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THE EFFECTS OF AGING ON
ASSOCIATIVE LEARNING AND MEMORY IN CAUSAL JUDGMENT

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

In Partial Fulfillment
Of the Requirements of the Degree
Master of Science

By
Jessica Parks Arnold

December 2015

THE EFFECTS OF AGING ON
ASSOCIATIVE LEARNING AND MEMORY IN CAUSAL JUDGMENT

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Research has shown that detecting and judging causal relationships requires associative learning and memory. Retrospective revaluation of causal cues requires associative memory (Aitken, Larkin, & Dickinson, 2001) to bind multiple cues together and use these associations to retrieve unseen cues for revaluation of their associative value. The difficulty that older adults experience with respect to retrospective revaluation could occur because of their deficit in associative binding and retrieval (Mutter, Atchley, & Plumlee, 2012). Like retrospective revaluation, blocking requires cue – outcome associative learning, but unlike retrospective revaluation, blocking does not require binding two cues together nor does it require using the resulting association between these cues for retrieval. Older adults display no deficit in blocking (Hannah, Allan, & Young, 2012; Holder & Mutter, in submission). To assess the effects of aging on associative learning and memory in causal judgment, this study examined age effects in retrospective revaluation and blocking using an allergy scenario in a streamed-trial task (Hannah, Crump, Allan, & Siegel, 2009; Hannah et al., 2012). This study found that older and younger adults both displayed blocking effects, which supports past research. Additionally, it was found that older and younger adults displayed retrospective revaluation in working memory. The ability for older adults to display retrospective revaluation in working memory is a new finding. It suggests that there may be a

decrement in associative long-term memory, but associative processes in working memory may be intact.

Chapter 1: Introduction

As a people age, they may have some moderate cognitive decline. Research has shown that older adults have greater difficulty compared to younger adults with associative binding (i.e., the associative binding deficit), leading to problems creating and retrieving associations (Chalfonte & Johnson, 1996; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Old & Naveh-Benjamin, 2008). This difficulty with associative memory is also responsible for the finding that older adults do not retrospectively revalue the associative strength of causal cues (Mutter, Atchley, & Plumlee, 2012).

Retrospective revaluation tasks are comprised of two phases. In Phase One a compound cue (i.e., target + companion) is paired with an outcome. During Phase One, both cues are given the same associative value. During Phase Two, only the companion cue is presented. If the companion cue is not presented with the outcome, then the associative value for the target cue is ‘revalued up.’ If the companion cue is presented with the outcome, then the associative value of the target cue is ‘revalued down.’ Successful retrospective revaluation of the associative value of the unseen target cue requires the ability to retrieve this cue using the association between it and the companion cue. After retrieving the target cue, the associative strength of the unseen target cue is revalued either up or down, depending on the new associative value of the companion cue. Since retrospective revaluation requires associative memory (Aitken, Larkin, & Dickinson, 2001), the difficulty that older adults experience with retrospective revaluation could occur because of their associative binding deficit (Mutter et al., 2012). Specifically, older adults cannot retrieve the target cue using its association with the

companion cue, because they were unable to originally bind the two cues together in the compound cue (Mutter et al., 2012).

In contrast to retrospective revaluation, blocking requires associative learning (i.e., associating cues with outcomes), but it does not require binding two cues together or using the resulting association between these cues for retrieval. Blocking is also comprised of two phases. During Phase One, the companion cue is paired with an outcome and acquires all of the available associative value. During Phase Two, the companion and a target cue (i.e., compound cue) are paired with the outcome. Because the companion cue has all of the associative value, it blocks the target cue from gaining any associative value in Phase Two. Prior research shows that older adults display blocking effects, such that they learn the predictive relationship between the companion cue and the outcome, and ignore the irrelevant target cues (Holder & Mutter, in submission). Therefore, older adults seem to have difficulty with associative binding and retrieval, but not with simple associative learning.

The effects of aging on associative learning and memory in causal judgment have generally been studied with conventional causal learning procedures (Holder & Mutter, 2014; Mutter et al., 2012). However, with the creation of the streamed-trial causal learning task (Crump, Hannah, Allan, & Hord, 2007; Hannah et al., 2012; & Hannah et al., 2009), it is possible to assess both associative learning and associative memory in a single task that is completed very quickly. Specifically, each streamed trial is about 22 seconds and participants make a causal judgment immediately after each streamed trial. This streamed-trial task has been used to test the blocking effect with younger adults (e.g., Hannah et al., 2009). In the Hannah et al. one-phase blocking task, the single and

compound cues were presented in the same phase. Participants were told to assume the role of allergists and were quickly presented with either a single picture of a food and the outcome (i.e., single-cue phase) or two pictures of food item and an outcome (i.e., compound-cue phase). The participant learned whether a single food or a combination of foods predicted an outcome (i.e., a rash). Once the streamed-trial ended, participants were presented with a cue and used the causal knowledge gained from the previous learning trials to rate the degree to which this cue was associated with the outcome. The results demonstrated that younger adults showed a blocking effect with this procedure. Specifically, younger adults showed a decrease in the associative rating of the target cue in the experimental condition (i.e., the companion cue remained the same throughout the trial) as the predictive strength of the companion cue increased from .25 (i.e., the companion cue was only presented with the outcome eight times out of 32 trials) to .75 (i.e., the companion cue was presented with the outcome 24 times out of 32 trials). Additionally, the results showed that younger adults could display retrospective reevaluation. Specifically, the experimental condition had lower ratings for the associative value of the target cue than the control condition (i.e., the companion cue changed throughout the trial) throughout all the predictive strengths.

The streamed trial task has also been used to compare the blocking effect for older and younger adults; however, abstract shape stimuli were used (Hannah et al., 2012). A one-phase blocking design was given. In this design, participants were sometimes shown one shape stimulus and the outcome, a red circle, or two shape stimuli (i.e., compound cues) and the outcome, a red circle. After a streamed-trial, participants were signaled by a small picture of the outcome and one of the shape cues to make the contingency

judgment between those two shapes. Younger adults did show a blocking effect, but older adults showed no blocking effect (Hannah et al., 2012). However, this age-related difference was eliminated when diagonal lines were placed on the screen to perceptually segregate the cues and outcome. Participants were informed that these lines indicated the stream's most relevant cue-outcome pairing. This finding suggests that older adults are capable of detecting the most predictive cues if the cue – outcome pairings are segregated for them (Hannah et al., 2012).

The current study assessed the effects of aging on associative learning and memory in causal judgment using the streamed-trial (Hannah et al., 2012) allergist scenario (Hannah et al., 2009) to allow for a less abstract learning scenario. The streamed trial causal learning task assessed both associative learning and memory by using two different learning orders: forward and backward. The forward order was characterized by the single-cue phase occurring before a compound-cue phase, which assessed associative learning in blocking. Participants saw a single companion cue with an outcome and learned to associate this cue with the outcome. Then they saw this companion cue together with the target cue paired with the outcome (i.e., compound cue). Based on past research, it was hypothesized that both younger and older adults would display blocking effects. Specifically, during phase two gaining associative value for the target cue would be blocked by the companion cue that has gained all the associative value in Phase One.

The backward order was characterized by the compound-cue phase occurring prior to the single-cue phase, which assessed associative memory in retrospective reevaluation. Participants first learned an association between a compound cue (i.e., companion cue and target cue) and an outcome, followed by a single cue from the

compound cue (i.e., companion cue) and an outcome. With regard to retrospective reevaluation, there were two possible hypotheses: (1) older adults may have a general associative deficit that prevents them from displaying a retrospective reevaluation effect (e.g., Mutter et al., 2012) or (2) because the presentation of the stimuli is so quick in the streamed trial task, older adults may be able to retrieve associations from working memory instead of long-term memory and display a retrospective reevaluation effect.

Chapter 2: Literature Review

Associative memory can be studied with retrospective reevaluation tasks because these tasks require the ability to retrieve an unseen target cue using an association between this cue and a second cue previously presented together. After the target cue has been retrieved, participants must revalue the associative strength of the target cue either up or down depending on the predictive strength of the second cue. Retrospective reevaluation requires associative memory (Aitken et al., 2001), the difficulty experienced by older adults in displaying retrospective reevaluation could be due to their associative binding deficit (Mutter et al., 2012). In contrast, associative learning can be studied with blocking tasks because these tasks do not require binding two cues together or using the association between the cues for retrieval. Past research has shown that as a person ages, he or she continues to display a general blocking effect. The proposed research seeks to analyze the different ways aging impacts a person's associative learning and associative memory in the same task. Before discussing the proposed study, it is important to examine past research on associative binding, performance differences between younger and older adults on contingency detection in causal learning tasks, and performance

differences between younger and older adults on contingency detection in streamed-trial tasks.

Associative Binding Deficit

Older adults have an associative binding deficit, such that older adults have greater difficulty than younger adults with regard to creating an association between unrelated items (Naveh-Benjamin et al., 2003, 2004; Old & Naveh-Benjamin, 2008). For example, Naveh-Benjamin et al. (2003) used picture pairs that were not related. While studying the picture pairs, younger and older adults were either placed in a full attention condition or a divided attention condition. In the study phase, participants were told to prepare for an upcoming item and associative recognition task. In the item, test participants were asked to indicate the target pictures that had appeared in the study phase, whereas, in the associative test participants were asked to indicate the intact pairs. Overall, this study found that older adults had difficulties on the tasks requiring associations than on tasks requiring item recognition. However, older adults showed less of an associative deficit when the pairs were already related and, therefore, connected in memory. Additionally, this study showed that this deficit is not due to attentional resources because younger adults, under divided attention, did not show a deficit.

The age-related associative binding deficit has also been examined with more practical and applicable, name-face pairings (Naveh-Benjamin et al., 2004). Older and younger adults were told during the study phase that they must pay attention to the name-face pairs because their memory would be tested. Additionally, during the study phase, some younger adults were assigned to a divided attention condition. After the study phase, the test phase began, in which participants' memories for the names, faces, and pairings

were assessed. A forced choice name recognition test was given, and participants were told to indicate on a test pair which of the names had appeared in the study phase. A forced choice face recognition was also given, and participants were asked to indicate for each test pair which of the faces had appeared in the study phase. Finally, a forced choice associative recognition test was given in which participants were told to choose the correct pairing on each trial. It was found that younger adults performed better in the full attention condition than older adults in the same condition. Additionally, performance was better for the face recognition than the name recognition and the name recognition performance was better than the name-face associative recognition test. Overall, the results showed that older adults had an associative deficit even for meaningful units, such as face-name pairings. Additionally, attentional processes were once again found to not be the only mediator of this deficit (Naveh-Benjamin et al., 2004). Finally, in a meta-analysis that included over 90 studies totaling of over 3,000 younger adults and 3,000 older adults, there was support for an age-related associative binding deficit (Old & Naveh-Benjamin, 2008).

The age-related problems with associative memory support the associative-deficit hypothesis, which states that older adults have more difficulty binding features into one cohesive unit (e.g., Naveh-Benjamin et al., 2003, 2004; Old & Naveh-Benjamin, 2008). This deficit shows greater age differences in remembering associative information than item information (e.g., Old & Naveh-Benjamin, 2008) and has been reported using numerous stimuli such as: picture stimuli (e.g., Naveh-Benjamin et al., 2003), name-face pairs (e.g., Naveh-Benjamin et al., 2004), source, context, temporal order, spatial location, and item pairings (e.g., Old & Naveh-Benjamin, 2008). Additionally, this deficit has not

been replicated in younger adults under divided attention (Naveh-Benjamin et al., 2003), which seems to make this associative binding deficit unique to older adults.

Contingency and Causal Learning Tasks

Even though declines in associative learning due to aging are still being studied, evidence suggests that these declines occur independently of other cognitive processes (e.g., attention, spatial, and strategy use) involved in paired associative learning (Lee, Archer, Wong, Chen, & Qiu, 2013). Contingency learning assumes that for learning to take place the stimulus might give the participant, or subject, information about the outcome. Specifically, the Rescorla-Wagner Model theorizes that participants and subjects learn through discrepancies between what is expected to happen and what actually happens (Rescorla & Wagner, 1972). Aging effects have been found in basic contingency learning.

Detecting the causal relationships is more difficult for older adults than younger adults (Mutter & Williams, 2004). The ability to learn contingencies was assessed with a task involving seven problems. Participants were instructed to determine whether pressing the spacebar would lead to a triangle flashing on the computer screen or not (Mutter & Williams, 2004). The study examined whether older and younger adults were able to detect response-outcome negative, positive, or random contingencies. This study found that it is more difficult to detect causal contingencies when the relationship is negative (i.e., a preventative contingency). There is also an age-related change that occurs in rule-based contingency learning involving absent cues and an outcome (Mutter & Williams, 2004). Additionally, in Mutter, DeCaro, and Plumlee's (2009) study, older and younger adults came into the lab for two sessions that were one week apart. Participants

were told that they would need to discover whether pressing the spacebar would lead to a triangle flashing on the computer screen or not. Additionally, participants were rewarded with a monetary incentive for every correct judgment. This study also examined age differences on generative causal contingency (i.e., the outcome is more likely to occur when a response is made) tasks and on preventative causal contingency (i.e., the outcome is less likely to occur when a response is made) tasks (Mutter et al., 2009). Overall, there were minor age-related differences for the generative causal learning, but the age-related difference for the preventative relationship was greater. Older adults could not judge the preventative aspect when the response and outcome were separated by a short delay (Mutter et al., 2009).

Furthermore, the influence of associative learning on causal learning was assessed with older and younger adults (Mutter & Plumlee, 2014). Participants were asked to play the role of an anthropologist who must learn to predict which foods were aversive to a group of natives from the jungles of South America. The discrimination training involved the participants predicting whether a food would or would not make the native sick. Specifically, single and compound cue phases were presented in a positive pattern (i.e., single cue led to no reaction, but the compound cue led to a reaction) and in a negative pattern (i.e., a single cue led to a reaction, but the compound cue led to no reaction). Participants then received a test trial, in which the original stimuli from the discrimination learning phase were used and then novel stimuli were added (i.e., partial patterning problems) to assess causal learning. Predictions were once again made in the test phase regarding whether a single cue phase or a compound cue phase led to a reaction, but no feedback was given. After the test trials, participants were asked to state

any general trend that could have helped them learn the relationship between the foods and the reactions of the natives. Overall, older adults learned cue – outcome associations, but could not learn compound cue – outcome associations. Specifically, older adults had more difficulty with discriminating the patterns, such that even when they had figured out a pattern, they still did not use it when given new stimuli (Mutter & Plumlee, 2014).

Age differences in cue competition in causal learning have also been studied (Hannah et al., 2009). Cue competition arises when more than one cue is a potential predictor for an outcome. For example, if one cue gains a high predictive value (i.e., gain more associative strength) this will lower the predictive value of any other potential predictive cues. One well-known cue competition is the blocking effect. In the first phase of the blocking effect, a single cue is presented with the outcome. The single cue essentially obtains all of the associative value. In the second phase two cues (i.e., compound cue) are presented with the outcome. One cue is the same cue from Phase One, which therefore, blocks the new cue from being able to obtain any associative value (Livesey & Boakes, 2004; Shanks, 1985). Age differences have not been observed in the blocking effect (Holder & Mutter, 2014).

Another type of cue competition is backward blocking or retrospective reevaluation. A retrospective reevaluation design involves a compound cue (e.g., a picture of a tomato and a picture of a ham) being paired with an outcome (e.g., a picture of an arm with a rash) in Phase One. Then, when only a single cue (e.g., a picture of a tomato) is shown with the outcome (e.g., a picture of an arm with a rash) in Phase Two, it retrieves a representation of the target cue (e.g., a picture of a ham). A strong companion cue will reduce the associative value of the target cue more than a weak companion cue.

Unlike the blocking effect, which is present in both older and younger adults, older adults do not display retrospective revaluation. Older adults have weaker associations for the two cues in the compound cue, which could prevent them from using the association to retrieve the representation of the absent cue in the single cue phase (Mutter et al., 2012). The only time older adults were capable of displaying retrospective revaluation was when a small icon of the associated cue was displayed in the corner to help the older adults retrieve this stimulus (Mutter et al., 2012).

Retrospective revaluation and blocking both require associative learning (i.e., cue-outcome), but they differ in their requirement for associative binding (i.e., cue-cue) and associative retrieval (i.e., cue-?). Retrospective revaluation involves associative learning, associative binding, and associative retrieval. Aitken et al. (2001) found that retrospective revaluation requires associative memory. Specifically, retrospective revaluation requires the ability to retrieve an unseen target cue using the association created between the cue and a different cue previously presented together with the outcome. After retrieving the target cue, participants must revalue the associative strength of the target cue based on the predictive strength of the second cue. In contrast, blocking involves associative learning (i.e., associating cues with outcomes); it does not require binding two cues together, nor does it require using the resulting association between these cues for retrieval. Due to the fact that retrospective revaluation includes associative learning, associative binding, and associative retrieval, it was proposed that older adults might not be able to display retrospective revaluation (Mutter et al., 2012). However, because blocking only requires associative learning, it was proposed that older adults would be able to show blocking (Holder & Mutter, 2014).

Streamed-Trial Causal Learning

Traditional contingency and causal learning tasks have provided a wealth of information on the impact of associative deficits on older adults' performance in these tasks. However, these tasks require many learning trials and lengthy learning phases that may actually increase the demands for episodic memory involvement. A novel streamed trial causal learning task (Crump et al., 2007) allows associative processes in causal learning to be examined when episodic memory requirements are minimal. The streamed-trial task involved colored shapes as the cues and the outcomes. A stream trial was comprised of 60 frames each of which displayed a cue-outcome pair. In each frame, the cue and outcome pair was presented for 100 ms and the frames were separated for 100 ms by a black screen (Crump et al., 2007). After each stream, a judgment decision was made. Overall, the streamed-learning task has been validated and is a reliable measure of associative processes in causal learning (Crump et al., 2007).

The streamed-trial procedure has been used to assess blocking effects in older adults (Hannah et al., 2012). In this version of the task, shape stimuli were once again used as cues and outcomes. A one-phase blocking task involving two cues was used. The two cues had different contingencies, but were presented with the same outcome. This study found that there was an age-related deficit for the blocking effect when cues were not perceptually segregated. However, when lines were added to visually separate the relevant cues, it was found that older adults performed just as well as younger adults (Hannah et al., 2012), which has been demonstrated in previous research with conventional procedures (e.g., Mutter et al., 2012). Additionally, in a one-phase blocking

task, older adults and younger adults displayed blocking effects, representative of associative learning (Hannah et al., 2012).

The Current Study

Older adults display the blocking effect in conventional causal learning tasks (Holder & Mutter, 2014) but do not display the retrospective revaluation effect (Mutter et al., 2012). However, these earlier studies examined how aging affects associative learning or associative memory using completely different tasks. In the current experiment, aging effects on both associative learning in blocking and associative memory in retrospective revaluation were studied in the same streamed trial causal learning task. The ability to assess both associative learning and associative memory processes in the same task is particularly interesting because these effects can be measured concurrently in the same individuals. The streamed-trial procedure was also chosen because it is similar to a traditional causal learning task, but it takes much less time to complete—approximately 25 minutes. Using this task, it was possible to see whether the age deficit in retrospective revaluation would still be present when the absent target cue was retrieved from working memory instead of long-term memory.

The streamed trial procedure with shape stimuli has been used to examine age differences in the blocking effect and perceptual segregation (Hannah et al., 2012). This earlier study found that there was an age difference for the blocking effect, but this difference was eliminated when lines segregating the relevant cues were added. This finding suggests that older adults can find the most relevant cues when the information is obviously segregated. The current study extended the Hannah et al. (2012) study by assessing age differences in blocking (i.e., associative learning) and retrospective

reevaluation (i.e., associative memory) in the same task and using similar realistic food stimuli and allergic reactions as outcomes (see Hannah et al., 2009). This study differed from Hannah et al. (2009) in that it examined age differences and only had two levels of predictive strength instead of three. A causal learning design involving forward blocking, and retrospective reevaluation allowed a test of both associative learning and associative memory in the same task, and it was ideal for answering the question of whether aging affects learning and memory differently when episodic memory requirements are minimal.

In the allergy scenario, streamed-trial causal learning task, participants viewed a set of rapidly presented trials in which they were told to assume the role of an allergist who was trying to learn which foods were associated with an allergic reaction for a patient. In a single cue learning phase, participants saw one food picture (i.e., the companion cue) paired with an outcome picture, and in a compound cue learning phase they saw two food pictures (i.e., companion cue and target cue) paired with an outcome picture. The outcome picture was either an arm with a rash (i.e., allergic reaction) or an arm without a rash (i.e., no allergic reaction). At the end of each streamed trial, they were shown the target cue and asked to rate the probability that the food produced an allergic reaction.

Blocking and retrospective reevaluation are tested in the streamed-trial learning task by manipulating order, predictive strength, and treatment. First, order is either forward or backward. Forward order occurs when a single-cue learning phase precedes a compound-cue phase. Specifically, forward order is a blocking design, which requires associative learning processes. For example, if the companion cue acquires a strong

predictive strength in the single-cue learning phase, acquiring associative value for the target cue will be blocked. This is because participants already associate the companion cue with the outcome. A strong companion cue will compete and block the associative value of the target cue more than a weak companion cue. The backward order occurs when a compound-cue phase precedes a single cue learning phase. It is a retrospective reevaluation design, which involves memory processes, because the companion cue and the target cue must be associated together into one unit (i.e., compound cue) in Phase One. The compound cue is then associated with an outcome. Then, when only the companion cue is shown with the outcome in Phase Two, the companion cue retrieves a representation of the target cue. The associative value of the target cue then decreases or increases based on whether or not the companion cue has a strong or weak predictive strength, respectively. A strong companion cue will reduce the associative value of the target cue more than a weak companion cue.

Another variable is predictive strength of the companion cue (e.g., B) occurring with the outcome (e.g., O) in the single cue learning phase (i.e., $P(O|\sim C_t C_c)$), which can either be strong (i.e., 0.75) or weak (i.e., 0.25). The different predictive strengths influence the amount of cue competition from the single cue. If the predictive strength is strong, there will be greater cue competition. If the predictive strength is weak, there will be less cue competition. For example, if a companion cue has a weak predictive value, then the associative value of the target cue, in theory, should be higher.

Finally, the third variable in the streamed-trial blocking task is treatment, which is comprised of experimental and control treatments. In the experimental treatment, the companion cue remains the same between the single-cue phase and the compound-cue

phase. This allows for cue competition because the companion cue gains associative value for predicting the outcome in the initial learning phase and competes with the other cue in the second learning phase. On the other hand, in the control treatment, the companion cue differs between the single-cue phase and the compound-cue phase, producing no cue competition.

Given that the current study is a direct replication of Hannah et al. (2009), it was expected that young adults' results for the forward and backward orders would be similar to the results Hannah et al. obtained from their younger adults. Figure 1 below is from Hannah et al.'s (2009) study and shows the predicted results for younger adults. The mean ratings of the target cue are shown as a function of the value of the probability of the companion cue occurring with the outcome, $P(O|C_t C_c)$, in the single cue learning phase. The top graph is forward order (i.e., associative learning) and the bottom graph is backward order (i.e., associative memory). Cue competition is illustrated in the figure, such that ratings for the target cue were lower in the experimental treatment compared to the control treatment. This result occurred because the companion cue did not change in the experimental treatment and competed with the target cue for associative value. Additionally, forward blocking is illustrated in the figure, such that the ratings for the target cue decreased as the predicted strength of the companion cue occurring with the outcome, $P(O|C_t C_c)$, increased from .25 to .75. This decrease in the associative value of the target cue, as the predictive strength of the companion cue increased, was a result of the companion cue gaining more associative value in Phase One. Finally, retrospective reevaluation is illustrated, such that ratings for the target cue were lower in the experimental treatment compared to the control treatment. Also, the ratings for the target

cue decreased as the predicted strength of the companion cue occurring with the outcome, $P(O|C_t C_c)$, increased from .25 to .75 because a strong companion cue in Phase two reduced the associative value of the target cue.

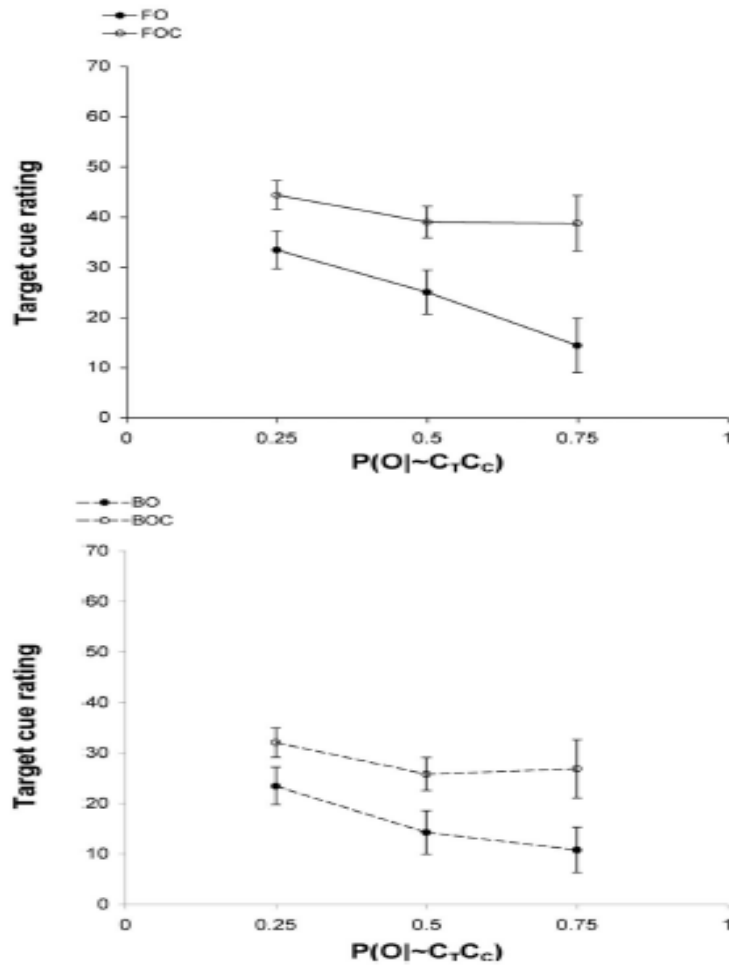


Figure 1. Results from Hannah et al. (2009) and predicted results for the younger adults in the current study.

With regard to age differences, it was expected that older and younger adults should have similar results for the forward order condition. The forward order is a test of the blocking effect, which requires associative learning processes, but not associative binding and retrieval. Since past research has shown that older adults display the blocking effect (Hannah et al., 2012; Holder & Mutter, 2014), the blocking effect here should be

approximately the same as in the younger adult sample. Ratings for the target cue were expected to be lower in the experimental treatment compared to the control treatment. This result was expected to occur because the companion cue does not change in the experimental treatment, which would cause cue competition. Unlike the experimental treatment, the control treatment involved the companion cue changing throughout phases, which would not cause cue competition. It was also expected that the ratings for the target cue would decrease as the predicted strength, $P(O|~C_t C_c)$, increases from .25 to .75. Figure 2 represents the predicted results for the experimental and control treatments in the forward order condition for the older adult sample.

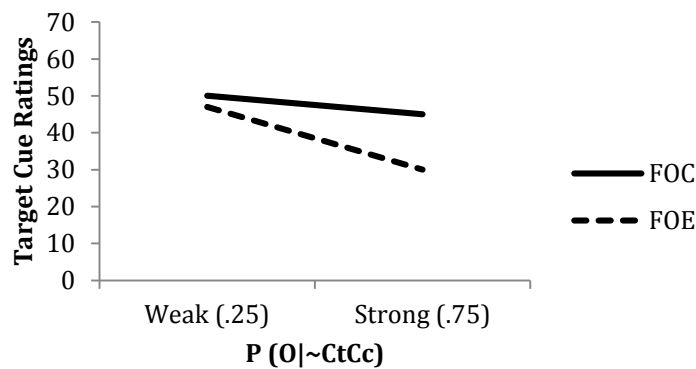
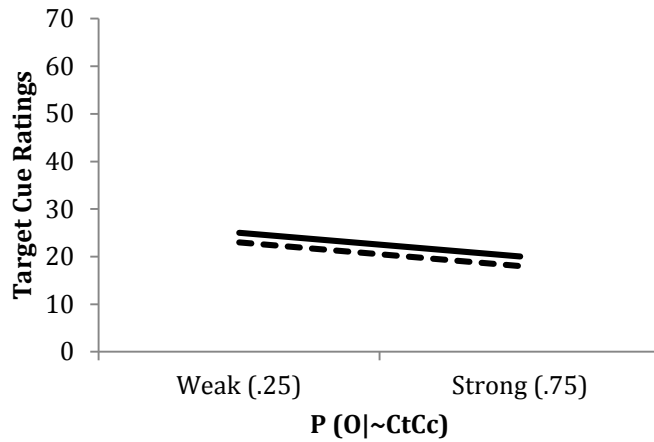


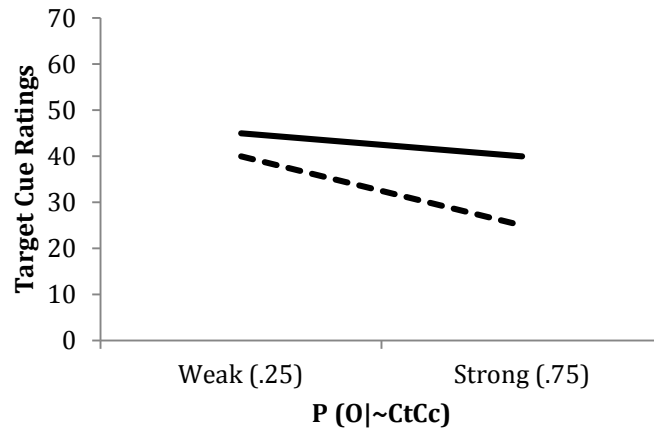
Figure 2. Predicted forward order results for the older adults in the current study.

It was not clear whether age differences would be seen for the backward order condition. The backward order tests the retrospective revaluation effect, which requires associative memory processes for the target cue. If older adults' previous failure to display retrospective revaluation (Mutter et al., 2012) is due to a general deficit in associative retrieval, older adult participants should not be able to retrieve and revalue the predictive value of the target cue in the streamed trial task and their ratings for the target cue should be about the same across the predicted strengths. This would make the causal

ratings for the target approximately the same across conditions (see top graph of Figure 3). Alternatively, older adults may be able to accomplish retrospective revaluation when only working memory is involved. If so, their results would look similar to those of younger adults, which are displayed in the hypothetical graph on the bottom of Figure 3. Specifically, the target cue will have a greater associative value in the control condition than in the experimental condition. Additionally, there will be a decrease in the associative value of the target cue when the predictive strength of the companion cue increases from .25 to .75.



a



b

Figure 3. Predicted backward order results for the older adults in the current study. Figure 3a indicates no retrospective reevaluation. Figure 3b indicates retrospective reevaluation.

Chapter 3: Method

Participants and Design

A total of 57 participants were recruited either through Western Kentucky University or through the community. Twenty-eight older adult community members of Warren County took part in the study and received \$15 per hour of participation. Community members were screened with the Telephone Mini Mental State Exam to assess cognitive ability prior to scheduling a session. Additionally, 29 younger adult

Western Kentucky University students took part in the study and received one study board credit for every 30 minutes of participation. The younger adult participants were recruited through Western Kentucky University's Department of Psychological Sciences and Department of Psychology Study Board, an online database where a student can create an account and volunteer to participate in various studies being conducted.

Western Kentucky University's Institutional Review Board (IRB) approved the study.

To determine that the older and younger adult samples were representative of their populations, individual difference measures were given and are reported in Table 1. Participants were asked to complete the Advanced Vocabulary Test (Ekstrom, French, Harman, & Dermen, 1976) to assess acquired verbal knowledge. The Conditional Associative Learning (CAL) test measured the participant's ability to learn associations (Salthouse, 1994), and the Reading Span (Daneman & Carpenter, 1980) was used to measure working memory. The results revealed that there was a significant difference in age between older and younger adults, between retained responses (i.e., younger adults learned and remembered the pairings to a greater extent than older adults), between reading span (i.e., younger adults had a greater working memory than older adults), and between vocabulary scores (i.e., older adults had better verbal knowledge than younger adults).

Table 1

Means and Standard Deviations for Participant Characteristics

Characteristic	<u>Younger</u> <i>M (SD)</i>	<u>Older</u> <i>M (SD)</i>
Age (years)**	19.48 (1.18)	69.04 (6.57)
CAL Successful Responses	6.52 (2.06)	6.89 (1.97)
CAL Retained Responses*	20.93 (9.92)	14.71 (9.71)
CAL Forgotten Responses	3.14 (2.66)	4.07 (2.45)
CAL Discrimination Failures	6.72 (7.08)	10.96 (8.80)
CAL Perseverations	0.17 (0.38)	0.43 (0.69)
CAL Unsuccessful Guesses	2.52 (1.15)	2.71 (1.08)
Reading Span**	2.90 (1.11)	1.89(1.26)
Advanced Vocabulary**	11.58 (5.53)	17.05 (7.12)

Note. The Conditional Associative Learning (CAL) test is from Salthouse (1994).

* $p \leq .05$. ** $p \leq .01$.

The study used a 2 (Age: younger, older) X 2 (Predictive Strength: strong, weak) X 2 (Order: forward, backward) X 2 (Treatment: experimental, control) mixed factorial design. The between-subject variables were age and predictive strength. Older adult participants were randomly assigned to the older-strong predictor group or the older-weak predictor group; whereas the younger adult participants were randomly assigned to the younger-strong predictor group or the younger-weak predictor group. Within each of these four groups, there were 14 participants. The within-subject variables were blocking, order, and treatment condition. A session contained four blocks of 16-streamed-trials. The four within-subject conditions (i.e., forward order experimental, forward order control, backward order experimental, and backward order control) were presented

randomly four times in each block. The dependent variable was the causal rating provided by each participant at the end of each stream.

Streamed-trial procedure. The streamed-trial procedure described in Hannah et al. (2009) was used in this experiment. Ten different colored food images, and two colored images of an arm with either a rash or without a rash, were used as a cue and outcome stimuli, respectively, and were presented on a Power Macintosh G3 computer. All of the pictures can be found in the appendix. Participants were informed that a picture of an arm with a rash represented an allergic reaction to a specific food, and a picture of an arm without a rash represented the absence of an allergic reaction to a specific food. The outcome pictures (i.e., an arm with or without a rash) were presented in the center of the top part of the frame. The cue pictures (i.e., varying foods) were presented at the bottom of the frame. The two foods were randomly chosen with replacement from the nine stimuli pictures (i.e., food) at the beginning of every stream to control for any preexisting connotations about food combinations (e.g., peanut butter and jelly). These two foods were also randomly assigned to cue designation (C_t (target cue) or C_c (companion cue)), and presentation position on the screen (right or left). The target cue was presented on the right side of the screen for half of the streamed trials for each of the four different within-subject conditions.

The causal learning task was a two-phase blocking task presented over four blocks of 16 streamed-trials each. Each streamed trial consisted of 64 cue-outcome frames—32 frames for single-cue phase and 32 frames for the compound-cue phase. Participants were not notified of the two different phases presented during a trial. Each cue-outcome frame was presented for 250 milliseconds and the interframe interval (IFI)

was 100 milliseconds. Ratings were made when only the target cue appears on the screen. At the end of each streamed trial, participants rated the probability of a food causing an allergic reaction using a scale ranging from -100 (perfect negative association) to +100 (perfect positive association). A midpoint of 0 indicated there was no association. Participants made their rating by using a scrollbar. The scrollbar always displayed 0 as the midpoint, and participants were not under a time constraint to make their decision.

The design of the two-phase blocking task is depicted in Table 2 below.

Table 2

Design of Streamed-Trial Task

	<u>Single-cue phase</u>	<u>Compound-cue phase</u>		
Predictive Strength	$P(O \sim C_t C_c)$	$P(O C_t C_c)$	$P(O \sim C_t C_c)$	ΔP_{C_t}
Strong	.75	.75	.25	.5
Weak	.25	.75	.25	.5

Note. C_t = the target cue; C_c = the companion cue; O = the outcome; $\sim C_t$ = without the target cue; $C_t C_c$ = the presentation of the compound cue; C_c = the presentation of the single cue.

Predictive strength concerns the associative value that is given to the companion and target cues. The predictive strength of the companion cue C_c varies between the strong and weak conditions only in the single-cue phase. The probability of an outcome occurring with the companion cue was either .75 (strong predictive value) or .25 (weak predictive value). In the single-cue phase, there were a total of 32 frames. In the strong predictive value condition, the cue occurred with the outcome in 24 frames and occurred without the outcome in eight frames. In the weak predictive value condition, the cue occurred with the outcome in eight frames and occurred without the outcome in 24 frames.

In the compound-cue phase, the companion cue appeared with the target cue on 50 percent of the frames (i.e., 16 frames) and the companion cue appeared alone for the remaining 16 frames. Additionally, during the compound-cue phase, the probability that an outcome occurs with the compound target and companion cue was .75 (12 frames), whereas the probability that an outcome occurs with only the companion cue was .25 (four frames). The contingency values for the target cue in the compound-cue phase conditions were 50 percent. The formula for contingency values is determined by subtracting the probability of an outcome occurring with only the companion cue from the probability of an outcome occurring with both the companion and target cues (e.g., $0.75 - 0.25 = 0.5$).

There were also two presentation orders for the single and compound cue learning phases in the blocking task. In the forward order, the single-cue phase was presented before the compound-cue phase. The forward order assesses associative learning because it requires learning whether the single cue led to an outcome or not. Learning what outcome is produced by the single cue is beneficial in the compound cue phase. In the backward order, the compound-cue phase was presented before the single-cue phase. The backward order assesses associative memory because it requires remembering whether the compound cue led to an outcome or not, and then deciding whether or not the single cue will lead to an outcome or not. In the experimental condition, the target cue (e.g., banana) and the companion cue (e.g., apple) stayed the same for both phases. The experimental condition assesses cue competition because the companion cue stays the same, thereby making it more difficult for the participant to decide whether or not the target cue leads to an outcome or not. In the control condition, the target cue (e.g.,

banana) remained the same across the two phases, but the companion cues (e.g., apple and cheese) changed from phase to phase so that the companion and target cues do not compete for associative value. The control condition therefore involves no cue competition. Each participant completed both orders and both conditions.

Procedure

Once the participant arrived in the Cognition Lab in Gary Ransdell Hall on Western Kentucky University's campus, he or she was given the informed consent document explaining the study. The session began with the Biographical and Health Questionnaire, which was created in the Cognition Lab at Western Kentucky University. This questionnaire screens for medical issues, such as stroke, past history of a concussion, and learning disabilities, which could affect the results of the study.

Streamed-trial procedure. As in Hannah et al., (2009), the causal learning task began with all participants being told that they are reviewing different patients' allergy tests in order to predict what food(s) associate with an allergic reaction for the participant. They were told that each patient consumed either a single food or a combination of foods, which resulted in an allergic reaction or no reaction, and that pictures of an arm with a rash or without a rash represent an allergic reaction or not, respectively. Participants were also told that multiple tests were conducted on each patient and that the frequent succession of multiple pictures in a single stream represents the multiple tests for a single patient. Once all the pictures in a streamed trial had been presented, participants were shown a single food item and instructed to state to what degree that food cue is associated with an allergic reaction. The streamed-trial causal learning task took approximately 25 minutes to complete.

After the experimental task ended, several individual differences tests were administered. At the end of the session, younger adult participants were debriefed, thanked for their time, and granted study board credit(s). Older adults were debriefed, thanked for their time, and given a monetary stipend at the end of their session. The entire session took approximately 90 minutes to complete.

Chapter 4: Results

Statistical Analyses

There were 64 target cue ratings from each participant (four blocks x four streamed trials x four within-subject conditions: forward order-experimental, forward order-control, backward order-experimental, backward order-control). Analyses were conducted on mean ratings for each treatment x order condition computed by collapsing over the four blocks and four streamed trials. For all analyses, reported p -values are two-tailed and an alpha of $p \leq .05$ was accepted as statistically significant.

There were six data points removed from a total of 1,856 data points (i.e., .32% of the data points) in the younger adult data due to a random virus pop-up window. Notes were made whenever the screen appeared and the y-axis was examined to assure accuracy. Twelve data points were removed from a total of 1,792 data points (i.e., .67% of the data points) for the older adult data due to a random virus pop-up window and because some older adults clicked the mouse prior to setting it on the scrollbar. The appearance of the virus pop-up window and inaccurate mouse clicks were noted and then examining the y-axis measurement ensured accuracy. Two summary data files were compiled: one with all the data points and one with the data points removed.

Both data files were subjected to a 2 (Age: Younger vs. Older) X 2 (Predictive Strength: Strong vs. Weak) X 2 (Order: Forward vs. Backward) X 2 (Treatment: Experimental vs. Control) mixed factorial ANOVA. The analysis on the data file without the errors showed that there was no significant difference between the older and the younger adults, $F(1, 53) = .348, p = .558, \eta_p^2 = .007$. There were also no significant interactions for age X strength, $F(1, 53) = .025, p = .874, \eta_p^2 = .000$, age X order, $F(1, 53) = 2.598, p = .113, \eta_p^2 = .047$, or age X order X strength, $F(1, 53) = .040, p = .843, \eta_p^2 = .001$. The within-subject condition means changed slightly but the analysis done on the full data file produced the same results. Because the predictions focused specifically on separate group performance, the data from the younger and older adults were separated and subjected to a 2 (Predictive Strength: Strong vs. Weak) X 2 (Order: Forward vs. Backward) X 2 (Treatment: Experimental vs. Control) mixed factorial ANOVA.

Younger Adults – Results

The young adults' forward order – blocking data and their backward order – retrospective revaluation data are shown in Figure 4. For the younger adults, there was a main effect of order, $F(1, 27) = 23.635, p = .000, \eta_p^2 = .467$, showing higher causal ratings for the target cue in the forward order condition compared to the backward order condition. There was also a main effect of predictive strength, $F(1, 27) = 6.103, p = .020, \eta_p^2 = .184$, showing that the weak predictive strength led to higher causal ratings for the target cue than the strong predictive strength. Furthermore, there was a main effect of treatment, $F(1, 27) = 26.825, p = .000, \eta_p^2 = .498$, such that the control condition led to higher causal ratings for the target cue than the experimental condition. There was not an

interaction between order and treatment, $F(1, 27) = 0.280, p = .601, h_p^2 = .010$. There was also not an interaction between order and predictive strength, $F(1, 27) = .065, p = .801, h_p^2 = .002$, but there was an interaction between predictive strength and treatment, $F(1, 27) = 14.146, p = .001, h_p^2 = .344$. Specifically, causal ratings were higher for the weaker predictive strength than the stronger predictive strength in the experimental treatment, but there was little to no difference in the control treatment. There was not a three - way interaction between order, treatment, and predictive strength, $F(1, 27) = .085, p = .772, h_p^2 = .003$.

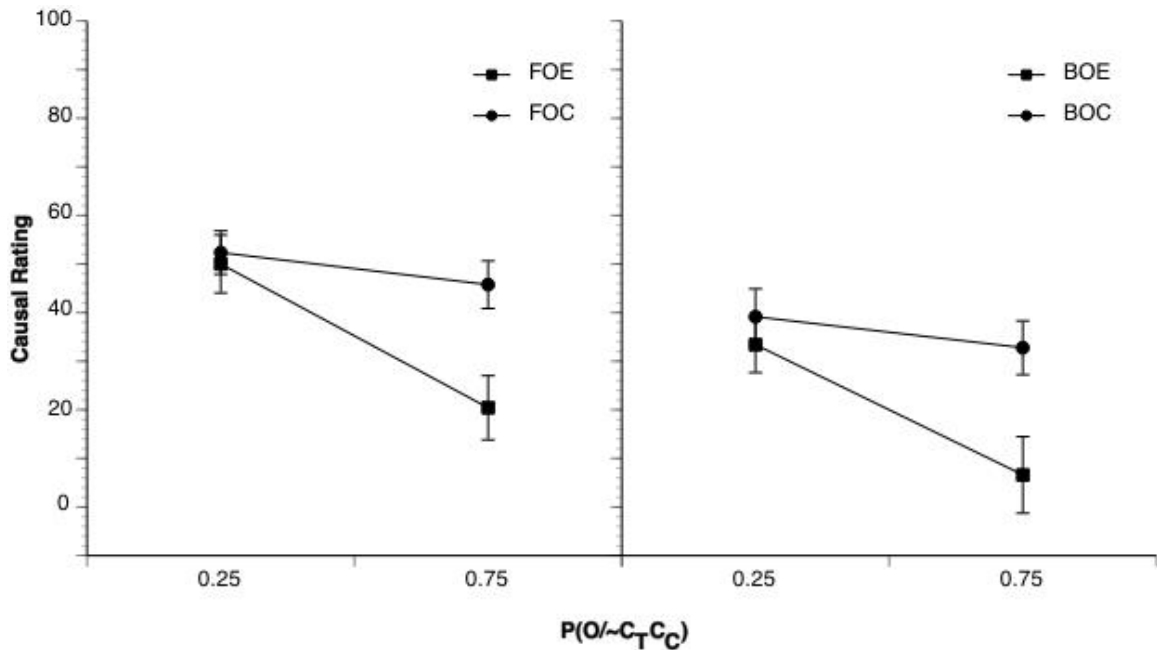


Figure 4. Younger adults' target cue causal ratings for the forward order and backward order conditions.

These results show that for the forward order, younger adults displayed the blocking effect most notably during the experimental condition in the .75 predictive strength condition. Their ratings for the target cue during the control treatment remained stable throughout both predictive strengths; however, their target cue ratings during the

experimental condition decreased as the predictive strengths increased. For the backward order, the target cues during the control treatment were rated above the experimental treatment throughout both predictive strengths. Additionally, the target cue ratings for the experimental condition once again decreased as the predictive strengths increased from .25 to .75. Therefore, younger adults displayed the retrospective revaluation effect.

Older Adults – Results

The older adults' forward order – blocking data and their backward order – retrospective revaluation data are shown in Figure 5. For the older adults, there was a main effect of order, $F(1, 26) = 5.817, p = .023, \eta_p^2 = .183$. Specifically, the causal ratings for the target cue were higher in the forward order condition than in the backward order condition. There was also a main effect of treatment, $F(1, 26) = 3.038, p = .093, \eta_p^2 = .105$, such that the causal ratings for the target cue were higher in the control condition than in the experimental condition. Finally, there was a main effect of strength, $F(1, 26) = 3.789, p = .062, \eta_p^2 = .127$, showing that the ratings for the target cue were higher in the .25 predictive strength condition than in the .75 predictive strength condition.

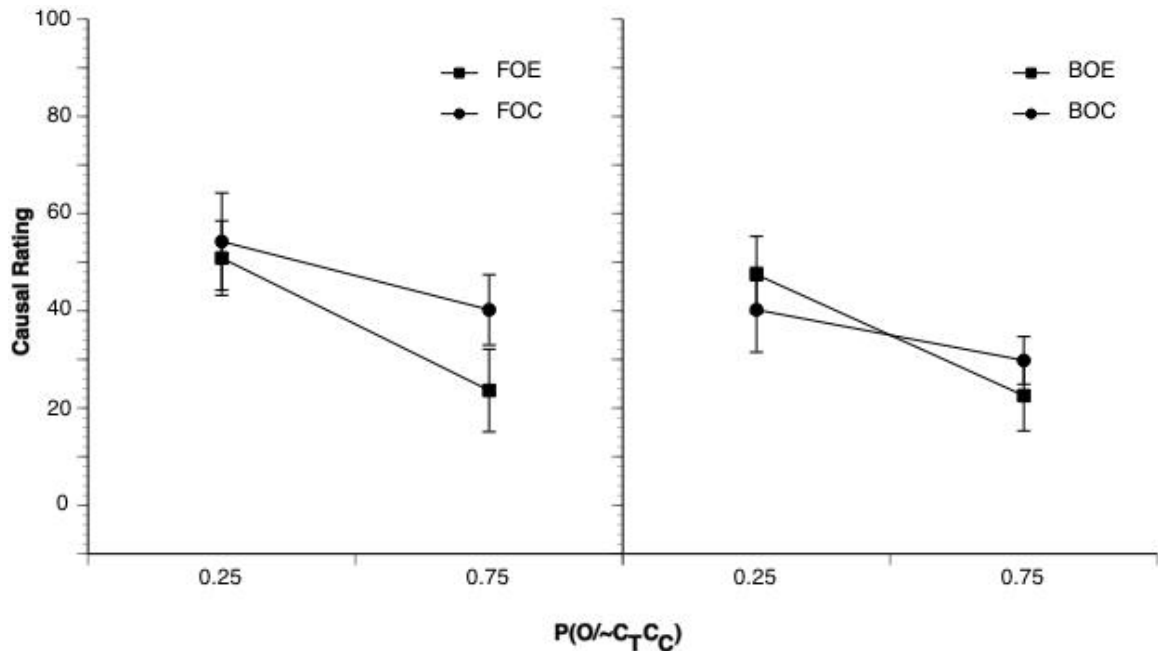


Figure 5. Older adults' target cue causal ratings for the forward order and backward order conditions.

There was also an order \times treatment interaction, $F(1, 26) = 3.151, p = .088, \eta_p^2 = .108$, such that the difference between causal ratings in the forward order experimental condition (i.e., the target cue gained more associative value) and the backward order experimental condition (i.e., the target cue gained less associative value) was larger than the difference between the causal ratings in the forward order control condition (i.e., the target cue gained more associative value) and the backward order control condition (i.e., the target cue gained less associative value). Specifically, the causal ratings for the target cue attained greater associative value in the forward order experimental condition compared to the backward order experimental condition and the causal ratings for the target cue attained greater associative value in the forward order control condition compared to the backward order control condition. The causal ratings for the target cue gained the highest associative value in the forward order control condition, but received the least amount of associative value in the backward order experimental treatment.

There was not an order X predictive strength interaction, $F(1, 26) = .268, p = .609, \eta_p^2 = .010$. However, there was a predictive strength X treatment interaction, $F(1, 26) = 5.509, p = .027, \eta_p^2 = .175$, showing that there was a greater difference in the ratings of the target cue for the control and the experimental treatment in the strong predictive strength condition compared to the difference in ratings for the control and the experimental treatment in the weak predictive strength condition. There was no three-way interaction between predictive strength, order, and treatment, $F(1, 26) = .027, p = .871, \eta_p^2 = .001$.

These results show that for the forward order, older adults displayed the blocking effect most notably during the experimental condition in the .75 predictive strength condition. Their ratings for the target cue decreased as the predictive strength increased for both the control and the experimental treatment conditions. However, at the strong predictive strength (i.e., .75), the target cue in the experimental treatment gained less associative value than in the control treatment.

For the backward order, the associative value of the target cue was slightly higher in the experimental treatment compared to the control treatment for the weak predictive strength condition. However, the reverse was shown at the strong predictive strength. Additionally, the target cue ratings for the control and the experimental conditions decreased as the predictive strength increased from .25 to .75, but the decrease was greater for the experimental treatment than the control condition. Overall, the associative value of the target cue was higher for the weak predictive strength condition when the companion cue and outcome were not presented together very much. Therefore, older adults displayed the retrospective revaluation effect.

Chapter 5: Discussion

The current study examined the effects of aging on associative learning and associative memory. Associative learning was assessed through a blocking effect, which requires associative learning (i.e., cue-outcome); whereas, associative memory was assessed through a retrospective revaluation effect, which requires associative learning (i.e., cue-outcome), associative binding (i.e., cue-cue), and associative retrieval (i.e., cue-?). Both effects were examined in a streamed-trial contingency task. It was predicted that younger and older adults would be able to use associative learning and therefore would not differ in their ability to show blocking effects. This prediction was supported. Both older and younger adults' predictions showed blocking effects. This finding is consistent with prior findings in the literature (Hannah et al., 2012; Holder & Mutter, 2014). It was predicted younger adults would be able to use associative memory and would therefore show a retrospective revaluation effect and that either: (1) older adults would not be able to use associative memory to retrospectively revalue causal cues (e.g., Mutter et al., 2012) or (2) older adults would display retrospective revaluation in the streamed trial task because this rapid causal learning task might allow associative retrieval from working memory instead of episodic memory. The results revealed that both younger and older adults did display retrospective revaluation effects. This finding is inconsistent with past literature (Mutter et al., 2012), which could be because this earlier study examined older adults' retrospective revaluation when associative retrieval from episodic memory was required.

Younger Adults – Associative Learning and Memory

For associative learning, it was expected that younger adults' ratings would demonstrate blocking effects. The results revealed that the associative value for the target cue was blocked by companion cues that were presented with the outcome to a greater extent (i.e., experimental treatment in the strong predictive strength). This decrease for the target cue during the experimental condition was expected because the companion cue was only presented with the outcome eight times with the .25 predictive strength condition compared to 24 times with the .75 predictive strength condition, which altered the causal ratings of the target cue. Regarding associative memory, it was predicted that younger adults would be able to retrospective revalue the target cues, which was supported in this study. Specifically, the associative value of the retrieved target cue was revalued up (i.e., weak predictive strength) or down (i.e., strong predictive strength) in Phase Two depending on the predictive value of the companion cue that was presented in that phase. Therefore, when the companion cue was a strong predictor, the associative strength of the absent, but retrieved target was revalued down; but, when the companion cue is a weak predictor, the absent, but retrieved target cue was revalued upward. The results also showed that the associative value for the target cue was higher in the control treatment compared to the experimental treatment. This finding was expected because in the control condition the companion cue did not remain the same, which allowed the target cue to gain more associative value than in the experimental treatment where the companion cue remained the same and competed for associative value. These results replicated Hannah et al. (2009). This successful replication demonstrated that the streamed trial was properly administered and conducted in this study, that the task is a

reliable and effective causal learning task, and that younger adults use associative learning and memory processes in this task.

Older Adults – Associative Learning and Memory

With regard to older adults, it was predicted that older adults would display associative learning. The results for older adults showed that the target cue's associative value was blocked when the companion cue was presented with the outcome more frequently (i.e., experimental treatment in the strong predictive strength). This finding is consistent with past literature showing that older adults display blocking effects (Hannah et al., 2012; Holder & Mutter, 2014). Blocking requires associative learning (cue – outcome learning) and the present finding confirms that older adults are capable of forming these simple associations (see Mutter & Plumlee, 2014). Additionally, this finding shows that older adults are also able to ignore the irrelevant cue that is presented along with the original predictive cue and outcome (Hannah et al., 2012; Holder & Mutter, 2014).

Along with examining age-related differences in the blocking effect, it was predicted that older adults would either (1) have a general associative deficit that prevented them from displaying a retrospective revaluation effect (e.g., Mutter et al., 2012) or (2) retrieve associations from working memory because the stimuli were presented so quickly in the streamed trial task, and were able to display a retrospective revaluation effect. The results supported the hypothesis that older adults show the retrospective revaluation effect when asked to retrieve associations from working memory.

The results of the older adults differed from the findings of the young adults in the current study and in Hannah et al. (2009). Specifically, the decrease in the experimental condition was greater than the decrease in the control condition, which led to a crossover interaction. Although, this finding differed from the younger adults, it still demonstrates retrospective revaluation because older adults assigned more associative value to the target cue (i.e., revalued upward) when the companion cue had not been presented with the outcome as often (i.e., weak predictive strength) in the earlier learning phase. To the author's knowledge, the ability of older adults to demonstrate retrospective revaluation through retrieving associations from working memory instead of episodic memory due to the quick presentation of the stimuli has not been found prior to this study. The results suggest that retrospective revaluation is possible in older adults when associative retrieval is from working memory, which could imply that there is not a general decrease in associative memory, but a more specific decrease in episodic associative memory.

Limitations and Future Research

One problem encountered in this study was that some older adults complained about the speed at which the stimuli were presented and one older adult asked to leave the study due to the presentation speed of the stimuli. However, the performance of the older adults who expressed difficulty with the speed was similar to that of older adults who did not complain. A second problem was that some responses were missed due to a random virus pop-up window and the tendency of a few older adults to accidentally click the mouse before placing the cursor on the rating scale. In both cases, it was not possible to determine the actual rating. However, only six data points (i.e., .32% of all data points) were excluded from the younger adult data due to the virus pop-up window and 12 data

points (i.e., .66% of all data points) were excluded from the older adult data due to either the virus pop-up window or from accidentally clicking prior to placing the cursor on the scrollbar. Dropping these few points did not compromise the conclusions of this study.

These results show that older adults can display retrospective revaluation effects in working memory, which has not been found before. Therefore, to continue to explore exactly what older adults are capable of, it is important for this study to be replicated. Additionally, it would be interesting to assess these findings with different stimuli. Although, the younger adults did not state that they were trying to use pre-existing knowledge to complete the task, many older adults did verbalize the use of prior knowledge to help decide what foods were associated with allergic reactions (e.g., “Tomatoes are acidic so I think they would cause an allergic reaction.”). The use of pre-existing information occurred even when participants were told to consider each patient differently and to observe what was actually being shown. These comments were noted and there was not an observed trend between participants who tried to use pre-existing information and those who did not. Replicating this study would be interesting to see if these results remain stable with different stimuli that do not have pre-existing connotations.

Summary and Conclusion

Young and older adults show the blocking effect in a streamed-trial task. This finding supports past research (Hannah et al. 2012; Holder & Mutter, 2014). Additionally, young and older adults show retrospective revaluation during the streamed-trial task. This finding is inconsistent with past research, which has shown that older adults do not display a retrospective revaluation effect when episodic associative memory is required

(Mutter et al., 2012). Previous findings and the results of this study are consistent with aging producing a decline in associative memory that is limited to episodic associative memory.

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Appendix

Companion Cue and Target Cue Stimuli:



Outcome Stimuli:

No Rash: No Outcome



Rash: Outcome

