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# Relationships in Aging, Cognitive Processes, and Contingency Learning

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# RELATIONSHIPS IN AGING, COGNITIVE PROCESSES, AND CONTINGENCY LEARNING

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This study investigated the influence of age, processing speed, working memory, and associative processes on the acquisition of contingency information. Young and older adults completed positive (+.65) and negative (-.65) contingency tasks that measured their ability to discover the relationship between a symptom (e.g., FEVER) and a fictional disease (e.g., OLYALGIA). Both *d'* scores, i.e., contingency learning, and contingency estimates, i.e., contingency judgment, were examined. Participants were also asked to complete cognitive tasks that measure the constructs of processing speed, working memory resources, associative memory, and associative learning.

Structural equation modeling was used to examine the direct and indirect relationships between processing speed, working memory resources, associative memory, associative learning, and positive and negative contingency learning and judgment for young and older adult groups. Young adults outperformed older adults on the cognitive tasks and on contingency learning and judgment tasks. However, age differences were smaller for the positive contingency than for negative contingency. A comparison of the structural equation models for young and older adults showed no relationship between any cognitive construct and negative contingency learning. However, young adults' judgment for the negative contingency was directly influenced by associative learning,

while their learning and judgment for the positive contingency was directly influenced by associative memory. For older adults, working memory executive function directly influenced their judgment for the negative contingency and their learning and judgment for the positive contingency. Processing speed had an indirect effect on older adults' contingency learning and judgment that was mediated by working memory executive functioning.

The differences in the young adults' models as well as the difference between the young and older adults' models for positive and negative contingencies suggest that while associative processing is important, it may not account for all of the variation in contingency learning and judgment. The young adults' models for the negative contingency task indicates that higher level processes, such as inductive reasoning, maybe involved in negative contingency judgment because the associative learning task required some level of hypothesis testing. In contrast, positive contingency learning and judgment could rely primarily on more basic associative processes. The present findings therefore suggest that an overall model of contingency learning must include both associative processes and inductive reasoning processes.

Older adults' general contingency performance was most directly related to their working memory executive functioning, suggesting that the decline in their working memory has the strongest effect on their ability to acquire and use information about contingencies. In fact, the age related decline in working memory seems to affect older adults' ability to acquire both positive and negative contingencies. The similarities across the older adult models for positive and negative contingencies indicate that the underlying deficit in older adults' working memory executive functioning that affects their overall contingency learning and judgment performance. This basic working memory executive functioning deficit for older adults also explains why their models for positive and negative contingency did not exhibit direct relationships between associative tasks and contingency learning as observed for the young adult models.

# CHAPTER 1

## Introduction

Over the years, two broad categories of models (rule-based and associative) have emerged to explain how people assess the contingency between events. Both types of models seek to explain how the relationships between one or more cues and an outcome are acquired and used. However, rule-based models focus primarily on how contingency information is integrated using various rules (i.e., mathematical comparison processes), whereas associative models focus primarily on how contingency information is acquired through the process of forming associations between events presented closely together in space and time (i.e., Pavlovian associations). There is a plethora of research providing evidence in support of both of these models of contingency learning. This study uses an associative model to explain the age differences that have been observed in contingency learning (Mutter & Pliske, 1996; Mutter & Williams, 2004; Parr & Mercier, 1998).

Many studies have provided suggestive evidence for associative processes in contingency learning. Shanks (1985, 1987) demonstrated that contingency learning produces learning curves postulated by the Rescorla-Wagner theory of associative learning (Lieberman, 2004). Shanks, Pearson, and Dickinson (1989) showed that contiguity between cues and outcomes in contingency learning is as important as contiguity between the conditioned and unconditioned stimuli in classical conditioning. Chapman and Robbins (1990) showed that multiple cues for an outcome compete for associative strength with the outcome. Finally, Lopez, Shanks, Almaraz and Fernandez

(1998) showed that the order of presentation of trials is very influential in the final perceived contingency, which is a basic assumption of associative learning theory.

In investigations of aging effects in contingency learning, it has consistently been found that older adults' learning performance is worse than younger adults' performance (Mutter & Pliske, 1996; Mutter & Williams, 2004; Parr & Mercier, 1998). Parr and Mercier found that introducing time constraints in a contingency learning task was related to decreased accuracy for both young and older participants, but more so for older adults. Mutter and Williams found that as the time between the presentation of the cue and outcome decreased and as the number of trials increased, older adults' contingency learning performance increased for positive contingencies, but not for negative contingencies. They also found that older adults' contingency learning performance was related to their performance on an associative learning task: the contingency estimate errors and errors on the conditional associative learning task were positively related. These studies suggest that there is a relationship between the age-related decrements in older adults' contingency learning and their associative learning ability.

Research has shown that aging produces a decline in associative learning. Levine, Stuss, and Milberg (1997) found that older adults' performance on a conditional associative learning task resembled the performance of participants with focal frontal brain lesions. These results suggest that the decline in older adults' associative learning may be related to decline in frontal lobe function, which is the brain area responsible for working memory. There has been extensive research looking into the mediators of age effects in associative learning. Salthouse (1996) investigated processing speed as a mediator of cognitive abilities and found that when processing speed was statistically controlled, age differences in various measures of cognitive ability were greatly reduced. Salthouse (1994) specifically investigated the effect of processing speed on associative learning abilities and found that age-related declines in associative learning were related to associative memory failure, which were in turn due to age-related declines in processing speed. Similarly, Salthouse (1995b) found that the age differences in associative learning are mediated through processing speed and associative memory, and Salthouse and Babcock (1991) found that age-related decrements in working memory ability are mediated through processing speed. Salthouse (1995a) put all of these mediators of the aging effect in working memory and associative learning relationships together and found that age-related decreases in processing speed were related to decreases in working memory executive functioning, which, in turn, were related to increases in errors in associative learning. These two variables - processing speed and working memory - directly or indirectly affect age differences in associative processes.

The current study attempted to integrate these findings of age differences in associative processes with evidence of age differences in contingency learning. Specifically, structural equation modeling was used to evaluate an associative model of aging and contingency learning for both positive and negative contingencies. In these models, the direct and indirect relationships between processing speed, working memory, associative processes, and contingency learning will be investigated using a multiple group analysis where the age differences in model fit were investigated. For both positive and negative contingency models, it was expected that the relationships between contingency learning, processing speed, working memory, and associative processes would be strong and dependent, especially for older adults.

# CHAPTER 2

## Literature Review

## *Contingency Learning*

### *Contingency Learning Basics*

Contingency learning is a basic function of human learning. Every day humans and animals use contingency information to guide behavior. The relationships between dark clouds in the sky and rain and the number of vaccines taken and disease occurrence are simple examples of contingency relationships. These examples illustrate positive and negative contingency relationships, respectively. The presence of dark clouds in the sky tends to predict rain. Here the presence of one event predicts the occurrence of another event; the two events have a positive relationship. On the other hand, the fewer vaccines a person receives, the greater the number of diseases that person might acquire. Here the absence of one event predicts the occurrence of another event; the two events have a negative relationship.

Researchers have set up contingency problems in many ways. War-based video games (Shanks, 1985), stock market evaluation (Chapman & Robins, 1990), and medical diagnosis (Chapman, 1991; López, Shanks, Almaraz & Fernández, 1998) are some examples of the problem contexts used in contingency learning tasks. Contingency information is always represented by the combination of events in a 2x2 contingency table consisting of four cells (A, B, C and D) that contain the frequency of occurrence of the four possible combinations of the events' states in the problem (Mutter & Pliske, 1996; Mutter & Williams, 2004). A typical contingency table for a causal relationship would be:

| | | OUTCOME | |
|---|---|---|---|
| | | PRESENT | ABSENT |
| CUE | PRESENT | A | B |
| | ABSENT | C | D |

*Figure 1.* 2x2 Contingency table.

All the information provided in contingency tables must be used to obtain an accurate picture of the relationship between the cue and the outcome. For positive contingencies, cells A and D confirm that the cue must be present for the outcome to occur, while cells B and C disconfirm that the cue must be present for the outcome to occur. For negative contingencies, cells B and C confirm that the cue must be absent for the outcome to occur, while cells A and D disconfirm that the cue must be absent for the outcome to occur. The contingency co-occurrence information is used to calculate two conditional probabilities. These probabilities are the probability of the outcome given the cue or $P(O|C)$, and the probability of the outcome given no cue or $P(O|\sim C)$. The $P(O|C)$ is calculated by dividing the number of times the cue and outcome occurred together (CELL A of the contingency table) by the total number of times that the cue was present (CELL A plus CELL B). The $P(O|\sim C)$ is calculated by dividing the number of times the outcome occurred without the cue (CELL C) by the total number of times that the cue was absent (CELL C plus CELL D). To calculate normative contingency or $\Delta P$ the

P(O|~C) is subtracted from P(O|C). The contingency information provided by the table cells is typically presented in two broad ways, these being serial presentation of events over trials or presentation of summary tables for probability matrices.

Assessment of contingency learning has been investigated within the framework of rule-based and associative models. Rule-based models assume that cell frequency information acquired during presentation is stored for later analysis and integration. Once all the information has been acquired, the information is integrated using some kind of operation, whether it be mathematical or simple comparison, to judge the contingency between the cue and outcome. For example, the Cell A and Sum of the Diagonals strategies are examples of rule-based strategies for making contingency judgments. These rules are derived from the contingency table used in constructing the contingency problem. When using the Cell A rule, one would only pay attention to the frequencies of information provided by Cell A where both the cue and outcome were present. This rule is the least effective way to utilize the contingency information provided by the cell frequency (Allan, 1993). When using the Sum of the Diagonals rule, the confirming cell frequencies are compared to the disconfirming cell frequencies. This rule is more effective than the Cell A rule and uses all of the contingency information, but still does not provide consistently accurate contingency judgments. Because rule-base models focus primarily on the judgment process, they are less effective in explaining factors that influence how contingency information is learned. For example, rule-base models of contingency cannot explain why the order of trials affects judgment accuracy. These models assume that trial order is irrelevant and that contingency information is typically presented in summary form (Chapman, 1991).

Associative models propose that contingency information is acquired over a series of trials through a process whereby the associative strength between the cues and outcomes increases or decreases each trial. The Rescorla-Wagner model is an example of an associative model that has been applied to contingency learning. All of these models incorporate a process of building associations between events as information is presented and have the basic premise that the predictive strength of a cue changes after each trial, making the order of trials and serial presentation of trials key factors in evaluating predictive strength for the cue (Chapman, 1991). This associative view of contingency learning is of primary interest in this study.

*Contingency Learning and Associative Processes*

In 1972, the Rescorla-Wagner theory of classical conditioning was proposed to explain, using an associative strength framework, several major factors in learning, including the occurrence of conditioning, the effect of contingency on conditioning, and cue blocking phenomenon (Lieberman, 2004). This theory has been applied to the contingency learning process. The Rescorla-Wagner theory explains how the typical learning curve is produced. At the start of learning there will be large changes in associative strength; the size of these changes level off or asymptote after the association has reached its maximum level. The mathematical formula for this model is $\Delta V_n = c(V_{max} - V_n)$, where $V_n$ denotes the strength of the association at the beginning of trial n, $\Delta V_n$ denotes the change in the strength of the association produced by trial n, $V_{max}$ denotes a constant that reflects the maximum level of association for the current stimuli, and c denotes a constant that reflects variations in the speed of learning in different situations. The variables of prime interest in this formula are $V_{max}$ and $V_n$, and the negatively accelerated learning curves they produce. Before learning has occurred, the difference between $V_{max}$ and $V_n$ will be large because the presentation of the outcome stimulus with the cue stimulus will be surprising or novel. The amount of surprise or novelty associated with the occurrence of the outcome stimulus determines how much or well the stimuli will be associated on each trial. As the stimuli develop associative strength, the difference between $V_{max}$ and $V_n$ grows smaller creating the asymptotic characteristic of the learning curve.

The Rescorla-Wagner theory provides a mathematical model that can be used to explain how associations between cues and an outcome develop across trials in contingency learning. Shanks (1985) applied the Rescorla-Wagner model in two experiments to the detection of response-outcome (R-O) contingencies in young adults. In his study, Shanks used a war game paradigm. Participants were instructed to evaluate the effectiveness of a new type of gun shell in tank destruction. When the participants fired the gun, the shells would sometimes explode the tanks or not explode the tanks that were passing across a computer screen. Four sets of 40 trials were administered, with contingency estimations requested after every five trials. A range of contingencies from -.60 to +.60 was used. It was found in both experiments that contingency development followed growth curves predicted by the Rescorla-Wagner model. That is, positive contingency estimations increased over trials toward the actual contingency, non-contingent problem estimates remained fairly stable around zero, and negative contingency estimations decreased over trials toward the actual contingency. These two experiments show that contingency learning develops over time (or trials) in a way that parallels what would be expected if such learning involved an associative process.

To bolster these findings, Shanks (1987) asked participants to learn the contingency between pressing a spacebar and a triangle flashing. A range of contingencies from -.75 to +.75 was used. In the first experiment, participants were asked to report their judgments of contingency after 10, 20, 30, 60, 90, 120,150, 180, 210, and 240 trials and in the second experiment the task ended after 120 trials. The request for estimations throughout the contingency acquisition phase enabled Shanks to measure how contingency learning developed over trials. It was observed in both experiments that the learning curves for positive contingency estimations increased over trials, non-contingent problem estimations remained somewhat steady at zero, and negative contingency estimations decreased over trials. These findings again suggest the involvement of associative processes in contingency learning. Both Shanks (1985) and Shanks (1987) demonstrated that as the trials presenting contingency information increase, the overall accuracy of contingency judgments increase.

Shanks, Pearson and Dickinson (1989) provided further evidence to support the associative nature of contingency learning. Using the same R-O task used by Shanks (1987), they looked at the effects of temporal contiguity on contingency learning. Basic associative theory predicts that if there is a long interval between the action and the outcome, the association between the action and the outcome will be weaker. Shanks et al. conducted three experiments that manipulated the time between the presentation of the stimulus and the flashing of the triangle. There were two conditions in their first experiment: one with no delay between the participants' spacebar press and the triangle flash and one with a two-second delay. The second experiment had four conditions: one with no delay, one with a four second delay, one with an eight second delay, and one with a 16 second delay. The third experiment was the same as the second, except they dropped the condition with the 16-second delay. In all three experiments, the participants' estimates of contingency became less accurate as the time between the cue and outcome presentations increased.

Another variable investigated in contingency learning from an associative standpoint is cue interaction (Chapman & Robbins, 1990). Cue interaction is typically studied using two learning phases. In the first phase, only one cue is a predictor of the outcome across a series of trials. In the second phase, two cues are presented in combination and this combination is a predictor of the outcome. During this phase the two cues compete for associative strength. The Rescorla-Wagner theory can be used to explain the interaction between two cues (Lieberman, 2004). The change in the mathematical formula used in the Rescorla-Wagner theory when more than one cue is present involves adding the associative strength of the cues together. This additive property does not allow for the second cue to develop associative strength across the trials because the first, previously associated, cue is always present.

In Chapman and Robbins' (1990) study, participants in two experiments judged the relationship between four fictional stock prices and a fictional stock market. Stocks were either non-predictors (increases in prices did not predict increases in the overall stock market) or they were predictors (increases in prices predicted increases in the overall stock market). Four stocks were presented to the participants in two phases. In the first phase, one stock was a predictor and one was a nonpredictor (or a predictor of no change in overall stock market value). In the second phase, the stocks in the first phase retained the same predictive value, while one of the added stocks was a predictor and the other was a nonpredictor. During both phases of the task, participants were asked to evaluate the individual predictive value of the stocks periodically. The results from the two experiments support the associative theory. The predictive cue and the nonpredictive cue were rated appropriately in the first phase, while the cues added in the second phase were rated as having approximately no relationship to the outcome. In the second phase, both cues that were predictive of overall stock increases were rated as predictors with the original cue being rated higher, and both cues that were not predictive were rated as non-predictors, but the original cues were not rated as highly as they were during the first phase, indicating that each set of cues competed for associative strength resulting in lowered ratings of their individual (non)predictive strength.

Lopez et al. (1998) investigated both the blocking effect and trial order effects in contingency learning. In the four experiments of this study, participants were asked to judge the relationship between symptoms a patient presented and the presence of a disease. Participants received two blocks of trials containing different contingencies presented consecutively to ensure that the blocks were indistinguishable. In these blocks, two symptoms, a target and a non-target, were presented together indicating that the combination predicted the occurrence of the disease. Interspersed throughout the compound symptom trials, individual trials of the non-target symptom were presented indicating it was either a slightly weaker predictor of disease occurrence than the combination (contingent block) or was a predictor of no disease occurrence (non-contingent block). Participants were presented with both contingent and non-contingent blocks in one of two conditions: receive the contingent block then the non-contingent block or receive the non-contingent block then the contingent block. However, the target symptoms in both conditions held the same actual predictive value, indicating that if there was any difference in participants' estimates, the trial order was the cause. Participants were then asked to judge the predictive value of the target symptom. In all four of the experiments trial order effects were exhibited. That is, when the non-contingent block was presented last, the contingencies between target symptoms and diseases were rated low, but when the contingent block was presented last, the contingencies were rated high.

From this research review, we have seen that contingency learning resembles what would be expected if it involved the acquisition of associative strength across a series of trials, the influence of contiguity between the cue/action and the outcome/response on learning the contingency, the competition for associative strength between multiple cues, and the effects of the final information received in the perception of the contingency. All of these findings support an associative learning model of contingency learning.

*Contingency Learning and Age*

There has not been much research looking at how aging influences associative processes in contingency learning. However, the research that has been conducted has shown that older adults consistently perform worse than younger adults on contingency judgment tasks (Mutter & Pliske, 1996; Mutter & Williams, 2004; Parr & Mercier, 1998). In one of the first experiments to look at older adults' contingency learning, Parr and Mercier (1998) compared young and older adults' positive contingency learning using a paradigm similar to Shanks' (1985) war game. Participants were instructed to discover the relationship between the safety of a tank when camouflage was present or absent. Parr and Mercier manipulated two variables known to affect basic associative learning to assess the effects on the two groups' contingency learning. Specifically, they manipulated the intertrial interval and the number of trials participants received. The rationale behind manipulating intertrial interval was that as the time between trial presentations decreases, less information would be processed and stored in memory, thereby decreasing the associative strength between cue and outcome and ultimately decreasing performance on contingency estimation. This phenomenon is called priming and occurs when stimuli, both cue and outcome, are activated in memory when the next presentation of the stimuli occurs. This activation during the current stimuli presentation typically results in no change in associative strength during the current presentation. Manipulating the number of trials a participant receives also affects participants' associative learning because as the number of trials increases, there is more opportunity to increase associative strength between the cue and the outcome.

In Parr and Mercier's (1998) first experiment, participants were given 8, 24, or 40 trials, intertrial intervals of either 100, 300, or 1,000 ms, and the true contingency values to be judged were either .27, .50, or .80. Participants were exposed to all combinations of number of trials, intertrial intervals and contingency values. Trial number manipulations allowed comparisons between older and young adults' abilities to acquire contingencies with the varied number of trials, and it was expected that as the number of trials decreased, the less accurate judgments would be, especially for older adults. The results of this experiment showed that both young and older adults could reliably discriminate contingencies with large numbers of trials and long intertrial intervals, but as the number of trials decreased and time between trials decreased, participants' accuracy in judgment decreased. Moreover, this deterioration in accuracy was worse for the older participants.

Also, older participants underestimated all contingencies, while younger participants tended to be accurate.

In their second experiment, Parr and Mercier (1998) investigated what effect maximizing priming would have on young and older adults' contingency judgments using problems with 8 or 24 trials, intertrial intervals of 50 or 200 ms and true contingency values of .13, .50, or .83. The manipulation of intertrial interval was used to maximize priming resulting in a reduction in accuracy for younger participants' judgments. These manipulations indeed resulted in reduced accuracy, but more so for older participants than for the younger participants. And again, older participants tended to underestimate all contingencies more than did younger participants. Parr and Mercier suggested that there might be some mechanism related to short term memory that contributed to older adults' tendency to underestimate contingencies. Older participants' abilities to fully acquire associations seemed to be limited by the ability to take in information (their perceptual speed) that resulted from manipulations of stimulus presentation (variations in intertrial intervals).

Mutter and Williams (2004) conducted a series of three experiments that specifically looked at the influence of aging on basic cognitive processes and how these were related to both positive and negative contingency learning. In all three experiments, data on participants' processing speed, working memory executive function, associative learning and response-outcome (R-O) contingency detection were collected. In the first two experiments, participants were instructed to discover the R-O contingency between a key press and the flashing of a triangle. In the third experiment, participants were instructed to learn how to make the triangle flash. In all three experiments, participants completed six contingency problems with values of -.80, -.40, .00, .00, .40, and .80. Serial presentation of the R-O contingency trials was used to allow associative strength of the action and outcome relationship to develop across trials. Mutter and Williams also manipulated the R-O interval between the action and outcome and the number of trials the participants received. Manipulating the R-O interval allowed Mutter and Williams to test the effects of contiguity (the closeness of presentation of the cue and outcome in time) on young and older participants' ability to detect the contingencies. As in Parr and Mercier's study, manipulating the number of trials the participants received allowed Mutter and Williams to compare young and older adults' abilities to acquire contingency information across situations where there were greater or fewer trials.

In their first experiment, Mutter and Williams (2004) specifically wanted to see if varying the R-O intervals (long or short) and number of learning trials (60 or 240) would have different effects on young and older adults' ability to acquire knowledge regarding the R-O contingency. Mutter and Williams found that older adults' overall contingency estimations were closer to zero than those of the younger adults, because older adults were generally less able to acquire the negative contingencies. When the trends of participants' estimates were assessed using linear trend analysis, the linear trend in the young adults' estimates was greater than that in the older adults' estimates. In the short interval, 60-trial learning condition, older adults estimated positive contingencies lower and negative contingencies closer to zero than did younger participants. Also, in this condition, older adults were unable to discriminate between the -.40 and .00 contingencies, while younger adults discriminated among all contingencies. In the short interval, 240-trial learning condition, there was no age difference between younger and older participants' estimates of positive contingencies, but older adults continued to give closer to zero estimates than did younger participants for the negative contingencies. When older adults had more learning trials, their contingency estimations did improve for the positive contingencies, but not for the negative contingencies. In the long interval, 60-trial learning condition, there were no age differences between younger and older adults contingency estimations across positive and negative contingencies, but neither older nor younger adults discriminated between the -.40, .00 and .40 contingencies. Thus, when the R-O interval was long, the absence of age differences could not be attributed to improvement of older adults' estimations, but rather to the deterioration of the younger adults' estimations.

In their second experiment, Mutter and Williams (2004) investigated the learning curves of younger and older adults. Participants were given the same six contingency problems, but only the short interval and 240 learning trials condition was used. Participants were asked to estimate contingency after 10, 20, 60, 90, 120,180 and 240 learning trials. Asking participants to estimate the contingency after each of these numbers of trials allowed Mutter and Williams to see how participants' estimations evolved over trial presentations. This, again, represents a manipulation of a basic associative learning variable; associative strength should build across presentations of action and outcome. Over trials, younger adults estimations increased for positive contingencies and decreased for negative contingencies as expected, but the older adults' learning curves did not follow this same pattern. Older adults' estimates increased over trials for the positive contingencies, but remained relatively constant at approximately zero for the negative contingencies. These results resemble those of the first experiment in that age differences in positive contingency estimation were smaller than those in negative contingency estimations.

Mutter and Williams' (2004) third experiment investigated the idea that older adults may have a harder time making overt numerical estimates of contingency. Therefore, instead of having the participants make contingency estimates, participants were simply instructed to learn how to make the triangle flash on the monitor, and their probabilities of responding were used as the determination of contingency acquisition. For positive contingencies, rates of responding should increase, because the action is required to produce the outcome, while in negative contingencies, rates of responding should decrease, because the absence of the action is required to produce the outcome. Younger participants' response probabilities increased from negative contingencies to positive contingencies, typically following the expected responding patterns. However, older adults' response probabilities did not follow this pattern. Between the -.80 and -.40 contingencies, their responding remained the same, responding increased between -.40 and .00, remained the same between .00 and .40, and increased between .40 and .80 contingencies. These results resemble the findings from the first two experiments demonstrating that older participants have more difficulty than younger participants acquiring contingency information, especially for the negative contingencies.

Finally, when Mutter and Williams (2004) investigated the relationships between contingency learning and the cognitive ability measures, they found that older adults' performance on the associative learning measure was related to their ability to acquire contingency information. That is, the more errors that were made on the associative learning measure, the less accurate older adults were on the contingency learning task.

None of the other cognitive ability measures were related to older adults' contingency learning performance suggesting that the reduction in older adults' associative learning ability inhibited their learning of contingencies.

In summary, Parr and Mercier's (1998) study shows that as the number of trials decreases, and the time between trial presentations decreases, older adults' contingency learning abilities decrease. Mutter and Williams' (2004) study shows that even in the best associative learning conditions with stimuli that have high contiguity and many learning trials, older adults do not acquire the same amount of contingency information that younger adults do, especially for negative contingencies. Their results also show that older adults' performance on contingency learning tasks is related to their associative learning abilities. Both of these studies found that older adults' contingency learning abilities are poorer with fewer learning trials. From the limited research on aging influences in contingency learning discussed here, it is clear that older adults have more difficulty than younger adults acquiring contingency information, especially for negative contingencies. This age difference could be due to decreases in older adults' associative learning abilities.

### *Mediators of Age Effects in Associative Learning*

There has been a long history of research showing that age has detrimental effects on associative learning (Salthouse, 1994; 1995a). More recently, Levine et al. (1997) investigated the idea that possible brain dysfunction in older adults leads to their deficits in associative learning abilities. In this study, three groups (young, older and focal frontal lesion adults) were assessed on their associative learning ability using the Conditional Associative Learning task. This task required participants to learn to associate pairs of symbols across a series of trials. Levine et al. examined three scores: the number of correct first responses (successful and retained responses), prior-response repetitions (discrimination failure), and incorrect-pairing repetitions (perseverations). The performance scores for the three groups were significantly different. Young participants exhibited more correct first responses and fewer errors in responding on the associative learning task than did either the older or lesion groups, and the performance of the older and lesion groups was similar. However, older participants made fewer errors overall than did the lesion participants. This study suggests that adults' associative learning abilities decrease with age in a fashion similar to the abilities of persons with focal frontal brain lesions.

Why do normal older adults' associative learning abilities resemble those of people with frontal lobe brain lesions? The frontal lobe of the brain is associated with working memory abilities. Since the older participants' associative learning in the Levine et al. (1997) study resembled that of the participants with damage to the brain area in control of working memory; working memory abilities may be a mediator of the age differences in associative learning. Age-related declines in both processing speed and working memory have been studied as mediators of the aging decline in associative learning performance. According to Salthouse (1996), processing speed is the major contributor to the age differences in cognitive abilities. Specifically, older adults' slower processing of information leads to their lower performance on a wide variety of cognitive tasks because less information can be processed and stored. There are two mechanisms to this theory: the limited time mechanism and the simultaneity mechanism. The limited time mechanism is based on the assumption that because of earlier processing still being done, later processing is limited; this is considered to be more of an external time limitation. For example, this mechanism may play a role in tasks where time is restricted. The simultaneity mechanism is based on the assumption that earlier processing will have been lost after completion of later processing. For example, this mechanism may play a role in tasks that require information to be remembered for a period of time while other tasks are being completed. Salthouse reported on the findings of thirteen studies that demonstrated that if processing speed was statistically controlled, then age differences in various measures of cognitive ability are greatly attenuated.

Salthouse (1994) also investigated the specific influence of processing speed on associative learning abilities. In two studies, measures of processing speed, associative learning, and associative memory were administered to younger and older adults. The associative learning task, similar to Levine et al. (1997), required participants to learn pairs of symbols across a series of trials (Conditional Associative Learning task). For the associative memory task, participants learned associations between pairs of letters and digits. Interspersed in the presentations were queries regarding previous letters and digits requiring participants to remember whether the presented items had been paired previously. The processing speed measures included six measures of both basic motor speed and cognitive speed. These tasks included box completion, pattern comparison, letter comparison, digit copying, and the WAIS-III Digit Symbol Substitution task (Wechsler, 1997).

In the first study (Salthouse, 1994), the overall relationship between age, processing speed, associative memory, and associative learning was tested using path analysis. This analysis indicated that as age increased, processing speed decreased, which in turn was related to decreases in associative memory performance, which in turn was related to higher frequencies of forgotten correct responses on the associative learning task. The decrease in processing speed was also directly related to decreases in overall correct responses on the associative learning task, although this relationship was not strong. The results from this analysis suggested that age and processing speed do not directly affect associative learning, but do so indirectly. The second study replicated the findings from the first study. The overall findings of these studies suggested that the influence of age on associative learning is due to age-related failure in associative memory that is in turn due to age-related reductions in information processing.

Salthouse (1995b) further investigated the influence of age and processing speed on associative memory. Participants in this study were administered measures of processing speed and associative learning. The measures of processing speed used in this study were the same and the associative memory task used in this study was similar to the one used in Salthouse (1994). In this task, participants were required to learn word-digit pairs across a series of trials where query trials were interspersed throughout learning trial presentations. These queries questioned participants about previous word-digit pairs requiring them to remember if the query pair had previously been presented. The results from a hierarchical regression analysis suggested that decreases in processing speed associated with increased age contributed to age-related decrements in associative memory abilities.

Salthouse and Babcock (1991) investigated the relationships between aging, processing speed and working memory using tasks similar to those previously discussed (Salthouse, 1994; 1995b) and found that increased age leads to lower performance on measures of working memory, but that this age difference is mediated by processing speed. Salthouse (1995a) then investigated the relationships between all of these variables and associative learning. In his first study, participants were administered processing speed measures (pattern comparison and letter comparison tasks) and an associative learning measure (Conditional Associative Learning). Processing speed was a mediator in the relationship between age and associative learning. That is, as age increased, processing speed decreased, and this decrease in processing speed was related to decreases in associative learning ability.

The second study was more elaborate than the first study (Salthouse, 1995a). Four more tasks were administered to participants. Two additional processing speed measures [i.e., Digit-Digit and Digit-Symbol Substitution], and two measures of working memory executive functioning (storage and manipulation of information) [i.e., Reading and Computation Span] were administered. The results of a path analysis suggested that increases in age were related to decreases in processing speed and that decreases in speed were related to decreases in working memory executive function, which, in turn, were related to increases in errors in associative learning. Specifically, the decreases in working memory executive function ability were related to increases in proportion of correct responses that were forgotten in the associative learning task. Thus, based on these studies, it appears that the relationship between age and associative learning is mediated by processing speed, working memory, and associative memory.

*Current Study*

The current study attempted to integrate findings of age differences in contingency learning and associative processes into an associative model of aging and contingency learning. Contingency learning has been shown to require associative learning mechanisms (Chapman & Robbins, 1990; Lopez et al., 1998; Shanks, 1985, 1987; Shanks et al., 1989), and older adults have been shown to perform worse than younger adults on contingency learning tasks (Mutter & Williams, 2004; Parr & Mercier, 1998). Age-related decrements in processing speed, working memory, and associative processes (Salthouse, 1994, 1995a, 1995b, 1996; Salthouse & Babcock, 1991) may be related to the decreased contingency learning of older adults, and this decrement could be due to decreased associative learning abilities that have been shown in older adults in comparison to young adults (Levine et al., 1997). The relationships between aging, processing speed, working memory and associative processes have been demonstrated (Salthouse & Babcock), as have the relationships between associative processes and contingency learning (Chapman & Robbins; Lopez et al.; Shanks; Shanks et al.). The goal of this study was to integrate the aging, processing speed, working memory, associative processes, and contingency learning relationships.

Structural equation modeling using a multiple group analysis was used to simultaneously analyze the relationships between processing speed, working memory, associative processes and contingency learning constructs while investigating the age differences in these relationships. Both positive and negative contingencies were examined to see if the same model fits both kinds of learning tasks. Figure 2 depicts the proposed structural equation model for this study.

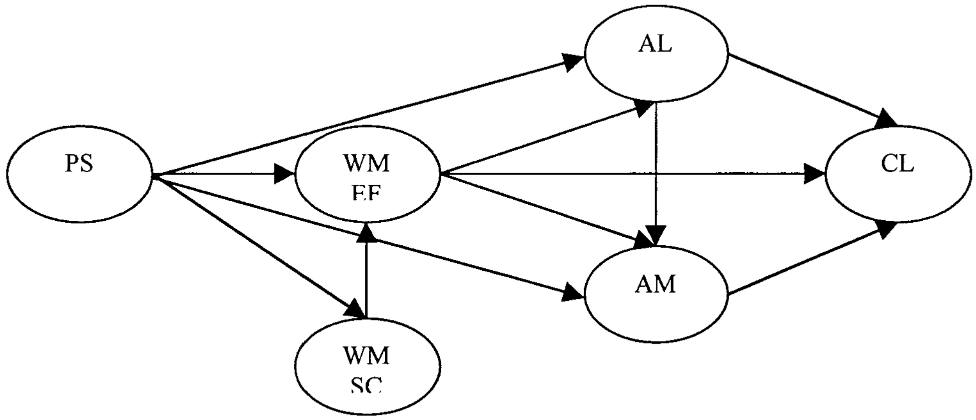



*Figure 2.* Proposed structural equation model.

In this model, the latent constructs are processing speed (PS), memory storage capacity (WMSC), working memory executive function (WMEF), associative memory (AM), associative learning (AL), and contingency learning (CL), and the relationships demonstrated in the previously discussed literature are illustrated together. The hypothesis of this study was that increased age would be related to decreased processing speed abilities, which in turn would be related to decreased working memory and associative process abilities, and that these decreases in working memory and associative process abilities would be related to decreased contingency learning abilities. More specifically, processing speed was expected to have a direct influence on both working memory and associative processes. Working memory has been divided into working memory storage capacity and working memory executive functioning, and associative processes have been divided into associative memory and associative learning to investigate the relationships within the overall constructs. Direct relationships between the working memory constructs and the associative processes constructs were also predicted. That is, a direct relationship from working memory storage capacity to working memory executive functioning was expected because working memory executive functioning incorporates both how much information is stored and also manipulation of that information. Also, a direct relationship from associative learning to associative memory was expected because one must be able to learn associations to remember them; they are dependent. I also expected that working memory executive functioning would have a direct relationship to both associative processes. And finally, I expected that working memory executive functioning, associative memory and associative learning would have direct relationships to contingency learning.

When the model is analyzed for positive and negative contingencies, model fit was predicted to be the same for both contingency types. When the model was analyzed for age differences, older adults' contingency learning performance was expected to be more dependent on their processing speed, working memory, and associative processing abilities than younger adults' contingency learning performance. By investigating the aging effects on processing speed, working memory, associative processes and contingency learning, I hoped to develop a model of contingency learning that incorporates these cognitive abilities into one model.

# CHAPTER 3

## Method

### *Participants*

The data that will be used for this study are part of a large archival data set that has been collected over the past four years at a university in the south. This data set contains a variety of cognitive measures for young and older adults. The young adults were recruited by flyers around the university campus and from lower level psychology courses. The older adults were all from the surrounding community and were recruited through direct mailouts to homes, flyers around the community, and presentations for a variety of senior groups. Volunteers in both groups were screened for physical problems, such as vision inabilities and motor skill deficits, and cognitive deficits, such as impairment from strokes, head injuries, neurological diseases, and drugs known to affect cognitive functioning that would impair their ability to participate in the research. In addition, older participants were administered the Mini Mental State Exam (MMSE), a measure used to screen for dementia, in a telephone screening prior to arrival at the testing site. This screening consisted of 21 questions (e.g., "What is the date today?" and "Begin with 100 and count backward by seven.") that participants had to successfully answer to be eligible to participate in the study. Finally, all participants had to speak English as their native language, and older adults had to have a minimum eighth-grade education. Participants were compensated for their participation with course credit and/or $5 cash (young participants) or $50 cash (older participants). Biographical information was collected from participants prior to testing via a biographical questionnaire. This information included age, race, gender, marital status, and education level.

To be selected, participants had to have completed all cognitive measures for the study. Seventeen participants, 12 younger adults and five older adults were eliminated because of failure to complete all measures required for this study. The remaining 379 participants consisted of 170 older adults, with ages ranging from 60 to 91 and a mean age of 70.00 ($SD$ = 7.07), and 209 young adults, with ages ranging 18 to 29 years and a mean age of 19.68 ($SD$ = 2.07). Of the 170 older participants, 67.6 percent were female, 90.6 percent were European American, 6.5 percent were African American and 2.9 percent did not indicate their race. Of the 209 young participants, 75.6 percent were female, 89 percent were European American, and 8.6 percent were African American. The mean years of education were 13.20 ($SD$ = 1.41) for young participants and 14.34 ($SD$ = 3.17) for older participants.

*Materials and Instrumentation*

*Contingency Learning Criterion Task*

To investigate associative processes in contingency learning, a serial contingency learning task was used. Two sets of contingency problems with medical diagnosis scenarios were constructed for this task. Each set contained a zero (+/- .05), a moderate positive (+.62 or +.65), and a moderate negative (-.62 or -.65) contingency problem. To construct the contingencies for these problems, 24 trials were divided among the four cells of a 2x2 contingency table so that the overall contingency equaled the desired value (see Appendix A). The overall contingency was calculated from this table using the formula $\Delta P = P(\text{Disease}|\text{Symptom}) - P(\text{Disease}|{\sim}\text{Symptom})$. The positive and negative contingencies were constructed by switching the cell frequencies in these tables. Specifically, the frequencies for disease/symptom and disease/no symptom cells that were used to create the positive contingency were switched with the frequencies for no disease/symptom and no disease/no symptom cells to create the negative contingency.

Three different symptom-disease pairs were used in the contingency problems: fever-olyalgia, rash-paviria, and headache-curviosis and each symptom-disease pair was tested in a positive and a negative contingency. In Set 1, the fever-olyalgia pairing was used for the +.65 problem, rash-paviria for the -.62, and headache-curviosis for the +.05. In Set 2, the fever-olyalgia pairing was used for the -.65 problem, rash-paviria for the +.62, and headache-curviosis for the -.05. To avoid presenting two problems using the same four cell frequencies, if a participant received a +.62 contingency for one problem, he/she received a -.65 contingency for the other problem. To control for presentation order effects, participants were divided equally among six possible presentation orders for each set (see Appendix A for contingency set and order set up). These six presentation orders enabled the researchers to test each contingency value in every presentation position, as well as counteract any ordering effects that could be caused by presenting one contingency value before another value.

The contingency learning task consisted of a practice problem followed by three criterion problems. For each problem, participants were asked to imagine themselves as physicians learning to diagnose the presence or absence of fictional diseases given symptom information from patients' charts. For example, if a patient presented with the symptom "fever," a doctor might diagnose that patient with "olyalgia." The participants were shown a series of patient charts telling them whether or not the patient had the symptom and were asked to predict whether or not the disease was present. They saw 10 patient charts during the practice problem and 24 patient charts during each of the criterion problems. After participants made their prediction, they were given feedback on whether the disease was present or absent. After receiving the feedback, the next patient chart was presented until all charts for the specific contingency problem had been viewed.

After viewing all the patient charts for a specific problem, participants were given detailed descriptions of the scales used for the estimation of contingencies and conditional probabilities and asked to make these estimations for the problem. The overall contingency estimation scale ranged from –100 to +100, where –100 indicated that the absence of the symptom was a perfect indicator that the disease would be present, 0 indicated that there was no relationship between the disease and the symptom, and +100 indicated that the presence of the symptom was a perfect indicator that the disease would be present. The conditional probability scales ranged from 0% to 100%, where 0% indicated that the patient definitely will not have the disease, 50% indicated that the patient is as likely to have the disease as not, and 100% indicated that the patient would definitely have the disease. Participants were then asked to estimate the base rates of occurrence of symptom, no symptom, disease and no disease, and the contingency table cell frequencies (see Appendix B for an example of the instructions and answer booklets).

Two measures of positive and negative contingency judgment performance were used for this study. One was the participants' overall contingency estimations for these problems and the other, *d'*, was derived from the predictions made during the trial presentations. The *d'* measure, based on Signal Detection Theory, derives a measure of the ability to detect when a target/outcome will or will not be present (Perales, Catena, Shanks & Gonzalez, 2005). The first step in calculating this measure of detection is to categorize the predictions made during trial presentations as hits, false alarms, misses, or correct rejections. Figure 3 illustrates how predictions are categorized.

| | | Outcome | |
|---|---|---|---|
| | | Present | Absent |
| Response Prediction | Present | Hit | False Alarm |
| | Absent | Miss | Correct Rejection |

*Figure 3.* Prediction categorization.

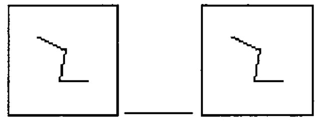
After categorizing the predictions, the second step in calculating *d'* is to calculate the proportions of hits (*h*) and false alarms (*f*), where *h* is calculated by dividing the number of hits by the sum of hits and misses, and *f* is calculated by dividing the number of false alarms by the sum of false alarms and correct rejections. These proportions are then standardized and the inverse of the standard scores are calculated to create z(*h*) and z(*f*). Finally, z(*f*) is subtracted from z(*h*) to obtain *d'*. The higher the value of *d'* the better the ability to determine participants ability to distinguish between outcome present and outcome absent cues.

*Cognitive Measures*

Processing speed, working memory, and associative processes constructs will be used to predict contingency learning performance. The tasks used to measure each of these constructs are described in the following paragraphs.

*Processing Speed.* Speed of processing was measured using the WAIS-III Digit Symbol Substitution task (Wechsler, 1997) and the Pattern Comparison and Letter Comparison tasks (Salthouse & Babcock, 1991). In the Digit Symbol Substitution task participants were presented with nine digit/symbol pairs and had to transfer the correct symbols to empty squares beneath a series of digits. The goal in this task was to accurately transfer as many symbols as possible within a two-minute time limit. The score was the number of correct transfers; the more correct transfers, the faster the processing speed. The test/retest reliability of this measure has been reported as .95 (Salthouse, 1994).

In the Pattern Comparison task (Salthouse & Babcock, 1991) participants compared two line segment patterns to determine if they were the same (identical) or different. There were three sections in this task. The first section was comprised of patterns containing three-line segments, the second of patterns containing six-line segments, and the third of patterns containing nine-line segments. The line segments included both closed and open patterns. Participants were presented with each section separately. They compared each pair of patterns then wrote an "S" on the line between them to indicate "same" or a "D" to indicate "different." An example of a three-line segment comparison is shown below:



Because the two-line segment patterns are the same, an "S" should be written on the line between them to indicate that they are identical. As the number of line segments increased, the task became more difficult. Participants were given 30 seconds for each section. Scores for participants were obtained by counting the number of correct comparisons; the more correct comparisons, the faster the speed of processing. Test/retest reliability for this measure has been reported as .77 (Salthouse, 1996).

In the Letter Comparison task (Salthouse & Babcock, 1991) participants were shown a series of two sets of letters and were required to determine if the letters were the same (identical) or different. This task was similar in structure to the Pattern Comparison task. Again, there were three sections in this task. The first section comprised sets containing three letters, the second comprised sets containing six letters, and the third comprised sets containing nine letters. Participants were presented each section separately. They compared each pair of letters then wrote an "S" on the line between them to indicate "same" or a "D" to indicate "different." An example of the three-letter comparison is shown below:

ABC _____ ABC

Because the two sets of letters are the same, an "S" should be written on the line between them to indicate that they are identical. Again, as the number of letters increased, the task became more difficult. Participants were given 30 seconds for each section. Scores for participants were obtained by counting the number of correct comparisons; the more correct comparisons, the faster the processing speed. Test/retest reliability for this task has been reported as .62 (Salthouse, 1994).

*Working Memory.* Measures of both working memory storage capacity and executive function will be included in this study. Working memory storage capacity was measured using the Forward Digit Span (Salthouse & Babcock, 1991; Wechsler, 1997), Backward Digit Span (Wechsler), and Word Span (Salthouse & Babcock) tasks. In the Forward Digit Span task, participants silently read a series of digits presented on the computer screen and then recalled them in the order of presentation. There were nine levels of difficulty in this task and each level consisted of three trials. The first level consisted of trials with two digits. An additional digit was added to the trials on each successive level, which increased the difficulty of each level. The participant was required to successfully recall the digits on at least one trial to move to the next level. Participants received the score of the highest level for which they correctly recalled at least two of the trials; the higher the level, the greater the storage capacity. Odd/even reliability for this task has been reported as .89 (Salthouse & Babcock). The Word Span task is identical to the Forward Digit Span task except that series of words are presented instead of numbers. The odd/even reliability for the Word Span task has been reported as .84 (Salthouse & Babcock).

In the Backward Digit Span task (Wechsler, 1997), the experimenter read a series of digits to participants and they had to recall the digits in reverse order. Each level had two trials and the difficulty increased with each level. The first level contained trials with two digits, with an additional digit being added to the trials on each successive level. The participants had to successfully recall one trial in a level to move to the next level.

Participants were given one point for every successful trial; the higher the total number of points, the larger the storage capacity. The split half reliability for this task has been reported as .87 for younger adults and .84 for older adults (Wechsler).

Working memory executive function was measured using the Reading Span and Computation Span tasks (Salthouse & Babcock, 1991). In the Reading Span task, participants were required to read out loud a sentence that was presented on the computer screen, answer a question related to the sentence using a keyboard response, and remember the final word of the sentence. The level of difficulty increased in this task. The first level contained three trials, each with one sentence and question. One sentence and question was added to each trial in the successive levels to increase the difficulty of the task. Once the sentence or series of sentences had been presented and the questions were answered, participants had to recall the final words of the sentences in the order of presentation. To move to the next level, participants were required to correctly answer all of the questions and accurately recall the final words for at least one trial in the level. Participants were given the score for the highest level in which they successfully completed at least two trials; the higher the level, the better the executive function. Odd/even reliability for this task has been reported as .86 (Salthouse & Babcock). The Computation Span task is similar to the Reading Span task except that instead of using sentences and their final words, simple arithmetic problems and their final numbers were used. Odd/even reliability for this task has been reported as .90 (Salthouse & Babcock).

*Associative Processes.* Measures of both associative learning and associative memory will be included in this study. The Conditional Associative Learning task (Levine et al., 1997; Salthouse, 1994) was used to measure associative learning. In this task, participants attempted to learn pre-established pairings of four symbols with four patterns. The four symbols were presented randomly within 10 blocks of four trials. In each trial one symbol and the four patterns were presented and participants had to choose the pattern that went with the symbol until the correct response was chosen. If the participant successfully remembered all the pairings in two consecutive blocks the task was ended; otherwise, all 40 trials were administered. The participants' first choice for each trial was scored as a successful response, a retained response, a forgotten response, a discrimination failure, a perseveration, or an unsuccessful guess.

Successful responses occurred when the correct pattern was chosen first either without prior exposure to the correct pairing for the symbol or after an incorrect choice on the immediately preceding presentation of the same symbol. Retained responses occurred when the correct pattern was chosen for a symbol, and the previous trial for the same symbol was either a successful response or a retained response. Forgotten responses occurred when the first pattern chosen for a symbol was incorrect, and the pattern chosen in previous trial for the symbol was correct (a successful response or a retained response). Discrimination failures occurred when an incorrect pattern was chosen for a symbol, although this pattern was correctly paired with a different symbol since the previous presentation of the current symbol. Perseverations occurred when the same incorrect pattern was chosen for a symbol on the current trial and on the previous trial for that symbol, and the chosen pattern has not been correctly paired with another symbol between the two trials. Unsuccessful guesses occurred when an incorrect pattern was chosen, when either there has been no previous exposure to the pairing, or when the chosen pattern cannot be categorized as a forgotten response, discrimination failure or a perseveration. A greater number of retained responses indicated greater associative learning ability. A greater number of forgotten responses indicated a loss of confirming information for the stimulus symbol. A greater number of discrimination failures indicated a loss of confirming information for another stimulus symbol. A greater number of perseverations indicated a loss of disconfirming information for the stimulus symbol. Scores from the Conditional Associative Learning task were used to derive three measures of associative learning: proportion forgotten response, proportion discrimination failure, and proportion perseveration (all measures of error). Proportion forgotten was calculated by dividing the raw forgotten score by the total number of forgotten responses and retained responses. Proportion discrimination failure was calculated by dividing the raw discrimination failure score by the total number of incorrect responses (forgotten responses, discrimination failures, perseverations, and unsuccessful guesses). Proportion perseveration was calculated by dividing the raw perseveration score by the total number of incorrect responses. These are the only measures that could be used because they are the only independent scores/measures. For example, proportion correct response (derived from all of the scores in the task) is dependent on the number of errors made during the course of the task.

The WAIS-III Digit Symbol Incidental Learning (Wechsler, 1997) and WMS-III Verbal Paired Associates (Wechsler) were used to measure associative memory. The Digit Symbol Incidental Learning task consisted of recalling the symbols that were paired with the numbers in the earlier WAIS-III Digit Symbol Substitution task. The Incidental Learning task was administered as soon as the Substitution task was completed. Participants were given two lines of numbers and asked to fill in the corresponding symbols and then asked to recall all the symbols that were used in the task. The number of correct digit-symbol pairings and correct symbols were added together for a total correct score; the higher the number of correct recollections, the better associative memory.

In the Paired Associates task, participants read aloud a list of paired words presented on the computer screen. After this presentation, the first word of each of the word pairs was presented as a cue and the participant was instructed to recall the word paired with it. Two lists of word pairs were administered. The pairs in the first list were associated (i.e., pepper – sneeze, town - meeting). The same words were used in the second list but they were paired differently (i.e., pepper – meeting, whiskey – sneeze). Each list of word pairs had five study-test trials. After all of the study-test trials, participants were instructed to recall both of the response words paired with each cue word listed on a piece of paper (Modified Modified Free Recall or MMFR). Participants' performance during the study-test phase was scored by tallying the number of correct responses per trial and the total correct per list, the total perseverations per list (giving same incorrect response on two consecutive trials), and the total intrusions for the second list (giving a response word for the cue from the first list pairings). Participants' performance during the MMFR was scored by tallying the total correct recollections of word pairs and the total perseverations from the last study-test trial of the second list. The greater the number of correct responses, the better associative memory ability was assumed to be. Two scores were used from the Paired Associate task in this study. These scores were the number of correct response words recalled during the first two test trials from the second list of word pairs, because these scores showed the most variance between participants.

### *Procedure*

Participants were tested individually in two sessions that were no more than two weeks apart. These sessions lasted between two and three hours, depending on how quickly the participant completed the tasks. A seven-minute break was offered halfway through each session. All tests were conducted in a small, quiet room in a building at a university in the south. The majority of the tasks were presented in paper and pencil format, and the rest were presented using a Macintosh Power Mac G4 computer. All participants were tested using the same task procedures described in the previous sections of this chapter. On completion of all tasks, participants were debriefed as to the nature of the research. Table 1 depicts the order of administration for the tasks used in this study.

Table 1

*Study Protocol*

| Session | Study protocol |
|---|---|
| 1 | Informed consent |
| | Biographical Questionnaire |
| | Overview of study |
| | WAIS III Digit Symbol Coding |
| | WAIS III Digit Symbol Incidental Learning |
| | Reading Span |
| | Pattern Comparison |
| | WAIS Backward Digit Span |
| | Conditional Associative Learning |
| 2 | Contingency Learning |
| | Word Span |
| | Letter Comparison |
| | Computation Span |
| | Paired Associate Learning |
| | Digit Span |
| | Debriefing |

*Note*: Each session lasted between two and three hours.

# CHAPTER 4

## Results

### *Preliminary Analyses*

The data set for these analyses was first examined for missing data points. In the young adult participant sample there was one in the forward digit span task, two each in the word span task, computation span task, the conditional associative learning proportion forgotten, proportion perseveration and proportion discrimination failure measures, and four each in the reading span task and positive *d'* criterion measure. Each of these was replaced with the mean of the variable for the young group. In the older adult participant sample there was one each in the forward digit span and backward digit span tasks and two in the reading span task. Each of these was replaced with the mean of the variables for the older group.

After the missing data were replaced, the data set was analyzed for univariate and multivariate outliers. All variables within each group were converted to *z* scores. If a participant's score for a particular variable was $z < = - 3.30$ or $z > = 3.30$, it was considered to be an outlier and was replaced with the next highest or lowest value of that variable for the participants' age group. Univariate outliers in the young adult sample included one each in WAIS-III Digit Symbol Incidental Learning, Conditional Associative Learning proportion forgotten and positive *d'* criterion measure, two in pattern comparison, and three in reading span. Univariate outliers in the older adult sample included one each in reading span and Conditional Associative Learning proportion discrimination failure, and two each in word span, positive contingency estimation criterion and positive *d'* criterion measure. There were no multivariate outliers in the data set.

After the outlier analyses, the data sets were analyzed for departures from normality. Seven of the eighteen variables in the data set required transformation due to either positive or negative skew in the distribution. The transformations for the following variables were chosen because they were the most common forms of transformations for the type of variable and skew present in the distribution (Tabachnich & Fidell, 2001). The word span task was transformed using a square root transformation. The positive contingency estimation measure was transformed using a square transformation. The Conditional Associative Learning proportion forgotten and proportion perseveration measures were transformed using the arcsin transformation. The WAIS-III Digit Symbol Incidental Learning, computation span, and positive *d'* measures were reflected (inversed), transformed using the square root transformation, and then reflected again to ensure that the direction of effects in results for the transformed variables would be the consistent with the original variables.

### *Criterion Measure Analyses*

Two 2 (young versus old) x 2 (negative contingency versus positive contingency) repeated measures ANOVAs were conducted for the *d'* scores and contingency estimates. Contingency estimations and *d'* were analyzed separately because they measure contingency in different ways. The *d'* scores measure prediction accuracy for the outcome event during online contingency learning. Contingency estimates measure the ability to integrate the contingency information acquired during learning into an overall numerical judgment. Young and older adults' mean *d'* scores for positive and negative contingency are illustrated in Figure 4. There was a main effect of contingency, $F(1, 377) = 1081.71$, $MSE = .39$, $p < .00$, $\eta^2 = .74$, indicating that prediction accuracy was higher for the positive contingency ($M = 1.73$, $SD = .22$) than prediction accuracy for the negative contingency ($M = .25$, $SD = .90$). There was also a main effect of age group, $F(1, 377) = 51.53$, $MSE = .40$, $p < .00$, $\eta^2 = .12$, indicating that the young adults' prediction performance ($M = 1.14$, $SD = .03$) was higher than that of the older adults' ($M = .81$, $SD = .03$). However, these effects were qualified by an interaction between age group and contingency, $F(1, 377) = 16.53$, $p < .00$, $\eta^2 = .04$. Analyses of the effect of age group within each contingency indicated that young adults' prediction accuracy for negative contingency ($M = .48$, $SD = .86$) was higher than that of the older adults ($M = -.03$, $SD = .86$), $F(1, 377) = 33.62$, $MSE = .74$, $p < .01$, $\eta^2 = .08$. Young adults' prediction accuracy for positive contingency ($M = 1.80$, $SD = .21$) was also higher than that of the older adults ($M = 1.65$, $SD = .21$), $F(1, 377) = 43.06$, MSE = .05, $p < .01$, $\eta^2 = .10$. However, the difference in the two groups' means was smaller for the positive contingency than that for the negative contingency.

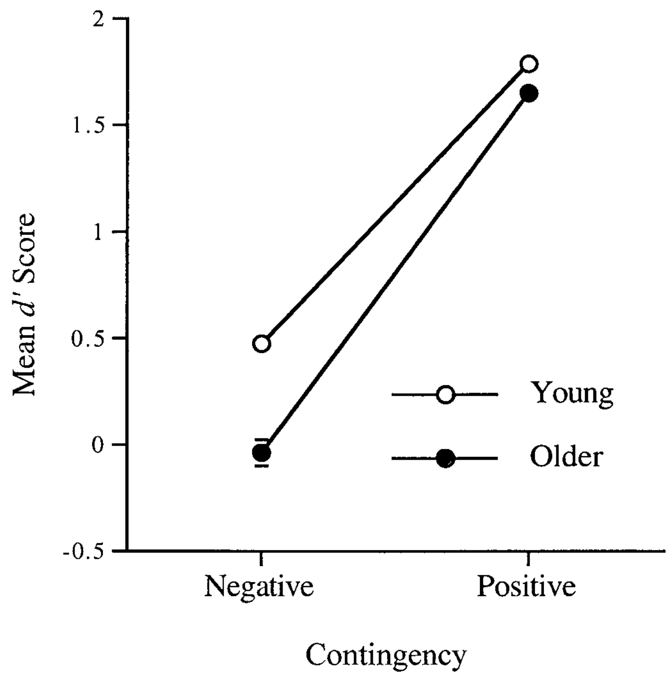



*Figure 4.* Mean *d'* score as a function of contingency and age group. The standard errors for the positive contingency variable and for the young group's negative contingency variable were smaller than .03.

Young and older adults' mean contingency estimate for positive and negative contingency are illustrated in Figure 5. There was a main effect of contingency, $F(1, 377) = 412.39$, $MSE = .16$, $p < .00$, $\eta^2 = .52$, indicating that estimates for the positive contingency ($M = .44$, $SD = .28$) were higher than estimates for the negative contingency ($M = -.17$, $SD = .50$). There was again a main effect of age group, $F(1, 377) = 28.43$, $MSE = .14$, $p < .00$, $\eta^2 = .07$, indicating that the young adults' estimates ($M = .07$, $SD = .02$) were lower than those of the older adults' ($M = .22$, $SD = .02$). However, these effects were qualified by an interaction between age group and contingency, $F(1, 377) = 50.27$, $p < .00$, $\eta^2 = .12$. Analyses of the effect of age group within each contingency indicated that young adults' estimates for negative contingency ($M = -.33$, $SD = .46$) were lower than those of the older adults ($M = .02$, $SD = .48$), $F(1, 377) = 52.42$, $MSE = .22$, $p < .01$, $\eta^2 = .12$, and that young adults' estimates for positive contingency ($M = .47$, $SD = .28$) were higher than those of the older adults ($M = .41$, $SD = .28$), $F(1, 377) = 2.14$, $MSE = .08$, $p < .05$, $\eta^2 = .01$. However, the age group effect was smaller for the positive contingency than for the negative contingency. In addition, the linear trend of contingency was stronger in contingency estimates for young adults than the older adults.

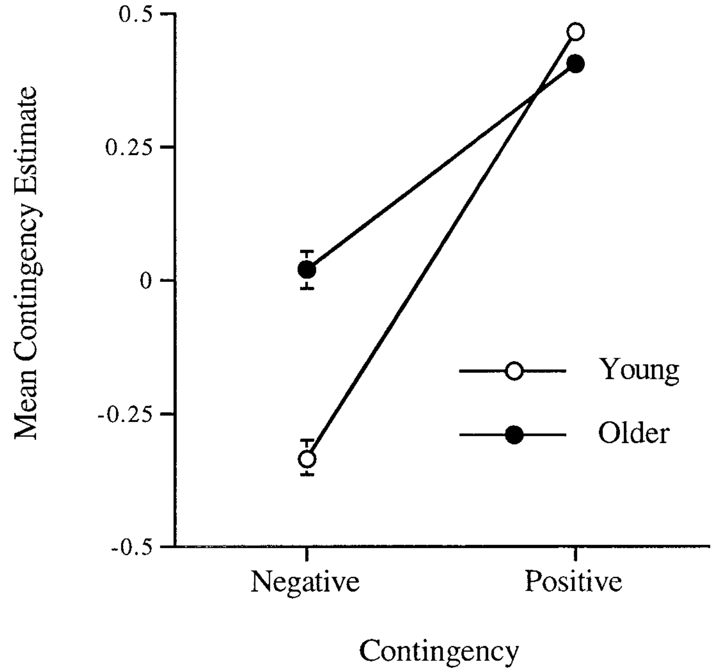



*Figure 5.* Mean contingency estimates as a function of contingency and age group. The standard errors for the positive contingency variable were smaller than .03.

*Cognitive Measure Analyses*

The WAIS-III Digit Symbol Substitution (DS), pattern comparison (PC) and letter comparison (LC) tasks were chosen to represent the construct of processing speed (PS). The backward digit span (BDS), forward digit span (FDS) and word span (WS) tasks were chosen to represent the construct of memory storage capacity (SC). The reading span (RS) and computation span (CS) tasks were chosen to represent the construct of working memory executive function (WMEF). The WAIS-III Digit Symbol Incidental Learning (DIL) and the first and second test trials of the second list from the paired associates task (PA1 and PA2) were chosen to represent the construct of associative memory (AM). The conditional associative learning proportion forgotten (PrFR), proportion discrimination failure (PrDF) and proportion perseveration (PrP) were chosen to represent the construct of associative learning (AL).

*Multivariate Analysis of Variance*

A MANOVA for age group was first conducted using all the cognitive variables to determine if age group accounted for the variance within each of the cognitive variables in the same way and to correct for probability pyramiding. This analysis indicated that the young group's overall performance on the cognitive measures was significantly higher than that of the older group, $F(14, 364) = 3692.93$, $p < .00$, $\eta^2 = .64$. Univariate ANOVAs for each cognitive variable were then conducted. The means and standard deviations for each group and the univariate age comparisons and effect sizes for each cognitive variable are presented in Table 2. With the exception of backward digit span, $F(1, 377) = 1.03$, $MSE = 4.61$, $p = .31$, $\eta^2 = .00$, significant age differences were observed for all of the univariate comparisons, with the young group outperforming the old group on each cognitive measure.

Table 2

*Means Standard Deviations, Age Comparisons, and Effect Sizes for Cognitive Measures*

| Cognitive Measure | Young Adults *M* | Young Adults *SD* | Older Adults *M* | Older Adults *SD* | *F* | *p* = | $h^2$ |
|---|---|---|---|---|---|---|---|
| Processing Speed | | | | | | | |
| WAIS-III DSC | 86.67 | 12.62 | 57.69 | 15.17 | 412.26 | .00 | .52 |
| Pattern Comparison | 57.36 | 8.87 | 41.96 | 9.75 | 258.44 | .00 | .41 |
| Letter Comparison | 45.28 | 7.32 | 31.96 | 7.37 | 308.77 | .00 | .45 |
| Working Memory EF | | | | | | | |
| Reading Span | 2.47 | .95 | 1.92 | 1.01 | 28.95 | .00 | .07 |
| Computation Span | 2.10 | .43 | 1.72 | .50 | 63.42 | .00 | .14 |
| Working Memory SC | | | | | | | |
| Forward Digit Span | 6.53 | 1.18 | 5.85 | 1.32 | 27.75 | .00 | .07 |
| Backward Digit Span | 7.20 | 2.07 | 6.98 | 2.24 | 1.03 | .31 | .00 |
| Word Span | 2.06 | .21 | 1.89 | .20 | 64.56 | .00 | .15 |
| Associative Memory | | | | | | | |
| WAIS-III DIL | 4.20 | .99 | 3.20 | .93 | 100.60 | .00 | .21 |
| PA ABR Test 1 | 5.40 | 2.38 | 2.62 | 1.85 | 154.94 | .00 | .29 |
| PA ABR Test 2 | 8.04 | 2.78 | 4.32 | 2.81 | 166.04 | .00 | .31 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Associative Learning | | | | | | | |
| CAL Pr FR | .81 | .56 | 1.24 | .60 | 28.95 | .00 | .07 |
| CAL Pr P | .49 | .41 | .68 | .38 | 63.42 | .00 | .14 |
| CAL Pr DF | .15 | .12 | .21 | .11 | 21.74 | .00 | .06 |

*Note.* DSC = Digit Symbol Coding, EF = Executive Function, SC = Storage Capacity, DIL = Digit Symbol Incidental Learning.CAL = Conditional Associative Learning, Pr = proportion, FR = Forgotten Response, P = Perseveration, DF = Discrimination Failure.

*Correlations*

Correlations between all of the cognitive measures were obtained to ensure that the measures chosen to represent each construct were more highly interrelated with each other than with variables representing other constructs. These correlations are shown in Table 3. Only one variable was not strongly related to the other measures for its hypothesized construct. Specifically, the correlation between proportion discrimination failure and proportion perseveration was not significant ($r$ = .09, $p$ = .08). There were also five variables that were intercorrelated that were not from the same hypothesized construct. Specifically, computation span CS and forward digit span were correlated ($r$ = .46, $p$ < .00), computation span and backward digit span were correlated ($r$ = .43, $p$ < .00), and paired associate list two/test 2 and reading span were correlated ($r$ = .46, $p$ < .00). These correlations were not surprising, because as theory suggests all of the construct and measured variables are related (Salthouse, 1995a; 1995b; 1996; Salthouse & Babcock, 1991). However, the correlations between each of the measures for a specific construct were either the highest or among the highest correlations for those variables. These correlations are indicated in Table 3 by bold print.

Table 3

*Intercorrelations for Cognitive Variables*

| Measure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 DSC | -- | | | | | | | | | | | | | |
| 2 PC | **.77*** | -- | | | | | | | | | | | | |
| 3 LC | **.77*** | **.81*** | -- | | | | | | | | | | | |
| 4 FDS | .30* | .29* | .34* | -- | | | | | | | | | | |
| 5 BDS | .17* | .24* | .22* | **.46*** | -- | | | | | | | | | |
| 6 WS | .37* | .38* | .44* | **.55*** | **.41*** | -- | | | | | | | | |
| 7 RS | .37* | .34* | .35* | .33* | .35* | .37* | -- | | | | | | | |
| 8 CS | .44* | .44* | .45* | .46* | .43* | .47* | **.43*** | -- | | | | | | |
| 9 DIL | .47* | .42* | .43* | .23* | .20* | .33* | .35* | .33* | -- | | | | | |
| 10 PA1 | .49* | .44* | .45* | .30* | .26* | .35* | .38* | .35* | **.48*** | -- | | | | |
| 11 PA2 | .55* | .49* | .54* | .38* | .34* | .42* | .46* | .39* | **.58*** | **.80*** | -- | | | |
| 12 PrFR | -.37* | -.40* | -.38* | -.23* | -.25* | -.29* | -.37* | -.40* | -.38* | -.37* | -.47* | -- | | |
| 13 PrP | -.29* | -.27* | -.25* | -.12* | -.17* | -.14* | -.25* | -.26* | -.25* | -.27* | -.31* | **.56*** | -- | |
| 14 PrDF | -.16* | -.16* | -.17* | -.11* | -.15* | -.17* | -.13* | -.16* | -.16* | -.18* | -.17* | **.13*** | **.09** | -- |

*Note.* Astericks indicate $p < .05$ for correlations, bold type indicate groupings of measures expected to be hightly correlated, DSC = WAIS-III digit Symbol Substitution, PC = Pattern Comparison, LC = Letter Comparison, FDS = Forward Digit Span, BDS = Backward Digit Span, WS = Word Span, RS = Reading Span, CS = Computation Span, DIL = WAIS-III Digit Symbol Substitution Incidental Learning, PA1 = Paired Associates ABR Test 1, PA2 = Paired Associates Test 2, PrFr = CAL proportion Forgotten Response, PrP = CAL proportion Perseveration, PrDF = CAL proportion Discrimination Failure.

## *Structural Equation Model*

### *Initial Analyses*

The first step in the structural equation model analysis was to conduct a multiple group confirmatory factor analysis (CFA) to confirm that the measured variables represented the latent constructs they were chosen to measure and to check for differences between the measurement models for the young and old groups. For the initial analysis, all five cognitive construct variables and their corresponding measured variables were tested, yielding a model with moderate fit, $\chi^2(143, N = 379) = 182.947$, $p = .01$, comparative fit index ($CFI$) = .97, $RMSEA$ = .03. Thus, the chosen measured variables did measure their corresponding constructs.

On completion of this analysis, multiple group structural equation model (SEM) analyses for positive and negative contingency were conducted to examine the relationships among the three main latent construct variables and between these variables and the contingency construct variable as measured by the *d'* and contingency estimation variables and to examine any age differences in models for young and older groups. For both positive and negative contingency, these analyses produced unidentified models for the young and older groups. There are three levels of identification in SEM, unidentified, just-identified, and over-identified (Byrne, 2001). Unidentified means that there was no unique set of estimates for the parameters being estimated by the proposed model, while just-identified means that there is only one unique set of parameters for the model, and over-identified means that there is more than one set of parameters. Multiple group analyses were conducted for both positive and negative contingency where contingency was indicated by each of the individual measured variables *d'* and contingency estimation. These models were unidentified as well. Finally, analyses of each individual group were conducted for both positive and negative contingency using the contingency construct variable as measured by the *d'* and contingency estimation variables and using each of the measured variables separately. For both positive and negative contingency, all of these analyses produced unidentified models for the young and older groups, which suggested that the number of participants in each group was insufficient for the number of parameters being estimated in the models (Byrne, 2001). To fix this problem, the cognitive latent variable working memory storage capacity and its corresponding indicators were removed from the models. The removal of this set of variables was the most theoretically sound because the construct working memory executive function includes both storage and processing of information.

Multiple group SEM analyses were conducted next for positive and negative contingency without the latent variable working memory storage capacity to examine the relationships among the three main latent construct variables and between these variables and the construct variable contingency, measured by the *d'* and contingency estimation variables and to examine any age differences in models for young and older groups. These models were problematic as well, producing unidentified models for both positive and negative conditions. In a different set of multiple group SEM analyses, contingency was changed in the model from a construct variable to a single measured variable and analyzed individually for both *d'* and contingency estimation in each of the positive and negative conditions. Again, these models proved to be problematic. All models presented negative error variances for the second test trial of the second list from the Paired Associates task (PA2) for the young group, while the models for the older group presented no problems. Therefore, the following results are from analyses of the CFAs and SEMs for each group individually with Fishers' *z* transformations used to compare paths for age differences, which are commonly reported (Rogers, Hertzog & Fisk, 2000).

*Confirmatory Factory Analyses*

Figure 6 illustrates the final individual CFA models for each age group and the age comparisons. The fit of the CFA model was good for both groups [Young: $\chi^2(38, N = 209) = 26.12, p = .93$, $CFI = 1.00$, $RMSEA = .00$, Older: $\chi^2(38, N = 170) = 52.73, p = .06$, $CFI = .98$, $RMSEA = .05$]. This confirmed that the measured variables represent the latent constructs they were chosen to measure and that the same measurement model could be applied to both young and older samples.

There were age differences in how well some of the measures indicated latent construct variables. Specifically, for the processing speed construct, the WAIS-III Digit Symbol Substitution was a better indicator for older participants' processing speed than for younger participants', $z = -4.84, p < .00$. Likewise, the Pattern Comparison was a better indicator for older participants' processing speed than for younger participants', $z = -2.36, p < .01$, and Letter Comparison was a better indicator for older participants' processing speed than for younger participants', $z = -4.48, p < .00$. For the working memory executive function construct, the Reading Span was a better indicator for older participants' working memory executive function than for younger participants', $z = -2.20, p < .05$, and the Computation Span was a better indicator for older participants' working memory executive function than for younger participants', $z = -2.19, p < .05$. For the associative memory construct, the paired associate list two/test two was a better indicator for younger participants' associative memory than for older participants', $z =$

5.36, $p$<.00. For the associative learning construct, the CAL proportion forgotten response was a better indicator for younger participants' associative learning than for older participants', $z = 8.91$, $p < .00$, and the CAL proportion discrimination failure was a better indicator for younger participants' associative learning than for older participants', $z = 3.00$, $p < .01$. These differences were expected due to the fact that the variance in the measures for the processing speed and working memory executive function variables was greater for the older adults than for young adults, while the variance for the measures for the associative process variables was greater for the young adults than for the older adults.

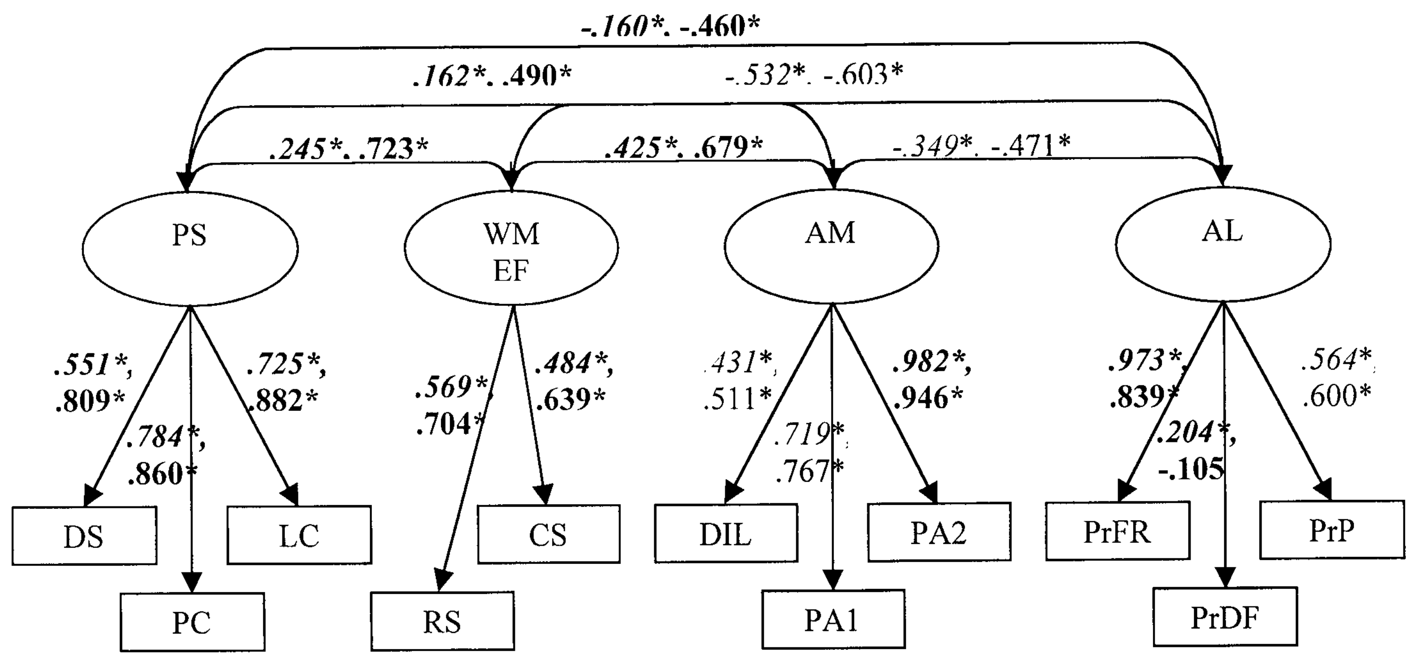



*Figure 6.* Confirmatory factor analyses. Asterisks indicate significant path coefficients at $p < .05$, numbers in italic print indicate the young groups' standardized path coefficients, while numbers in normal print indicate older groups, and numbers in bold indicate a significant age difference at $p < .01$.

*SEM: Negative Contingency Learning*

Figure 7 illustrates the individual models for each age group and the age comparisons using *d'* as the negative contingency criterion variable. The fit of the model was good for each age group [Young: $\chi^2(46, N = 209) = 30.54, p = .96, CFI = 1.00, RMSEA = .00$, Older: $\chi^2(44, N = 170) = 54.91, p = .13, CFI = .99, RMSEA = .04$]. Only the direct paths between processing speed and working memory executive function, working memory executive function and associative memory, and working memory executive function and associative learning were significant at $p < .05$ in the young and older group models. There were no significant direct paths from working memory executive function or either of the associative processes to *d'* for either the young or older adult models. The direct paths among the cognitive constructs indicate that when processing speed increased, working memory executive function improved; when working memory executive function improved, associative learning errors decreased; and when working memory executive function improved, associative memory increased. These relationships show that the influence of processing speed on the associative processes is mediated through working memory executive function.

There were also age differences in two of the direct paths in these models. First, older participants' working memory executive function was more highly related to processing speed than was younger participants', $z = -4.44, p < .00$, and second, older participants' associative memory was more highly related to working memory executive function than was younger participants', $z = -4.44, p < .00$.

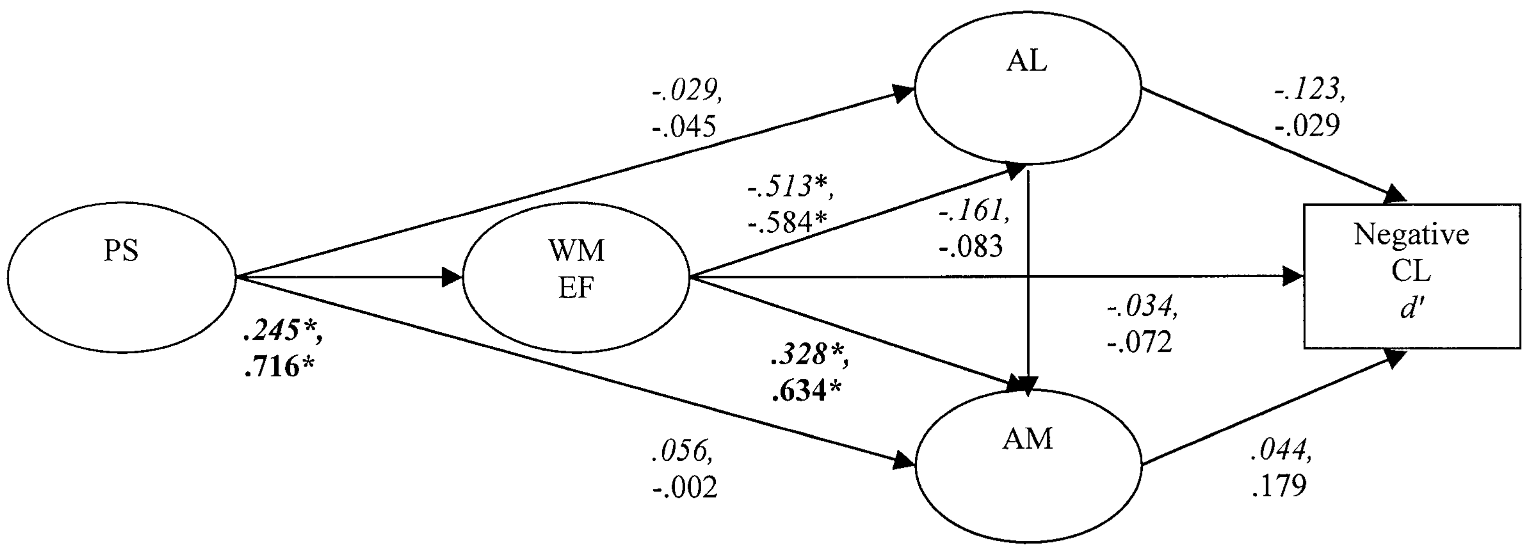



*Figure 7*. SEM: *d'* for negative contingency. Asterisks indicate significant path coefficients at $p < .05$, numbers in italic print indicate the young group's standardized path coefficients, while numbers in normal print indicate the older groups, and numbers in bold indicate a significant age difference at $p < .01$.

The indirect effect of each of the construct variables in this set of models for both age groups is shown in Table 4. There were no indirect effects of any cognitive construct on *d'* for negative contingency for either the young or older group. However, processing speed had a stronger indirect effect on associative learning and associative memory for the older group than for the younger group, $z = 3.06, p < .00, z = -4.16, p < .00$, respectively. That is, as processing speed increased, associative learning errors decreased and associative memory increased more for the older group than for the young group.

Table 4

*Standardized Indirect Effects for SEM: d' for Negative Contingency.*

| Construct | PS | | WMEF | | AL | | AM | |
|---|---|---|---|---|---|---|---|---|
| | Young | Older | Young | Older | Young | Older | Young | Older |
| AL | **-.126** | **-.418*** | -- | -- | | | | |
| AM | **.105*** | **.492*** | .082 | .048 | -- | -- | | |
| *d'* | .018 | .049 | .081 | .139 | -.007 | -.015 | -- | -- |

*Note.* Asterisks indicate significant path coefficients at $p < .05$. Bold print indicates significant age differences at p < .01.

The total effect of each of the construct variables in this set of models for both age groups is shown in Table 5. There were no total effects of the cognitive constructs on *d'* for negative contingency for either the young or older group. However, there was an age difference in the total effect of processing speed on working memory executive function, for processing speed on associative learning, for processing speed on associative memory, and for working memory executive function on associative memory.

Processing speed had a stronger total effect on working memory executive function for the older group than for the young group, $z = -4.44, p < .00$, and also had a stronger total effect on associative learning for the older group than for the young group, $z = 3.31, p < .00$. Processing speed had a stronger total effect on associative memory for the older group than for the young group, $z = -3.58, p < .00$. Working memory executive function had a stronger total effect on associative memory for the older group than for the young group, $z = -3.80, p < .00$. That is, as processing speed increased, working memory executive function increased, associative learning errors decreased, and associative memory increased more for the older group than for the young group. And finally, as working memory executive function increased, associative memory increased more for the older group than for the young group.

Table 5

*Standardized Total Effects for SEM: d' for Negative Contingency.*

| Construct | PS | | WMEF | | AL | | AM | |
|---|---|---|---|---|---|---|---|---|
| | Young | Older | Young | Older | Young | Older | Young | Older |
| WMEF | **.245*** | **.716*** | -- | -- | | | | |
| AL | **-.155*** | **-.463*** | -.513* | -.584* | -- | -- | | |
| AM | **.162*** | **.490*** | **.411*** | **.682*** | -.161 | -.083 | -- | -- |
| *d'* | .018 | .049 | .047 | .067 | -.130 | -.044 | .044 | .179 |

*Note.* Asterisks indicate significant path coefficients at $p < .05$. Bold print indicates significant age differences at $p < .01$.

Figure 8 illustrates the individual models for each age group and the age comparisons using contingency estimates as the negative contingency criterion variable. The fit of the model for the both groups was good [ Young: $\chi^2(46, N = 209) = 31.40, p =$

.95, *CFI* = 1.00, *RMSEA* = .00, Older: $\chi^2(46, N = 170) = 60.68, p = .07$, *CFI* = .98, *RMSEA* = .04]. As expected from the previous set of models using negative *d'* for contingency, the same direct paths among the cognitive latent construct variables were significant and exhibited age differences. In this case, however, the direct path between associative learning and the contingency estimate criterion variable was significant for the young adult model but not for the older model. Also, the direct path between working memory executive function and the contingency estimate criterion variable was moderately significant and negative for the older adult model, but not for the young model. There was no direct path from processing speed to the contingency estimate criterion variable for either of the groups' models. Both of the direct paths from associative learning and working memory executive function to the contingency estimate criterion variable exhibited significant age differences ($z = 3.61, p < .00, z = 3.9, p < .00$, respectively). These paths suggest that for the young group, as associative learning errors decreased, contingency estimates decreased towards the actual negative contingency value, and that for the older group, as working memory executive function increased, contingency estimates decreased towards the actual contingency value. The age differences suggested that for the young group, associative learning was the strongest predictor of negative contingency estimation performance, where for the older group, working memory executive function was the strongest predictor for negative contingency estimation performance.

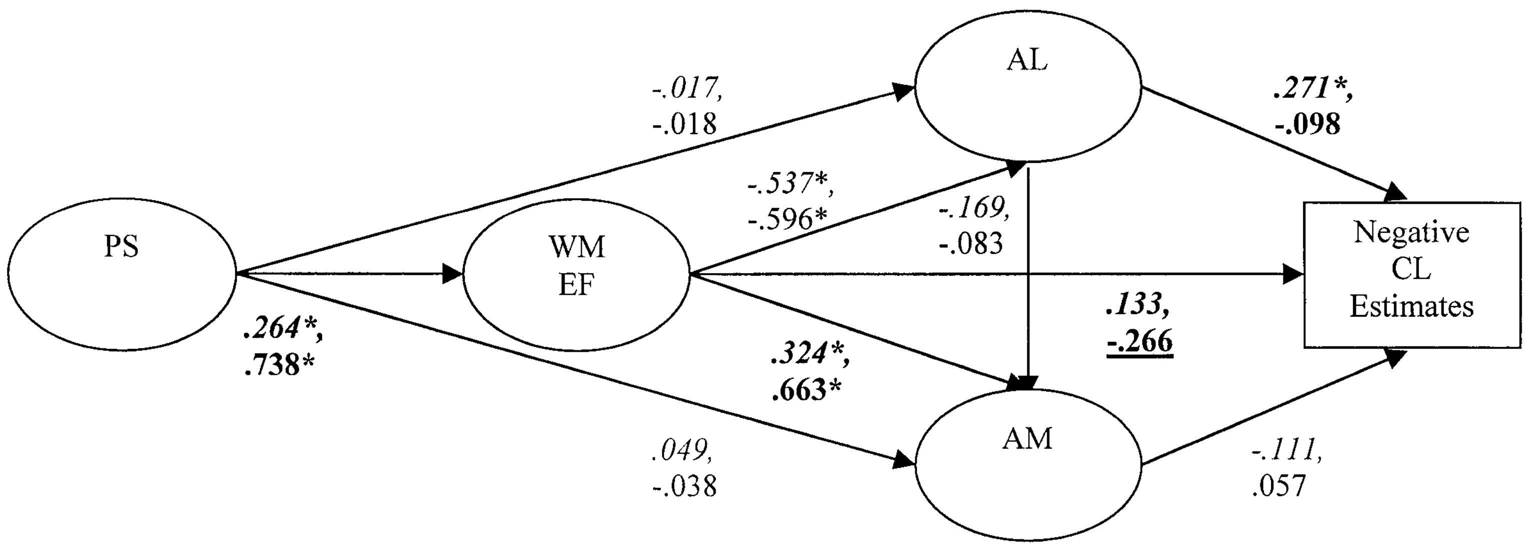



*Figure 8.* SEM: Contingency estimates for negative contingency. Asterisks indicate significant path coefficients at $p < .05$, numbers in italic print indicate the young group's standardized path coefficients, while numbers in normal print indicate the older groups, numbers in bold indicate a significant age difference at $p < .01$, and an underlined number indicates a moderately significant path coefficient at $p = .13$.

The indirect effect of each of the construct variables in this set of models for both age groups is shown in Table 6. The indirect effects for these models were the same as those in the previous set of models using *d'* for negative contingency. There was no indirect effect of any cognitive construct on the contingency estimate criterion variable.

Table 6

*Standardized Indirect Effects for SEM: Contingency Estimates for Negative Contingency.*

| Construct | PS | | WMEF | | AL | | AM | |
|---|---|---|---|---|---|---|---|---|
| | Young | Older | Young | Older | Young | Older | Young | Older |
| AL | **-.142*** | **-.440*** | -- | -- | | | | |
| AM | **.112*** | **.528*** | .091 | .050 | -- | -- | | |
| Estimates | -.026 | -.124 | .192 | .099 | -.192 | -.005 | -- | -- |

*Note.* Asterisks indicate significant path coefficients at $p < .05$. Bold print indicates significant age differences at $p < .01$.

The total effect of each of the construct variables in this set of models for both age groups is shown in Table 7. The total effects for these models were the same as those in the previous set of models using *d'* for negative contingency.

Table 7

*Standardized Total Effects for SEM: Contingency Estimates for Negative Contingency.*

| Construct | PS | | WMEF | | AL | | AM | |
|---|---|---|---|---|---|---|---|---|
| | Young | Older | Young | Older | Young | Older | Young | Older |
| WMEF | **.264*** | **.738*** | -- | -- | | | | |
| AL | **-.159*** | **-.458*** | -.537* | -.596* | -- | -- | | |
| AM | **.162** | **.490*** | **.415*** | **.713*** | -.169 | -.083 | -- | -- |
| Estimates | -.026 | -.124 | -.059 | -.167 | .289 | -.102 | -.111 | .057 |

*Note.* Asterisks indicate significant path coefficients at $p < .05$. Bold print indicates significant age differences at p < .01.

*SEM: Positive Contingency Learning*

Figure 9 illustrates the individual models for each age group and the age comparisons using *d'* as the positive contingency criterion variable. The fit of the model was good for both groups [Young: $\chi^2(46, N = 209) = 30.54, p = .96$, $CFI = 1.00$, $RMSEA = .00$, Older: $\chi^2(46, N = 170) = 59.20, p = .09$, $CFI = .98$, $RMSEA = .04$]. As expected from the previous sets of models using *d'* and contingency estimates for negative contingency, the same paths among the cognitive latent construct variables were significant and exhibited age differences. However, the path between working memory executive function and the *d'* contingency criterion variable was significant in the older adults' model, but not in the young adults' model. Also, the path between associative memory and the *d'* contingency criterion variable was significant for the young adult model, but not for the older model. Both paths exhibited age differences ($z = -5.51, p < .00$, $z = 3.45, p < .00$, respectively). These paths suggested that as the older group's working memory executive function increased, their prediction accuracy increased, and that as the young group's associative memory increased, prediction accuracy increased. The age differences show that working memory executive function was the strongest predictor for positive prediction performance for older adults, whereas associative memory was the strongest predictor for positive prediction performance for young adults.

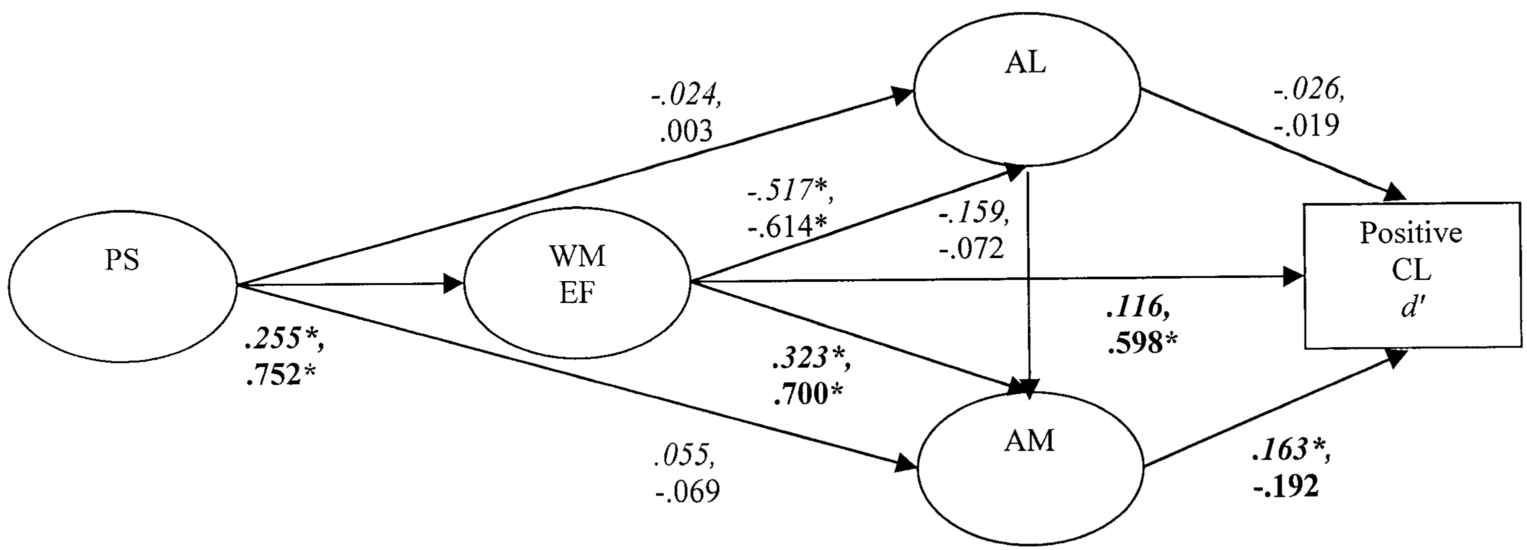



*Figure 9*. SEM: *d'* for positive contingency. Asterisks indicate significant path coefficients at $p < .05$, numbers in italic print indicate the young group's standardized path coefficients, while numbers in normal print indicate the older groups, and numbers in bold indicate a significant age difference at $p < .01$.

The indirect effect of each of the construct variables in this set of models for both age groups is shown in Table 8. The indirect effects for these models were the same as those in the previous sets of models using *d'* and contingency estimates for negative contingency. In addition, processing speed had a significantly stronger indirect effect on positive prediction for the older group than for the young group, $z = -3.09, p < .01$. That is, as processing speed increased, positive prediction performance increased more for the older group than for the young group.

Table 8

*Standardized Indirect Effects for SEM: d' for Positive Contingency.*

| Construct | PS | | WMEF | | AL | | AM | |
|---|---|---|---|---|---|---|---|---|
| | Young | Older | Young | Older | Young | Older | Young | Older |
| AL | **-.132*** | **-.462*** | -- | -- | | | | |
| AM | **.107*** | **.559*** | .082 | .044 | -- | -- | | |
| *d'* | **.060** | **.364*** | .080 | -.132 | -.026 | .014 | -- | -- |

*Note.* Asterisks indicate significant path coefficients at $p < .05$. Bold print indicates significant age differences at p < .01.

The total effect of each of the construct variables in this set of models for both age groups is shown in Table 9. The total effects for these models were the same as those in the previous set of models using *d'* for negative contingency with three differences. Processing speed had a significantly stronger total effect on positive prediction for the older group than for the young group, $z = -3.09, p < .01$, working memory executive function had a stronger total effect on positive prediction for the older group than for the young group, $z = -2.95, p < .00$, and associative memory had a significantly stronger total effect on positive prediction for the older group than for the young group, $z = 3.45, p <$ .00. That is, as older adults' processing speed increased, positive prediction performance increased, and as older adults' working memory executive function increased, positive prediction performance increased. Also, as associative memory performance increased for the young group, positive prediction performance increased.

Table 9

*Standardized Total Effects for SEM: d' for Positive Contingency.*

| Construct | PS | | WMEF | | AL | | AM | |
|---|---|---|---|---|---|---|---|---|
| | Young | Older | Young | Older | Young | Older | Young | Older |
| WMEF | **.255*** | **.752*** | -- | -- | | | | |
| AL | **-.155** | **-.458*** | -.517* | -.614* | -- | -- | | |
| AM | **.162*** | **.490*** | **.405*** | **.744*** | -.159 | -.072 | -- | -- |
| *d'* | **.060** | **.364*** | **.196** | **.467*** | -.052 | -.005 | **.163*** | **-.192** |

*Note.* Asterisks indicate significant path coefficients at $p < .05$. Bold print indicates significant age differences at p < .01.

Figure 10 illustrates the individual models for each age group and the age comparisons using contingency estimates as the positive contingency criterion variable. The fit of the model for the both groups was good [Young: $\chi^2(46, N = 209) = 29.37, p =$ .97, $CFI = 1.00$, $RMSEA = .00$, Older: $\chi^2(46, N = 170) = 58.19, p = .11$, $CFI = .98$, $RMSEA = .04$]. As expected from the previous sets of models using *d'* and contingency estimates, the same paths among the cognitive latent construct variables in these models were significant and exhibited age differences. The path between associative memory and the contingency criterion variable was significant for the young adult model, but not for the older model, and the path between working memory executive function and the contingency criterion variable was moderately significant for the older adult model, but not for the young model. There was a significant age difference in the relationship between working memory executive function and the contingency criterion variable ($z = -2.31, p < .05$). These paths suggested that for the young group, as associative memory increased, contingency estimates for positive contingency increased, and for the older group, as working memory executive function increased, contingency estimates for positive contingency increased. The age differences show that for the older group, working memory executive function was the strongest predictor for positive contingency estimation performance, where for the young group, associative memory was the strongest predictor for positive contingency estimation performance.

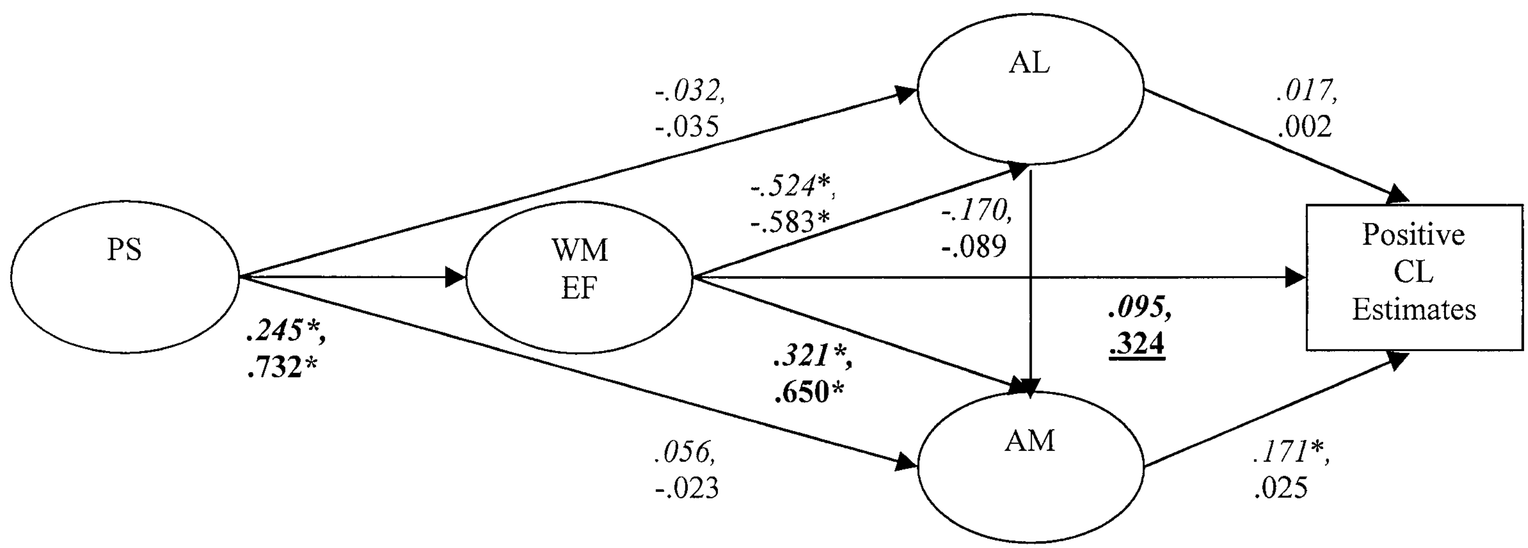



*Figure 10.* SEM: Contingency estimates for positive contingency. Asterisks indicate significant path coefficients at $p < .05$, numbers in italic print indicate the young group's standardized path coefficients, while numbers in normal print indicate the older groups, numbers in bold indicate a significant age difference at $p < .01$, and an underlined number indicates a moderately significant path coefficient at $p = .06$.

The indirect effect of each of the construct variables in this set of models for both age groups is shown in Table 10. The indirect effects for these models were the same as those in the previous sets of models using *d'* and contingency estimates for negative contingency. However, in addition, processing speed had a significantly stronger indirect effect on positive contingency estimates for the older group than for the young group, $z = -1.98, p < .05$. That is, as processing speed increased, estimates for positive contingency increased more for the older group than for the young group.

Table 10

*Standardized Indirect Effects for SEM: Contingency Estimates for Positive Contingency.*

| Construct | PS | | WMEF | | AL | | AM | |
|---|---|---|---|---|---|---|---|---|
| | Young | Older | Young | Older | Young | Older | Young | Older |
| AL | **-.128*** | **-.426*** | -- | -- | | | | |
| AM | **.106*** | **.517*** | .089 | .052 | -- | -- | | |
| Estimates | **.048** | **.249*** | .061 | .016 | -.029 | -.002 | -- | -- |

*Note.* Asterisks indicate significant path coefficients at $p < .05$. Bold print indicates significant age differences at p < .01.

The total effect of each of the construct variables in this set of models for both age groups is shown in Table 11. The total effects for these models were the same as those in the previous set of models using *d'* for negative contingency with one difference. Processing speed had a significantly stronger total effect on positive contingency estimates for the older group than for the young group, $z = -1.98, p < .05$. That is, as processing speed increased, estimates for positive contingency increased more for the older group than for the young group.

Table 11

*Standardized Total Effects for SEM: Contingency Estimates for Positive Contingency.*

| Construct | PS | | WMEF | | AL | | AM | |
|---|---|---|---|---|---|---|---|---|
| | Young | Older | Young | Older | Young | Older | Young | Older |
| WMEF | **.255*** | **.732*** | -- | -- | | | | |
| AL | **-.160*** | **-.461*** | -.524* | -.583* | -- | -- | | |
| AM | **.162** | **.493*** | **.410*** | **.702*** | -.170 | -.089 | -- | -- |
| Estimates | **.048** | **.249*** | .156 | .340* | -.012 | .000 | .171 | .025 |

*Note.* Asterisks indicate significant path coefficients at $p < .05$. Bold print indicates significant age differences at $p < .01$.

# CHAPTER 5

## Discussion

Prior research shows that young adults outperform older adults on contingency learning tasks, especially for negative contingencies (Mutter & Pliske, 1996; Mutter & Williams, 2004; Parr & Mercier, 1998). Contingency learning is due in part to associative processes (Chapman & Robbins, 1990; Shanks, 1985; 1987; Shanks et al., 1989). This suggests that older adults' poor performance on contingency tasks could be due to age-related deficits in associative learning abilities (Mutter & Williams, 2004). However, this age-related deficit in associative learning could in turn be due to age-related decreases in working memory executive function or processing speed (Salthouse, 1995a; 1995b; 1996; Salthouse & Babcock, 1991). The goal of this study was to use SEM to determine whether these findings from the cognitive aging and contingency learning literatures could be integrated into an overall model of age differences in contingency learning. Before turning to this issue, the findings for the contingency learning and cognitive variables will be discussed individually.

### *Criterion Measures*

Both *d'* and contingency estimates were used to measure positive and negative contingency in this study. It has been argued that the *d'* score is a measure of contingency learning, while contingency estimates are a measure of judgment (Allan, Siegel & Tangen, 2005; Vadillo, Miller & Matute, 2005). The *d'* score measures the ability to distinguish between trials where the outcome would be present when the cue is present from trials where the outcome would be absent when the cue is present. The contingency estimation measure indicates the ability to integrate contingency information (i.e., frequency of cue and outcome together, cue without the outcome, outcome without the cue, and neither cue nor outcome) into an overall numerical judgment of the relationship between the cue and outcome. The *d'* scores were higher for the positive contingency task than for the negative contingency task, indicating that contingency learning performance for the positive contingency was better than that for the negative. The findings of this study are consistent with prior research in showing that both contingency learning and judgment performance are better for positive than for negative contingencies. For example, Perales et al. (2005) also found that young adults' *d'* for positive contingencies was significantly higher than their *d'* for negative contingencies, and this corresponded with more accurate contingency estimates for the positive contingency than for the negative contingency.

Young adults' positive and negative *d'* scores were higher than those of the older adults' scores. These findings show that young adults' contingency learning was better than that of the older adults. Young adults' negative contingency judgments were lower than those of the older adults. Likewise, their positive contingency judgments were higher than those of the older adults, but this effect size was smaller than that for the negative judgments and the linear trend was more pronounced in young adults estimates. These findings show that the young adult's contingency judgment performance was better than that of the older adults, especially for the negative contingency. The findings for this study are therefore consistent with prior research findings showing that young adults outperform older adults on contingency learning tasks, with the largest age differences occurring for negative contingencies (Mutter & Williams, 2004; Parr & Mercier, 1998).

According to Maldonado, Jimenez, Herrera, Perales and Catena (2006) differences in positive and negative contingency learning are due to a positivity bias (i.e., perceived relationship is higher than actual relationship). Positive contingencies are confirmed when the cue and outcome occur together and when neither the cue nor the outcome occurs, while negative contingencies are confirmed when either the cue or the outcome is absent in the presence of the other stimulus. The positivity bias occurs because when a cue and outcome are presented together, acquiring an association is accomplished relatively automatically without requiring substantial working memory/attentional resources. However, when either the cue or the outcome is absent, the acquisition of an association is not automatic. Instead, greater working memory/attentional resources are required to notice that the absence of either the cue or outcome is important and to acquire the association between the absence of the cue and presence of the outcome or the presence of the cue and absence of the outcome. This positivity bias therefore leads to increased accuracy for positive contingencies, but decreased accuracy for negative contingencies. The older adults in this study showed a greater effect of this bias than the young adults. The age differences were greater for negative contingency learning and judgment than for positive learning and judgment. This age difference in contingency learning and judgment could therefore be due to deficits in working memory, which especially affect the attentional and associative processes required for the acquisition of negative contingencies (see also Mutter & Williams, 2004).

*Measurement Model*

The young adults outperformed the older adults on all of the cognitive tasks except the backward digit span task. This outcome parallels previous research in demonstrating that as age increases, processing speed, working memory and associative processing decrease (Levine, et al., 1997; Salthouse, 1995a; 1995b; 1996; Salthouse & Babcock, 1991). More importantly, correlations of the cognitive measures demonstrated that the tasks chosen to be measures of the hypothesized constructs were generally related to each other and not as highly related to tasks measuring different constructs. In addition, despite some age differences in the strength of the indicators of their corresponding constructs, the confirmatory factor analyses using the cognitive measures and their hypothesized constructs confirmed that the measures used in this project were good indicators of their corresponding constructs. These results are consistent with previous research using the same or similar tasks as indicators for processing speed, working memory and associative processes (Salthouse, 1995a; 1995b; Salthouse & Babcock).

The paths in the SEMs between the cognitive constructs were also consistent with previous research. For both groups, as processing speed increased, working memory executive functioning improved, and as working memory executive functioning improved, associative learning and associative memory improved. However, working memory executive function had greater direct and total effects on associative memory for older adults than for young adults. These findings have been previously demonstrated in whole or in part by Salthouse and his colleagues (Salthouse, 1994; 1995a; 1995b; 1996; Salthouse & Babcock, 1991).

The direct effect of processing speed on working memory executive function was greater for older adults than for young adults showing that older adults' working memory executive function was more dependent than the young adults' upon processing speed. In addition, processing speed had stronger indirect and total effects on working memory executive function, associative learning, and associative memory for the older adults than for the young adults. These findings of stronger effects of processing speed for older adults are consistent with Salthouse's (1996) processing speed theory that the age-related slowing of processing speed affects multiple aspects of cognitive processing. These consistencies are important because they show that the responses of the young and older adults in this study on the measures selected for this study are similar to those in prior research.

*SEM: Processing Speed*

Processing speed had no direct effect on young or older adults' positive or negative contingency learning or judgment performance suggesting that the influence of processing speed on contingency learning and judgment was mediated through working memory executive function for the older adults and then through the associative processes for the young adults, which is contradictory to the processing speed theory of aging (Salthouse, 1996). However, processing speed had strong indirect and total effects on positive contingency learning and judgment performance for older adults, showing that the effect of processing speed on positive contingency learning and judgment was mediated by working memory executive function.

*SEMs for Negative Contingency Learning*

The SEM using *d'* for negative contingency showed no significant direct or indirect effects for any cognitive process and negative contingency learning for either young or older adults. This could be due to the fact that negative contingency learning was poor overall for both young and older adults. However, the SEM using contingency estimates for negative contingency showed that certain basic cognitive processes did have a direct influence on contingency judgment. Young adults' associative learning was the strongest direct predictor of their negative contingency judgment and there was a strong total effect of associative learning on their judgment as well. This influence of associative learning on negative contingency judgment is consistent with prior research findings suggesting that associative processes are required for contingency learning and judgment (Chapman & Robbins, 1990, Mutter & Plumlee, 2004; Shanks, 1985; 1987; Shanks et al., 1989).

In contrast to young adults, older adults' working memory executive functioning was the strongest predictor of their associative learning, associative memory, and negative contingency judgment. In addition, there were no direct paths for associative learning and memory to contingency learning. Thus, older adults' working memory deficit reduced both their associative learning and memory as well as their ability to acquire and integrate the information for negative contingencies into an overall judgment of the contingency. This influence of working memory executive function on negative contingency judgment for the older adults suggests that age-related working memory decline is a more significant factor in their contingency learning and judgment. These findings are consistent with the Maldonado et al. (2006) hypothesis that greater involvement of working memory/attentional resources is required to acquire the necessary associations for negative contingencies. The working memory deficits for older adults' may also explain why there was a difference in the young and older adults' negative contingency models. Young adults showed less variation in working memory executive function than in associative learning, and the effect of working memory executive function on their negative contingency judgment was mediated through associative learning. Therefore, their working memory abilities did not directly influence their contingency judgment performance, but their associative learning abilities did contribute to their contingency judgment performance. In contrast, the effect of working memory executive function for older adults was not mediated through associative learning because their working memory deficit was fundamental. Older adults cannot acquire the associations that are necessary in contingency learning if they do not have intact working memory abilities to start with.

*SEMs for Positive Contingency Learning*

The SEM using *d'* for positive contingency showed that for young adults, associative memory was the strongest predictor of positive contingency learning. There are differences in the paths for young adults' positive and negative contingency learning and judgment that will be discussed more fully later in this section. This influence of associative memory on positive contingency learning is consistent with prior research findings suggesting that associative processes are involved in contingency learning and judgment (Chapman & Robbins, 1990, Shanks, 1985; 1987; Shanks et al., 1989). However, older adults' working memory executive functioning was again the strongest predictor of positive contingency learning. Working memory executive function also had a strong total effect on positive contingency learning for the older adults. This influence of working memory on positive contingency learning suggests that even for positive contingencies, older adults may not have had sufficient cognitive resources to acquire the associations when both cue and outcome are presented together. In contrast, this sort of processing is relatively automatic for young adults (Maldonado et al., 2006).

The SEM using contingency estimates for positive contingency also showed that for young adults, associative memory was, again, the strongest predictor of positive contingency judgment. This finding is again consistent with prior research findings suggesting that associative processes are required for contingency learning (Chapman & Robbins, 1990, Shanks, 1985; 1987; Shanks et al., 1989). However, older adults' working memory executive functioning continued to be the strongest predictor of positive contingency judgment.

In summary, for positive contingencies the models using *d'* corresponded to the models using contingency estimates for both young and older adults. The strongest predictor of young adults' positive contingency learning and judgment was associative memory, while the strongest predictor of older adults' performance was working memory. For older adults, the working memory executive functioning deficit reduced their associative learning and memory processes, as well as their contingency learning and judgment abilities. These working memory deficits for older adults also explain why there was a difference in the young and older adult positive contingency models. Young adults did not show a deficit in working memory executive function. The correspondence in the young adults' positive contingency models could be because in both learning and judgment for positive contingency, the probability of the outcome given the cue is of more importance in prediction and judgment (Allan, 1993; Allan, Siegel & Tangen, 2005; Vadillo, Miller & Matute, 2005). In negative contingencies, however, learning is again sensitive to the probability of the outcome given the cue (Allan, 1993; Allan, Siegel & Tangen, 2005; Vadillo, Miller & Matute, 2005). However, judgment requires equal consideration and integration of the probability of the outcome given the cue and the probability of the outcome given no cue. Therefore, learning may not be the same as judgments for negative contingencies.

*Negative versus Positive Contingency*

One of the most interesting findings in this study was that young adults' negative contingency performance was most directly related to associative learning, while their positive contingency performance was most directly related to associative memory. This difference in the young adults' models suggests that positive and negative contingency learning involve somewhat different associative processes. The associative learning task used in this study was designed to measure participants' ability to acquire associations between pairs of symbols and patterns across a series of trials. They are presented with one symbol and four patterns and have to choose a pattern until they select the correct one. Participants have to continually test their learning and memory on each trial of this task, and this task involves reasoning and hypothesis-testing because of the constant storing and manipulation of information in an attempt to discover which one is the correct pairing. This task also requires working memory/attentional resources again because of the constant changing of hypotheses. The associative memory tasks used in this study were designed to measure participants' ability to recall the paired information after the presentation of its corresponding cue. In these types of tasks, the stimulus/cue and response/outcome are always present during learning and no reasoning is required. Participants only have to encode the association between these two stimuli on each trial, and to retrieve that association when presented with the stimulus/cue. It is therefore likely that the associative learning task required more working memory/attentional resources than the associative memory task. This is consistent with the Maldonado et al. (2006) suggestion that negative contingency learning requires more attentional resources. Also consistent with Maldonado et al., in positive contingency learning the associations between the cue and outcome are acquired relatively automatically requiring less working memory/attentional resources because the cue and outcome are frequently presented together and seem to require only that these easily acquired associations be retrieved to make predictions and/or contingency judgments.

The similarities across the older adult models for positive and negative contingencies indicate that the underlying working memory deficit in older adults' cognitive processes is instrumental in reducing their overall contingency learning and judgment performance. The age-related working memory executive functioning deficit for older adults reduced their associative processes, and their ability to learn or make judgments regarding contingency. This working memory executive functioning deficit for the older adults could explain why their models did not exhibit similar relationships between the associative processes and contingency learning as did the young adult models.

The differences in the models and underlying processes in the young adult models for positive and negative contingencies indicate that associative processing does not account for all of the variation in contingency learning and judgment. In addition, the differences in underlying processes in the young adults' models suggest that there could be more high-level processes, such as inductive reasoning, involved in negative contingency judgment since the associative learning task in this study does indeed require some level of hypothesis testing. In contrast, positive contingency learning and judgment could rely primarily on more basic-level processing, such as automatic association. There are models of contingency that include inductive reasoning in contingency, i.e., rule-based models of contingency (Allan, 1993). An overall model of contingency that includes both associative processes and inductive reasoning processes needs to be investigated. However, older adults' general contingency performance was most directly related to their working memory executive functioning. This relationship between working memory executive function and contingency learning and judgment for older adults suggests that working memory executive function abilities in general determine their ability to acquire and use information about contingencies. This could be due to the idea that older adults have to use more working memory and attentional resources to acquire both positive and negative contingencies.

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APPENDICES

Appendix A

Table 12

*Contingency task cell frequencies for Set 1.*

| Contingency | Symptom | Disease | | Total |
|---|---|---|---|---|
| 0.65 | | Olyalgia | No Olyalgia | |
| | Fever | 8 | 3 | 11 |
| | No Fever | 1 | 12 | 13 |
| | Total | 9 | 15 | 24 |
| -0.62 | | Paviria | No Paviria | Total |
| | Rash | 4 | 11 | 15 |
| | No Rash | 8 | 1 | 9 |
| | Total | 12 | 12 | 24 |
| 0.05 | | Curviosis | No Curviosis | Total |
| | Headache | 9 | 5 | 14 |
| | No Headache | 7 | 3 | 10 |
| | Total | 16 | 8 | 24 |

Table 13

*Contingency task cell frequencies for Set 2.*

| Contingency | Symptom | Disease | | Total |
|---|---|---|---|---|
| -0.65 | | Olyalgia | No Olyalgia | Total |
| | Fever | 1 | 12 | 13 |
| | No Fever | 8 | 3 | 11 |
| | Total | 9 | 15 | 24 |
| 0.62 | | Paviria | No Paviria | Total |
| | Rash | 8 | 1 | 9 |
| | No Rash | 4 | 11 | 15 |
| | Total | 12 | 12 | 24 |
| -0.05 | | Curviosis | No Curviosis | Total |
| | Headache | 7 | 3 | 10 |
| | No Headache | 9 | 5 | 14 |
| | Total | 16 | 8 | 24 |

Table 14

*Contingency presentation order for both Set 1 and Set 2.*

| Set | Order | Contingency Presentation Order | | |
|---|---|---|---|---|
| 1 | 1 | 0.65 | -0.62 | 0.05 |
| | 2 | -0.62 | 0.05 | 0.65 |
| | 3 | 0.05 | 0.65 | -0.62 |
| | 4 | 0.65 | -0.05 | -0.62 |
| | 5 | -0.05 | -0.62 | 0.65 |
| | 6 | -0.62 | 0.65 | -0.05 |
| 2 | 1 | 0.62 | -0.65 | -0.05 |
| | 2 | -0.65 | -0.05 | 0.62 |
| | 3 | -0.05 | 0.62 | -0.65 |
| | 4 | 0.62 | 0.05 | -0.65 |
| | 5 | 0.05 | -0.65 | 0.62 |
| | 6 | -0.62 | 0.62 | 0.05 |

$\Delta P = P(D|S) - P(D|{\sim}S)$ We first calculate the conditional probabilities of the disease given the symptom, $P(D|S)$, and the disease given no symptom, $P(D|{\sim}S)$. For $P(D|S)$ one divides the number of instances where both the symptom and disease occurred together (in this case 8) by the total number of instances where the symptom was present (in this case 11). The $P(D|{\sim}S)$ is calculated similarly. After calculating these values, the contingency is obtained by subtracting $P(D|{\sim}S)$ from $P(D|S)$.

Appendix B

## INSTRUCTIONS

For this task, I would like you to imagine that you are a physician who is learning to diagnose whether or not your patients have certain diseases using symptom information given in their medical charts.

You will see a series of screens, each which shows the medical chart of one patient. At the top of the patient's chart, you will see information on whether or not that patient has a particular symptom and at the bottom you will see a "?." The "?" indicates that you should predict whether the patient has the disease in question. Hit the key labeled "YES" if your prediction is that the patient has the disease or "NO" if your prediction is that the patient doesn't have the disease. You will then receive feedback on whether or not the patient does or does not have the disease.

As you work through the medical charts, it will be to your advantage to try and discover the nature of the relationship between the symptom and the disease. The symptom could be an indicator that a patient probably does have the disease, the symptom could be an indicator that a patient probably does not have the disease, or there may be no relationship between the symptom and the disease. After you have seen all of the medical charts, I will ask you some questions about the relationship between the symptom and disease. Do you have any questions?

The following screens contain patient charts for the symptom CHILLS and the disease TALIOMA.

Any one of these patients could have either CHILLS or NO CHILLS and either TALIOMA or NO TALIOMA.

Therefore, you should try to discover the nature of the relationship between the symptom CHILLS and the disease TALIOMA. Does having CHILLS suggest that patients probably do have TALIOMA, does having CHILLS suggest that patients probably don't have TALIOMA, or is there no relationship between having CHILLS and having TALIOMA?

PN __________________________________SET/ORDER_________________________

CHILLS - TALIOMA QUESTIONS

Instructions:

Your fellow physicians are interested in what you have learned about the relationship between the symptom "CHILLS" and the disease "TALIOMA." They have submitted several questions to you, which are listed on the following pages. Using what you have learned from the medical charts of your patients, answer their questions to the best of your ability.

What is your estimate of the relationship between the symptom "CHILLS" and the disease "TALIOMA"?

Please indicate your estimate on the scale shown below. Note that the scale ranges from -100 to +100. The value -100 means that the symptom is a perfect indicator that the disease is not present; in other words, if a patient has CHILLS, then that patient definitely does not have TALIOMA. The value +100 means that the symptom is a perfect indicator that the disease is present; in other words, if the patient has CHILLS, then that patient definitely has TALIOMA. The value 0 means that the symptom is unrelated to the disease; in other words, the presence or absence of CHILLS in the patient tells you nothing about the likelihood of TALIOMA in the patient. To make your estimate, place a slash mark ( | ) on the scale at the point you believe is most representative of the relationship between CHILLS and TALIOMA. Then indicate the numerical value of your estimate in the blank.

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| −100 | −90 | −80 | −70 | −60 | −50 | −40 | −30 | −20 | −10 | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |

Numerical Value: ____________

Suppose a new patient comes to you and you find that the patient has CHILLS. Based on the information in the medical charts of your former patients, what is the probability that this patient has TALIOMA?

Please indicate your estimate of this probability on the scale shown below. Note that this scale ranges from 0% to 100%. The value 0% means that the patient is certain not to have TALIOMA; the value 50% means that the patient is as likely to have TALIOMA as to not have TALIOMA, and the value 100% means the patient is certain to have TALIOMA. To make your estimate, place a slash mark ( | ) on the scale at the point you believe is most representative of the probability that the patient would have TALIOMA. Then record the numerical value of your estimate in the blank.

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Numerical Value: _____________

Suppose a new patient comes to you and you find that the patient does not have CHILLS. Based on the information in the medical charts of your former patients, what is the probability that this patient has TALIOMA?

Please indicate your estimate of this probability on the scale shown below. The meaning of the endpoints of this scale are the same as those above. After you have indicated your estimate of the probability on the scale, record the numerical value of your estimate in the blank.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Numerical Value: ____________

Based on the medical charts of your former patients, estimate (1) how many patients had CHILLS; (2) how many patients did not have CHILLS; (3) how many patients had TALIOMA; and (4) how many patients did not have TALIOMA.

CHILLS: ____________

No CHILLS: ____________

TALIOMA: ____________

No TALIOMA: ____________

Based on the medical charts of your former patients, estimate (1) how many patients had both CHILLS and TALIOMA; (2) how many patients had CHILLS, but did not have TALIOMA; (3) how many patients did not have CHILLS, but did have TALIOMA; and (4) how many patients had neither CHILLS nor TALIOMA.

CHILLS and TALIOMA: ____________

CHILLS and No TALIOMA: ____________

No CHILLS and TALIOMA: ____________

No CHILLS and No TALIOMA: ____________