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AGE DIFFERENCES IN REVISION OF CAUSAL BELIEF

A Thesis
Presented to
The Faculty of the Department of Psychology
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
Of the Requirements for the Degree
Master of Arts

By
Kristi M. Simmons

December 2011

AGE DIFFERENCES IN REVISION OF CAUSAL BELIEF

Date Recommended 11/14/11

Sharon Mutter, Director of Thesis

Steven Haggbloom

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30-JAN-2012

Dean, Graduate Studies and Research Date

I dedicate this thesis to my parents, Ron and Brenda Simmons. Without your support none of this would have been possible. You have been my lighthouse throughout the years and your loving words of encouragement helped develop me into the capable, caring woman I am today. A daughter could not ask for more thoughtful, devoted parents. I love you both and truly appreciate everything you do for me!

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Kristi M. Simmons December 2011 62 Pages

Directed by: Sharon Mutter, Steven Haggbloom, and Steven Wininger

Department of Psychology Western Kentucky University

Inductive reasoning (IR) requires efficient working memory (WM). Research shows that the prefrontal cortex (PFC) is involved during WM tasks and that PFC functioning declines with age. The ability to comprehend and update text-based information requires an intact PFC and efficient WM and IR. The current study presented a series of messages about the investigation of a warehouse fire to 48 young and 48 older adults. One message contained a piece of misinformation which another message corrected later. It was hypothesized that a memory cue to the misinformation with the correction statement should benefit older adults the most during the updating process. A text-based level and situation model level measured updating. The text-based level is only information from the text but is not necessarily verbatim. The situation model level is the overall meaning of the text, including inferences and assumptions. Results show that unlike young adults, older adults are not capable of recalling the text at the text-based level. However, older adults are capable of performing like young adults at the situation model level. This suggests that older adults are capable of updating causal information in text material as long as a memory cue to the misinformation is provided within the correction statement.

Introduction

The ability to update and comprehend text requires the reader to make causal inferences. Determining causal relationships involves working memory executive function (Fry & Hale, 1996; Kail, 2007; Waltz et al., 1999). Research has shown that declines in working memory executive function result in declines in comprehension (Norman, Kemper, Kynette, Cheung, & Anagnopoulos, 1991; Stine & Wingfield, 1990; Tun, Wingfield, & Stine, 1991). Furthermore, the prefrontal cortex is involved during working memory and causal reasoning tasks (Baddeley, 1992; Fugelsang & Dunbar, 2005; Prabhakaran, Smith, Desmond, Glover, & Gabrieli, 1997). For example, Monchi, Petrides, Petre, Worsley, and Dagher (2001) found that while participants completed the Wisconsin Card Sorting Task, a task sensitive to working memory executive function, different areas of the prefrontal cortex were activated.

Research has consistently shown age differences on tasks involving the PFC and working memory executive function (Haut, Kuwabara, Leach, & Callahan, 2000; Rypma & D'Esposito, 2000). For example, Hartman, Bolton, and Fehnel (2001) showed that older adults' decline in working memory functioning led to declines in performance on the WCST. Likewise, declines in working memory functioning influence comprehension (Daneman & Carpenter, 1980; Norman et al., 1991; Stine & Wingfield, 1990; Tun et al., 1991). Comprehending text requires the reader to update working memory with new information as it is acquired. However, prior information can interfere during the updating process for young adults (Johnson & Seifert, 1994, 1998, 1999; Seifert & Patalano, 2001). Due to declines in working memory and PFC functioning, older adults may have more difficulty than young adults when updating causal information.

Research has shown that memory cues to prior information provide older adults with the necessary information to update working memory with new information (Hartman et al., 2001; Mutter, Strain, & Plumlee, 2007). The current study investigated whether there are age differences in updating causal information in text and whether providing cues to the erroneous causal information reduced these differences. Participants read text information that contained a piece of misinformation. Later, that misinformation was corrected and either a direct cue to the prior misinformation or an indirect cue to prior information was provided. Older adults should benefit more than young adults from the extra memory support provided from a direct cue to the prior misinformation than an indirect cue to prior information.

Literature Review

Reasoning is a process of identifying and integrating multiple relations between objects and events in order to make inferences (Waltz et al., 1999). Inductive reasoning involves determining whether events provide grounds for a plausible conclusion (Goel & Dolan, 2004). In other words, induction involves moving from specific instances to a generalization (Kinshuk, Lin, & McNab, 2006). Acquiring causal information and making causal inferences requires inductive reasoning because causal cues are used to determine the likelihood and plausibility of outcome occurrence. For example, inductive reasoning is involved in the determination of whether smoking is a plausible cause of lung cancer.

The ability to comprehend text also requires inductive reasoning because information acquired must be integrated to determine if a conclusion is plausible. For example, if a reader encounters the information that Jack is taller than Bob and Bob is taller than Steve, then by integrating this information the reader can reason that Jack is taller than Steve. Revising text information is a form of comprehension referred to as "updating" (Rapp & Kendeou, 2007). This includes the correction of misinformation in memory (Johnson & Seifert, 1998), retrieval of prior text information during reading (O'Brien, Rizzella, Albrecht, & Halleran, 1998), and the evaluation of new information against previous information (Zwaan & Madden, 2004). Updating processes during comprehension of text information involve inductive reasoning because the reader must integrate new, possibly contradictory information with prior text to determine whether the outcome is plausible. For example, if the text provides information that Jack received a poor grade on his math test, the reader may infer that Jack is a poor student. However, if the text that follows provides information that Jack normally performs well in his math class, but the upcoming school dance has been clouding his thoughts for days, the reader may integrate this information with prior information and come to a new conclusion that Jack is normally a good student but that social activities are currently a distraction.

Performing inductive reasoning and comprehension tasks requires hypothesis testing, analogous thinking, generalization and learning transferability, categorization, planning, and problem solving (Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000; Holland, Holyoak, Nisbett, & Thagard, 1987; Heit, 2000; Hulshof, 2001; de Jong & van Joolingen, 1998; Delis, Squire, Bihrle, & Massman, 1992; Milner & Petrides, 1984; Owens, Downes, Sahakian, Polkey, & Robbins, 1990; Shallice & Burgess, 1991). All of these cognitive tasks have, in turn, been linked to working memory (WM) executive function. Intact WM functioning is a crucial determinant of success in reasoning and comprehension because WM is required to integrate information and to maintain the information as inferences are made (Waltz et al., 1999). In support of this, Fry and Hale (1996) and Kail (2007) found that as children's processing speed and working memory increased, their inductive reasoning skills improved. Furthermore, in a study by Buehner, Krumm, Ziegler, and Pluecken (2006), working memory executive function was found to predict reasoning after controlling for intelligence in young adults. Working memory is also correlated with comprehension (Stine, Cheung, & Henderson, 1995). For example, older adults demonstrate a decline in working memory (Van der Linden, Beerten, & Pesenti, 1998; Van der Linden, Bredart, & Beerten, 1994) that leads to difficulties with comprehension of text (Norman et al., 1991; Stine & Wingfield, 1990; Tun et al., 1991).

The prefrontal cortex (PFC) has been linked to working memory executive processes that maintain appropriate attentional and coordinative functions during inductive reasoning tasks. Baddeley (1992) showed in an fMRI study that the dorsolateral prefrontal cortex (DLPFC) is involved in working memory executive function. Likewise, an fMRI study using Raven's Standard Progressive Matrices Test, a test commonly used to measure inductive reasoning, revealed activation in multiple brain regions, including the DLPFC (Prabhakaran et al., 1997). Moreover, damage to the PFC is associated with poorer performance on inductive reasoning tasks. In a study by Waltz et al. (1999), participants either had damage to the PFC or the anterior temporal cortex. Both groups performed Raven's Standard Progressive Matrices Test to assess inductive reasoning. Results revealed a dissociation in that the PFC group was impaired during the integration of multiple relations, while the anterior temporal group was able to perform this task. In other words, an intact PFC was essential to successful inductive reasoning. Other studies have shown that damage to the PFC results in a decline in performance on inductive reasoning tasks (i.e., Shallice & Burgess, 1991; Stuss & Alexander, 2000).

Increased activity in the DLPFC may also be associated with the generation and evaluation of hypotheses (Grafman, 2002). The Wisconsin Card Sorting Task (WCST), a test that involves testing hypotheses about categories is often used to measure both deficits in executive function and a decline in frontal lobe function. Participants are asked to match each of the cards in the deck to one of four key category cards. They are not told how to match the cards (color, shape, or form), only whether they are correct or not. The correct category changes once the participant has matched the cards for 10 trials in a row. This forces the participant to inhibit the previous responses and choose another category to match the cards. Monchi et al. (2001) found that depending upon the stage of the WCST (receiving positive feedback, receiving negative feedback, reception of feedback, and response period), greater activity was found in different prefrontal areas. Receiving either positive or negative feedback was associated with increased signal in the middorsolateral PFC. This area is involved in monitoring information in working memory (Fugelsang & Dunbar, 2005). In other words, this area was activated when the subject had to relate the current information to earlier events stored in working memory. The midventrolateral prefrontal area was involved while receiving negative feedback. This area is considered to be more involved in basic executive functioning such as the active comparison of stimuli held in working memory. This differs from the role of the middorsolateral PFC because the midventrolateral PFC is involved when the subject needs to switch to a new response. However, the middorsolateral PFC was activated regardless of whether a new response was required. The posterior prefrontal cortex showed increased activity during both the reception of feedback and the response period. This indicates a role in the association of specific actions to stimuli.

Recent research has shown that the PFC is also involved in causal reasoning. Fugelsang and Dunbar (2005) examined the degree to which plausible and implausible causal theories biased the evaluation of statistical covariation-based causal data and also examined the areas of the brain involved in this reasoning process. Participants received information about the effectiveness of drugs relieving depressive symptoms. Data were presented in combination of a cause (a red pill or a blue pill) and an effect (happiness or neutral outcome). Under some conditions, the red pill and happiness covaried strongly, while under other conditions the red pill and happiness covaried weakly. The plausibility of a causal theory was manipulated by presenting participants with a brief introductory statement that contained either a direct causal mechanism linking a red pill to a mood outcome or no direct causal mechanism linking the pill to a mood outcome. Fugelsang and Dunbar found that both the plausibility of the theory and the covariation between the occurrence of the red pill and the outcome influenced the participants' causal judgments. Specifically, the effects of covariation were larger when evaluating a plausible as opposed to an implausible causal theory. Using fMRI, Fugelsang and Dunbar were able to demonstrate that bilateral prefrontal regions and the left inferior frontal gyrus were significantly more activated when participants processed data during the evaluation of a plausible theory as opposed to an implausible theory. These areas were also active during working memory executive function tasks suggesting that their participants were devoting more working memory resources to processing covariation data during the evaluation of the plausible theory. Furthermore, different areas of the brain were activated depending upon whether the data were consistent versus inconsistent with the theory. Evaluation of data consistent with a plausible causal theory activated the parahippocampal gyrus and the caudate, which are associated with learning and memory, while evaluation of data inconsistent with a plausible causal theory activated the anterior cingulate, the precuneus and the dorsolateral prefrontal cortex, which are involved in error detection and conflict monitoring.

Recent research has looked at the PFC's involvement in causal inferences during text comprehension. In an fMRI study, Mason and Just (2004) had participants read two-sentence passages that varied in their degree of causal relatedness. Results showed that the DLPFC was activated when comprehension required the generation of a causal inference. This suggests that the PFC plays an important role during sentence comprehension.

Aging, Reasoning, and Comprehension

Older adults' performance on tasks involving the PFC and working memory executive function (i.e. Reading Span, Backward Digit Span, and Computation Span) is consistently poorer than younger adults' performance. In a study by Rypma and D'Esposito (2000), PFC activity was observed through fMRI during the encoding, maintenance, and retrieval stages of working memory. Results showed age-related differences in dorsolateral PFC only during retrieval of information. Furthermore, the inability to retrieve information was associatated with increases in cortical activity in the dorsolateral PFC for young adults but was associated with decreases in cortical activity in the dorsolateral PFC for older adults. Further evidence that age differences in performance on working memory tasks is a result of differences in the activity level of the PFC comes from a study by Haut et al. (2000). In this study, PET was used to assess age-related differences in brain activity during two verbal working memory tasks. One working memory task was a self-ordering task where young participants were asked to say the numbers 1-10 in a different order on each trial. The other working memory task was externally ordered where the young participants listened to numbers from 1-10 in a random order. One number would be left out and the participant was required to say the missing number. To enable older participants to perform at the same level, numbers 1-6 were used on the two working memory tasks. The results demonstrated that both groups had activation in the anterior cingulate gyrus and the dorsolateral PFC. However, young participants had increased activation in the right dorsolateral PFC during the self-ordering task and the right anterior cingulate gyrus on the externally ordered task, while older adults had greater activation in the left prefrontal cortex on the externally ordered task.

Neuroanatomical explanations maintain that the WCST is sensitive to dysfunction of the prefrontal cortex (Mountain & Snow, 1993) and that changes in this part of the brain account for the poor performance of older adults (Hartman et al., 2001; Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998). Consistent with this explanation, Raz et al. (1998) have shown that shrinkage of the prefrontal cortex in older adults produces age-related perseverations on the WCST. For example, older adults display more perseverations (Axelrod & Henry, 1992; Daigneault, Braun, & Whitaker, 1992; Heaton, Chelune, Talley, Kay, & Curtis, 1993) and complete fewer categories than young adults on the WCST (Axelrod & Henry, 1992; Beatty, 1993; Daigtneault et al., 1992; Fristoe, Salthouse, & Woodard, 1997; Parkin & Walter, 1991). Hartman et al. (2001) manipulated the demands of working memory on the WCST by varying the amount of processing needed to select a rule and the amount of stored information required for selecting the correct rule. When a new rule has to be selected, more processing is needed. Therefore, errors that followed an incorrect sort were a high processing load and errors that followed a correct sort were a low processing load. The other variable that determined working memory demands was the amount of information needed to determine how to sort each card (i.e. memory load). Errors had either high or low memory load depending upon whether the preceding sort contained enough information to select the correct rule. For example, if trial n-1 consisted of a correct sort and the key card could only be matched correctly on one dimension, trial n was considered a low memory load. However, if trial n-1 consisted of a correct sort and the key card could be matched on more than one dimension, then the error on trial n occurred under high memory load conditions. Memory loads for incorrect sorts were determined under the same conditions. Results showed that low performance older adults demonstrated a deficit in working memory and a decline in performance on the WCST. This reduced working memory may represent a deficit in the ability to update the contents of working memory due to problems during encoding and integrating relevant information from completed sorts into working memory. In a second experiment, Hartman et al. tested this theory by comparing performance on the original version of the WCST with a modified version of the test that consisted of cues to inform participants whether the most recent sort was correct or not. Results showed that the cues improved older adults' performance to the level of younger adults' performance on the original version of the WCST. In other words, age-related differences in errors on the WCST can be explained by an inability to adequately update working memory with new information which hinders older adults' ability to remember prior sorts.

Older adults also experience difficulties on inductive reasoning tasks that may be due to PFC decline and working memory executive function impairment. Raven's Progressive Matrices task, a test used to measure inductive reasoning, requires working memory executive function because one must combine information to make relations. A study by Viskontas, Holyoak, and Knowlton (2005) tested inductive reasoning in young, middle-aged, and older participants using the Raven’s Progressive Matrices task. Results showed that older participants had more difficulty in solving the reasoning problems that required integrating multiple relations. In an fMRI study, Prabhakaran et al. (1997) found that when participants solved the problems in Raven's Progressive Matrices task, frontal regions were activated. This suggests that working memory processes are involved during reasoning.

PFC and executive function decline may also provide an explanation for the difficulty older adults experience during causal reasoning. In a simple discrimination task, Mutter, Haggbloom, Plumlee, and Schirmer (2006) had young adults, young adults with a concurrent working memory load, and older adults determine whether the occurrence (feature positive; FP) or the nonoccurrence (feature negative; FN) of a distinctive feature predicted reinforcement. In other words, participants had to determine the causal relationship between the presence or absence of the distinctive feature and the reinforcement. Results revealed that initial discrimination was affected by both age and WM load. However, with additional experience, only the FN discrimination was affected by age and WM load. Young adults with reduced WM capacity performed like old adults, especially during FN discrimination, suggesting that the more difficult inductive reasoning processes places greater demands on WM.

Comprehension also requires inductive reasoning processes and intact working memory (Caplan & Waters, 1999). Not only must one maintain information in working memory while new information is processed, but one must also be able to update inferences by incorporating the new information and inhibiting irrelevant information in order to integrate meanings to ensure coherence. Several studies have demonstrated that executive function as measured by a working memory span task influences comprehension (Daneman & Carpenter, 1980; Norman et al., 1991; Stine & Wingfield, 1990; Tun et al., 1991). Furthermore, considerable research has shown there are age differences in the ability to represent textual materials. There are three levels of representation for text that are required for comprehension. The surface level consists of a representation of the actual words and syntax. The propositional text-based level involves an abstract representation of only information that is in the text but does not need to be verbatim like the surface level. Finally, the situation model is a representation of the overall meaning including inferences and assumptions about the events in the text. Comprehension requires successful representations of text at all three of these levels, as well as the ability to monitor and update new information as it is acquired (Radvansky & Curiel, 1998).

Stine-Morrow, Gagne, and DeWall (2004) demonstrated that there are age differences at the surface level. They had young and old participants read a passage of text twice. Reading times were used to determine the amount of attention participants placed on the actual words during the rereading. If readers are able to represent text at the surface level, they should be familiar with the words during the second reading and would not need to spend as much time reading each word. Results showed that older adults spent more time on the words during the second reading compared to young adults. This suggests that older adults have more difficulty than young adults representing text at the surface level.

Stine and Wingfield (1990) demonstrated that there are age differences at the text-based level. They asked young and old adults to listen to a passage of text. Older adults recalled less of the text. For simpler texts, this was seen in terms of their inability to hold as much information in working memory as measured by the word span task. Therefore, individuals with a lower working memory span were unable to hold as much information from the text in working memory as individuals with a higher working memory span. This results in the inability to recall as much information and a decline in comprehension.

Other studies have shown that while younger adults are superior at the text-based level, older adults perform better at the situation model level (Radvansky, Curiel, Zwaan, & Copeland, 2001). In a study by Radvansky et al. (2001), influences of aging on different levels of representation were considered. Participants were either instructed to summarize the material (summary group) or relate the material to historical knowledge (knowledge acquisition group). The summary group represented comprehension at the text-based level, while the knowledge acquisition group represented comprehension at the situation model level. After reading the text, participants were given a recognition test in which the probes were blocked by story, with the title appearing before the probes. Participants indicated whether a sentence had been read earlier by pressing the corresponding key. Participants were warned that sentences might be similar in nature but contain some wording changes. Four types of probes were used in the recognition test: verbatim probes of the sentences that had appeared in the text, paraphrase probes that contain the same propositions but were expressed differently, inference probes that were not mentioned but were consistent with the described situation, and incorrect probes. The ability to discriminate between verbatim and paraphrase probes was an index of the surface representation. The ability to discriminate between paraphrase and inference probes was an index of the text-based representation. Finally, the ability to discriminate between inference and incorrect probes was an index of the use of situation models. Results revealed that younger adults were superior at the text-based level. However, older adults were better than younger adults at the situation model level. Older adults relied on the use of situation models more than younger adults. In a second experiment, when some participants were asked to take the recognition test one week following the reading, older adults still relied more on situation models and performed as well as younger adults at this level of comprehension. Thus, there seem to be age differences in the preferred levels of representation of text. Young adults rely more on what the text actually was, while older adults rely more on what the text was about.

Other cognitive abilities play a role in comprehension. During encoding of text, older adults make associations between relevant and irrelevant information, while during retrieval of text, older adults access more information than necessary. The interference of irrelevant information at both encoding and retrieval could explain why older adults show a deficit in memory at the text-based level. In a study by Van der Linden et al. (1999), the objective was to demonstrate the extent to which working memory deficits account for the age-related differences seen in comprehension by using structural equation modeling. Participants were required to complete a battery of tests that measured working memory, interference, processing speed, and the ability to represent text at the text-based level. Results suggested that the age-related differences at the text-based level were accounted for by a decline in working memory capacity and that this decline in capacity was a result of a reduction in processing speed and the inability to inhibit irrelevant information.

Although age differences in working memory affect comprehension, expertise on domain-relevant tasks may help older adults compensate for this age-related decline. Expertise allows the load on working memory capacity to be reduced, enabling experts to understand domain-relevant tasks better than nonexperts because more working memory capacity will be available to interpret and update inferences made from the text. Morrow, Leirer, and Altieri (1992) observed younger and older pilots and nonpilots ability to understand and recall domain-specific texts. Participants read either aviation or general narratives. Demands on working memory were manipulated by either facilitating (well-organized text) or interfering with (poorly organized text) referent assignment. Following the target sentence, participants were asked to answer questions about the referent by writing down the character's name. After each narrative, participants were asked to recall the narrative. Results demonstrated that expertise helped older adults update and recall situation models from narratives to the same extent as younger adults. Young and old pilots both used knowledge more than narrative cues to update the situation model. However, working memory was needed more when target sentences were more difficult, resulting in the inability to use aviation knowledge. This produced deficits in the older pilots' ability to understand and recall the text. In other words, only when older adults are able to access knowledge do the benefits of knowledge-based strategies offset age-related capacity declines that affect comprehension.

Older adults are also able to remove information about a completed goal from their situation model as effectively as younger adults. Radvansky and Curiel (1998) tested the ability of younger and older adults to select relevant information while updating their situation model. Participants were required to read a narrative with either a failed goal, completed goal, or a neutral scenario. In the failed goal narrative, the character was initially unable to successfully complete the goal. Only later, was the goal accomplished. In the completed goal narrative, the character was able to successfully accomplish the goal early in the story. In the neutral narrative, the character did not set out to accomplish a specific goal; instead, the narrative described a succession of events the character experienced. Following each narrative, participants answered questions by identifying whether they were true or false. Reaction times were measured, where a slower response indicated that the goal information was no longer available in their situation model. Results revealed that both young and old adults responded more slowly to probes for the completed goal than for the failed goal. In other words, neither group actively maintained information for the completed goal but both maintained information for a failed attempt at a goal. However, reaction times to probes for neutral information were slower than reaction times to probes for completed goal information, indicating that completed goal information was more available for both groups than neutral information. Therefore, age was not a factor when updating goal information after story characters completed their goals.

Current Study

Several studies have demonstrated that an intact PFC is crucial to efficiently perform working memory executive function tasks (Baddeley, 1992; Prabhakaran et al., 1997; Waltz et al., 1999) and that working memory executive function is involved during causal reasoning (Fugelsang & Dunbar, 2005). PFC functioning declines with age (Hartman et al., 2001; Raz et al., 1998; Rypma & D'Esposito, 2000); and thus, the ability to perform working memory executive function tasks declines (Haut et al., 2000). This decline in working memory executive function results in a decline in reasoning tasks, including causal reasoning (Fry & Hale, 1996; Kail, 2007; Waltz et al., 1999). Studies have also demonstrated that an age-related decline in working memory executive function results in a reduction in memory for text and a decline in comprehension (Stine & Wingfield, 1990; Van der Linden et al., 1999). Age differences have been found in the ability to represent text. Younger adults are superior at recalling the actual words and sentences from text (Stine-Morrow et al., 2004) and abstract representations (Stine & Wingfield, 1990). However, older adults perform just as well as young adults at determining the overall meaning and making inferences from the text (Radvansky et al., 2001). Additionally, age differences in working memory executive function affect older adults' ability to update causal information (Hartman et al., 2001).

The goal of this research was to investigate whether there are age differences in updating causal information in text material. Causal information from text material may originally be ambiguous or turn out to be inaccurate (Gerrig, 1993). Research has demonstrated that young adult readers sometimes fail to update memory to include new causal information (Johnson & Seifert, 1994, 1998, 1999; Seifert & Patalano, 2001). For example, Johnson and Seifert (1994) asked participants to read a series of messages about the investigation of a warehouse fire. Early in the messages, participants read about a possible cause of the fire (i.e., volatile materials stored in a closet). Later in the messages, some participants read a correction of that information (i.e. the closet was actually empty). Following the messages, participants completed a free recall test. Participants described the contents of the closet as a potential cause of the fire, whether they had read the revised or unrevised version of the messages. This suggests that when later information contradicts earlier information, that earlier information remains available and influential in memory (Van Oostendorp & Bonebakker, 1999). These results are not due to the readers ignoring the revisions (Otero & Kintsch, 1992; Seifert, 2002; Wilkes & Leatherbarrow, 1988). In another experiment, Johnson and Seifert (1994) provided a plausible alternative cause of the fire. Results showed that participants were affected less by the misinformation when a plausible alternative cause was provided.

In the present study, older and younger adults were asked to read and comprehend text that included causal information about an event in the text. They were required to update this causal information in their situation model of the text. A series of messages about the investigation of a warehouse fire was presented to participants. A plausible causal explanation for the fire was given in one of the messages. However, this was misinformation that was corrected in a later message. In the correction statement, a memory cue to the misinformation was provided for some participants. Participants were then given a memory test to observe whether this correction was incorporated into their situation model.

Participants' performance at the text-based level and situation model level was measured. It was expected that older adults, like younger adults, would be able to generate the situation model for the text including the initial causal reason for the fire (Radvansky & Curiel, 1998; Radvansky et al., 2001; Stine & Wingfield, 1990). However, older adults should perform more poorly than younger adults when recalling information at the text-based level (Radvanksy et al., 2001; Stine & Wingfield, 1990). In addition, it was expected that age-related decline in working memory executive function might produce differences in younger and older adults' ability to update their knowledge of the causal information. Prior research suggests that when older adults have strong causal beliefs, they don't update beliefs with new information (Mutter et al., 2007). Updating working memory with new causal information from a text requires efficient working memory executive function (Caplan & Waters, 1999; Daneman & Carpenter, 1980; Norman et al., 1991; Radvansky & Curiel, 1998; Stine & Wingfield, 1990; Tun et al., 1991). One must be able to retrieve and hold the old situation model in working memory, including the original causal relationship. Also, one must be able to process new causal information in working memory, determine the plausibility of the causes, and then replace the old causal information with new information in the situation, if necessary. Moreover, greater inhibitory processes may be required to suppress and replace an erroneous cause for an event. Because these aspects of cognition are impaired in older adults (Radvansky & Curiel, 1998; Van der Linden et al., 1999), a decline in the situation model updating process was expected for older adults compared to younger adults. In particular, older adults should have more references to words in the text from the corrected statement than younger adults because they experience difficulties when updating causal beliefs in working memory (Mutter et al., 2007).

Prior work has suggested that memory cues provide older adults with sufficient information to recall prior information and integrate the new information into current working memory models (Hartman et al., 2001). Older adults should therefore perform better during the updating process when memory cues to the correction statement are present than when memory cues to the correction statement were not provided. This study investigated whether a direct cue to the prior misinformation benefited older participants during the updating process to a greater extent than an indirect cue to prior information. It was expected that both age groups would recall more erroneous information when a direct cue to previous misinformation was provided within the correction statement than when no correction statement was provided and that both age groups would recall more erroneous information when an indirect cue to previous misinformation was provided within the correction statement than when a direct cue was provided. It was also hypothesized that older adults would recall more erroneous information than young adults when a direct cue to previous misinformation was provided within the correction statement than when no correction statement was provided and would recall even more erroneous information than young adults when an indirect cue to previous misinformation was provided within the correction statement than when a direct cue was provided.

Finally, this study investigated whether cognitive functioning is related to the ability to update and comprehend text. Participants received a battery of tests that measured cognitive function. Correlations between cognitive functioning and ability to update text material were analyzed. Table 1 contains the predicted correlations. It was hypothesized that frontal lobe scores would be positively correlated with text-based scores for young adults but negatively correlated with text-based scores for older adults. There should be no correlation between these scores and the situation model scores for either young or older adults. Temporal lobe scores should be positively correlated with text-based scores and situation model scores for young adults but negatively correlated with text-based scores and situation model scores for older adults. Finally, it was expected that semantic knowledge scores would be negatively correlated with text-based scores for young adults and positively correlated with text-based scores for older adults, but there should be no correlation between these scores and the situation model scores for either young or older adults.

Table 1

Correlations Between Cognitive Functioning and Ability to Update Text Material

[Positive Correlation (+); Negative Correlation (-); No Correlation (0)]

	Young			Older		
Model	Frontal Lobe	Temporal Lobe	Semantic Knowledge	Frontal Lobe	Temporal Lobe	Semantic Knowledge
Text-Based	+	+	-	-	-	+
Situation	0	+	0	0	-	0

Method

Participants

Forty-eight young (ages 18-30) and forty-eight older (age > 60) adults participated in this experiment. Young adults were recruited from introductory psychology classes through the departmental study board and received course credit and a $5 monetary stipend for their participation. Older adults were recruited from the community via mass mailings and advertisements and went through a screening process via the phone to ensure that they were capable of performing cognitive tasks and that any medications they were on would not interfere with cognitive processes. Older adults were paid a $25 monetary stipend for their participation. Biographical data (age, race, gender, socioeconomic status, years of education, and marital status), as well as measures of basic health (e.g. heart disease, head injury, stroke, etc.) were collected for both groups. Participants who reported current use of medications known to affect cognitive ability or who suffered from any neurological or psychological impairment were excluded from the study.

Design and Materials

A 2 (Age: Young vs. Older) x 3 (Condition: Mention Control, Direct Negation, Indirect Negation) factorial design was used. The materials were a modified version of the series of messages from Wilkes and Leatherbarrow (1988) and Johnson and Seifert (1994). Participants received fourteen messages, each 2-4 sentences long, about the investigation of a warehouse fire (see Appendix A). Message 5 was a causal statement, indicating that volatile materials located in the closet were responsible for the fire. In each condition, the way that participants receive a correction statement concerning the volatile materials located in the closet was manipulated. In the Direct Negation condition, the correction statement contained elements of the previous statement to provide a retrieval cue that helps participants retrieve the earlier information more easily. In the Indirect Negation condition no cue for the previous message was provided, forcing participants to retrieve the information from memory. In the Mention Control condition, a correction statement did not appear within the series of messages. Table 2 indicates how messages were combined to create the different conditions. In the Mention Control, Direct Negation, and Indirect Negation conditions, Message 5 indicated that cans of oil paint and pressurized gas cylinders were present in a closet in the warehouse. In the Direct Negation and Indirect Negation conditions, a correction to the misinformation in Message 5 appeared in Message 11. In the Direct Negation condition, Message 11 restated elements of Message 5 before indicating that the closet had been empty in order to provide a direct cue to remind about the earlier information. For example, if a direct memory cue was provided for the misinformation it stated in a second message received from Police Investigator Lucas regarding the investigation into the fire that the closet reportedly containing cans of oil paint and gas cylinders had actually been empty before the fire. In the Indirect Negation condition, Message 11 stated only that the earlier message had been incorrect and that the closet had been empty. Therefore, if no direct memory cue was provided for the misinformation it stated in a second message received from Police Investigator Lucas regarding the investigation into the fire that the previous statement was incorrect, the closet had actually been empty. Thus, in this condition, participants did not receive a direct cue for the previous message and they were required to retrieve the information from memory. In the Mention Control condition, Message 11 only referred to firefighters having been released from the hospital.

Table 2

Content of Critical Messages by Group

Group	Message 5	Message 11
Mention Control	Volatile Materials	Firefighters
Indirect Negation	Volatile Materials	Empty closet No cue for previous message
Direct Negation	Volatile Materials	Empty closet Cue for previous message

Following the messages, a free recall test was administered in which participants were instructed to write down as accurately as possible their account about the event in question, including the cause of the fire (see Appendix B). Upon completion of the free recall test, participants were given a 30 minute retention interval, during which they completed a portion of the battery of tests assessing cognitive function (see Table 3). This battery included measures of frontal lobe integrity such as working memory executive function [i.e., Reading Span Test (Daneman & Carpenter, 1980)], perseverative responding [i.e., Modified Wisconsin Card Sorting Test (Hart, Kwentus, Wade, & Taylor, 1988)], and verbal fluency [i.e., Controlled Oral Word Association (Benton & Hamsher, 1976)]. The battery also included measures of temporal lobe functioning such as incidental associative learning [i.e., WAIS-III Digit Symbol Incidental Learning (Wechsler, 1981)], episodic memory [i.e., WMS-R Logical Memory I (Wechsler, 1987)], learning and schema formation [i.e., WMS-R Verbal Paired Associates I (Wechsler, 1987)], and processing speed [i.e., WAIS-III Digit Symbol (Wechsler, 1981); Pattern Comparison (Salthouse & Babcock, 1991)]. Tests also included a measure of semantic knowledge [i.e., Mill Hill Vocabulary (Raven, 1998)].

Table 4 shows young and older adults' average age, gender, and composite frontal lobe, temporal lobe, and semantic knowledge scores for each condition. The frontal lobe composite score was the average of the z-scores for Reading Span, WCST, Digit Symbol, Pattern Comparison, and FAS, the temporal lobe composite score was the average of z-scores for Digit Symbol Incidental Learning, Logical Memory I, and Verbal Paired Associates, and the semantic knowledge composite score was the Mill Hill Vocabulary score.

Table 3

Tests of Cognitive Function

Author	Assessment	Measures
Hart, Kwentus, Wade, & Taylor, 1988	Modified Wisconsin Card Sorting Task	# of categories achieved
Benton & Hamsher, 1976	Controlled Oral Word Association	# of words; strategies
Daneman & Carpenter, 1980	Reading Span	Highest level achieved with 2 correct responses
Wechsler, 1981	WAIS-III Digit Symbol	Total correct responses
Salthouse & Babcock, 1991	Pattern Comparison	Total correct responses
Wechsler, 1981	WAIS-III Digit Symbol Incidental Learning	Total correct responses
Wechsler, 1987	WMS-R Verbal Paired Associates I	Total correct pairings for first 3 trials
Wechsler, 1987	WMS-R Logical Memory I	Total repeated items
Raven, 1998	Mill Hill Vocabulary	# of correct responses

Table 4

Participant Characteristics

	Young Adults			Older Adults		
Characteristic	Mention Control	Direct Negation	Indirect Negation	Mention Control	Direct Negation	Indirect Negation
Age						
M	21.88	19.88	21.19	67.44	65.25	69.19
SD	2.55	1.26	2.90	5.48	4.86	7.71
Gender						
M	1.44	1.31	1.31	1.38	1.38	1.44
SD	0.51	0.48	0.48	0.50	0.50	0.51
Frontal Lobe						
M	103.69	98.19	105.81	97.81	96.25	99.25
SD	10.35	10.93	11.58	10.70	9.45	9.72
Temporal Lobe						
M	204.06	198.06	209.81	142.56	158.94	160.44
SD	18.81	18.30	21.70	30.21	19.77	28.23
Semantic						
Knowledge	29.94	32.38	33.88	34.81	36.50	36.00
M	5.86	4.77	6.16	7.51	6.68	5.55

Following the retention interval, an open-ended questionnaire containing questions about the event was administered (see Appendix B). This questionnaire included a total of 23 questions: 10 questions on facts directly presented in the messages, 11 questions requiring the participants to make inferences about the event, and 2 questions regarding their awareness of a correction or contradiction. In a second session, participants completed the remaining tests in the battery assessing cognitive function (see Table 3).

Procedure

Participants were tested individually in two sessions lasting approximately an hour and a half. All testing was conducted in the Cognition Laboratory or similar experimental room. Some tasks were completed on a Macintosh computer and some were completed using a pencil and paper. Young and older adults completed the same procedure.

Participants first completed an informed consent form and a demographic and health questionnaire. They were also given an opportunity to ask questions or voice concerns at this time. They then completed the experimental task and the battery of tests that assessed cognitive functioning. The experimental task was run on a Macintosh computer. Participants were instructed that we were interested in how people understand and remember reports and that a series of statements all related to one event would be presented on the computer screen, one message at a time. Participants were also told that they would be asked to recall the information later. They were told that pressing the spacebar would allow them to advance to the next message and that they would not be able to refer back to previous messages but that they could take as much time as they needed to read each message. When all the messages were presented, the participants received the free recall test and were instructed to write down as accurately as possible their account of the event in question. Following the free recall test, they were given a portion of the battery of tests assessing cognitive function to work on for 30 minutes. All tests during this retention interval were timed to ensure that all participants received the same duration. To accommodate variability across subjects, participants did not begin a task if it would not be completed in the allotted time. In such a case, participants completed these tasks at a later time. Additionally, if participants completed the tasks in under 30 minutes, they were able to sit in the laboratory and take a short break until the retention interval had passed. Afterwards, participants received the open-ended questionnaire and were instructed to answer each question on the basis of their understanding of the reports. They were given as much time as they needed to complete this questionnaire. Upon completion of the session, participants were debriefed and given the opportunity to ask questions about the study. They were then compensated for time spent participating in the study. In a second session scheduled on a separate day, the participants completed the remaining tests of cognitive function.

Results

Scoring

Two researchers, one of whom was unaware of the different conditions, scored the free recall and open-ended questionnaire. Scores were first obtained separately by each researcher. Then both researchers came together to discuss and come to a consensus on the final score received by the participant for each measure. In most instances, it was not difficult to come to an agreement for the final score. However, when a disagreement did exist, an additional researcher's opinion was consulted to settle this difference. Two text-based measures were scored. Summary Recall from the free recall test was the total number of non-correction idea units recalled. The idea units were derived from Wilkes and Leatherbarrow (1988). Only idea units common to all three conditions were included in this score. An idea unit was considered recalled if the participant reported a recognizable portion of the idea unit. Some of the idea units were long and difficult for participants to recall entirely. However, receiving a lenient and strict score is a common technique in text comprehension research (Tan & Nicholson, 1997). Participants stated half of the idea unit for a correct lenient response. For example, one idea unit was "…and an intense heat that made the fire particularly difficult to bring under control." If the participant only recalled that there was a strong heat, a correct lenient response was recorded. However, participants were required to recall more than half or the entire gist of the idea unit for a correct strict response. Taking our example from above, if the participant stated that there was a strong heat that made it hard to control the fire, a correct strict response was recorded. A higher lenient or strict score indicated that the participant was more capable of recalling information at the text-based level. Fact Recall was the percent correct recall of the fact questions from the open-ended questionnaire. Questions four and seven had answers that were long and difficult for participants to recall entirely. Again, receiving a lenient and strict score is a common technique in text comprehension research; therefore, a lenient and strict score for this measure was received. A correct lenient response for question four meant that the participant only stated one feature of the fire. If the participant stated at least two features of the fire a correct strict response was recorded. For question seven, a correct lenient response meant that the participant only stated one item in the storage room. A correct strict response meant that the participant stated at least two items in the storage room. Higher lenient and strict scores indicated an ability to recall information at the text-based level.

Four situation model measures were scored: Thematic Inference, Direct Reference, Global Cause, and Correction Recall. The Thematic Inference measure came from the eleven inference questions in the open-ended questionnaire. For this measure, references to the key words from the discredited message (i.e. oil, paint, gas, cans, cylinders), mentioning the closet itself without indicating it was empty, or making attributions of carelessness or negligence were counted as inferences. References to stored stationary at the warehouse or the structure of the building were not included as careless or negligent inferences. Higher scores in the Thematic Inference measure indicated less updating because on the inference questions participants had more references to the volatile materials. The Direct Reference measure came from the free recall test and the fact and inference questions from the open-ended questionnaire. Only references to the volatile materials themselves (i.e. oil, paint, cans, gas, cylinders) without indicating a correction later were counted. High scores on the Direct Reference measure indicated that the participant did not update their situation model because on the free recall, fact questions, and inference questions they had more references to the volatile materials without acknowledging that this was misinformation. The Global Cause measure came from the free recall test and indicated whether participants referred to the volatile materials as the cause of the fire without mentioning the correction within the messages. Therefore, this measure indicated difficulty in updating at the situation model level when an answer for the cause of the fire did not reference that the message had been corrected. For the Correction Recall measure, an accurate reference to the correction in either the free recall test or the open-ended questionnaire was accepted and indicated the ability of the participant to update at the situation model level. Alpha was set at 0.05 for all analyses of these measures.

Text-Based Level

The average number of idea units recalled from the summary recall is shown in Table 5. Because only the messages common to all conditions (i.e. Mention Control, Direct Negation, Indirect Negation) were included in the Summary Recall measure, there should not be differences between the conditions (i.e. Mention Control, Direct Negation, Indirect Negation). However, condition was included in the analyses to ensure that there was no difference for the three scenarios. A 2 (Age: Young vs. Older) x 3 (Condition: Mention Control vs. Direct Negation vs. Indirect Negation) factorial ANOVA was conducted on the lenient Summary Recall measure to determine whether age and condition affected the number of idea units recalled. A significant main effect of age was found, $F(1, 90) = 12.98$, $p = .001$, $\eta^2 = 0.13$, showing that older adults recalled fewer idea units than young adults. As expected, there was no significant main effect of condition,

$F(2, 90) = 1.72$, $p = .19$, $\eta^2 = 0.04$, nor was there an interaction between age and condition, $F(2, 90) = 0.98$, $p = .38$, $\eta^2 = 0.02$.

A 2 (Age: Young vs. Older) x 3 (Condition: Mention Control vs. Direct Negation vs. Indirect Negation) factorial ANOVA was also conducted for the strict Summary Recall data. A significant main effect of age was again observed, $F(1, 90) = 9.56$, $p = .003$, $\eta^2 = 0.10$, showing that older adults recalled fewer idea units than young adults. There was no significant main effect of condition, $F(2,90) = 1.39$, $p = 0.26$, $\eta^2 = 0.03$, nor was there was an interaction between age and condition, $F(2, 90) = 0.50$, $p = 0.61$, $\eta^2 = 0.01$.

The average percent correct on the fact recall from the open-ended questionnaire is shown in Table 5. A 2 (Age: Young vs. Older) x 3 (Condition: Mention Control vs. Direct Negation vs. Indirect Negation) factorial ANOVA was conducted for the lenient Fact Recall data to determine whether fact recall was affected by age and condition. A significant main effect of age was found, $F(1, 90) = 10.04$, $p = .002$, $\eta^2 = 0.10$. Older adults recalled fewer fact questions than young adults. There was not a significant main effect of condition, $F(2, 90) = 0.69$, $p = 0.50$, $\eta^2 = 0.02$, and there was no interaction between age and condition, $F(2, 90) = 1.62$, $p = 0.20$, $\eta^2 = 0.04$.

Table 5

Number of Idea Units Recalled from Summary Recall & Percent Accurate on Fact Recall

	Summary Recall		Fact Recall	
Group	Lenient	Strict	Lenient	Strict
Young				
M	8.58	5.67	5.38	4.44
SD	4.84	3.56	1.83	1.89
Older				
M	5.56	3.71	4.25	3.25
SD	3.29	2.56	1.66	1.45

Analyses for the strict scoring method produced similar results. A 2 (Age: Young vs. Older) x 3 (Condition: Mention Control vs. Direct Negation vs. Indirect Negation) factorial ANOVA showed a significant main effect of age, $F(1, 90) = 12.05$, $p = .001$, $\eta^2 = 0.12$, with older adults recalling fewer fact questions than young adults. There was not a significant main effect of condition, $F(2, 90) = 1.01$, $p = 0.37$, $\eta^2 = 0.02$, nor was there an interaction between age and condition, $F(2, 90) = 1.48$, $p = 0.23$, $\eta^2 = 0.03$.

Situation Model Level

The average number of inferences for the volatile materials in each group is shown in Table 6. Analyses for these data answered the question of whether age and condition affected the number of references to volatile materials, the closet itself, or attributions to carelessness/negligence. A 2 (Age: Young vs. Older) x 3 (Condition: Mention Control vs. Direct Negation vs. Indirect Negation) factorial ANOVA was conducted on the Thematic Inference scores. There was not a significant main effect of age, $F(1, 90) = 1.25$, $p = 0.27$, $\eta^2 = 0.01$, indicating that there was no difference between young and older participants in the overall number of references to volatile materials, the closet itself, or attributions to carelessness/negligence. There was not a significant main effect of condition (e.g. Mention Control vs. Direct Negation vs. Indirect Negation), $F(2, 90) = 0.33$, $p = 0.72$, $\eta^2 = 0.01$, indicating that there was not a difference in the number of references to volatile materials, the closet itself, or attributions to carelessness/negligence between the three conditions. Finally, there was not a significant interaction between age and condition, $F(2, 90) = 0.98$, $p = 0.38$, $\eta^2 = 0.02$, indicating that differences in the number of references to volatile materials, the closet itself, or attributions to carelessness/negligence did not vary for the six age by condition groups.

Table 6

Average Number of References and Inferences to Volatile Materials for Each Group

	Young		Old	
Condition	Thematic Inference	Direct Reference	Thematic Inference	Direct Reference
Mention Control				
M	8.13	9.56	7.31	7.94
SD	3.50	5.57	4.83	5.66
Indirect Negation				
M	5.88	5.69	7.75	7.69
SD	2.47	3.75	6.20	7.21
Direct Negation				
M	6.44	5.75	8.56	8.31
SD	4.07	3.32	5.78	5.45

To ensure that these results were not due to the similar means for the Indirect and Direct Negation conditions, the data for the two Negation conditions were collapsed and these Thematic Inference scores were entered into a 2 (Age: Young vs. Older) x 2 (Condition: Mention Control vs. Negation) factorial ANOVA. There were again no significant main effects of age, $F(1, 90) = 0.35$, $p = 0.55$, $\eta^2 = 0.00$, or condition, $F(1, 90) = .32$, $p = 0.58$, $\eta^2 = 0.00$, nor was there a significant interaction between age and condition, $F(1, 90) = 1.98$, $p = 0.16$, $\eta^2 = 0.02$. The results for the Thematic Inference scores were not due to the similar means in the Negation conditions.

The average number of Direct References to volatile materials in each group is shown in Table 6. Analyses were run on the Direct Reference scores to determine whether age and condition affected the number of references to the volatile materials. A 2 (Age: Young vs. Older) x 3 (Condition: Mention Control vs. Direct Negation vs. Indirect Negation) factorial ANOVA was conducted. There was not a significant main effect of age, $F(1, 90) = 0.81$, $p = 0.37$, $\eta^2 = 0.01$, nor was there a significant main effect of condition, $F(2, 90) = 1.38$, $p = 0.26$, $\eta^2 = 0.03$, or a significant interaction between age and condition indicating that the number of references to the volatile materials was not affected by condition, $F(2, 90) = 1.46$, $p = 0.24$, $\eta^2 = 0.03$.

The Direct References scores for the two Negation conditions were again collapsed to ensure that the results were not affected by the similar means of the Indirect and Direct Negation conditions. A 2 (Age: Young vs. Older) x 2 (Condition: Mention Control vs. Negation) factorial ANOVA produced no significant main effect of age, $F(1, 90) = 0.08$, $p = 0.77$, $\eta^2 = 0.00$. There was a marginal effect of condition, $F(1, 90) = 2.75$, $p = 0.10$, $\eta^2 = 0.03$, and a marginal interaction between age and condition, $F(1, 90) = 2.94$, $p = 0.09$, $\eta^2 = 0.03$. These effects provide some evidence that the number of references to volatile materials was affected by the combination of age and condition. Specifically, young adults made fewer references to volatile materials when a correction to the misinformation was provided. However, older adults had almost the same number of references to volatile materials in the Negation conditions. This suggests that young adults were somewhat better at updating their situation model in the Negation conditions.

Analysis of the Global Cause measure for older adults indicated that 37.50% made attributions to flammables as the cause of the fire in the Mention Control condition, 6.25% made attributions to the flammables as the cause of the fire in the Direct Negation condition, and 12.50% made attributions to the flammables as the cause of the fire in the Indirect Negation condition. The likelihood of attributing the cause of the fire to flammables in the three conditions was marginally different, $\chi^2(2, N = 48) = 5.74$, $p = .06$, indicating that older adults were somewhat more likely to attribute the cause to flammables in the Mention Control condition than in the Negation conditions. For young adults, 50% made attributions to flammables as the cause of the fire in the Mention Control condition, 0% made attributions to the flammables as the cause of the fire in the Direct Negation condition, and 12.50% made attributions to the flammables as the cause of the fire in the Indirect Negation condition. The difference between these conditions was significant, $\chi^2(2, N = 48) = 13.14$, $p = .001$, showing that young adults were more likely to attribute the cause to flammables in the Mention Control condition than in the Negation conditions.

The Correction Recall measure showed that 100% of older adults did not recall the correction in the Mention Control condition, 18.75% of older adults did not recall the correction in the Direct Negation condition, and 37.50% of older adults did not recall the correction in the Indirect Negation condition. The difference between these conditions was significant, $\chi^2(2, N = 48) = 23.21$, $p = .001$. This suggests that older adults were more likely to provide a correction in the Negation conditions than in the Mention Control condition. No young adults recalled a correction in the Mention Control condition and 25% did not recall the correction in each of the two Negation conditions. The difference between these conditions was significant, $\chi^2(2, N = 48) = 24.00$, $p = .001$.

This suggests that young adults were more likely to provide a correction in the Negation conditions than in the Mention Control condition.

Correlational Analyses

Composite scores for frontal and temporal lobe integrity and semantic knowledge and the text-based, and situation model measures were obtained for young and older adults. All composite scores were obtained separately for young and older adults. For the frontal lobe measure, Reading Span, WCST, Digit Symbol, Pattern Comparison, and FAS scores were converted into z-scores and the average of these z-scores was computed. For the temporal lobe measure, Digit Symbol Incidental Learning, Logical Memory, and Verbal Paired Associates were converted into z-scores and the average of the z-scores was computed. The semantic knowledge score was the Mill Hill Vocabulary score. The text-based composite score came from the lenient Summary Recall and lenient Fact Recall measures. Lenient Summary Recall and Fact Recall were converted into z-scores and averaged to produce the text-based composite score. Finally, the situation model score came from the Direct Reference measure. Only the Direct and Indirect Negation conditions were included. The Mention Control Condition was not included because it did not require a revision in belief. The Direct Reference scores were converted into z-scores. Correlations between the composite scores for frontal and temporal lobe integrity, semantic knowledge, and the text-based and situation model measures are shown in Table 7.

There was not a significant correlation between frontal lobe integrity and text-based measures or between frontal lobe integrity and situation model measures for either age group. Temporal lobe integrity was positively related to the text-based measures for older adults, but not for young adults. This indicates that as older adults' temporal lobe scores increased, there was an increase in their text-based scores. There was not a significant correlation for temporal lobe integrity and situation model measures for either young or older adults. Semantic knowledge was positively correlated with text-based measures for young adults, but there was not a correlation between semantic knowledge scores and text-based measures for older adults. This indicates that for young adults when there was an increase in the semantic knowledge scores, there was an increase in the text-based scores. Finally, semantic knowledge was positively correlated to situation model measures for older adults, but not for young adults. As older adults' semantic knowledge scores increased their situation model scores increased.

Table 7

Correlations between Composite Scores for Cognitive Ability and Comprehension

	Young Adults			Older Adults		
Measure	Frontal Lobe	Temporal Lobe	Semantic Knowledge	Frontal Lobe	Temporal Lobe	Semantic Knowledge
Text-Based						
r	0.21	0.18	0.41	0.21	0.41	0.20
p-value	0.24	0.32	0.02	0.25	0.02	0.26
Situation Model						
r	-0.02	0.03	0.08	-0.02	0.06	0.45
p-value	0.91	0.89	0.68	0.93	0.76	0.01

Discussion

The goal of the present research was to investigate whether there were age differences in updating causal information in text material. The hypotheses were that older adults would recall fewer idea units than young adults at the text-based level. At the situation model level it was hypothesized that for both young and older adults, a direct cue (Direct Negation condition) to causal misinformation presented prior to the correction would facilitate updating more than an indirect cue (Indirect Negation condition) to the misinformation. It was further hypothesized that age differences would exist when updating causal information at the situation model level. Specifically, older adults would not update their situation model as effectively as young adults in either of the Negation conditions.

As expected, older adults' performance was worse than younger adults' performance at the text-based level. For example, both strict and lenient scores in the Summary Recall measure showed that older adults recalled fewer idea units than young adults. Also, older adults got fewer questions correct in the Fact Recall measure for strict and lenient scores. This provided evidence that age differences exist when recalling information at the text-based level. The data for the situation model level provided mixed results. There were no differences between the Mention Control, Direct Negation, and Indirect Negation for the Thematic Inference measure, suggesting that neither young nor older adults updated their causal beliefs when a direct or indirect cue to misinformation was provided. Even after collapsing over the Direct Negation and Indirect Negation conditions due to their similar means, there were no overall age differences, differences between the Mention Control and Negation conditions, or interaction between age and condition in the Thematic Inference measure. In contrast, the Global Cause and Correction Recall measures showed that both young and older adults were less likely to attribute the cause of the fire to flammables and were more likely to provide a correction in the Negation conditions than in the Mention Control condition. While these findings did not provide support for the hypothesis that the type of cue provided would make a difference during updating, they did provide some support for the hypothesis that young and older adults update their situation model in the Negation conditions.

Finally, when the Direct Reference measure was collapsed over the Direct Negation and Indirect Negation conditions, a marginal effect of condition and a marginal age by condition interaction was observed. Young adults made fewer references to volatile materials when a correction to the misinformation was provided, suggesting that they updated their situation model in the Negation condition. In contrast, older adults had almost the same number of references to volatile materials in the Negation condition as in the Mention Control condition, suggesting that they were less likely to update their causal model in the Negation condition. This finding offers some support for the hypothesis that older adults do not update their situation model as effectively as young adults.

The correlational analysis showed that frontal lobe composite scores were not related to the text-based measures for either young or older adults. However, for older adults the lower the temporal lobe score, the lower the text-based score, suggesting that the decline seen in temporal lobe functioning due to aging may have played a role in the poorer performance seen in older adults on the text-based measures. Neither the frontal nor temporal lobe composite scores were correlated with the situation model measures for young or older adults. However, for older adults the lower the semantic knowledge score, the lower the situation model score, suggesting that older adults' semantic knowledge influenced their situation model score. Furthermore, for young adults the higher the semantic knowledge score, the higher they scored on the text-based measures, suggesting that the young adults' semantic knowledge contributed to their text-based score.

In summary, older adults did not perform as well as young adults at the text-based level. Furthermore, the findings suggest that young and older adults do update their situation model with causal information. Although the Thematic Inference measure suggested that there was no updating, the Global Cause, Correction Recall, and Direct Reference measures all suggested that young and older adults were capable of updating causal information in their situation model. The hypothesis that older adults would not update their situation model as effectively as young adults received less support. Finally, the results did not support the hypothesis that a direct cue to prior misinformation would facilitate more updating for young and older adults than an indirect cue to prior misinformation. It appeared that the type of cue (i.e. Direct Negation vs. Indirect Negation) did not affect whether the situation model was updated.

Text-Based Level

This research showed that age had a small effect on ability to recall text at the text-based level; older adults recalled fewer idea units and answered more fact questions incorrectly than young adults. This finding is consistent with prior studies showing that young adults are superior to older adults at recalling text at the text-based level (Radvansky et al., 2001). For example, in a study by Radvansky et al. (2001) participants read passages and either summarized the material (summary group) or related it to historical knowledge (knowledge acquisition group). The summary group represented comprehension at the text-based level, while the knowledge acquisition group represented comprehension at the situation model level. Following the reading, participants were given a recognition test where the sentence provided could be verbatim (surface level), paraphrased (text-based level), an inference (situation model level), or incorrect. Young adults performed better at the surface level and text-based level, while older adults were better at the situation model level. Furthermore, Stine and Wingfield (1990) showed that older adults recalled less of the text than young adults. This was explained in terms of their low working memory span, which produces declines in comprehension and recall. The current study, however, did not support that older adults recalled less of the text than young adults due to the shrinkage of the prefrontal cortex and corresponding decline in working memory.

Instead, the correlational analysis in the present research showed that the temporal lobe composite score had a medium effect on text-based measures for older adults. The temporal lobe is involved in episodic memory (Preston & Wagner, 2007), memory of a specific time and/or place. Logical Memory I (Wechsler, 1987) measured episodic memory. The participant listened to a paragraph read by the researcher. Following the reading, the participant was asked to retell the paragraph as close to how it was read to them as possible. Likewise, the text-based measures in the current study required the participant to recall idea units and answer fact questions. In order to correctly identify an idea unit, the participant needed to remember the correct time and location of that episode. Furthermore, the fact questions asked the participant to recall specific times and locations. Thus, episodic memory is needed to recall text at the text-based level (Weaver & Kintsch, 1996). The decline in episodic memory seen in older adults (Head, Rodrigue, Kennedy, & Raz, 2008) may be related to changes in temporal lobe function (Zacks & Hasher, 2006). Likewise, age-related changes in temporal lobe functioning resulting in declines in episodic memory may explain the correlation between the temporal lobe composite score and episodic text-based measures for older adults.

Situation Model Level

Johnson and Seifert (1994) found that young adults had problems updating causal inferences when misinformation was corrected. However, in the current study, three of the situational model measures (Global Cause, Correction Recall, and Direct Reference) showed that young and older adults did update their situation model. For example, both the Global Cause and Correction Recall measures showed that young and older adults were less likely to attribute the cause of the fire to flammables and were more likely to report a correction in the Direct and Indirect Negation conditions than in the Mention Control condition. Therefore, consistent with Hartman et al. (2001), the mere presence of a cue does help young and older adults update their situation model. After collapsing the Direct and Indirect Negation conditions for the Direct Reference measure, a marginal effect of condition and a marginal interaction was found between age and condition. Young adults referenced the volatile materials less, indicating that updating was taking place. Older adults referenced the same number of volatile materials in the Mention Control condition and Negation Condition. This suggested that older adults did not update as much as young adults and provides some support for the hypothesis that older adults would not update their situation model as effectively as young adults. However, there were no differences between the Mention Control, Direct Negation, and Indirect Negation conditions for young and older adults for the Thematic Inference measure. Furthermore, no age differences where found when referencing volatile materials, the closet itself, or attributions to carelessness/negligence. A significant effect may not have been seen because the power to observe an effect for this analysis was only .2 or less. Although this analysis may have lacked power, a trend in the correct direction can be seen in the data. This measure may have been less sensitive than the other situational model measures (Global Cause, Correction Recall, and Direct Reference) and additional participants may be needed to see a significant effect in the analysis of this measure. However, these findings do not call into question prior findings (Radvansky et al., 2001) that older adults can update their situation models.

It should be noted that half of the young adults in the Mention Control condition did not attribute the cause of the fire to flammables and 62.50% of older adults in this condition also did not attribute the cause of the fire to flammables. In fact, in many instances older adults even mentioned that the cause of the fire was due to an electrical problem. Message four suggested that the fire could have occurred from electrical problems. Participants apparently knew that volatile materials were there but recognized that the real reason behind the cause of the fire was the electrical short. If many young and older participants never thought the volatile materials were the cause of the fire in the first place, this would have reduced any potential differences between young and older adults in the situation model. Future research should consider eliminating the electrical short from the message in order to reduce unintentional inferences about the cause of the fire.

Consistent with prior findings (Radvansky et al., 2001; Radvansky & Curiel, 1998), the frontal lobe composite score did not correlate with the situation model scores for either the young or older adults, suggesting that the situation model was not related to working memory executive function. The temporal lobe composite score and situation model scores were unrelated for both young and older adults. This is not surprising because as mentioned above the temporal lobe is most important for episodic memory. Inconsistent with prior findings (Cosentino, Chute, Libon, Moore, & Grossman, 2006), the semantic knowledge composite score and situation model scores were not correlated for young adults. Consistent with prior findings (Cosentino et al., 2006), the semantic knowledge composite score and situation model scores were correlated for older adults. Older adults' better vocabulary may enable them to make better inferences and form their situation model.

In conclusion, age differences were found at the text-based level; young adults are superior to older adults. It appears that older adults' decline in performance at the text-based level might be related to decreased episodic memory which is a result of the decline seen in temporal lobe functioning as one ages. Furthermore, the present research showed that both young and older adults do update causal information in situation models. Although there does not seem to be much difference in this effect as a function of the type of cue, the findings did suggest that the presence of a cue led to updating. Relatively minor age differences in updating causal information in the situation model were found. Finally, the situation model does not appear to be related to working memory. However, older adults seem to use their semantic knowledge to help form their situation model, while young adults use their semantic knowledge at the text-based level to help encode and recall text.

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APPENDIX A

Message 1

Jan. 25th 8:58 p.m. Alarm call received from premises of a wholesale stationery warehouse. Premises consist of offices, a display room, and a storage room.

Message 2

A serious fire was reported in the storage room, already out of control and requiring instant response. Fire engine dispatched at 9:00 p.m.

Message 3

The alarm was raised by the night security guard, who had smelled smoke and gone to investigate.

Message 4

Jan. 26th 4:00 a.m. Attending fire captain suggests that the fire was started by a short circuit in the wiring of a closet off the main storage room. Police now investigating.

Message 5

4:30 a.m. Message received from Police Investigator Lucas saying that they have reports that flammable materials, including cans of oil paint and pressurized gas cylinders, had been stored in the closet before the fire.

Message 6

Firefighters attending the scene report thick, oily smoke and sheets of flames hampering their efforts, and an intense heat that made the fire particularly difficult to bring under control.

Message 7

It has been learned that a number of explosions occurred during the blaze, which endangered firefighters in the vicinity. No fatalities were reported.

Message 8

Two firefighters are reported to have been taken to the hospital as a result of breathing toxic fumes that built up in the area in which they were working.

Message 9

A small fire had been discovered at the same warehouse six months previously. It had been successfully extinguished by the workers themselves.

Message 10

10:00 a.m. The owner of the affected warehouse estimates that total damage will amount to hundreds of thousands of dollars, although the premises were insured.

Message 11a (Mention Control)

10:40 a.m. A second message received from Police Investigator Lucas regarding the investigation into the fire. It stated that the two firefighters taken to the hospital had been released.

Message 11b (Direct Negation)

10:40 a.m. A second message received from Police Investigator Lucas regarding the investigation into the fire. It stated there were no cans of oil paint or gas cylinders in the closet that had reportedly contained them. The closet had been empty before the fire.

Message 11c (Indirect Negation)

10:40 a.m. A second message received from Police Investigator Lucas regarding the investigation into the fire. It stated that the earlier message was incorrect. The closet had actually been empty before the fire.

Message 12

11:00 a.m. The shipping supervisor has disclosed that the storage room contained bales of paper; mailing and legal-size envelopes; scissors, pencils, and other school supplies; and a large number of photocopying machines.

Message 13

The display room was reported to contain display cases, catalogs, and the sales staffs' desks. It was only staffed from 11 a.m. to 2 p.m. due to declining sales.

Message 14

11:30 a.m. Attending fire captain reports that the fire is now out and that the storage room has been completely gutted.

APPENDIX B

Free Recall Instructions

Now, we would like you to write down, as accurately as possible, your account of what is known about the event in question, including the cause of the fire.

Fact Questions

1. What was the extent of the warehouse's premises?
2. Where did the attending fire captain think the fire started?
3. Where on the premises was the fire located?
4. What features of the fire were noted by the security guard?
5. What business was the firm in?
6. When was the fire engine dispatched?
7. What was in the storage room?
8. What was the cost of the damage done?
9. How was it thought the fire started?
10. When was the fire eventually put out?

Inference Questions

1. Why did the fire spread so quickly?
2. For what reason might an insurance claim be refused?
3. What was the possible cause of the toxic fumes?
4. What was the relevance of the closet?
5. What aspect of the fire might the police want to continue investigating?
6. Why do you think the fire was particularly intense?
7. What is the most likely cause of the fire that the workers successfully put out earlier?

8. What could have caused the explosions?

9. Where was the probable location of the explosions?

10. Is there any evidence of careless management?

11. How might the owner of the warehouse feel about the fire?

Manipulation Check Questions

1. What was the point of the second message from the police?

2. Were you aware of any corrections in the reports that you read?