, Thompson, Turner, and Pennycook (2011) explored how processing fluency influenced the level of confidence in a retrieved response (i.e., feelings of rightness), with respect to dual process theory. First a conflict between Type I and Type II thinking was initiated for the stimuli using conditional reasoning, base-rate problems, and syllogistic reasoning. Researchers intentionally triggered a "Type 1 response" by instructing participants to respond as quickly as possible with the first response that came to mind. After rating their confidence for the initial response, participants were then given unlimited time to rethink and change their answers if desired ("Type II response"). Processing fluency, measured by the speed with which the response was produced, was found to have a positive association for confidence regardless of accuracy. Responses with increased fluency were rated with higher confidence, and less likely to be corrected during the given the opportunity. The less-fluent responses were not only rated with less confidence, but were more frequently replaced with a new response compared to items rated with high confidence. Moreover, a key finding is that the subjective experience of confidence was not relevant to accuracy, and responses that were updated were just as likely to be incorrect as correct. Overall, the subjective feelings that coincide with fluent processing are often used as a heuristic for assessing how confident one should be in the accuracy of the information, often irrespective of true accuracy.

Fluency, Familiarity, and Perceived Validity

The associations between fluent processing, and the subjective experiences used to make judgements about our thinking, are well demonstrated when it comes to familiarity. Familiarity is experienced when the subjective experiences that coincide fluent processing are unconsciously attributed to previous experience with the stimuli (e.g., Jacoby, 1983, 1981; Wagner & Gabrieli, 1998). Information that has been processed on previous occasions is processed with greater speed and ease than new information, producing the sensation of being “familiar” (Pikulski & Chard, 2005; Nunes, Ordanini, & Valsesia, 2015). However, the converse can also occur, and increasing the fluency of processing, for example with priming, can foster that same sense of familiarity for even novel stimuli (Whittlesea, 1993; Unkelbach, 2007). This outcome distinguishes the construct of familiarity from recollection/recognition, as the unconscious process of attributing familiarity is not necessarily based on existing implicit/explicit memory for the stimuli. Prior exposure facilitates feelings of familiarity when recognizing known stimuli due greater representativeness or availability for those items in mind (Tversky & Kahneman, 1973; Unkelbach & Rom, 2017). The familiarity heuristic can be seen in errors such as the tendency to overestimate the probability of an event occurring or the amount of people in a crowd, if they have recently been exposed to the event or recognize famous faces among the crowd (Tversky & Kahneman, 1973; Whittlesea & Williams, 2001). In these scenarios, rather than using any relevant information to calculate the true probability or crowd size, the inaccurate response reflects heuristics-based thinking grounded in the accessibility or focus on that information. The affective information, not necessarily rooted in any evidence of validity, is used to make a judgement in place of applying prior knowledge, experience, or effortful calculations.

Relatedly, there is a robust effect of familiarity on perceptions of accuracy or truthfulness for information. In a meta-analysis, Dechêne et al., (2010) found across multiple studies, that manipulating familiarity for information influences how truthful the information is perceived to be. Increased familiarity induced by repeated exposure resulted in higher ratings of truthfulness and accuracy compared to novel, unfamiliar information. The results suggest the affective experience of familiarity seems to be somewhat perceptually conflated with the confidence felt for accuracy (i.e., *feeling of rightness*; De Neys & Franssens, 2009; Thompson, 2009; Arkes et al., 1991). However, there is also evidence that the familiarity heuristic may require more than just repeated exposure to the stimuli. Boehm (1993) had participants, with and without prior knowledge on the topic, rate their familiarity and perceived validity for statements they had been presented more than once. Only participants with knowledge and experience with the subject matter prior to the study, had positive associations between their ratings of familiarity and perceived validity of the statements. In other words, repeated exposure to the statements was not enough for participants to associate familiarity with the perceived accuracy of the information. The relationship only occurred when there was foundational basis of stored memories in long-term memory for the information. The authors interpreted these outcomes to mean the use of familiarity as an indicator of accuracy/validity is more about the subjective experience that occurs with recognition of known information (e.g., Unkelbach & Rom, 2017). There is pre-existing experience processing the information in that past and unconsciously recognizing the information as familiar is misinterpreted as evidence of truth.

In summary, the subjective experiences associated with how fluently information is processed and retrieved impacts our assessment of that information (Schwarz, 1989; Schwarz et al., 1991; Alter & Oppenheimer, 2009). Familiar information is processed and retrieved more fluently and in turn, is perceived as more truthful and accurate than unfamiliar information Jacoby, 1983; Dechêne et al., 2010). However, these associations operate in the converse manner, and manipulating processing fluency can also influence perceptions of familiarity and accuracy (Whittlesea, 1993; Schwarz, 2004; Gill, Swann Jr, & Silvera, 1998). The following section will revisit semantic illusions within the context of the research discussed in the previous section.

Semantic Illusions Revisited: Dual-Process Theory and the Effect of Fluency

Applying the research reviewed in the previous section to the occurrence of semantic illusions may offer an alternative perspective as the occurrences of these errors. Previous research indicates that familiarity at times is used as a heuristic for validity (Tversky & Kahneman, 1973). Given that semantic illusions are defined as overlooking known information, it would follow that the familiarity felt for the subject matter could be misattributed for accuracy (Whittlesea, 1993; Unkelbach, 2007). As discussed previously, the semantic overlap between the target word and illusory word replacing it, combined with any semantically related details in included, provide enough conceptual cohesiveness to facilitate this effect (Erickson & Mattson, 1981; Hannon & Daneman, 2001). These factors suggest that disrupting the cohesiveness would facilitate detecting the error, consistent with similar findings that reduced fluency has a negative relationship with subjective appraisals of familiarity and validity (Whittlesea, 1993; Unkelbach, 2007).

Indeed, Fazio et al. (2015) assessed the tradeoff between fluency and prior knowledge when assessing the validity of known falsehoods (i.e., false statements for which participants know the correct information). The authors compared for best-fit to the data, two multinomial models: The knowledge-conditional model assumes that, when encountering the items, participants first search their memory for relevant information. If none is available, participants will fall back on the fluency of the statement to determine validity. The fluency-conditional model assumes the inverse, and that participants automatically rely on fluency for validity; only if the fluency is disrupted do participants search their memories for relevant information. Only the fluency-conditional model replicated the patterns in the data appropriately, and confirmed the dual process interpretation offered by Fazio et al. Fluency, and the feelings associated with it, is an automatic process that guides initial assessments of validity. Only if fluency is disrupted, does the more deliberative process initiate, to search and retrieve any relevant information in LTM.

However, there is scant research examining semantic illusions in which processing fluency is manipulated to affect detection, and the available research is somewhat mixed. For example. Song and Schwarz (2008) examined the role of processing fluency in the detection of contradictory information. Using a standard semantic illusion paradigm, participants were presented with statements containing illusory names written in either easy- or difficult-to-read font. As anticipated the disruption of processing initiated from the difficult font facilitated the detection of the error and reduced the occurrence of semantic illusions. Song and Schwarz (2008) replicated this effect in a second experiment using different stimuli and again demonstrated that the more difficult font reduced the rate of semantic illusions compared to font that is easier to read (see also Song, 2009). Alter (2013) discusses these outcomes as an example of the cognitive benefits of reduced fluency. Disrupted processing due to a difficult font creates what Alter refers to as a "cognitive roadblock". The additional effort needed to overcome the difficulties facilitates deeper processing and this analytical approach leads to a greater likelihood of spotting errors (Alter et al., 2007).

However, more recent research has revealed that using visual characteristics, such as font appearance, to manipulate processing fluency may not produce consistent effects. Janouskova et al., (2022) were unable to replicate the effect from Song and Schwarz (2008; Song, 2009) despite using the same stimuli and instructions. However, due to the study materials and overall design the results should be interpreted with caution. The materials included only two semantic illusion items (and two filler items), and both were biblical stories; the original Moses question and the another about Jonah and the whale. Obviously, not everyone is familiar with stories from Judeo-Christian scripture, and alternatively, the specific "Moses Illusion" example could be used too frequently in popular culture to be effective. Furthermore, the illusory effect would seem more robust if it were elicited across multiple items of varying subject matter.

Another problematic detail, the comparison between the difficult-to-read versus easy-to-read font conditions were between-subject, so participants only saw one font style. Not only would using a within-subject comparison increase the power of the study design, but it would also be consistent with research suggesting *relative* fluency is impactful, not absolute. Wänke et al., (2015) describes this phenomenon, the change or shift from effortless to effortful is what makes an impact on processing fluency due to the expectations held. For example, with the associations between fluency and familiarity, novel high-fluency words are only rated as more familiar when there are also novel low-fluency words with which to make comparisons for the ease of processing (Whittlesea & Williams, 1998). Similarly with the relationship between fluency and perceptions of truth/accuracy, high-fluency items are rated as more truthful when the fluency level deviated from the items that preceded it (i.e., were low-fluency). Finally, the original study by Song & Schwarz (2008) was conducted 15 years prior to the study from Janouskova et al., (2022). It seems possible within that timeframe that people have become more accustomed to reading various font styles, including less legible ones, due to increases in the cultural emphasis on online content.

Overall, although Janouskova et al., (2022) were not able to replicate the effect of reduced processing fluency for detection of semantic illusions, the methodological issues yielded speculation about the true reliability of the outcomes. The authors stated that manipulations to processing fluency are not effective if the difficulty is not taxing enough on cognitive processes to disrupt processing. Additionally, there is evidence that using visual distortions can influence the subjective experiences associated with processing fluency (e.g., judgements of learning), but do not necessarily offer enough impact on processing to improve tasks performance (e.g., memory; Yue, Castel & Bjork, 2013). In other words, a manipulation of processing that has greater depth than just surface-level details or appearance may be more effective in impacting detection of illusions, beyond font that is difficult to read. The following section will briefly review some other manipulations to processing fluency involving characteristics to the text or language structure.

Language-based Manipulations of Processing Fluency

Fluency has been described as the difference between anticipated ease or difficulty, and the actual level of difficulty experienced when processing or retrieving information

(Oppenheimer, 2008; Whittlesea & Williams, 1998). However, an important aspect to consider is that fluency can serve as a metacognitive cue in both a direct and indirect manner (e.g., Shah & Oppenheimer, 2007). For example, words that are easier pronounce are often rated as more familiar regardless of actual novelty/experience (Whittlesea, 1993). In this example, the fluency of the word directly impacts the perception or judgment of the word. However, the indirect cueing process is a bit more complex, in that it does not directly affect the judgement but the approach to resolving the problem. For example, Alter et al., (2007) compared favorability for product advertisements that were either written in fluent or disfluent font conditions. Every advertisement contained elements that could encourage a heuristic-based strategy for assessing the product (i.e., seller's appearance), or a systematic-based strategy (i.e., detailed description of product features). For conditions that were disfluent, participants preferred systematic approaches for making decisions about the product. But when it came to the heuristic-based strategy option fluency was not relevant. Overall, the authors interpreted this to mean that disfluency or disrupted processing fluency can serve as an indirect cue to engage in more systematic or analytical thinking strategies to resolve a problem.

Other than visual acuity associated with font readability, there are other examples of indirect fluency manipulations that serve as indirect influences on processing, beyond surface-level appearance of the text (Alter et al., 2007; Shah & Oppenheimer, 2007; Alter & Oppenheimer, 2008). For example, language structure has also been shown to influence performance for both semantic illusions (e.g., Neil/Louie Armstrong) and reasoning problems (e.g., bat and ball problem). Deckert (2015) manipulated the "conventionalism" of the language structure for semantic illusion and reasoning items. The fluent condition contained commonly used conventionalisms, "What was Louis/Neil Armstrong's *famous line*…". While the disfluent condition used low-frequency phrasing “What was Louis/Neil Armstrong’s *memorable phrase*…”. For both semantic illusion item and reasoning problems, the fluent condition resulted in greater detection of the error and correct solutions to the problem. Although this was in the opposite direction as anticipated, the author concluded the awkward phrasing may have distracted participants from noticing the error, and was not difficult enough to facilitate greater effort for the task. Regardless, this and other recent examples have demonstrated that language structure, including syntax can be used to manipulate processing fluency. Furthermore, as with Mata et al., (2014) semantic illusions seem to elicit congruent effects as reasoning problems when language structure is manipulated, supporting the use of dual-process perspective to understand both phenomena.

Other examples of language-related manipulations of processing fluency includes the use of sentence context and semantic relatedness (Fazendeiro et al., 2005; Whittlesea, 1993). Sentences with greater conceptual or semantic fluency are perceived as more familiar than sentences that less have weaker semantic associations among the sentence contexts. For example, sentences were more likely to classified as “seen previously” if conceptual fluency was manipulated such that the sentence context strongly predicted the final word compared to just being consistent with it. For example, even if both sentences are novel “The storm tossed the (boat)” was more likely to be classified as seen previously than “he saved his money to buy a (boat)”. Although the word is consistent with both sentence contexts, when there is greater semantic relatedness between sentence context and the final word, it produces a stronger sense of familiarity. Relatedly, when processing fluency is manipulated by language complexity, it can also influence perceptions about the information (Shulman et al., 2022). For example, voters are less likely to believe and endorse voting initiatives if self-reported processing fluency is disrupted with increased language complexity via word difficulty compared to legislative initiatives that use less difficult language.

However, the effect of language complexity on perceptions of the information via processing fluency may not be consistent across different types of complexity. For example, Tolochko et al (2019) examined how increased semantic and syntactic complexity influenced the recall for the knowledge presented in political advertisements. Increased semantic complexity decreased recall of the factual knowledge included in the advertisement, but did so indirectly, and the relationship was mediated by the perceived difficulty on processing fluency. In other words, participants were aware of the increased difficulty in understanding the message, and these perceptions contributed to the reduced recall. Conversely, increased syntactic complexity directly reduced the amount of factual knowledge recalled from the advertisement, despite participants being unaware of the increased structural complexity on processing fluency. Overall, this suggests that increased language complexity can both indirectly and directly influence memory or understanding of the information being processed; and perceptions of our own thinking at times can serve as a mediating variable between complexity and performance outcomes depending on conditions. Another important takeaway is that increased syntactic complexity can influence memory and understanding for information, outside our awareness of its impact, but the influence of semantic complexity is more obvious. In other words, increased language complexity and perceptions of complexity can both influence our understanding of the information, but syntactic complexity is more likely not to go unnoticed (O'Keefe, 2003).

Previous research has shown the successful use of syntax to manipulate processing fluency. Stromswold et al. (1996) compared judgments for semantic plausibility of sentences in both complex (i.e., middle-branching) and simple syntax conditions (right-branching). As expected, it took more time and effort to process and accurately assess the semantic plausibility of the complex syntax sentences compared to simple syntax sentences. These findings are a corollary to the previously discussed Song (2009; Song & Schwarz, 2008) results. Increasing processing difficulties, via difficult-to-read font, promotes the detection of semantic illusions compared to easier-to-read font. Given that many people use fluency as an evaluative cue (Tversky & Kahneman, 1973), increasing syntactic complexity enough to cause disruption of processing fluency could facilitate greater awareness of illusory information.

Syntactic structures that are more complex compared to standard right-branching sentences, such as left-branching sentences or middle-branching sentences, reduce processing fluency due to an increased burden on working memory (King & Just, 1991; Just & Carpenter, 1992). Left-branching sentences have considerable information presented prior to the subject of the sentence, so individuals must *wait and see* before knowing what the sentence is about (e.g., "Consistent with his flying experience the month prior, Ben's palms were already sweaty". Scott, 2009). This type of sentence is more difficult to read and understand, compared to standard right-branching sentences, because holding words in mind that came prior to the subject places a greater demand on WMC. Indeed, children and older adults often struggle with left-branching sentences, due to the overload on working memory (Anderson & Davison, 1988; Craik & Jennings, 1992; Light, 1991). Furthermore, during processing of left- and middle-branching sentences, working memory is required to mentally rearrange several words to determine the meaning of the sentence. Reading comprehension, particularly online sentence processing, is dependent on WMC (Miyake, Carpenter, & Just, 1994; Just & Carpenter, 1992). As such, syntactic structures that particularly tax working memory should be more likely to require enough effort to promote a shift to Type II thinking. Given previous findings showing that complex syntactic structures are particularly difficult for people with age-related decline in working memory capacity and reading comprehension (Norman, Kemper, & Kynette, 1992; De Beni, Borella, & Carretti, 2007; Anderson & Davison, 1988); it is possible increased syntactic complexity could promote shifts to Type II deliberative thinking strategies more frequently for older adults compared to young adults.

Due to a dearth of research specifically examining how the manipulation of processing fluency influences the detection of illusory information; the potential cognitive processes underlying these occurrences will be further explored in the following section. Individual difference factors have not been frequently explored in relation to semantic illusions, so for certain cognitive abilities the closest relevant research will be discussed. It should be noted that many of these variables were included in the current study due to availability, as part of a larger study being collected alongside this study. Certain cognitive variables were only included due to being available and not by design, so investigations of these effects are not necessarily firmly grounded within a theoretical framework or an extensive history of empirical evidence. The exploration of individual differences on semantic illusions was largely an exploratory, data-driven process permitted by having accessible variables. Thus, at times, there is minimal relevant research to present for certain constructs in this context and/or not enough information to make specific predictions or to confirm any specific theoretical implications.

Semantic Illusions: Individual Differences

As mentioned previously, Hannon and Daneman (2001) replicated two distinct language-based effects on semantic illusions: (a) increasing the semantic overlap between the target information and the illusory information increases the likelihood of semantic illusions; and (b) including more contextual details related to the target information increases the likelihood of semantic illusions. An additional goal of their study was to examine how individual differences in knowledge-based processes and text-based processes interact with language structure to influence the detection of semantic illusions. Knowledge-based processes include access and retrieval of relevant information stored in memory; these processes were measured using a *Knowledge Access Measure* created by the authors (see Hannon & Daneman, 2001; Kintsch, 1988; Erickson & Mattson, 1981). Text-based processes refer to the integration and manipulation of incoming information with existing knowledge structures. The working memory span task, reading span, was used to assess text-based operations (see Just & Carpenter, 1980).

Hannon and Daneman used orthogonal condition comparisons and both text-based and knowledge-based processes were more/less predictive of avoiding semantic illusions, depending on other conditions. In conditions with a high degree of semantic similarity between the target word and illusory word, knowledge-based resources were necessary for retrieval of the correct word to facilitate detection. For those conditions, performance on the knowledge access measure was the best predictor of detection of the illusory terms. In conditions with a high amount of contextual detail related to the target word, text-based processes were required to integrate incoming and stored information for comparison to notice the contradiction. For those conditions, WMC was the best predictor of detection of the illusory information. The authors attribute these effects to the necessary recruitment of certain processes depending on the conditions or tasks at hand. Knowledge-based processes facilitate the accurate retrieval of the correct word/information whereas text-based processes facilitate the integration of incoming details with prior knowledge.

This pattern of individual differences is intriguing. However, other than the work of Hannon and Daneman (2001), there is very little research on individual differences in cognitive abilities and semantic illusions. The next few sections will therefore review literature concerning individual difference factors that are expected to influence semantic illusions.

Working Memory Capacity (WMC)

Results from Hannon and Daneman (2001) suggest that when illusory information is embedded within rich contextual detail, greater working memory capacity (WMC) is associated with the detection of illusory information or misinformation (see also Hannon, 2012). The authors discussed the role of working memory in detecting illusory information, such as maintaining a representation of the sentence in mind to detect discrepancies. To confirm the role of WMC for detecting illusions and misinformation, Bütner (2012) compared the detection of semantic errors for a single-task control condition versus a dual-task condition. In the dual-task condition, a secondary, concurrent task, such as articulatory suppression or random-number generation, was performed in addition to the semantic error task. Compared to the single-task condition, the rate of semantic illusions was higher in the dual-task conditions (e.g., Laurieguaderie et al., 1998). Thus, for successful detection of semantic illusions, WMC plays a necessary role in the integration of incoming information with existing knowledge structures for evaluation. Thus, it could be assumed that reductions in WMC, due to task load or natural variability, would be associated with an increased likelihood of overlooking illusory information.

Individual differences in cognitive abilities may contribute to the detection of semantic illusions via the role of WMC in online [sentence] processing (e.g., Just & Carpenter, 1992; King & Just, 1991). For example, increased verbal WMC is associated with the use of *integrative* language strategies for comprehension, such as reexamining an entire sentence for clarifying contextual cues (Kim, Oines, & Miyake, 2018; Nakano, Saron, & Swaab, 2010; Bornkessel, Fiebach & Friederici, 2004). Conversely, decreased verbal WMC is associated with cognitive strategies that focus solely on information that is inconsistent with prior knowledge. For example, repeatedly re-reading a difficult or contradictory word, but ignoring the context of the full sentence. The use of integrative reading strategies that emphasize the global context, rather than an incongruent detail, is associated with greater language proficiency (Tanner, McLaughlin, Herschensohn, & Osterhout, 2013). Furthermore, strategies that facilitate a global understanding of the text are more effective for catching semantic discrepancies between the overall sentence context and individual words. In sum, the limited available data suggests that WMC underlies many of the important processes that are necessary in detecting illusory information (Hannon & Daneman, 2001; Büttner, 2012; Tanner et al., 2013). Greater WMC is associated with the ability to integrate information with current knowledge to spot discrepancies, and with better language proficiency overall.

Reading Comprehension

One issue that adds to the complexity of studying semantic illusions is delineating the individual sources of variability from the many underlying cognitive processes involved in reading performance. Broadly speaking, processing information that contradicts prior knowledge reduces reading comprehension performance across all reading skill levels (e.g., Cook, Halleran, & O'Brien, 1998). This is apparent when comparing the processing times for information that is consistent versus inconsistent with prior knowledge (i.e., *inconsistency effect*; Isberner & Richter, 2013; Albrecht & O'Brien, 1993; Cook, Halleran, & O'Brien, 1998). However, for individuals with reduced reading comprehension skills, performance is particularly diminished when processing contradictory information (Cook & O'Brien, 2014; Cook & Gueraud, 2005).

Additionally, individuals with reduced reading comprehension skills do not detect illusory information/misinformation as frequently as more advanced readers (e.g., Hannon & Daneman, 2004; Hannon, 2014; Long & Chong, 2001, Todaro, Millis, Dandotkar, 2010).

Several cognitive mechanisms have been hypothesized to explain the disparity between less advanced and more advanced readers in detecting contradictory information. Long and Chong (2001) suggest that less-skilled readers overlook contradictory information more frequently than more skilled readers due to poor text integration (see previous WMC section). If incoming information is not fully integrated with prior knowledge, then information from memory is not available for comparison. Alternatively, Todaro et al. (2010) attribute the disparity to less-skilled readers reliance on semantic-relatedness for global comprehension of the text. If comprehension is based on associations then any semantically related word could replace the target word without affecting contextual cohesion. According to this perspective, more-skilled readers understand via causal-relatedness and associations between action and outcome. This framework is less amenable to overlooking a semantically similar replacement word, from which the causal sequence of events/actions did not occur. Finally, it is important to note that these perspectives are not necessarily in opposition with one another, nor with the previously reviewed research. The logic would follow that detection of illusory information requires input from multiple cognitive processes, and is simultaneously influenced by many language-based characteristics.

Crystallized Intelligence

As mentioned, Hannon and Daneman (2001) showed that increased access to information stored in long-term memory (LTM) is positively associated with the detection of illusory information. The *Knowledge Access Measure* was used to measure the ease/accuracy of retrieval of information stored in LTM. Participants were given passages to read and then asked questions that intentionally could not be answered with the information in the text. Rather, the correct response required reasoning among multiple sources of prior knowledge. Results indicated that ease of access to information in LTM was particularly important when the target and illusory word were highly similar (in conditions with low contextual detail). However, having greater knowledge does not guarantee detection of illusory information, or prevent occurrences of semantic illusions. Although increased crystallized intelligence does not always prevent overlooking illusory information, having more knowledge at least increases the odds of detection. Having the correct knowledge is the most basic requirement for noticing contradictory information. The fact that it is not a guarantee suggests that there is more than one factor contributing to overlooking contradictory information and neglecting prior knowledge. More research is needed to identify which variables, and in what conditions, prevent or facilitate the use of correct knowledge.

There are several perspectives as to why having relevant knowledge does not always prevent overlooking illusory or contradictory information (Umanath & Marsh, 2012; Umanath et al., 2014). One perspective is that during initial processing of the illusion, there is a clash between the context of the text (i.e., episodic memory) and prior knowledge (i.e., crystallized intelligence; Cook & O'Brien, 2014; O'Brien & Cook, 2016; Williams et al., 2018). Cook and O'Brien (2014) used the location of the word within a sentence containing a semantic illusion to determine when the deleterious effects on reading performance are experienced. It was expected that if related contextual details were presented near the illusory information, it would not allow for enough time for retrieval of prior knowledge to conflict with information right away. Thus, the contextual details would predominate the initial processing of the text and effects of the contradiction would occur later. This was reflected in the diminished reading performance occurring after a delay, rather than immediately (Williams et al., 2018; Myers et al., 1994). Comparatively, contextual details placed far from the illusory information were expected to have degraded by the time the illusory information is processed. This frees up resources for immediate retrieval of any stored knowledge that contradicts the illusory information. In that case, the processing difficulties are experienced immediately, rather than after a delay. These effects occurred even when of participants were unaware of the discrepancy or the impact on reading performance. These outcomes indicate that the presentation and timing of the illusory information can affect the influence of prior knowledge depending on processing demands. In other words, the fact that contradictory information is not always noticed immediately could be dependent on the when or in what proximity to, the information is presented/processed.

It is unclear if prior knowledge may at times prove to be a hinderance when it comes to confidence in a response or overall assessments of our own knowledge. For example, Arkes et al. (1989) found that only individuals who claimed they had prior knowledge in the area, misattributed familiarity as evidence of truth. For individuals with no prior related knowledge, repetition was not enough to induce the familiarity-as-truth effect. However, Fazio et al. (2015) offered an alternative perspective on this outcome. The "prior knowledge" measure in Arkes et al., (1989) was only a self-report measure inquiring if the individual had *related* knowledge in the subject area. The study did not assess the actual knowledge each participant had, nor whether they had the exact knowledge needed in the study. The authors concluded that having related knowledge allowed for enough familiarity to feel confident about their response but did not necessarily provide them with the correct knowledge to overcome the discrepancy. In other instances, prior knowledge seems to do the opposite and offers a protective factor against mistaking familiarity as evidence of truth, but this could vary by age group. Brashier et al., (2017) compared young and older adults on misattributions of truth for known and unknown information they were exposed to repeatedly. Young adults displayed positive associations between familiarity and perceived accuracy regardless of actual prior knowledge. Yet, older adults only misattributed accuracy for familiarity when they had no prior knowledge on the subject matter. Overall, it seems knowledge has a complex role when it comes to encountering contradictory information. Having related knowledge, but not the exact information, may mistakenly boost one's confidence enough to mistake familiarity for accuracy. But prior knowledge seems still offer some protection when it comes to noticing contradictions, at least for older adults.

Overall, crystallized intelligence influences the occurrence of semantic illusions, but it is not necessarily a straightforward relationship. For example, if contextual details are included in the same sentence as the illusory word/information then there may not be enough time for retrieval of stored knowledge to protect the reader from an illusion. If this is true, then increasing the processing demand of target sentences could provide more time for retrieval of relevant information, allowing the reader to detect the illusion. Additionally, being knowledgeable may provide some protection against overlooking incorrect information, however in some instances it may also facilitate overlooking the error.

Fluid Intelligence

Although fluid intelligence is not mentioned specifically in studies of semantic illusions, there are areas of research that have examined a similar construct. For example, the *Illusory Truth Effect* is the tendency to believe information is correct if it is familiar (e.g., Arkes et al., 1991; Bacon, 1979; Hasher et al., 1977; Roggeveen & Johar, 2002; Johar & Roggeveen, 2007).

Crystallized intelligence plays an obvious role in the occurrence of semantic illusions, but fluid intelligence, should be explored as well even if just to control for overlapping variability with other cognitive variables. Fluid intelligence is associated with our ability to solve complex problems, particularly in novel situations (Greiff & Neubert, 2014; Horn & Cattell, 1966). Individual differences studies suggest that greater fluid intelligence is associated with better performance on tasks involving retrieval/recall fluency (Engle, 2002; Shipstead et al., 2016), and better reading comprehension and verbal fluency (Rosen & Engle, 1997). Fluid intelligence also influences one's ability to disengage from information that is faulty, irrelevant, or distracting (Harrison et al., 2015; Ecker et al., 2014; Kane et al., 2001). Given these results, it seems likely increased fluid intelligence would be associated with a better ability to spot inconsistencies or information that is contradictory to prior knowledge.

Additionally, fluid intelligence is highly correlated with WMC (Kane et al., 2005; Engle 2002; Kyllonen & Christal, 1990), and WMC is positively associated with greater detection of semantic illusions. Yet the work investigating this effect did not find any association between fluid intelligence and the robustness of the illusory truth effect (De Keersmaecker et al., 2020; Dechêne et al., 2010). Overall fluid intelligence has not been specifically studied with semantic illusions, but related constructs suggest this ability may have some involvement in the processes underlying occurrence of semantic illusions.

Rationality

Given the proposed theoretical framework, dual process theory, was largely developed to explain the confluent in responses pm reasoning/rationality; it is necessary to consider how rationality might relate to semantic illusions. Mata et al., (2014) conducted a series of experiments to determine if errors made on reasoning tasks can be attributed to reduced language comprehension, rather than problem-solving abilities. In other words, the study sought to determine if most incorrect responses to reasoning problems occurred due to incorrect understanding or the language, or from a miscalculation while solving the problem. The authors speculated that individuals who are cognizant of the conflict between the easy response (Type 1) and difficult response (Type II) on rationality/reasoning tasks, would also be better at spotting illusory information. Problem-solving was measured using CART-related reasoning/rationality tasks (*Cognitive Reflection Test*, Frederick, 2005; Syllogisms and Base-rate problems, adapted from De Neys & Franssens, 2009), and semantic illusion tasks were used to test verbal/language comprehension (general knowledge questions from Erickson & Mattson, 1981; the *survivor problem* from Barton & Stanford, 1993). Results indicate that solving reasoning problems with the deliberative versus intuitive conflict, was positively associated with detecting illusory information/less semantic illusions (Mata et al., 2014). Although the overall aims of the study are beyond the scope of the current research, the shared variance suggests reasoning problems and detecting illusory information potentially have a shared underlying mechanism. Indeed, although there is minimal research exploring rationality/rational thinking and semantic illusions, the limited research suggest reasoning problems are experienced in a similar manner as semantic illusions; in that there is a conflict between automatic and more deliberate processes. For example, Reber & Zupanek (2002) demonstrated that disrupting fluency using difficult-to-read font improved performance on reasoning problems involving frequency and probability estimates, compared to a font that is easier to read (see also Alter et al., 2007). This effect is consistent with expectations for semantic illusions, which may be a similar phenomenon as the reasoning problems per the conflict between Type 1 and Types II.

Current Study

An important context to consider for the current project is that it was a smaller sub-study, within a much larger study collected over three testing sessions. The larger project was designed to investigate age-related changes in fluid intelligence, crystallized intelligence, and rationality within the context of dual-process theory. This impacted many decisions for the current project regarding overall design, theoretical perspectives, and variable/measure inclusion. First, the current project's methodological design and predictions were consistent with the broader project's theoretical approach, i.e., dual process theory. However, due to the lack research approaching semantic illusions from a dual-process theory perspective, predictions were largely based on logical deduction rather than previous empirical evidence or a specific theoretical model. Additionally, the methodological design of the current study, was largely governed by the timing and other needs for the overarching project data collection. However, although the larger project somewhat limited theoretical and methodological approaches for the current project it also enabled access to variables, such as the cognitive composites for fluid intelligence, crystallized intelligence, and rationality, that would not have otherwise been included if this was a standalone study.

Because these variables were not included in this study based on specific theoretical predictions or empirical evidence, the portion of the study that includes investigation of the cognitive composites, is largely atheoretical/exploratory. Although relevant research will be presented to inform expected patterns of effects, the lack of research specific to semantic illusions and the cognitive composite variables limited the ability to make specific predictions for these variables. As such the experimental section of the study will be more theory-driven, and the correlational portion is mostly data-driven and less specific to theoretical predictions.

The current study takes a combined experimental/correlational approach to investigate developmental and individual differences associated with the detection of semantic illusions. The experimental design is a 2x2 mixed factorial with age group (young, older) as the between groups variable and syntactic complexity as the within groups variable (high complexity, low complexity). The correlational design of the study allows for an investigation of individual differences in cognitive abilities, such as crystallized intelligence, fluid intelligence, and rationality, as they relate to semantic illusions.

Broadly speaking, the purpose of the current study is to understand how language structure, age, and cognitive abilities contribute to the detection or facilitation of semantic illusions. Additionally, non-illusion items will be used as a comparison to determine whether the pattern of outcomes is similar for illusion versus non-illusion items. More specifically, the current study will examine the effect of age group (young, older) and syntactic complexity (simple, complex) on the frequency of:

(a) accurately detecting illusory information (*Detection score*)

(b) failing to detect illusory information (*Illusion score*)

(c) providing accurate responses to target questions (*Target Score*).

Group-Level Predictions: Effects of Age*Syntax

For the experimental portion of the study, specific predictions were made per the effect of age, syntax condition, and the interaction effect. There is minimal research investigating age-related differences in semantic illusions, and none that also consider syntax complexity. Thus, at times, the predictions are based in somewhat disparate lines of research.

Main Effect of Age. Unlike fluid intelligence or working memory capacity, crystallized intelligence tends to increase or remain stable into older adulthood (Light & Salthouse, 1987; Mitchell, 1989; Salthouse & Babcock, 1991; Burke & Peters, 1986). In fact, older adults on average have more knowledge than young adults (Craik & Salthouse, 2011; Umanath & Marsh, 2012). According to available research with age-group comparisons, older and young adults detect information that contradicts their prior knowledge at equivalent rates (Umanath & Marsh, 2012; Umanath, 2014). However, there is some research suggesting older adults experience more semantic illusions than young adults. This is true despite older adults being able to provide more correct knowledge afterwards (Umanath et al., 2014; Umanath & Marsh, 2014). Due to these outcomes, it is expected that older adults will have more knowledge than young adults but will detect illusory information at the same rate as young adults. In other words, young and older adults will have equivalent detection scores. However, it is possible older adults may fall for the illusion more frequently overall and thus have higher illusion scores compared to young adults. Furthermore, it is anticipated that older adults will answer more target questions correctly, and provide more correct responses on the knowledge check afterwards.

Main Effect of Language Structure: Syntactic Complexity. As discussed in the previous section, processing fluency can be manipulated by increasing the complexity of the language, e.g., more difficult, or obscure syntax structures (Stromswold et al., 1996; Lowrey, 1998; Alter & Oppenheimer, 2007). Specific to semantic illusion research, the likelihood of illusory information being detected is sensitive to the syntactic structure of the text (Reder & Kusbit, 1991; Bredart & Modolo, 1988; Büttner, 2007). Additionally, disrupting processing fluency via the manipulation of text-based features has been demonstrated to impact how frequently illusory information is detected; disrupted fluency is associated with fewer semantic illusions (Song, 2009). Familiar, easy-to-read, and less complex text promotes processing fluency and is consistently rated more truthful or believable than text that is difficult, complex, or unfamiliar text (Alter & Oppenheimer, 2007; Schwarz, 1989; Schwarz et al., 1991;

Oppenheimer, 2008). In addition, syntactic structures that tax working memory, such as left-and middle-branching sentences, increase the amount of time and effort it takes to correctly assess the semantic plausibility of a clause compared to right-branching sentences (Stromswold et al., 1996). Finally, there is also evidence that increasing the linguistic complexity can improve performance on language-related tasks compared to less complexity due to an increased amount of effort and engagement (Kuiken & Vedder, 2008; Robinson, 2001).

Given the presented results it was anticipated that illusory information will be detected more frequently in complex syntax compared to simple syntax. Detection scores were predicted to be higher in complex syntax conditions compared to simple conditions, regardless of age group. This facilitative effect of syntax complexity was similarly predicted for items that contain the correct information (*target scores*), and more correct responses were anticipated for complex versus simple syntax. For this prediction due to a lack of previous research on semantic illusions and syntax complexity, detection scores and illusion scores and their associated effects are predicted to be mirror inverses of one another – conditions that result in more detection will also lead to less illusion occurrences and vice versa. However, given the results suggesting older adults detect at equivalent rates as young adults, but *fail* to detect more frequently it is also likely that detection scores and illusion scores will only follow a similar, but not identical pattern of effects, or be entirely different from one another.

The main effects for age and syntax, although important for contributing to an area in need of more research, neither effect is the true focus of the current study. Rather the interaction of age and syntax condition is the most compelling effect to be researched given the implications for the potential outcomes. The interaction is particularly important for determining future lines of research that could be explored to further build out additional theoretical structure for research involving semantic illusions, aging, and language structure.

Interaction of Age*Syntactic Complexity. Due to the minimal age-related research for semantic illusions in general, and especially in conjunction with the effects of syntax there is limited guidance with which to base specific predictions. As discussed in the previous section, complex syntactic structures (e.g, left-branching, middle-branching) decrease processing fluency due to demands on working memory (Stromswold et al., 1996; King & Just 1991; Just & Carpenter, 1992). Due to age-related changes in cognitive ability, older adults are particularly disadvantaged by complex, difficult or unfamiliar language structures, such as complex or obscure syntax (Anderson & Davison, 1988; De Beni, Borella, & Carretti, 2007; Norman, Kemper, & Kynette, 1992). From this it can be anticipated older adults will be more disadvantaged by the complex syntax than young adults, meaning it may require more time and effort to process the items (Salthouse & Babcock, 1991; Stromswold et al., 1996). Additionally, the disruptions/reductions in processing fluency associated with increased syntax complexity may also facilitate more effortful thinking patterns and retrieval/application of stored knowledge (Stromswold et al., 1996; Schwarz & Xu, 2008; Thompson et al., 2009). The disruptions to processing fluency could facilitate detection, which could be particularly beneficial for older adults with more prior knowledge compared to young adults (Song, 2009; Umanath et al., 2014; Umanath & Marsh, 2014). Yet, this advantage for older adults would not be present for simple syntax items due to processing fluency being facilitated by the familiarity of the semantic content and ease of the syntax structure (Whittlesea et al., 1990; Kelley & Jacoby, 1996; Alter & Oppenheimer, 2009). Thus, it is anticipated that there could be an interaction, such that the effect of complex syntax is not as strong for young adults versus older adults. In other words, older adults will have higher detection scores than young adults, but only when experiencing complex syntax items, not for simple items.

Individual Differences in Cognitive Abilities

A secondary goal of the current study is to better understand the role of cognitive abilities in the detection or facilitation of semantic illusions. The purpose of this approach was to identify the individual differences in cognitive abilities that predict detecting contradictory/illusory information (*detection scores*) and those that predict failures to detect illusory information (*illusion scores*). Due to the positive manifold, that describes the consistent positive correlations among cognitive measures it can be assumed that cognitive abilities will likely be positively associated with the detection of illusory information (Spearman, 1927; Jensen, 1986). Although it does not guarantee detection of contradictory information, having more knowledge is necessary for improving the odds of detection (Hannon & Daneman, 2004; Umanath, 2014). Thus, it is anticipated that crystallized intelligence will be the primary predictor of detecting illusory information. Due to a greater reliance on stored information, crystallized intelligence may be a stronger predictor of detection scores for older adult data than young adults (Bowles & Salthouse, 2008; Hess, 1990). Additionally, as supported by Mata et al., (2014), rational thinking/rationality is anticipated to be positively associated with detecting illusory/contradictory information and a secondary predictor of detection scores. Finally, due to the correlational and conceptual overlap between fluid intelligence and WMC, it is anticipated that fluid intelligence and WMC will also be positively associated with detection scores, but at a weaker magnitude than crystallized intelligence or rational thinking.

Although the previous predictions were specific to detection scores, the patterns for failures to detect illusory information (illusion scores) are assumed to be the inverse. The occurrences of illusions will be negatively associated with the cognitive abilities. Although it should be cautioned that these predictions are not as firm nor substantiated by literature as the predictions for detection scores. As stated previously the predictions that detection scores and illusion scores will result in inverse effects, is based largely in logic rather than empirical evidence that detection, and failures to detect ,are two-sides of the same coin. From this logic it would follow that any condition that facilitates detection would automatically inhibit the occurrence of semantic illusions. However, the minimal available research suggests these two indicators are not necessarily the exact inverse of one another (Umanath et al., 2014).. Aspects that facilitate detection, may not in tandem, reduce illusion occurrences or maybe reduce occurrence only for specific individuals with high ability in certain traits, etc.

Method

Participants

Sample size was determined by conducting a power analysis to detect a significant interaction between age group (young, older) and syntactic complexity (simple, complex). However, it was difficult to estimate the effect size for the interaction because these two variables have never been included in the same study. Therefore, an alternative, conservative approach to power analysis was conducted by powering to the smallest interaction effect (η_p^2 = .01), using the standard benchmarks for alpha (α = .05) and power level (1-β = .8; Faul et al., 2007). Results indicated a total sample size of just under 200 participants (*N* = 196) was necessary to obtain adequate power = .80.

Data from nine waves of data collection for both young and older adults were exported and merged from *Qualtrics*. Data from both Version A and Version B (details below) of the study were merged (*N* = 220). Prior to further investigation, any observations without data for two critical measures were eliminated from the study, including the semantic illusion task and/or if no age information was reported. Observations with missing data for relevant but less critical variables (e.g., cognitive ability measures) remained in the study to preserve sample size. The following section describes the final sample after eliminations and data cleaning. See the results section for more information about the cleaning process and assumption checks.

Consistent with the power analysis, the final sample included 203 participants, with slightly more young adults (n = 114) than older adults (n = 89). Although the large overall sample size likely mitigates this issue, the discrepancy will be explored further in the data cleaning portion of the results section. Young adults ranged between 18-30 years of age and were around 25 years old on average (M = 24.98, SD = 4.06). The young adult sample included 60 men, 53 women, and 1 non-binary participant. Participants in the older adult group ranged between 60-84 years of age and were on average around 65 years old (M = 65.63; SD = 4.93). The older adult sample included 31 men, 55 women, 1 non-binary participant, and 2 who preferred not to indicate gender identity. Most participants had at least some college education, except 27 young adults and 5 older adults reported having a high-school diploma or less education. Most of the sample, 55.17%, identified as White/Caucasian American, followed by 27.10% as Asian American, 8.37% as Black/African American, 4.92% as Hispanic/Latino, and the remainder identified as Native American/Native Hawaiian, “Other”, or a mix of identities specified themselves. All participants were native English speakers living in the United States.

Materials

Participant recruitment and compensation was facilitated through the *CloudResearch* platform. Participants used *CloudResearch* accounts to access and complete the electronic study materials for all three testing sessions. Preparation of the testing measures and data collection was completed using *Qualitrics* programming software, and *Microsoft Excel* for data exportation. Data cleaning, visualization, and statistical analyses were conducted using *R Studio*, and facilitated via packages within the *tidyverse* (Wickham et al., 2019).

In addition to an electronic informed consent form, a demographic questionnaire was administered that included questions about age, gender, years of education, ethnicity, vision/hearing problems, spoken languages, and any other medical issues that may impact cognitive performance. To qualify for inclusion in the study, participants had to meet the initial age cutoff requirements (under 30 years, or over 60 years), and pass the electronic version of the *Telephone Interview for Cognitive Status* (TICS; Brandt & Folstein, 2020). The main components of the current study paradigm will be discussed in detail below, and included: the semantic illusions task, a general knowledge check, and a reading comprehension measure. Depending on the order version assigned, participants either experienced the current paradigm during the first or second testing session, out of the three testing sessions. This was due to data collection for the current study being part of a much broader project investigating age-related changes in cognitive abilities, that included a range of measures for fluid intelligence, crystallized intelligence, and rational thinking/rationality. Also included was a backward digit span measure that was given to participants twice to serve as a rough measure of WMC. All the additional cognitive measures were administered in varying order across all three testing sessions depending on the study version assigned. Although the cognitive ability measures will be described briefly below, see the citations provided for more information about each task.

Measures

Semantic Illusion Task. The semantic illusion task consisted of 60 items, including 48-critical items and 12 filler items. The filler items were unrelated trivia questions in random syntax structures and were irrelevant to the purpose of the study. The critical items included general knowledge questions modified from Umanath et al., (2014; originally adapted from Bottoms, et al., 2010), and contained either the correct information (target items) or illusory information (illusion items). The target items served largely as a control with which to compare performance on the illusion items, so participants completed18 target items and 30 illusion items. To compare syntax conditions, half of the critical items, 15 illusion items and 9 target items, were structured in simple syntax (right-branching), and the other half, 15 illusion and 9 target items, were structured in complex syntax (left-branching, middle-branching). Whether the participant experienced left versus middle-branching structure during the complex condition was randomized such that a nearly equal mix of both was experienced by each participant.

The original semantic illusion items were selected from previous age-related semantic illusion research to ensure the items had been used to successfully elicit semantic illusions from both young and older adults. The items selected from Umanath et al., (2014) were then modified to accommodate the syntax complexity manipulation. The syntax manipulation was implemented so that for each target/illusion item, there was a simple syntax version in right-branching structure, and a complex syntax version, in both left-branching and middle-branching structures. This process of creating items typically consisted of adding one to five additional words, replacing word/s with a synonym or similar alternative, or rearranging the order of the of the words. See example item below for sentence structures and modifications. There were six versions of each item created:

Original: In what state did *General XXXX* surrender to bring an end to the Civil War?

(a) *Simple Target*: In what state did *General Lee* surrender, bringing an end to the Civil War?

(b) *Simple Illusion:* In what state did *General Grant* surrender, bringing an end to the Civil War?

(c) *Complex Target [left]:* Bringing an end to the Civil War, in what state did *General Lee* surrender?

(d) *Complex Target [middle]:* In what state, bringing an end to the Civil War, did *General Lee* surrender?

(e) *Complex Illusion [left]:* Bringing an end to the Civil War, in what state did *General Grant* surrender?

(f) *Complex Illusion [middle]:* In what state, bringing an end to the Civil War, did *General Grant* surrender?

After creation of the semantic illusion items, some minor pilot testing was conducted to ensure that the complex syntax items in left-branching and middle-branching syntax structures were significantly more difficult to read than the simple syntax constructions in right-branching structures. Participants were asked to rate on a 6-point Likert scale (1 = very easy; 6 = very difficult) how difficult it was to read and understand items presented in simple syntax and complex syntax structures. Although the sample size was small (6 young and older adults), the complex syntax items (M = 4.12, SD = 0.47),were rated as more difficult to read and understand than the simple syntax items (M = 3.80, SD =0.59). These differences were not testable/significant due to the small sample size. However, the moderate-to-large effect size (*Cohen's d* = .60) indicates these differences would likely be significant with a larger sample. The left-branching (M = 4.07, SD =.0.42), and middle-branching structures M = 4.17, SD =.0.52) were rated much more similarly, as expected.

To ensure the differences in conditions were further entrenched, the five items with the smallest differences between simple and complex difficulty ratings were dropped from the semantic illusion task. Finally, the same participants were presented with two versions of the same item, in simple versus complex syntax, and asked to pick which one is more difficult to read and understand. All complex versions were consistently selected as being more difficult to read and understand than the simple versions, except for one item which was also dropped from the semantic illusion task.

After reading a target/illusory item, participants were presented with an open-ended response option to either type an answer to the question (e.g., "Virginia"), indicate that they do not know the answer ("DK"), or say that the question is unanswerable due to error ("NA"). These response options, along with instructions on how to respond (e.g., if the error is noticed) were presented alongside each item.

The semantic illusion task began with the following instructions:

> You will be asked to answer 60 trivia questions. Provide your best answer without spending too much time on one question.
>
> If you know the answer, type your response in the space provided.
>
> If you do not know an answer, you are encouraged not to guess, but to indicate that you "do not know" with: **DK**
>
> If you believe the question is unanswerable due to an error in the question, you can indicate that it is "not answerable" with: **NA**

Participants were also presented with an example illusion item at the start of the task, with a warning that certain questions may be unanswerable due to incorrect information. The example also showed the appropriate response when encountering contradictory errors.

> Example: "Carl Jung, who was known for developing theories such as the Oedipus complex, lived in what Austrian city?

Sigmund Freud developed the Oedipus complex, not Carl Jung.

This error would make the question unanswerable and should therefore be responded to with: **NA**

For target items, the goal was to respond to the question with the correct information, as that contributes to a higher overall target score. For illusion items, the goal was to notice the illusory information that makes the question unanswerable and respond with "NA" to the illusion item. Alternatively, responding to an illusion item with an answer to the question indicates that the illusory/contradictory information has been overlooked. Yet neither of these responses are counted as a true *detection* of illusory information or *failure* to detect, respectively, until it has been confirmed that the participant had the correct knowledge beforehand. The *General Knowledge Check*, discussed in the next section, has historically been used in semantic illusion research to confirm: (a) detection: the participant responded to an illusion item with "NA" and correctly responded to the corresponding item on the knowledge check; this contributes to a higher overall detection score; (b) [semantic] illusion: the participant overlooked the contradiction by responding to an illusion item with a response to the question, but knew the correct information on the corresponding item in the knowledge check; this contributes to a higher overall illusion score.

For the semantic illusion task, participants were randomly assigned to one of four condition-order groups. The condition-groups ensured that each participant saw an appropriate number of items in each syntax condition, but with a set order to ensure syntax conditions were not repeated in succession and that filler items were peppered throughout. The four different groups were counter-balanced across syntax condition to mitigate order effects and ensure that each version of the illusion/target items for each syntax condition were seen by an equal number of participants. To assist this design, items were separated into blocks, to ensure an illusion/target item in the same syntax condition were not within the same block. The order of the items within each block were randomized, and the order of the blocks were randomized. This design struck a balance between ensuring the participants did not pick up on the syntax condition manipulation or frequently experience the same type of item within proximity to one another, while allowing for some randomness in the order presentation. The counterbalancing structure for the illusion items was the same for the target items, but consistent with the desired target-to-illusion item ratio.

General Knowledge Check. A test of general knowledge questions was administered based on the information included in the semantic illusions task items. This measure is included to determine whether participants knew the correct information even if it was not utilized in the previous semantic illusion task. The test consisted of 60 multiple choice questions, corresponding to each of the 48 semantic illusions and 12 filler questions included in the previous task. Each question was presented with four multiple-choice options to select from, including the target/correct option, the illusory/incorrect option, another semantically related, incorrect option, and "don't know". For example, the following question corresponds the semantic illusion item example given in the previous section:

What General surrendered in Virginia to bring an end to the Civil War?

Participants will then have the option to select: (a) Grant, (b) Lee, (c) Washington, or (d) don't know.

Reading Comprehension. The reading comprehension task consisted of 3 short passages and five multiple-choice questions that were taken from a reading comprehension task (medium difficulty) in the Verbal Reasoning portion of the GRE. In addition to providing a quick assessment of reading comprehension, this task also serves as a distractor task between the semantic illusion task and the general knowledge check. Correct scores were summed and then divided by the total number of questions on the measure to obtain a proportion correct score.

Working Memory Capacity (WMC). To measure verbal WMC, the scores on a backward digit-span task, administered twice across testing, were summed to create a composite. Although a digit-span task is not as effective as a complex span task, there is evidence to suggest that backward digit span measures reflect age-related differences in WMC, due to declines in the central executive component of WM for older adults compared to young adults (Hester, Kinsella, & Ong, 2004). Scores on the digit span measure were indicative of the number of digits they were able to correctly produce, and the scores for both administration of the task were summed and standardized for a total backward digit-span score.

Crystallized Intelligence. Crystallized intelligence was assessed using four standard measures of vocabulary and general knowledge: (a) *The Boston Naming Task* (Kaplan, Goodglass, & Weintraub, 1978; 2001); (b) the *Synonyms* task from the Wechlser Adult Intelligence Scale-IV [WAIS-IV; Wechsler, 2008); (c) the *Antonyms* task also taken from the WAIS-IV (Wechsler, 2008); and (d) a 25-item multiple choice vocabulary task. The scores from these items were standardized and then aggregated to form a composite score for crystallized intelligence.

Fluid Intelligence. Fluid intelligence was assessed using four standard measures of reasoning and problem-solving: (a) the *Letter Series* task from the WAIS-IV (Wechsler, 2008); (b) the *Number Series* task from the WAIS-IV (Wechsler, 2008); (c) *Raven's Progressive Matrices* (*RPM*; Raven & Court, 1938); (d) *Cattell's Culture Fair Intelligence Test* (Cattell, 1973). Scores from these items were standardized and then aggregated to form a composite score for fluid intelligence.

Rationality Quotient or Rational Thinking. Rational thinking was assessed using the shortened version of the Comprehensive Assessment of Rational Thinking (CART; Stanovich, 2016). The subsections included in the rationality composite: (a) *Scientific Reasoning*; (b) *Syllogistic Reasoning*; (c) *Probabilistic Statistical Reasoning*; (d) *Probabilistic Numeracy*; (e) *Reflection Intuition*. Scores from the subsections were standardized and then aggregated to form a composite score for rational thinking.

Procedure

Participants were recruited via advertisements posted on a research platform, *CloudResearch*, that described a 3-day study examining knowledge across the lifespan. Only participants that qualified for the young adult age group (must be between 18-30 years) or the older adult age group (must be 60 years+, and no significant cognitive decline per the *TICs*) were retained for the study. Participants were offered $10 per testing session for a total of $30, with two 60 min sessions and one 90 min session. Each testing session included a separate informed consent and general/individual task-relevant instructions. After the conclusion of each testing session, participants were given a completion code to submit for each day’s compensation. Testing session materials were released three days apart from one another to provide participants with plenty of time to complete each testing session prior to the next sessions release date. The sessions were self-paced and could be started at any time within three days the materials were available. After the tasks were completed or the release time for the session had lapsed, the materials could no longer be accessed. Once a session had been launched, participants were capped at 3 h to complete all the tasks, however no participant required that much time.

Participants were encouraged to limit distractions, complete all tasks in one setting, and to limit breaks to the pauses in between tasks.

Tasks were administered online, in a self-paced manner for each of the three testing sessions. In addition to informed consent, demographics questionnaire, general instructions, and the electronic version of the TICs; the first testing session included a measure of fluid intelligence (*RPM*), a measure of rational thinking (*Scientific Reasoning*), and unrelated video clips, affect assessments, familiarity ratings, and a visual matching task for a separate study. The first backward digit span score was also collected during the initial testing session.

The second testing session included: fluid intelligence measures (*Letter Series, Number Series*), rational thinking measures (*Reflection and Intuition*, *Syllogistic Reasoning, Probabilistic Numeracy*) crystallized intelligence measures (*Synonyms, Antonyms*) and the items for the current paradigm, *Semantic Illusion Task*, *Reading Comprehension, General Knowledge Check*. After completing the 60-item semantic illusion task at their own pace, participants were presented with the 5-item multiple-choice reading comprehension task. Participants read the brief passages and answered the associated multiple-choice questions. Finally, the 60-item multiple-choice *General Knowledge Check* was completed. After completion of these tasks, participants finished the remainder of the tasks scheduled for that testing session and were debriefed and compensated.

Finally, the third testing session included: rational thinking measures (*Probabilistic Reasoning)*, a crystallized intelligence measure (*Boston Naming Task*, 25-item vocabulary task), and a fluid intelligence measure (*Cattell's Culture Fair*). Same as the first session, the final session included unrelated video clips, affect assessments, familiarity ratings, and a visual matching task for a separate study. The final backward digit span score was also collected during the last testing session.

Half of the participants were randomly assigned to a set of testing sessions referred to as Version A and half were assigned to Version B. Version A was consistent with the above description of which tasks were included in each testing session. Version B was identical to Version A, but the tasks for the first and second testing sessions were switched, such that testing started with materials from the second session of Version A. It is not uncommon in studies with multiple testing sessions for some participants to not return after the first testing session (e.g., Park et al., 2011). To prevent all data loss being primarily from one testing session, and to mitigate attrition-based patterns of missing data, half of the participants started with the first session (Version A) and half started with the second testing session materials (Version B). This manipulation also served as a counterbalancing scheme for task order across testing sessions, to prevent potential task-order effects.

Results

Data Scoring

General Knowledge Check. The final measure participants received was the 60-item general knowledge check. This measure was used to confirm the prior information each participant had stored in memory, that was relevant to the semantic illusion task. Each semantic illusion task item corresponded to a general knowledge check item. General knowledge check items were scored for accuracy and considered ‘correct’ only if the appropriate multiple-choice option was provided to the question. Incorrect options, as well as the “don’t know” option were considered incorrect and not tallied towards the overall score. Additionally, the corresponding items on the semantic illusion task were disqualified from contributing to detection/illusion scores. Results from this measure were used to confirm on the semantic illusion task, but general knowledge check scores were also generated by dividing the number of items answered correctly by the total.

Semantic Illusion Task Scores. The semantic illusion task generated scores for each syntax condition, and a combined score for target items and illusion items. In total, three outcome variables were calculated: target scores, detection scores, and illusion scores.

Target Scores. In the semantic illusion task, target items are general knowledge questions that contain the correct information. Responses to these items largely serve as a control comparison to illusory item responses and only assessed for accuracy. If the participant provides the correct response to the general knowledge question, the target item is considered 'correct' and tallied toward the overall target score. Target items are considered 'incorrect' if the wrong response is provided to the general knowledge question, if 'NA' or 'DK' response is provided, or if the item is left blank. In these three instances no point is awarded towards the overall target score. After tallying the number of correct responses to target items, this value is divided by the total number of target items in that syntax condition. If an item was left blank it was not included in the running total for target items seen in that condition. Target scores were generated for each syntax condition based on the proportion of target items answered correctly for both simple and complex (left and middle) sentence structures. These values will be referred to from this point on as "target scores", such that a "complex target score" would refer to the proportion of target items in the complex condition that were answered correctly..

The illusion items were general knowledge questions that contain illusory information. The scoring process detailed above for target items was similarly used for the illusion items, except two sets of scores were calculated: one score to represent the number of semantic illusion occurrences (illusion scores) and another score for the number of illusions detected (detection scores). Finally, unlike the scoring process for target items, the illusion item scoring procedure required cross-checking the responses on the semantic illusion task with the answers provided on the subsequent general knowledge check. Given that only detection/illusion responses confirmed with the general knowledge check contributed to detection/illusion scores, this measure will be described first.

Detection Scores. In the current study, illusory information was considered “detected” when the contradictory/incorrect information was not only noticed, but evidence of having the correct information was also demonstrated. Specifically, an illusion was considered “detected” if the participant: (a) correctly responded to an illusory item with “NA”, (b) and accurately answered the associated item on the general knowledge check. If the participant correctly responded “NA” but was unable to provide the correct information on the knowledge check, then the illusion was not detected, and the item is not counted towards detection (or illusion) scores. Similarly, if a general knowledge check item is answered correctly, but the illusory information was not spotted during the semantic illusion task, there has been no detection. The use of the general knowledge check measure confirms the participant truly noticed that the information contradicted their prior knowledge, and their response was not merely an artifact of being warned about unanswerable questions.

Like target scores, detected items were tallied and divided by the total number of illusion items in each syntax condition. Detections scores were generated for each syntax condition based on the proportion of illusion items in which illusory information had been detected in both simple and complex (left and middle) sentence structures.

Illusion Scores. In the current study, a semantic illusion occured when a participant failed to notice illusory/contradictory information but provided the accurate information when asked directly. Specifically, an item was tallied as an "illusion" when the participant: (a) provided a response, other than "NA" or "DK", to an unanswerable question, i.e., an illusion item, but (b) the associated item on the general knowledge check was answered accurately. Providing a direct response to the general knowledge question containing illusory information (e.g., the response "two" to the Moses question) signifies either a failure to notice the illusory information or a lack of the correct knowledge altogether. Therefore, if an unanswerable illusion item is given a response, but the subsequent item on the knowledge check is incorrect, this is not considered an illusion. Due to the illusion items being unanswerable, the actual content of the answer provided were not relevant to the current study. The illusion item responses were only assessed to ensure it was an earnest response to the question, and not some form of the 'NA' response "na/Na/NA/nA", the 'DK' response "dk/Dk/DK/dK", or a blatant non-answer (e.g., keyboard mashing, "sksksksjiwj"). These illusion item responses were only classified as a true "illusion" if the participant answered the associated item on the knowledge check, and effectively contradicted their initial response on the semantic illusion task.

As with the target and detection scores, illusion occurrences were tallied and divided by the total number of illusion items in each syntax condition. Illusion scores were generated for each syntax condition based on the proportion of illusion items in which illusory information has been detected in both simple and complex (left and middle) sentence structures.

Cognitive Composite Scores. Measures for crystallized intelligence, fluid intelligence, and rationality/rational thinking were scored consistent with standard scoring procedures for each task. See the method section for individual citations for more information about scoring each task. To reduce the dimensionality of the various cognitive measures, the data were collapsed into common cognitive ability constructs. Composite scores were generated for crystallized intelligence (gC), fluid intelligence (gF), and rationality quotient/rational thinking (RQ) by combining the standardized scores from each task for each cognitive construct (Andrade, 2021). Due to the multi-session testing design, it was not unusual for participants to have partial or missing data for one or more tasks used in the composite scores. However, list-wise deletion of observations with missing values would eliminate nearly 35% of the sample. Additionally, pairwise deletion of only the missing values would artificially reduce overall composite scores for participants without data for certain measures. Thus, prior to standardization, the median was imputed for any missing values from the measures that contributed to the three composite scores (Berkelmans et al., 2022) . The purpose of the median imputation was to provide a conservative placeholder that would facilitate the calculation of composite scores without drastically altering the outcomes. The imputed values were used solely for the creation of the composite scores and not used for evaluation on the individual measures. After the composites were summed, the values were divided by the number of tasks used to create the composite to put the values back into standard deviation units.

Data Cleaning and Assumption Checks

Extensive data cleaning and assumption checks were conducted on the raw data, utilizing statistical standards and benchmarks (Tabachnick et al., 2013; Field, 2013). See Appendix A for information about missing data, patterns of missingness, and the general assessment of univariate and multivariate outliers. Appendix A also includes ANOVA-based assumption checks for univariate and multivariate normality, homogeneity of variance, and homogeneity of covariance. Additionally, Appendix A includes regression-based assumption checks, including linearity between predictors and outcome, multicollinearity, heteroscedasticity, normal distribution of residuals, and a regression-specific reassessment of outlier observations (*tidyverse*, Wickham et al., 2019). Table 1 contains means and standard deviations by age group for rate of response type on the semantic illusion task for both illusion and target items. See Tables 2 and 3 for descriptive statistics and correlations among relevant variables for young and older adults, respectively.

Table 1

Participant Response Type by Age Group for Semantic Illusion Task

	Illusion Items		
Age Group	Illusion	"NA"	"DK"
YA	.27(.16)	.23(.23)	.15(.10)
OA	.35(.19)	.37(.25)	.20(.12)
	Target Items		
Age Group	Correct	"NA"	"DK"
YA	.36 (.15)	.01(.03)	.12 (.17)
OA	.43 (.15)	.01(.05)	.26 (.13)

Note. YA = young adults, OA = older adults, DK = don't know. For illusion Items: Illusion = semantic illusion occurred, NA = illusion detected. For target items: Correct = accurate answer, NA = false alarm

Table 2

Means, standard deviations, and bivariate correlations with confidence intervals for Young Adults (< 30 years old)

Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1. Target	0.36	0.15								
2. Detection	0.23	0.23	.22* [.04, .39]							
3. Illusion	0.27	0.16	.31** [.14, .47]	-.38** [-.52, -.21]						
4. CI	0.35	0.80	.52** [.37, .64]	.45** [.29, .59]	.14 [-.04, .32]					
5. CART	-0.06	0.99	.28** [.10, .44]	.50** [.35, .63]	-.10 [-.28, .08]	.63** [.51, .73]				
6. FI	0.01	0.78	.21* [.02, .38]	.39** [.22, .54]	-.03 [-.22, .15]	.51** [.36, .64]	.71** [.61, .79]			
7. RC	0.43	0.26	.16 [-.02, .33]	.25** [.07, .42]	.20* [.01, .37]	.30** [.12, .46]	.32** [.15, .48]	.38** [.22, .53]		
8. KC	0.68	0.21	.42** [.26, .56]	.41** [.24, .55]	.50** [.35, .63]	.41** [.25, .56]	.25** [.07, .42]	.27** [.09, .44]	.52** [.38, .65]	
9. BDS	0.01	0.56	.21 [-.00, .40]	.07 [-.14, .27]	.09 [-.12, .29]	.33** [.13, .50]	.18 [-.03, .37]	.32** [.12, .49]	.12 [-.09, .32]	.09 [-.12, .29]

Note. * indicates $p < .05$. ** indicates $p < .01$. Bracketed values indicate bootstrap 95% confidence interval for each correlation. Key: Target = proportion of target items correct, Detection = proportion of illusion items detected, Illusion = proportion detected across both syntax conditions, CI = crystalized intelligence composite, CART = Comprehensive Assessment of Rational Thinking (i.e., rationality composite), FI = Fluid intelligence composite, RC = reading comprehension proportion correct; KC = Knowledge Check, BDS = backward digit span total

Table 3

Means, standard deviations, and bivariate correlations with confidence intervals for Older Adults (> 65 years old)

Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1. Target	0.43	0.15								
2. Detection	0.37	0.25	.15 [-.06, .34]							
3. Illusion	0.35	0.19	.01 [-.20, .21]	-.70** [-.79, -.58]						
4. CI	0.42	0.66	.25* [.05, .43]	.44** [.26, .59]	-.13 [-.32, .07]					
5. CART	0.07	0.78	.33** [.14, .50]	.31** [.12, .48]	-.15 [-.34, .05]	.70** [.58, .79]				
6.FI	-0.01	0.67	.19 [-.02, .37]	.23* [.02, .41]	-.16 [-.35, .04]	.49** [.32, .63]	.64** [.50, .74]			
7. RC	0.43	0.24	.13 [-.08, .32]	.37** [.18, .54]	-.04 [-.24, .16]	.31** [.12, .48]	.31** [.11, .48]	.20 [-.01, .38]		
8. KC	0.78	0.19	.12 [-.08, .32]	.17 [-.03, .36]	.40** [.22, .56]	.26* [.06, .44]	.06 [-.14, .26]	.14 [-.06, .33]	.49** [.32, .63]	
9. BDS	-0.03	0.88	.13 [-.09, .33]	.12 [-.10, .32]	-.18 [-.38, .03]	.21 [-.01, .40]	.26* [.05, .45]	.39** [.20, .56]	.08 [-.13, .29]	-.04 [-.25, .17]

Note. * indicates $p < .05$. ** indicates $p < .01$. Bracketed values indicate bootstrap 95% confidence interval for each correlation. Key: Target = proportion of target items correct, Detection = proportion of illusion items detected, Illusion = proportion detected across both syntax conditions, CI = crystalized intelligence composite, CART = Comprehensive Assessment of Rational Thinking (i.e., rationality composite), FI = Fluid intelligence composite, RC = reading comprehension proportion correct; KC = Knowledge Check, BDS = backward digit span total

Group-Level Analyses: Effects of Age*Syntax

Illusion Items. The most important analyses of the current project concerned the illusion items, specifically the models involving detection scores and illusion scores. To assess the effect of age and syntax on both DVs, two separate sets of analyses were conducted on the illusion items. The first set of analyses examined detection scores: i.e., *knew the correct information and detected the illusory information*. The second set of analyses examine the illusion scores: i.e., *knew the correct information but overlooked the illusory information*. After conducting the initial analysis, 95% bootstrap confidence intervals were generated for the age group means based on 1,000 resamples from the original data (*apaTables* R package; Stanley & Spence, 2018).

Detection Scores. A 2 (Age: young, older) X 2 (syntax: simple, complex) mixed-factorial ANOVA was conducted comparing the detection of illusory information for young adults and older adults in simple versus complex syntax conditions. There was a significant main effect of age with a moderate-to-large effect size, $F(1, 200) = 22.21, p < .001, \eta_p^2 = 0.09$]. Older adults had higher detection scores ($M = .38, SD = .27$) compared to young adults ($M = .23, SD = .23$). There was a significant main effect of syntax with a small effect size, $F(1, 200) = 24.83, p < .001, \eta_p^2 = 0.01$. Illusory information was detected more often in complex syntax conditions ($M = .32, SD = .28$) compared to simple syntax conditions ($M = .27, SD = .24$).

Of particular interest for detection scores was the potential interaction between age group and syntax complexity. It was anticipated that older adults would benefit more than young adults from the complex syntax condition compared to the simple syntax condition. This was confirmed, and there was a significant interaction of age group by syntax condition, with a small effect size, $F(1, 200) = 17.66, p < .001, \eta_p^2 = 0.01$. Older adults' advantage over young adults in detecting illusory information increased with complex syntax ($M_y = .23, SD_y = .24; M_o = .43, SD_o = .29$) versus simple syntax ($M_y = .22, SD_y = .22; M_o = .34, SD_o = .24$). Pairwise comparisons revealed that older adults' detection scores significantly improved when going from simple to complex syntax conditions, $t(173.80) = 2.35, p = .02$. However, for young adults there was not significant difference in detection scores between simple versus complex syntax, $t(288.44) = 0.25, p = .79$. In other words, the advantage of complex syntax was not just larger for older adults compared to young adults, the syntax manipulation significantly increased detection scores *only* for the older adults. See Table 4 for *M*s and *SD*s of detection scores by age group and syntax. See Figure 1 for raincloud plots of the distribution of detection scores by age group and syntax condition. See Figure 2 for boxplot representation of the significant interaction between age group and syntax condition on detection scores.

Table 4

Means, Standard Deviations, and Confidence Intervals for the Proportion of Detection Items (i.e., questions with the incorrect word) Detected (Detection Scores) by Syntax Condition, Between Young and Older Adult Age Groups

Syntax: Complex			
Age Group	*M*	*M* 95% CI [LL, UL]	*SD*
YA	.23	[.19, .28]	.24
OA	.42	[.36, .48]	.29
Syntax: Simple			
Age Group	*M*	*M* 95% CI [LL, UL]	*SD*
YA	.22	[.18, .27]	.22
OA	.33	[.28, .38]	.24

Note. *M* and *SD* represent mean and standard deviation, respectively. *LL* and *UL* indicate the lower and upper limits of the 95% bootstrap confidence interval for the mean, respectively. The confidence interval is a plausible range of population means that could have created a sample mean (Cumming, 2014). *Note.* Key: YA = young adults; OA = older adults.

Figure 1

Raincloud Plot Visualization of the Distribution of Detection Scores by Age Group and Syntax Condition (Simple, Complex)

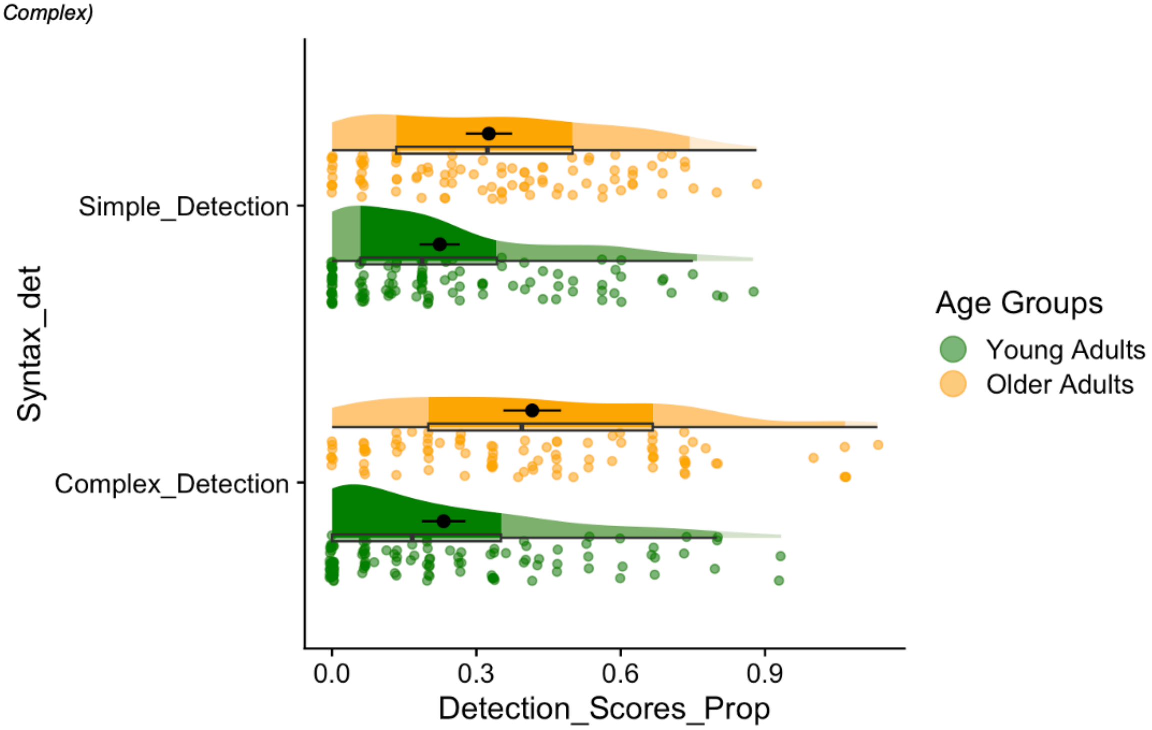
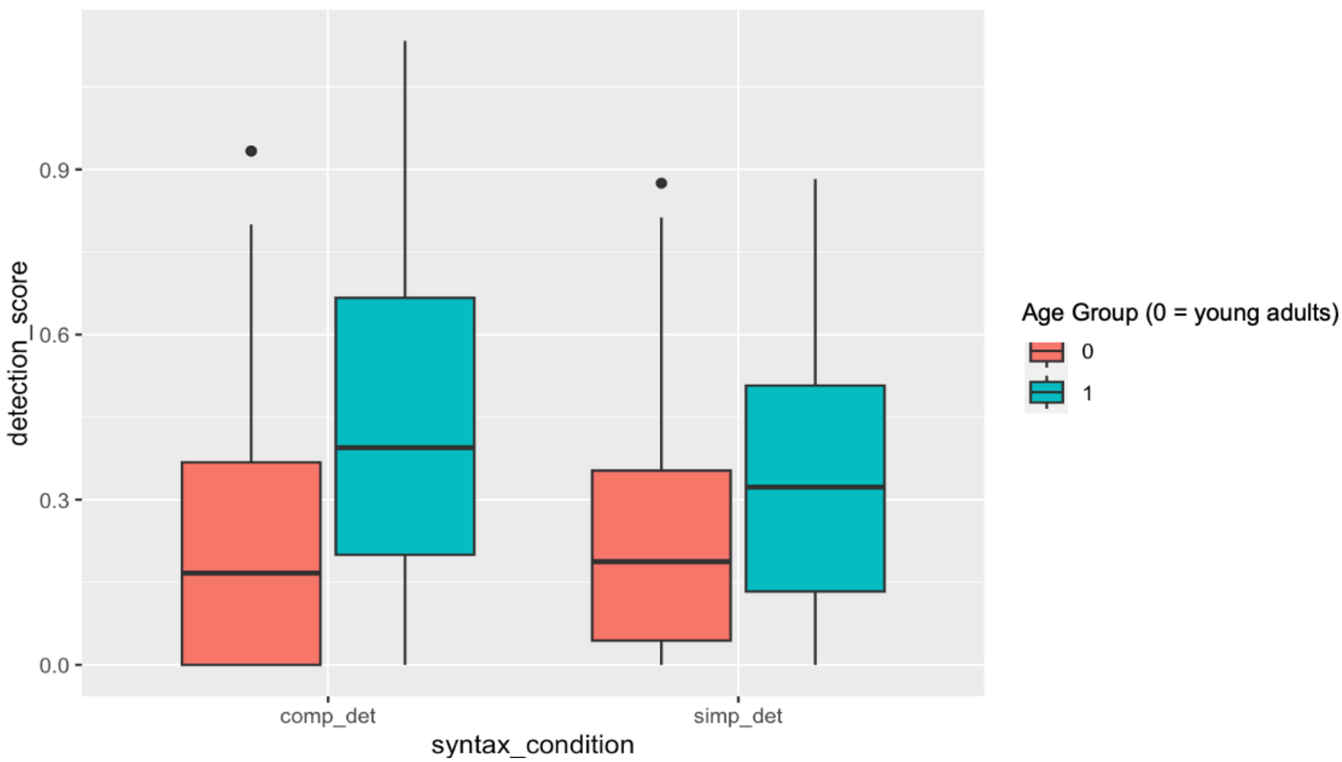


Figure 2

Boxplot of the Significant Interaction between Age Group (0 = young, 1 = older) and Syntax Condition (comp_det = complex, simp_det = simple) on Detection Scores



Finally, to control for any age-related differences in variables that may influence detection scores, the previous models were intended to be conducted again with WMC and reading comprehension added as covariates. However, WMC could not be used as a covariate as the variable violated the assumption of there being a significant relationship between the dependent variable (target scores; see Appendix B for correlations between covariates and target scores). Additionally, using reading comprehension as a covariate did impact the pattern or significant effects found for syntax and age on target scores. Because these analyses offered no novel information, the results of the ANCOVAs are reported in Appendix B.

Illusion Scores. A 2 (Age: young, older) X 2 (syntax: simple, complex) mixed-factorial ANOVA was conducted comparing the failure to detect illusory information (illusion scores) for young and older adults in simple versus complex syntax conditions. There was a significant main effect of age with a moderate effect size, $F(1, 200) = 12.11$, $p < .001$, $\eta_p^2 = .05$. Older adults (M = .35, SD = .20) had higher illusion scores compared young adults (M = .27, SD = .18). There was no significant main effect of syntax, $F(1, 200) = 0.20$, $p = .653$, $\eta_p^2 < .001$. Illusory items in complex syntax (M =.30, SD = .19) were overlooked equally often as illusory items in simple syntax (M =.31, SD = .20). Finally, there was no significant interaction of age group and syntax condition [$F(1, 200) = 0.97$ $p = .325$, $\eta_p^2 = .001$]. See Table 5 for *M*s and *SD*s of illusion scores by age group and syntax. See Figure 3 for raincloud plots of the distribution of illusion scores by age group and syntax condition.

Table 5

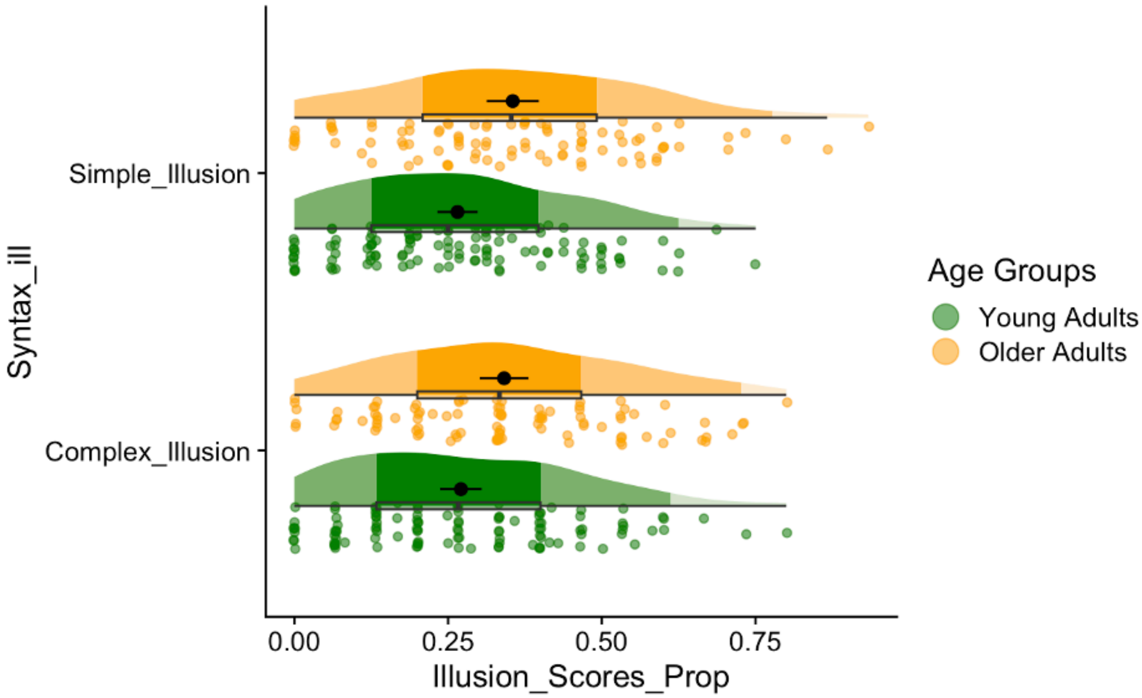
Means, Standard Deviations, and Confidence Intervals for the Proportion of Illusion Items (i.e., questions with the incorrect word) not Detected (Illusion Scores) by Syntax Condition, Between Young and Older Adult Age Groups

Syntax: Complex			
Age Group	*M*	*M* 95% CI [LL, UL]	*SD*
YA	.27	[.24, .30]	.18
OA	.34	[.31,.39]	.19
Syntax: Simple			
Age Group	*M*	*M* 95% CI [LL, UL]	*SD*
YA	.27	[.23, .30]	.18
OA	.36	[.32, .40]	.21

Note. M and *SD* represent mean and standard deviation, respectively. *LL* and *UL* indicate the lower and upper limits of the 95% bootstrapped confidence interval for the mean (samples = 1000), respectively. The confidence interval is a plausible range of population means that could have created a sample mean (Cumming, 2014). YA=young adults; OA = older adults.

Figure 3

Raincloud Plot Visualization of the Distribution of Illusion Scores by Age Group and Syntax Condition (Simple, Complex)



Like the previous scores, the illusion score models were to be conducted again on the with WMC and reading comprehension added as covariates. However, neither reading comprehension or WMC were deemed suitable as covariates due to the lack of relationship with illusion scores. No ANCOVAs were conducted on illusion scores. See Appendix B for full description and correlations between illusion scores, reading comprehension, and WMC.

Target Items. For each analysis, bootstrap confidence intervals were generated for age group averages based on 1,000 resamples from the original data (*apaTables* R package; Stanley & Spence, 2018). See Table 3 for CI values associated with target scores, along with group .

Target Scores. A 2 (age: young, older) X 2 (syntax: simple, complex) mixed-factorial ANOVA was conducted comparing how frequently targets were answered correctly for young adults and older adults in simple and complex syntax conditions. There was a significant main effect of age with a moderate effect size, $F(1, 200) = 21.75$, $p < .001$, $\eta_p^2 = .06$, such that older adults ($M = .56$, . $SD = .27$) had higher target scores than young adults ($M = .46$, .$SD = .29$). Additionally, there was a significant main effect of syntax with a large effect size, $F(1, 200) = 48.20$, $p < .001$, $\eta_p^2 = .10$), such that complex target items ($M_y = .58$, $SD_y = .18$) were answered correctly more often than simple syntax target items ($M_y = .40$, $SD_y = .35$). Finally, the interaction between age group and syntax condition was not significant [$F(1, 200) = 1.12$, $p = .396$, $\eta_p^2 = .002$]. See Table 6 for *M*s and *SD*s of target scores by age group and syntax. See Figure 4 for raincloud plots of the distributions of target scores by age group and syntax condition.

Table 6

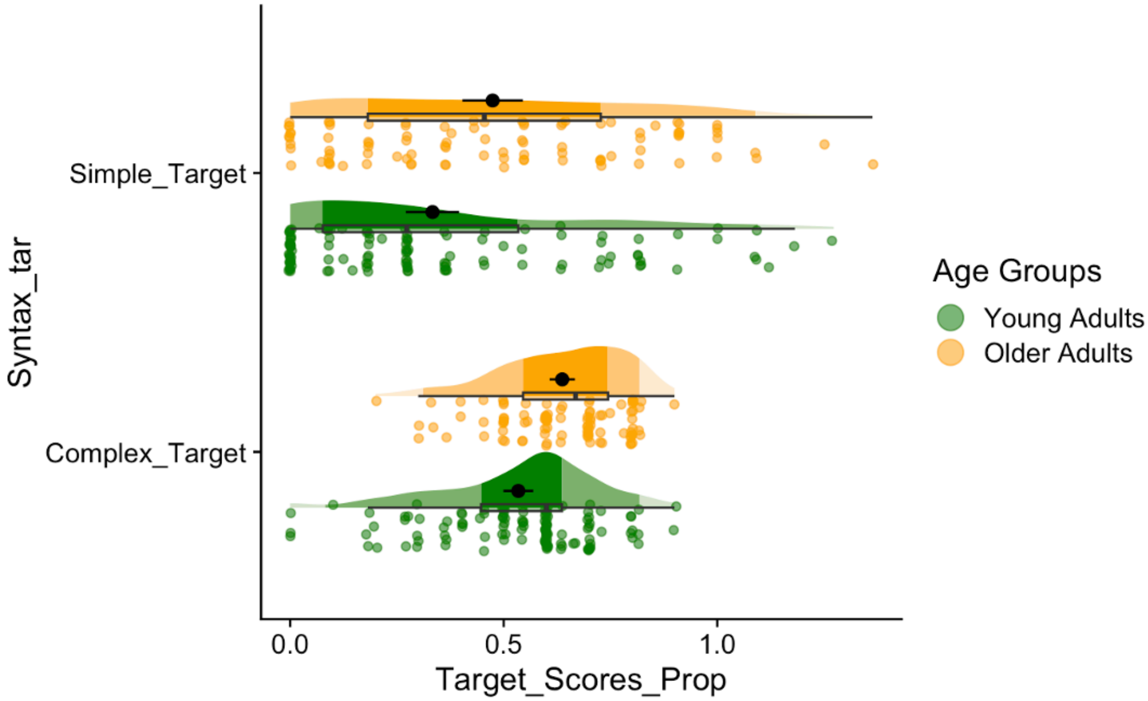
Means, Standard Deviations, and Confidence Intervals for the Proportion of Target Items (i.e., questions with the correct word) Answered Correctly (Target Scores) by Syntax Condition, Between Young and Older Adult Age Groups.

Syntax: Complex			
Age Group	*M*	*M* 95% CI [LL, UL]	*SD*
YA	0.53	[0.50, 0.57]	0.19
OA	0.64	[0.61, 0.67]	0.14
Syntax: Simple			
Age Group	*M*	*M* 95% CI [LL, UL]	*SD*
YA	0.33	[0.27, 0.40]	0.34
OA	0.48	[0.41, 0.55]	0.35

Note. M and *SD* represent mean and standard deviation, respectively. *LL* and *UL* indicate the lower and upper limits of the 95% confidence interval for the mean, respectively. The confidence interval is a plausible range of population means that could have created a sample mean (Cumming, 2014). YA = Young adults; OA = Older adults.

Figure 4

Raincloud Plot Visualization of the Distribution of Target Scores by Age Group and Syntax Condition (Simple, Complex)



Finally, to control for any age-related differences in variables that may influence target scores, the previous models were intended to be conducted again with WMC and reading comprehension added as covariates, i.e., an Analysis of Covariance (ANCOVA). However, WMC could not be used as a covariate as the variable violated the assumption of a significant relationship between the dependent variable (target scores; see Appendix B for correlations between covariates and target scores). Additionally, using reading comprehension as a covariate did not impact the pattern or significant effects found for syntax and age on target scores. Because these analyses offered no novel information, the results of the ANCOVA are reported in Appendix B.

Individual-Level Analyses: Detection of Illusory Information and Cognitive Abilities

Although the original plan was to assess the cognitive predictors of both detection scores and illusion scores, the illusion scores failed to meet the regression-based assumption of a linearity between the predictor variable and the outcome variable (see Table 1 and Table 2 for correlations between illusion scores and the cognitive composites for young and older adults respectively; Field, 2013). Therefore, the composites variables for crystallized intelligence, fluid intelligence, and rationality were not appropriate to use as predictors of illusion scores. Instead, the effects of age and cognitive ability on detection scores were further explored using bootstrapping/resampling, mediation, and moderation techniques. The initial regression models that were conducted are consistent with the current predictions for detection scores based on previous research. However, the additional modeling techniques were conducted more broadly in an exploratory, data-driven manner.

Detection Scores

Multiple Regression. Multiple regression models were conducted to determine which cognitive composites, along with age group, best predicted detection scores. Detection scores were collapsed across syntax and included in the model along with the dummy-coded variable for age group and the composite scores for crystallized intelligence, fluid intelligence, and rational thinking (see the Method section for specific measures underlying each construct). Resampling techniques were implemented to generate 95% bootstrap confidence intervals for the effect sizes associated with the standardized regression coefficients (ß) and the model's overall explanatory magnitude (R^2). Confidence interval values were based on 1,000 simulated resamplings of the original data (Algina, Keselman, & Penfield, 2008; Cumming, 2014).

The modeling approach was consistent with a priori predictions of the best predictors of detection scores. Variables were entered one-per-block, starting with the dummy-coded age group variable (0 = young adults, 1 = older adults), followed by each of the cognitive composite variables according to the predicted strength of the association with detection scores based on the limited previous research: crystallized intelligence, rationality, and fluid intelligence. Although the strength of the associations between detection and the composite scores for older adults was consistent with expectations (see Table 3 for bivariate correlations among older adult scores), for young adults, detection scores were more strongly associated with rationality than crystallized intelligence (see Table 2 for bivariate correlations among young adult scores). For the initial regression models the a priori predicted order was still used despite the discrepancy, but this discrepancy between the age groups motivated the moderation analyses in the following section. Model comparisons were conducted on the nested models after each predictor was added. If the model fit to the data was significantly improved by the added predictor, the model was retained for the next step. If the model was not significantly improved by the added predictor, the previous model that did not include the most recent predictor was retained for parsimony.

See Table 7 for regression model estimates, individual predictor coefficients, model comparisons, along with the generated 95% bootstrap confidence intervals. See Figure 5, Figure 6, and Figure 7 for visualizations of the relationship between each cognitive composite and detection scores, by age group (see *plotly* graphical library for *R*; Inc., 2015). Per the described modeling process, the best-fitting model included crystallized intelligence (β = .33, p < .001, CI_{95}[.15, .51]) and rational thinking (β = 0.20, p < .001, CI_{95}[.04, .37]), along with the non-significant dummy-coded variable for age-group (β = .12, p = .096, CI_{95}[-.03, .25]); $F(3, 204)$ = 27.05, p < .001, R^2 = .29, CI_{95}[.20,.39]. The three-predictor model (age, crystallized, rationality) showed significant improvement in explanatory power compared to the two-predictor model with just age group and crystallized intelligence, ΔR^2 = .18, p < .001CI_{95}[.10, .28]. Furthermore, the confidence intervals for the regression coefficient for fluid intelligence containing zero (β =

.04, $p < .001$, $CI_{95}[-.12, .08]$) and adding fluid intelligence to the model did not significantly improve fit, $\Delta R^2 < .001$, $p > .05$, $CI_{95}[-.00, .02]$.

Table 7

Multiple Linear Regression Models Predicting Detection of Illusory Information (Detection Scores) with Dummy-coded Variable for Age Group, and Composite Scores for Crystalized Intelligence, Rationality, and Fluid Intelligence with Bootstrap 95% Confidence Intervals around Effect Sizes

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	*r*	Fit	Difference
(Intercept)	0.23**	[0.19, 0.27]							
Age	0.14**	[0.08, 0.21]	0.28	[0.16, 0.41]	.08	[.02, .17]	.28**		
								R^2 = .081** 95% CI[.02,.17]	
(Intercept)	0.28**	[0.23, 0.32]							
Age	0.03	[-0.04, 0.10]	0.06	[-0.08, 0.21]	.00	[.00, .03]	.28**		
CI	0.04**	[0.03, 0.05]	0.48	[0.35, 0.59]	.18	[.10, .28]	.51**		
								R^2 = .261** 95% CI[.18,.36]	ΔR^2 = .180** 95% CI[.10, .28]
(Intercept)	0.27**	[0.23, 0.31]							
Age	0.06	[-0.01, 0.13]	0.12	[-0.02, 0.25]	.01	[.00, .04]	.28**		
CI	0.02**	[0.01, 0.04]	0.33	[0.15, 0.50]	.05	[.01, .11]	.51**		
rational	0.01*	[0.00, 0.02]	0.20	[0.05, 0.38]	.02	[.00, .08]	.42**		
								R^2 = .285** 95% CI[.21,.38]	ΔR^2 = .023* 95% CI[.00, .08]
(Intercept)	0.26**	[0.23, 0.30]							
Age	0.06	[-0.01, 0.13]	0.12	[-0.02, 0.26]	.01	[.00, .05]	.28**		
CI	0.02**	[0.01, 0.04]	0.32	[0.15, 0.51]	.05	[.01, .11]	.51**		
CART	0.01	[-0.00, 0.02]	0.18	[-0.02, 0.38]	.01	[.00, .05]	.42**		
FI	0.00	[-0.01, 0.02]	0.04	[-0.12, 0.18]	.00	[.00, .02]	.30**		
								R^2 = .285** 95% CI[.21,.39]	ΔR^2 = .001 95% CI[.00, .02]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *Note.* *LL* and *UL* indicate the lower and upper limits of a bootstrapped 95% confidence interval, respectively. Age = age group (0 = young adults, 1 = older adults); CI = crystalized intelligence; CART = rationality (quotient)
* indicates $p < .05$. ** indicates $p < .01$.

Figure 5

The Relationship between the Cognitive Composites (Crystalized Intelligence) and Detection Scores by Age Group (0 = Young Adults)

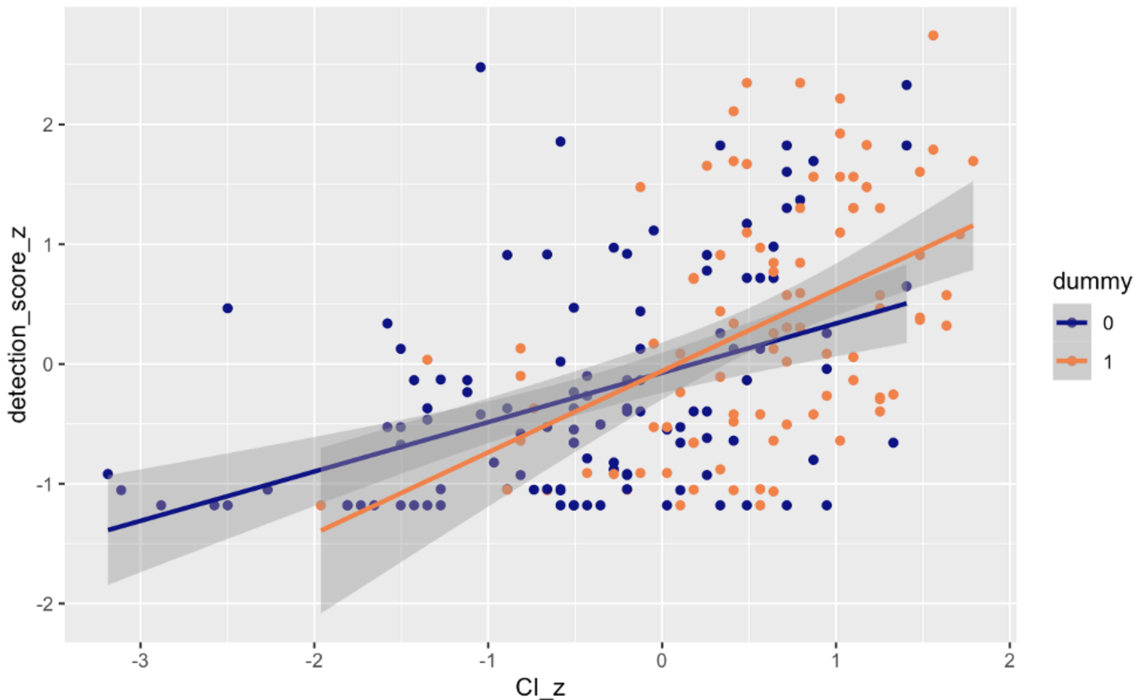


Figure 6

The Relationship between the Cognitive Composites (Fluid Intelligence) and Detection Scores by Age Group (0 = Young Adults)

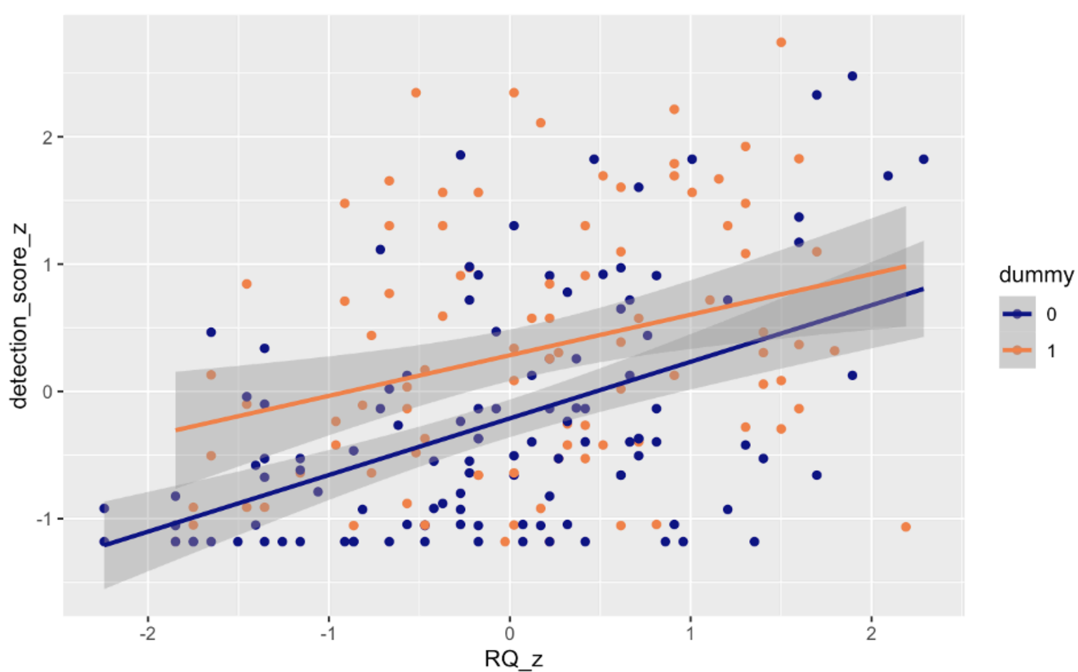
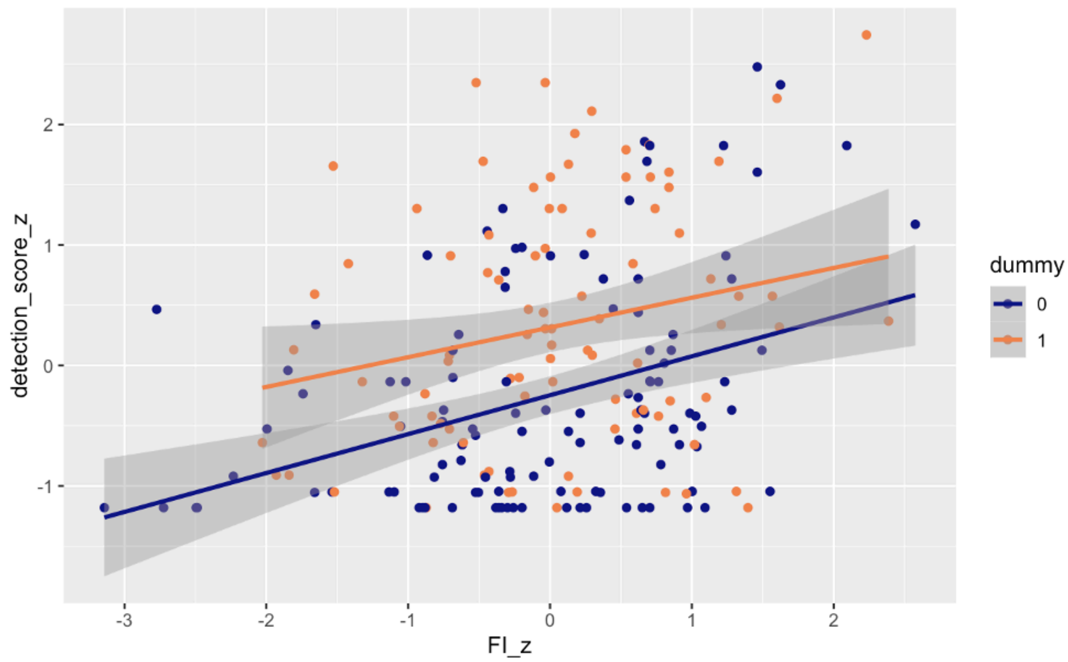


Figure 7

The Relationship between the Cognitive Composites (Rationality) and Detection Scores by Age Group (0 = Young Adults)



Ultimately, dropping the non-significant dummy-coded variable for age did not significantly impact the model effect size, $F(2, 205) = 27.91$, $p < .001$, $R^2 = .28$, $CI_{95}[.19, .36]$, $\Delta R^2 = .01$, $p > .05$, $CI_{95}[.00, .05]$, and the model with crystallized intelligence ($\beta = .41$, $p < .001$, $CI_{95}[.14, .50]$) and rational thinking ($\beta = .16$, $p < .001$, $CI_{95}[.02, .38]$) was retained for interpretation. See Table 7 for the model estimates for the two-predictor, final model (crystallized intelligence, rationality) in comparison to the three-predictor model with age included.

Moderation of Age*Cognitive Abilities. Moderation effects were explored due to the different pattern of associations between detection scores and the composites for crystallized intelligence and rationality between age groups (see Table 2 and Table 3 for bivariate correlation pattern discrepancies between age groups). This was also based on the best-fitting model in the previous section, that contained significant predictors for both crystallized intelligence and rationality (see Table 8 for model estimates).

Table 8

Multiple Linear Regression Models Predicting Detection of Illusory Information (Detection Scores)) with Dummy-coded Variable for Age Group, Composite Scores for Crystalized Intelligence and Rationality, with Bootstrap 95% Confidence Intervals around Effect Sizes

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	*r*	Fit	Difference
(Intercept)	0.29**	[0.26, 0.32]							
CI	0.03**	[0.02, 0.04]	0.41	[0.26, 0.54]	.10	[.04, .18]	.51**		
CART	0.01*	[-0.00, 0.02]	0.16	[-0.00, 0.32]	.02	[.00, .06]	.42**		
								R^2 = .28** 95% CI[.19,.36]	
(Intercept)	0.27**	[0.23, 0.31]							
Age	0.06	[-0.01, 0.12]	0.12	[-0.01, 0.25]	.01	[.00, .04]	.28**		
CI	0.02**	[0.01, 0.04]	0.33	[0.14, 0.50]	.05	[.01, .11]	.51**		
CART	0.01*	[0.00, 0.02]	0.20	[0.02, 0.38]	.02	[.00, .09]	.42**		
								R^2 = .29** 95% CI[.20,.39]	ΔR^2 = .01 95% CI[.00, .05]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *Note. LL* and *UL* indicate the lower and upper limits of a bootstrapped 95% confidence interval, respectively. Age = age group (0 = young adults, 1 = older adults); CI = crystalized intelligence; CART = rationality (quotient) * indicates $p < .05$. ** indicates $p < .01$.

Moderation terms were formed from the product of the dummy-coded age variable (0 = young adults), and the composite scores for crystallized intelligence (Mod_C = age*crystallized intelligence) and rationality (Mod_R = age*rationality). The composite scores were significantly associated with detection scores, and both Mod_C ($r = .39$, $p < .001$) and Mod_R ($r = .23.$, $p < .001$) were deemed appropriate for moderation analysis. Each of the terms were evaluated as a moderator separately in the following manner, first a two-predictor model is conducted, containing the main effects that formed the interaction (age group and composite score). Next the interaction term is added to the two-predictor model. Moderation is only achieved if both the coefficient for the moderation term is significant, and adding it to the model significantly improved the fit. Although both moderator terms were significantly associated with detection scores, neither Mod_C nor Mod_R significantly improved their respective models or remained significant when added to the models with the main effects for age and the composites. See Table 9 and Table 10 for model estimates for the analyses containing Mod_C and Mod_R, respectively.

Table 9

Multiple Linear Regression Models Predicting Detection of Illusory Information (Detection Scores) with Dummy-coded Variable for Age Group, and Composite Scores for Crystalized Intelligence, and Moderator Term (Age*Crystalized Intelligence) with Bootstrap 95% Confidence Intervals around Effect Sizes

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	*r*	Fit	Difference
(Intercept)	0.28**	[0.24, 0.32]							
Age	0.03	[-0.04, 0.10]	0.06	[-0.08, 0.20]	.00	[.00, .03]	.28**		
CI	0.04**	[0.03, 0.05]	0.48	[0.37, 0.60]	.18	[.10, .28]	.51**		
								R^2 = .26** 95% CI[.18,.36]	
(Intercept)	0.27**	[0.23, 0.32]							
Age	0.03	[-0.04, 0.09]	0.05	[-0.09, 0.19]	.00	[.00, .03]	.28**		
CI	0.03**	[0.02, 0.04]	0.43	[0.27, 0.58]	.09	[.03, .17]	.51**		
Mod_c	0.01	[-0.01, 0.03]	0.08	[-0.08, 0.25]	.00	[.00, .03]	.39**		
								R^2 = .26** 95% CI[.18,.37]	ΔR^2 = .003 95% CI[.00, .03]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *Note. LL* and *UL* indicate the lower and upper limits of a bootstrapped 95% confidence interval, respectively. Age = age group (0 = young adults, 1 = older adults); CI = crystalized intelligence; Mod_c = Age*CI
* indicates $p < .05$. ** indicates $p < .01$.

Table 10

Multiple Linear Regression Models Predicting Detection of Illusory Information (Detection Scores) with Dummy-coded Variable for Age Group, and Composite Scores for Rationality, and Moderator Term (Age*Rationality) with Bootstrap 95% Confidence Intervals around Effect Sizes

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	*r*	Fit	Difference
(Intercept)	0.23**	[0.20, 0.27]							
Age	0.13**	[0.07, 0.19]	0.25	[0.13, 0.37]	.06	[.02, .14]	.28**		
CART	0.02**	[0.02, 0.03]	0.40	[0.27, 0.50]	.16	[.07, .25]	.42**		
								R^2 = .24** 95% CI[.15,.33]	
(Intercept)	0.24**	[0.20, 0.27]							
Age	0.13**	[0.07, 0.19]	0.25	[0.14, 0.37]	.06	[.02, .14]	.28**		
CART	0.03**	[0.02, 0.04]	0.46	[0.29, 0.60]	.12	[.04, .20]	.42**		
Mod$_R$	-0.01	[-0.02, 0.01]	-0.09	[-0.25, 0.07]	.00	[.00, .03]	.23**		
								R^2 = .24** 95% CI[.16,.34]	ΔR^2 = .005 95% CI[.00, .03]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *Note. LL* and *UL* indicate the lower and upper limits of a bootstrapped 95% confidence interval, respectively. Age = age group (0 = young adults, 1 = older adults); CART = rationality; Mod$_R$= Age*CART
* indicates $p < .05$. ** indicates $p < .01$.

Because the moderator terms did not reach significance when included with the main effects for age and the composite scores, the data were subset by age group to explore the effects of crystallized intelligence and rationality for young and older adults separately. As expected there were discrepancies in the predictor patterns between age group. For young adults, rationality was best predictor of detection scores ($\beta = .36$, $p = .001$, CI_{95}[.12, .59]). Although crystallized intelligence was also a significant predictor ($\beta = .22$, $p = .04$, CI_{95}[-.01, .42]), the confidence intervals contained zero, suggesting the result could be spurious. See Table 10 for model estimates for young adults, $F(2, 111) = 21.65$, $p < .001$, $R^2 = .27$, CI_{95}[.15, .43]. For older adults, crystallized intelligence was the only significant predictor ($\beta = .44$, $p < .001$, CI_{95}[.22, .68]), but not rationality ($\beta < .01$, $p = .97$, CI_{95}[-.26, .25]). See Table 11 for model information for older adults, $F(2, 91) = 11.14$, $p < .001$, $R^2 = .18$, CI_{95}[.10, .34]. Overall, the identical model was more accurate for explaining young adult data (27%), compared to older adult data (18%).

Although neither model was particularly powerful in replicating the patterns in either subset of data.

Table 11

Multiple Linear Regression Models Predicting Detection of Illusory Information (Detection Scores) for Young Adults with Composite Scores for Crystalized Intelligence and Rationality with Bootstrap 95% Confidence Intervals around Effect Sizes

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	*r*	Fit
(Intercept)	0.26**	[0.21, 0.30]						
CI	0.02*	[-0.00, 0.03]	0.22	[-0.01, 0.42]	.03	[.00, .10]	.45**	
CART	0.02**	[0.01, 0.03]	0.36	[0.12, 0.59]	.08	[.01, .21]	.50**	
								R^2 = .27** 95% CI[.15,.43]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *Note. LL* and *UL* indicate the lower and upper limits of a bootstrapped 95% confidence interval, respectively. CI = crystalized intelligence, CART = rationality
* indicates $p < .05$. ** indicates $p < .01$.

Table 12

Multiple Linear Regression Models Predicting Detection of Illusory Information (Detection Scores) for Older Adults with Composite Scores for Crystalized Intelligence and Rationality with Bootstrap 95% Confidence Intervals around Effect Sizes

Predictor	*b*	*b* 95% CI [LL, UL]	*beta*	*beta* 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	*r*	Fit
(Intercept)	0.30**	[0.24, 0.36]						
CI	0.04**	[0.02, 0.07]	0.44	[0.22, 0.68]	.10	[.03, .23]	.44**	
CART	0.00	[-0.02, 0.02]	0.00	[-0.26, 0.25]	.00	[.00, .04]	.31**	
								R^2 = .18** 95% CI[.10,.34]

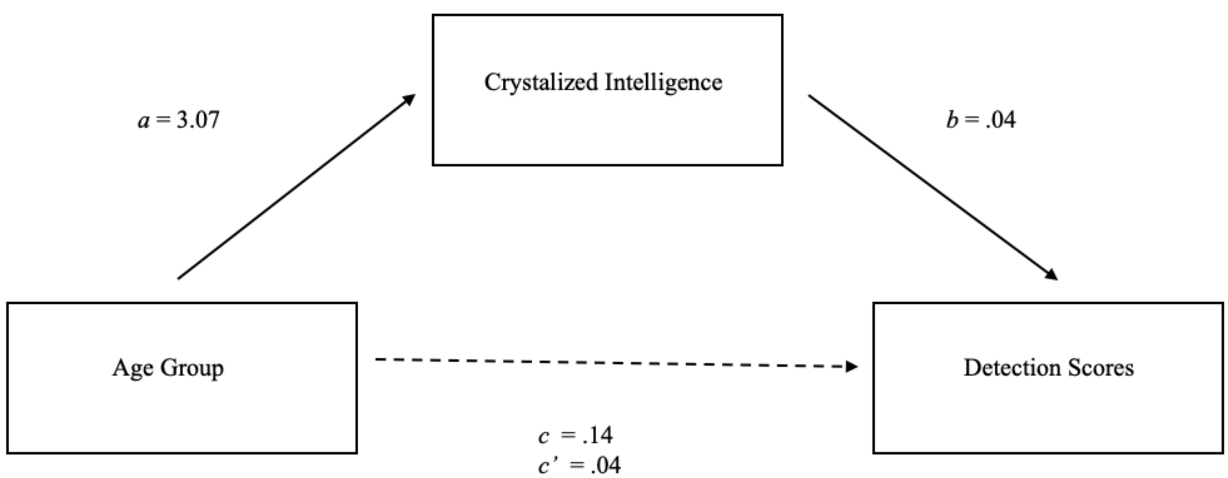
Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *beta* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *Note. LL* and *UL* indicate the lower and upper limits of a bootstrapped 95% confidence interval, respectively. CI = crystalized intelligence, CART = rationality
* indicates $p < .05$. ** indicates $p < .01$.

Mediation of Detection Scores and Age by Crystallized Intelligence. One issue that became apparent throughout the regression analyses is that the older adult age group consistently scored higher than young adults on any measure of stored information. The older adults not only had higher crystallized intelligence scores (M = 0.42, SD = 0.66) than young adults (M = 0.35 SD = 0.80), but also performed better on the general knowledge check following the semantic illusion task (M_y = .68, SD_y = .21; M_o = .78, SD_o = .19), and had higher target scores than young adults (M_y = .36, SD_y = .15; M_o = .43, SD_o = .15). At face-value these trends suggest that stored information or crystallized intelligence could be statistically conflated with any effects associated with age differences or specifically the older adult age group. For example, the association between age and detection scores may be explained by crystallized intelligence, such that older adults had higher detection scores because having more knowledge is ubiquitous to older adulthood. Mediation techniques suggest the independent variable influences the dependent variable *by way of* another third variable (e.g., MacKinnon et al., 2000). Although, mediation was not planned in the initial design, this approach may explain some of the patterns of effects and illuminate the root of the age-related differences in detection performance. It would also indicate that the effects of age and crystallized intelligence in detection scores cannot necessarily be delineated for the current data, as the difference between mediated-by and confounded-with is only conceptual.

A mediation model was conducted to determine if the relationship between detection scores and age group, is fully or partially explained by the crystallized intelligence composite scores. Crystallized intelligence was the only composite score that was significantly predicted by age group (IV) and thus appropriate to serve as a potential mediator. Alternatively, rationality and fluid intelligence were not significantly associated with age group and were deemed inappropriate for mediation modeling. The first step (path c, direct effect) included detection scores predicted by the IV, age group, which produced a significant coefficient (β = .28, p < .001, CI_{95}[.16, .40]) and overall model, $F(1, 206) = 18.13$, p < .001, R^2 = .08, CI_{95}[.02, .16]. When comparing young adults to older adults, older adulthood is associated with increased detection scores. Next, a model was conducted with age group predicting the variability in the mediator crystallized intelligence, (β = .46, $p < .001$, CI_{95}[.36, .57]) and produced significant coefficient and overall model, $F(1, 206) = 55.89$ $p < .001$, $R^2 = .21$, CI_{95}[.13, .32]. Increases in crystallized intelligence are significantly predicted by increasing age (path a). Finally, a model with both age group (β = .06, p =.58, CI_{95}[-.07, .20]) and crystallized intelligence (β =.48, $p < .001$, CI_{95}[.36, .59) predicting detection scores was conducted $F(2, 205) = 36.86$, $p < .001$, $R^2 = .26$, CI_{95}[.17, .36]; (path b and c', indirect effect). When controlling for crystallized intelligence by including it in the regression model, age no longer is a significant predictor of detection scores. See Figure 7 for the mediation model with unstandardized path estimates.

Figure 8

Mediation of the Relationship between Age Group and Detection Scores by the Composite Score for Crystalized Intelligence



Note. Path values are unstandardized. The dotted line indicates *ns* and the solid line indicates significance $p < .001$.

The significance of the direct versus indirect effect was further confirmed using a bootstrap resampling technique (n = 1,000). The analysis confirmed the direct effect of age on detection scores was no longer significant (direct = .03, p =.38) when including crystallized intelligence in the model. That combined with the indirect effect being significant (indirect = .11, $p < .001$) indicates full mediation. The estimate suggests that around 78% of the effect of age on detection scores is by way of, or can be explained by one's level crystallized intelligence.

Discussion

Group-Level Analyses: Effects of Age*Syntax

The experimental portion of the current study examined the effect of age and syntax complexity on the rate of semantic illusions. These effects were measured using the detection of illusory information (detection scores), the failure to detect illusory information (illusion scores), and these patterns were compared with the correct responses to target items (target scores).

In general, it was expected that older adults would have more relevant knowledge compared to young adults, and this would be reflected in more correct responses on the knowledge check and higher target scores regardless of syntax. The outcome was consistent with predictions, and older adults had higher target scores, crystallized intelligence, and knowledge check scores than young adults. The results were congruent with previous research indicating that older adults tend to have a larger store of general knowledge, or crystallized intelligence, compared to young adults (Salthouse & Babcock, 1991; Burke & Peters, 1986; Craik & Salthouse, 2011; Umanath & Marsh, 2012).

Few studies have examined age differences for semantic illusions and extant research is somewhat mixed on the role of prior knowledge. Additionally, age-related differences have varied depending on how semantic illusions are measured in the study: detection of the error (detection scores) versus the actual occurrence of semantic illusions (illusion scores). Given the previous research results, it was predicted that older adults and young adults would have equivalent rates for detecting illusory information (Umanath & Marsh, 2012; Umanath, 2014).

The results contradicted this prediction, and older adults had higher detection scores than young adults. This outcome was also contrary to the previous studies that have demonstrated that young and older adults detect errors at equal rates, despite older adults having more knowledge overall. Alternatively, for illusion scores it was predicted that older adults would experience more occurrences of semantic illusions than young adults based on previous research (Umanath et al., 2014). Unlike the prediction for detection scores, illusion scores were consistent with the predicted effect of age. Older adults experienced more semantic illusions than young adults regardless of syntax condition. Consistently, the stimuli used for the semantic illusion tasks were adapted from Umanath et al. (2014; originally from Bottoms et al., 2010) who similarly found more illusions for older adults compared to young adults.

Moreover, it was anticipated that increasing the difficulty of illusion items, by using more complex syntax structures could facilitate detecting more illusory information. The results showed complex syntax facilitated detecting semantic illusions (detecting scores), and similarly, producing correct answers on target questions (target scores). These results are consistent with studies that have found that increasing the reading difficulty of semantic illusion items increased detection (Song, 2009; Song & Schwarz, 2008). These results are also in line with research showing increasing linguistic complexity can lead to better outcomes on language-related tasks (Kuiken & Vedder, 2008; Robinson, 2001), and processing fluency-based explanations in which increasing the difficulty of items leads to more effortful approach (Alter & Oppenheimer, 2007; Schwarz, 1989; Schwarz et al., 1991; Oppenheimer, 2008). Additionally, this outcome is congruent with research indicating the detection of semantic illusions are sensitive to the manipulation of language structure or syntax (e.g., question vs. statement clauses, e.g.., Büttner, 2007).

However, the focus of this study is more concerned with the interaction of age and syntax complexity on the rate of semantic illusions. When further examining the effect on detection scores, pairwise comparisons revealed the facilitative effect of complex syntax, compared to simple syntax, only occurred for older adults, but not young adults. It was anticipated older adults would likely get more of an advantage from syntax complexity on detection scores due to having more prior knowledge compared to young adults. However, it was unexpected that young adults' detection scores did not show any significant changes in detection scores compared to the increases found for older adults. Furthermore, the interaction of syntax and age, in addition to any main effects of syntax condition, were not replicated for illusion scores. It was anticipated that any effects of syntax, or interaction effects of age and syntax on detection scores would automatically have the inverse effect on illusion scores. Yet illusion score results were contradictory to this prediction, the detection score results, and prior research from Song (2009; Song & Schwarz, 2008). Only the main effect of age indicating older adults experience more illusions than young adults was significant. However, given that Song (2009) only included a couple of items, and a between-subject design, it is also possible these results are not that reliable or only reproducible under certain circumstances.

Predicting the Detection of Illusory Information: Cognitive Abilities

The secondary, correlational portion of the study was to determine if the rate of semantic illusions could be predicted by individual differences in cognitive abilities. This component of the study was largely exploratory, and data driven. Initial plans were to explore relationships for detection scores and illusion scores among the cognitive ability composites for crystallized intelligence, fluid intelligence, and rationality. However, the illusion scores did not have any significant relationships with any of the cognitive composites. This finding was unexpected given the research supporting the association between semantic illusions and access to information in LTM (Hannon & Daneman, 2001), and performance on rationality-based tasks like those included in the CART (Mata et al., 2014). Furthermore, the association between WMC and fluid intelligence, would suggest the fluid intelligence would similarly be associated with the occurrence of semantic illusions as WMC (Hannon & Daneman, 2001; Kyllonen & Christal, 1990). Yet the only significant relationship for illusion scores within the dataset was for the knowledge check, which is necessarily associated with illusion/detection scores.

Furthering the unexpected nature of the results, the three composite scores were all significantly associated with detection scores, for both young adults and older adults (see Tables 1 and 2 for correlations). As discussed earlier with the group analysis and other age-related research on semantic illusions, depending on the semantic illusion task, detection of illusions and the failure to detect illusions do not necessarily follow congruent patterns (e.g., Umanath et al., 2014). These outcomes confirm that perhaps separate cognitive mechanisms underlie detecting illusory information versus experiencing a semantic illusion, and these effects should be explored individually. On the other hand, this could be a function of the scoring method – the current study divided the number of detections/illusions out the number of detection or illusion items experienced in each syntax condition. If the scores were instead based on total items in general, or known answers on the knowledge check etc., inverse patterns between illusion/detection scores would likely to emerge. Regardless, only detection scores were further explored with the cognitive ability composite models.

It was anticipated that crystallized intelligence would be the strongest predictor of detecting illusory information (e.g., Umanath & Marsh, 2014), but all cognitive abilities, including fluid intelligence and rational thinking were expected to have positive associations with detection scores (i.e., positive manifold; e.g., Jensen, 1986). Consistent with expectations and the limited research, all composite variables were significant predictors of higher detection scores, with the strongest being crystallized intelligence and rationality. Greater cognitive ability was associated with higher detection scores. However, when the data was broken down by age group, the relationship patterns varied between young and older adult subsets. For young adults, rationality was the strongest indicator of increased detection scores (see Table 10 for regression table). For older adults, crystallized intelligence was the better predictor of detection scores (see Table 11 for regression table). Older adults often relying on crystallized intelligence as a compensatory mechanism (Gordon & Kindred, 2011; Craik & Bialystok, 2006; Bowles & Salthouse, 2008; Hess, 199), and older adults often have more knowledge than young adults on average (Craik & Salthouse, 2011; Salthouse, 2006; Baltes, 1997; Baltes, Stauding, & Lindenberger, 1999); it was unsurprising that there may be some variation in the strength of the relationships between crystallized intelligence and the detection of illusory errors.

Further exploration of the effect was necessary; however, moderation analyses did little to illuminate the age discrepancies in predictors for detection scores. Moderator terms (rationality*age, crystallized*age) were no better at predicting detection scores compared to the main effect coefficients. Older adults had higher scores than young adults for the two best predictors of detection scores, crystallized intelligence, and rationality. However, a potential issue was that the effect of prior knowledge appeared to be conflated with age group for the current study. Older adults provided more correct answers than young adults to target questions, the general knowledge check, and all the measures of crystallized intelligence that formed the composite. This seemed to suggest the effect of increased crystallized intelligence could not readily be teased apart from effects relating to age, specifically that older adulthood is conflated with having more knowledge. Yet, age was only a significant predictor of detection scores when crystallized intelligence was not included in the model. Thus, mediation modeling techniques were used to determine if age was only influential on detection scores by-way of a third variable, crystallized intelligence. Results supported full mediation -- the effect of age on detection scores can be explained or attributed to the increased crystallized intelligence associated with the older adult group (compared to young adults). Conversely, due to young adults not having as much crystallized intelligence as older adults, it would make sense that the relationship with detection scores is weaker, and the measures rationality are more relevant. The CART tasks are difficult and high scores typically reflect greater educational advancement, which one could assume would also be significantly predictive of detection scores.

Overall composite scores for crystallized intelligence, fluid intelligence, and rationality were used to predict detection scores for the young adult, older adult subsets, and the total sample. The results supported the hypotheses, increased crystallized intelligence significantly predicted higher detection scores. While crystallized intelligence was the strongest predictor of detection scores for older adults, it was secondary to rationality scores for young adults. In sum, crystallized intelligence plays an important role in determining whether illusory information is detected across age group. Yet, for young adults, greater rationality is the strongest predictor of detection scores. Age is also a significant predictor of detecting illusory information, but only in that older adults tend to have more crystallized intelligence than young adults.

Dual-Process Theory

Dual-process theory describes the two paths or approaches to problem-solving that are utilized: the automatic, heuristic-style of thinking and the more effortful, deliberative style of thinking (Kahneman, 2011; Stanovich & West, 2000). In reasoning tasks, these two thinking patterns are intentionally pitted against one another such that the automatic response that comes to mind is typically incorrect, and the correct response requires more effortful calculations and/or retrieval of prior knowledge (e.g., probabilistic reasoning; Kahneman, 2011; Tversky & Kahneman, 1989). When applied to semantic illusions, it would suggest that overlooking the wrong but related name (e.g., Moses), could be tied to reflexive heuristic-based thinking. One suggestion for this mechanism could be the feeling of familiarity (i.e., familiarity heuristic) associated with recognizing the known information in the context of the sentence (e.g., the animals on the ark) and a semantically associated name (Schwarz, 2004; Alter & Oppenheimer, 2009; Jacoby, 1983). If this is assumed to be correct, it would suggest that the disruption of the feelings of familiarity could help individuals to notice the incongruency between the information being read and the information they already know. Previous research has shown that disrupting processes fluency, can lead to items being perceived as less familiar and less truthful (Whittlesea, 1993; Unkelbach, 2007).). Specific to semantic illusions there is also some evidence that disrupting processing fluency can lead to greater detection of illusory information (Song, 2009; Song & Schwarz, 2008). The current project attempted a similar effect as Song & Schwarz (2009), but rather than manipulating font-readability, syntax complexity was used to increase difficulty. It was anticipated that although syntax is evident in its effect on comprehension and reading difficulty, it is not as salient to participants at face-value like the appearance of words would be (Dechêne et al., 2010; Stromswold et al., 1996; Bohan, 2008).

Per dual-process theory, the disruption of familiarity or processing fluency disrupts the automatic thinking that occurs to facilitate semantic illusions. Increasing the difficulty would offer more time to retrieve relevant information, it may lead to rereading the item for clarity, and in general would facilitate more time and effort being spent on the item. If the correct information is not available in memory, these effects would do little more than slow response time. However, if the correct information is in LTM, it would provide a greater opportunity and time to apply the information or to notice more thinking is needed. This could explain why the increased complexity of the current project gave older adults an advantage over young adults particularly for complex compared to simple items. Older adults had the correct information needed for resolution, while in many cases the young adults did not (see Tables 1 and 2 for group *M*s and *SD*s).

However, the current results should also explore through the lens of other theoretical perspectives other than just dual process theory to help inspire next steps. For example, node structure theory (NST; MacKay, 1987) offers a compelling understanding of these phenomena. NST posits that information is stored in representational units, known as nodes, within a vast overlapping network of layered systems. These systems represent different types of information associated with specific layers of nodes. For example, the semantic information and phonological information for the name "Noah" would be stored in separate nodes clustered around and interconnecting with, the node representing the construct itself. The nodes of information are shared among constructs, for example "Noah" and "Moses" share common phonology and semantic associations. When shared nodes are activated for the constructs of Moses and Noah, a convergence of activation among the common nodes can lead one to read "Moses" but have the concept "Noah" activated in mind. This error can only be overcome if novel information is introduced that contradicts the information already activated in mind (MacKay, 1990). The effect is reminiscent of the reasoning problems discussed previously, where increasing the salience of the conflict or contradiction is what enables detection or overcoming the error. In this case, the semantic context of the sentence needs to be activated at the same time as contradictory information stored in memory. From the NST perspective the manipulation of syntax for the current study, could have facilitated this process by changing the order in which the words were read (left-branching vs. right-branching). Perhaps this allowed for certain contradictory nodes to be activated at the same time as others that otherwise would not have been. Another option is the complex syntax slowed down reading times enough that the contradictory information stored in memory had time to be retrieved/become activated in mind, whereas typically the reader would have already moved on to the next item. These are only speculations, but potential next steps would be to further explore these effects from multiple perspectives (NST, dual process theory) within the same study to better triangulate the issue.

Limitations

As stated in the previous section, the greatest limitation to the current study is that much of the design and theoretical underpinnings were established by the larger project that it was formed under. Although this was beneficial in that it made other variables accessible and allowed for a greater access to more participants, it created some disconnect between theoretical-underpinnings and overall methodological design.

There are some more generic limitations to the current study including that the data were collected online. Although this manner of collection is becoming more frequent and more tightly patrolled, it still limits the amount of control or knowledge the researcher has for the testing environment. Additionally, no checks were included to prevent cheating or looking up the answers online. Although strict instructions and attention-checks were included, with distractions like smartphones, researchers have no way of knowing whether the rules have been followed. One means of mitigating this issue has been to pay careful attention for outliers and remove any that fall into the "extreme" range, in addition to over-collecting under the assumption some of the data is not ideal. If a participant is distracted, this will likely be reflected in their response patterns with either multiple unanswered or incorrect responses in a row or repeat/unusually patterned responses. However, the few outliers that were found in the current data were not extreme scores and ultimately were viewed as reasonable to include in the final analysis. Additionally, each model was conducted both with and without the identified outliers, and none significantly impacted the model estimates.

A secondary limitation related to the first issue, is that due to the testing taking place over three separate days, many participants had missing data or did not participate in certain sections of the study. Each test day included many measures without desginated opportunities to take a formal break, and it would be easy for participants to miss specific items within a measure, skip multiple measures, or get bored/tired and not even try. Although it should be noted missing data remained under the acceptable 5% for the current variables of interest.

Finally, there were some decisions made specific to the study design that were less than ideal, but the best option given the practical circumstances. For example, WMC was measured using a backward-digit-span, rather than using a complex span task which is a more valid and reliable approach to capturing WMC (Just & Carpenter, 1980) The backward digit-span was selected due to only having a very limited amount of available time, and the larger study had to be given priority for the measures selected to be included. Similarly, the reading comprehension measure was a very brief set of passages and questions from the Verbal section of the GRE. Ideally, the effect of WMC and reading comprehension on semantic illusions will be assessed with stronger measures in future studies.

Future Directions

The current study approached the issue of semantic illusions from a broad, largely exploratory manner. This study was an initial attempt to gather information from various lines of research to investigate the occurrence of semantic illusions from a broad, all-encompassing perspective. However, the breadth of the current project also limited the focus on mechanistic underpinnings that would provide support for specific theories. This theoretical disconnect while beneficial for taking a broad, data-driven approach to semantic illusions, also weakened the theoretical specificity and only allowed for vague retroactive connections back to theoretical frameworks. Future directions should take the interesting effects learned from the current study and start narrowing the focus to allow for theory-driven comparisons. For example, the interaction of age group and syntax complexity on detection scores should be replicated but with other syntax structures to determine the reliability and boundaries of the effect; such as determining if detection increases when the contradictory information is punctuated with syntax structure (e.g., it-clauses). The effect of "noticeability" of the error could be pitted against the complexity manipulation from the current study to determine whether the benefits to detection are truly due to reading difficulty/processing fluency or something related to novelty and/or attentional resources, etc. This would allow more than one perspective to be considered and compared.

Additionally, semantic illusions and reasoning problems should continue to be explored together. Both types of constructions require the inhibition and application of specific knowledge at certain times. However, the subject matter and approach is different enough that the comparison can be informative. For example, the effect of complex syntax increased both target scores and detection scores, and it would be interesting to determine if this effect would replicate equivalently for some of the probability problems or scientific reasoning questions found in the CART. These types of questions should be examined alongside the role of expertise or prior experience for the knowledge. Arkes et al. (1989) found that having simple related knowledge in the area facilitated the misattribution of familiarity for the of truth. However, further investigation has demonstrated that having expertise and prior knowledge does reduce the likelihood of overlooking the error. This effect should be more specifically explored to understand the somewhat discrepant results.

Age effects similar to the interaction found in the current study, in which one age group benefits/is disadvantaged by a manipulation more so than another group should be further investigated. Given that older adults tend to have greater crystallized knowledge, but reduced fluid intelligence (the opposite for young adults), these age groups serve as good comparisons to better understand the tradeoff between knowledge/previous experience and general problem-solving abilities. It would be interesting to assess the pattern of results if the older adults were compared with young adults who had a similar level of knowledge, or if questions were used that young people would be more likely to know than older adults. If older adults were not able to leverage their superior prior knowledge, it would be interesting to determine whether fluid intelligence or WMC become a better predictor of success; or if rationality continues to predict detection data the best for young adults. The rationality subsections on the CART are quite varied too, so it would be interesting to determine which sections are most predictive of detection scores.

Finally, more research is needed to further explore the role of complexity for syntax or other types of language structure in how it contributes either to noticing or overlooking contradictory information. For example, it is unclear whether the disruption of processing fluency using complex syntax facilitated detection due to the manipulation slowing down individuals enough to notice the error – in other words directly influenced the processing of the error. Or the facilitation of detection was more indirect – the disruption of fluency reduced feelings of familiarity and confidence in the accuracy of the information, which in turn led people to be more skeptical or aware of the errors.

Conclusions

Overall, the current project approached semantic illusions from both an experimental and correlational approach to better understand the role of cognitive abilities and cognitive changes between age groups. Generally, this method determined that older adults have an advantage over young adults when detecting illusory information, but it is unclear whether the advantage was due solely to increased knowledge and complex syntax, or what specifically the underlying mechanism is that improved detection. Prior knowledge is clearly important for detecting contradictions, and having more knowledge predicts a greater likelihood for detection. But knowledge alone is not enough to prevent falling for semantic illusions or overlooking known misinformation. Similarly, even if the complex syntax facilitates improvements in older adult detection scores, without the existing prior knowledge the syntax manipulation would not be worthless for facilitating detection.. This phenomenon is clearly a complex issue with likely multiple interacting sources of influence from the environment, the stimuli, and the individual themselves. In sum the current study determined interesting information about the detection of illusory information and found important results, but many aspects of the occurrence of semantic illusions remains a mystery in need of solving.

Appendix A

Data Cleaning and Assumption Checks

Missing data

The initial merged dataset ($N = 220$) had 4.50% missing data, but certain variable columns had nearly 21% missing data. After eliminating participants without either of the two critical variables, age information or semantic illusion tasks scores, the sample included 208 participants. However, five participants had ages inconsistent with age group cutoffs, including two participants in their 30s, one in their 40's, and two in their 50's. These participants had responded to the initial qualifying question that their age was within the appropriate cutoffs (< 30 years or > 60 years), but then provided contradictory responses on subsequent questions about age. More than one question inquiring about age was included in the demographic's questionnaire as a consistency check to identify discrepancies for elimination. After removal of these observations ($N = 203$), the final sample had only 1.10% missing data across variables; the majority of this missingness was from the digit span tasks for participants who missed one or both administrations. This is an acceptable amount of missingness to overlook given the sample size, and no further action was deemed necessary (McNeish, 2017). Confirming this approach, visualizations generated in R using the *naniar* package revealed no systematic patterns in the missing data concept (Tierney & Cook, 2023).

Univariate/Multivariate Outliers

The current approach to outliers was not to remove any observations unless the values were extreme or impossible scores, or if inclusion of the outlier impacted the results significantly (Stevens, 1984). Cook's distance (Cook, 1977) was used to identify influential data points that could potentially impact the results of the analyses. Three multivariate outliers were identified among the relevant variables. After determining the data for all three observations did not contain [impossibley] extreme scores or entry errors, removal of the identified outliers was ultimately deemed unnecessary. However, all analyses were conducted with and without the identified multivariate outliers to ensure there was no significant change in estimates with their inclusion.

Next univariate outliers were assessed by creating box plots (by age group and syntax condition) for each dependent variable. For target scores, nine univariate outliers for young adults and 8 univariate outliers for older adults were identified. However, all but three of these scores were higher than average target scores for their age group but reasonable given the participant's overall performance. The three lower than average univariate outlier target scores were 3 young adults who did not get any target items correct, but that is also a reasonable outcome given their overall performance. Indeed ,all 17 outliers were found to not be *extreme* outliers and no additional action was deemed necessary. Similarly, 1 illusion score and 2 detection score values were identified as univariate outliers, all young adults. However, the values were within the legitimate range for scores, and were not extreme outliers. As with the multivariate outliers, analyses were conducted with and without the inclusion of all outliers to confirm the data points were not significantly impacting the results.

Statistical Assumptions: Analysis of Variance (ANOVA)

Multivariate and Univariate Normality. The significant *Shapiro-Wilk's* test suggested a lack of multivariate normality for young adult distribution of target scores, detection scores, and illusion scores ($Shapiro\text{-}Wilk's_{young} = 0.96$, $p < .001$; $Shapiro\text{-}Wilk's_{older} = 0.98$, $p = .02$). However, *Shapiro-Wilk's* test over-estimates deviations from normality with large sample sizes ($N >= 50$; Tabachnick & Fidel, 2013). Alternatively, QQ-plots (broken down by age group and syntax condition) revealed the current data points mostly fell along the line generated from the theoretical normal distribution, indicating the assumption of multivariate normality had been satisfied. Furthermore, univariate normality was confirmed by examining skew and kurtosis values for the dependent variables (target scores, detection scores, and illusion scores) were within the acceptable range included: *skew* = |3| and *kurtosis* = |10| (Tabachnick & Fidel, 2013).

Homogeneity of Variances & Covariances. Homogeneity of variance between age groups at each level of the syntax variable was confirmed using *Levene's test* for target scores ($Levene's\ test_{complex}$ = 0.67, *p* = .63; $Levene's\ test_{simple}$ = 2.39, *p* = .89), detection scores ($Levene's\ test_{complex}$ = 0.24 *p* = .63; $Levene's\ test_{simple}$ = 2.39, *p* = 14), and illusion scores ($Levene's\ test_{complex}$ = 0.23, *p* = .63; $Levene's\ test_{simple}$ = 2.39, *p* = .12). Homogeneity of covariances was examined using *Box's M* for target scores (*M* = 2.76, *p* =.10), detection scores (*M* = 2.76, *p* =.10), and illusion scores (*M* = 2.76, *p* =.10). However, unless the test is significant at *p* = .001 or less, the test is not robust for unequal sample sizes between groups (Tabachnick & Fidel, 2001). Due to the somewhat mixed results for demonstrating normality and homogeneity of covariances/variances, the current analyses were conducted using robust maximum likelihood techniques.

Appendix B

Analysis of Covariance (ANCOVA)

A final component of the group analysis included controlling for variables in which older adults may be disadvantaged compared to young adults. Older adults tend to have reduced WMC compared to young adults, and are also considerably more disadvantaged by complexity for reading comprehension (e.g., Kemtes & Kemper, 1997; Craik & Salthouse, 2011; Anderson & Davison, 1988; De Beni, Borella, & Carretti, 2007; Norman, Kemper, & Kynette, 1992). Additionally, both WMC and reading comprehension have positive associations with detecting illusory information (Hannon & Daneman, 2001; Hannon & Daneman, 2004; Hannon, 2014; Long & Chong, 2001, Todaro, Millis, Dandotkar, 2010). Ultimately, WMC was not an appropriate covariate for any of the three outcome measures due to a lack of linear associations with the necessary variables. Yet, it is worth mentioning that there was a significant correlation between WMC and fluid intelligence for young adults ($r = .32$, $p < .001$) and older adults ($r = .39$, $p < .001$) as would be expected for these constructs. At the very least, this confirms backward-digit-span captured WMC at least somewhat accurately (Engle 2002; Kyllonen & Christal, 1990). However, it could be due to the self-paced nature of the semantic illusion task, and WMC may not have been as taxed enough compared to tasks with a speed-accuracy trade-off (e.g., Craik & Jennings, 1992; Light, 1991).Reading comprehension when added to the previous models as a covariate for both target scores and detection scores, did not change the overall pattern of results. Controlling for differences in reading comprehension only emphasized the effects of age, particularly for complex items compared to simple.

It is typically considered poor practice to use repeated measures variables in an ANCOVAs due to issues with the partitioning of variance. Thus, the target score data were split into subsets by syntax condition, so the effect of age on the dependent variables, after controlling for WMC or reading comprehension, could be evaluated for complex and simple syntax separately. Prior to conducting one-way ANCOVAs, WMC and reading comprehension were evaluated as potential covariates by ensuring both were significantly correlated with simple-target scores, complex-target scores, simple-detection scores, complex-detection scores, simple-illusions scores, and complex-illusion scores.

For target scores, the measure used for WMC was not significantly correlated with target scores for the simple syntax condition (r = .06, p = .40, CI_{95} [-.09, .21]), nor for the complex syntax condition (r= .12, p =.12, CI_{95} [-.03, .26]). This variable was deemed inappropriate to use as a covariate. However, reading comprehension was significantly correlated with target scores for the simple syntax condition (r = .27, p < .001, CI_{95} [.14, .39]), and to a lesser extent, the complex syntax condition (r= .17, p =.02, CI_{95} [03, .30]).

After controlling for variability in reading comprehension, there was still a significant effect of age on simple-target scores $F(1, 205) = 9.82$ $p = .002$, $\eta_p^2 = 0.05$]. Adjusted means reflect older adults (M =.48, SE = .03) had higher detection scores than young adults (M =.33, SE = .03) for simple syntax after controlling for reading comprehension. The effect of age was also still significant after controlling for reading comprehension for complex-target-scores $F(1, 205) = 19.62$, $p = .001$, $\eta_p^2 = 0.09$]. Adjusted means reflect older adults (M =.64, SE = .02) had higher detection scores compared to young adults (M =.53, SE = .02) for complex syntax after controlling for reading comprehension.

As with target scores, the detection scores were split into subsets by syntax condition to evaluate the effect of age on simple and complex detection scores after controlling for both WMC and reading comprehension. For detection scores, the measure used for WMC was not significantly correlated with detection scores for the simple syntax condition ($r = .06$, $p = .44$, CI_{95} [-.09, .20]), nor for the complex syntax condition ($r = .09$, $p = .125$, CI_{95} [-.06, .23]). This variable was deemed inappropriate to use as a covariate. However, reading comprehension was significantly correlated with detection scores for the simple syntax condition ($r = .29$, $p < .001$, CI_{95} [.15, .41]), and the complex syntax condition ($r = .27$, $p < .001$, CI_{95} [.14, .39]).

After controlling for variability in reading comprehension, there was still a significant effect of age on simple-target scores $F(1, 205) = 11.53$, $p < .001$, $\eta_p^2 = 0.05$]. Adjusted means reflect older adults ($M = .32$, $SE = .02$) had higher detection scores compared to young adults ($M = .22$, $SE = .02$) for simple syntax after controlling for reading comprehension. The effect of age was larger and still significant after controlling for reading comprehension for complex-target-scores $F(1, 205) = 27.14$, $p < .001$, $\eta_p^2 = 0.12$]. Adjusted means reflect older adults ($M = .42$, $SE = .03$) had higher detection scores compared to young adults ($M = .23$, $SE = .02$) for complex syntax after controlling for reading comprehension.

As with target scores and detection scores, the illusion scores were spilt into subsets by syntax conditions, to evaluate the effect of age on simple and complex illusion scores after controlling for both WMC and reading comprehension. For detection scores, the measure used for WMC was not significantly correlated with detection scores for the simple syntax condition ($r < .01$, $p = .99$, CI_{95} [-.14, .14]), nor for the complex syntax condition ($r = -.08$, $p = .27$, CI_{95} [-.27, .07]). This variable was deemed inappropriate to use as a covariate. Additionally, reading comprehension was not significantly correlated with detection scores for the simple syntax condition (r = .08, p = .26, CI_{95} [-.06, .21]), and the complex syntax condition (r = .06, p = .35, CI_{95} [-.07, .19]). This variable was also deemed inappropriate as a covariate, and no ANCOVAs were conducted on the illusion scores

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