EXAMINING THE RELATIONSHIP BETWEEN LEARNING DISCRIMINATIONS, WORKING MEMORY, ATTENTIONAL CONTROL, AND FLUID INTELLIGENCE

By

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THESIS ABSTRACT

Examining the Relationship between Learning Discriminations, Working Memory, Attentional Control, and Fluid Intelligence

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Multiple cognitive processes have shown to be related to one another in recent studies. For example, one study found executive functions such as working memory, attentional control, and associative learning are correlated with fluid intelligence (Kaufman et al., 2009). The present study is the first study to look at specific learning patterns in associative learning with the constructs of working memory, attentional control, and fluid intelligence. The specific learning patterns studied here include negative patterning, positive patterning, and biconditional discriminations. First, the goal of this study was to see if specific associative learning patterns were related to working memory, attentional control, and fluid intelligence. It was further hypothesized that those who learn negative patterning would have higher scores on working memory, attentional control, and fluid intelligence. Furthermore, this study aimed to add support to the notion that negative patterning is harder to learn than biconditional discriminations. Our results conclude that negative patterning is harder to learn than biconditional discriminations and positive patterning. We found that negative patterning was significantly correlated with working memory and fluid intelligence. Additionally, we found that biconditional discriminations were significantly correlated with attentional control. Therefore, the results of this study suggest that specific learning patterns are related to performance in important cognitive constructs that are used every day. This has practical importance because people constantly learn to associate stimuli together. This study suggests that those who are better at learning more complex association patterns also perform better on other related cognitive tasks.

Keywords: Associative learning, working memory, attentional control, fluid intelligence.

Examining the Relationship between Learning Discriminations, Working Memory, Attentional Control, and Fluid Intelligence

Although there have been numerous studies linking different cognitive processes together, little attention has been paid to the role of specific associative learning patterns with different cognitive processes. Associative learning involves the ability to grasp that different stimuli occur together or are related to each other (Kaufman et al., 2009). There are many ways associative learning plays out in everyday life. A prominent example of associative learning occurs when one has an adverse reaction to food. If someone gets sick from eating at a particular restaurant, then that person may learn to associate that restaurant with the ill feelings of being sick, and as a result, avoid eating at that particular restaurant. Here, the person learns to associate different stimuli together, which in turn can affect future behaviors. The specific patterns of associative learning examined in the present study include positive patterning, negative patterning, and biconditional discriminations. Positive patterning refers to when two specific stimuli are only reinforced together, but not when presented with any other stimuli (Whitlow, 2013). Negative patterning refers to when two specific stimuli are reinforced with all stimuli except each other. Lastly, biconditional discriminations refer to when two pairs of stimuli are reinforced, but mismatching the pairs of stimuli is not reinforced.

The present study served to examine the relationship between associative learning and other cognitive processes such as working memory, attentional control, and fluid intelligence. There are reasons to believe that these variables predict associative learning. For example, working memory involves processing new and previously stored information. Associative learning also involves processing new stimuli and associating new stimuli with previously existing stimuli, therefore working memory ability should be related to associative learning ability. Attentional control is the ability for one to choose what they pay attention to and what they ignore (Unsworth, Spillers, & Brewer, 2009). Attentional control is important as the world offers an enormous amount of stimuli that can be attended to. It is important to have attentional control to focus on specific tasks while simultaneously tuning out potential distractions. A certain level of attentional control is necessary for associative learning as one must focus on the specific stimuli that are being reinforced while tuning out any distractions. Another part of mastering different associative learning patterns involves the ability to understand patterns. This is related to fluid intelligence which refers to the ability to think abstractly, identify patterns, and discern relationships (Tamez, Myerson, & Hale, 2012). Fluid intelligence is related to associative learning because they both involve the ability to identify patterns and discern relationships involving novel stimuli.

Previous studies have shown that cognitive processes such as attentional control, working memory, fluid intelligence and learning are related to one another (Unsworth et al., 2009; Unsworth & Spillers, 2010; Tamez, Myerson, & Hale 2008; Tamez et al., 2012). For example, Unsworth and Spillers (2010) studied working memory capacity, attentional control, and secondary memory to examine their effect on fluid intelligence. This study found that both attentional control and secondary memory are important factors in determining the variation in working memory capacity and its relation to fluid intelligence. Unsworth and Spillers (2010) referred to the influence of attentional control and secondary memory on working memory capacity as a dual-component model because they both significantly impact working memory capacity. In another study

Unsworth et al. (2009) examined the relationship between working memory, attentional control, and fluid intelligence, and found that attentional control accounted for unique variance in fluid intelligence when controlling for working memory. This suggests that attentional control alone plays a role in fluid intelligence even when accounting for the overlap of attentional control in working memory. Additionally, working memory accounted for a unique variance in fluid intelligence when controlling for attentional control. However, neither working memory nor attentional control fully mediated the relationship between fluid intelligence, which suggests that another process or processes may account for the variance. Therefore, there is still a need to know more about the relationship between working memory capacity, fluid intelligence, and other constructs which may account for variability in these processes.

It has been proposed that learning could help mediate the relationship between working memory and fluid intelligence (Tamez et al., 2008). This study is an example of how cognitive functions such as working memory, learning, and problem solving skills are related constructs. Learning relies on information being processed, encoded, and able to be retrieved so, suggesting that learning has an effect on fluid intelligence is related to previous research by Unsworth and Spillers (2010), which proposes that secondary memory has effects on fluid intelligence. Tamez et al. (2008) examined the relationship between a verbal and nonverbal contingency learning task, working memory, and fluid intelligence. In the verbal learning tasks participants were asked to read a word and press a corresponding letter, which would then show another word associated with that letter. Participants were then prompted with the original word and the corresponding letter. Then they were asked to type in the other word that is associated with that letter. The nonverbal learning task is the same, except this task uses images instead of words and the participants do not fill in the blank, but instead choose the correct learned image. Tamez et al. (2008) found a significant correlation between the verbal learning task and Raven's Advanced Progressive Matrices, a widely used measure of fluid intelligence (Raven, Raven, and Court, 1998). A regression analysis found that the working memory tasks used accounted for 47% of the variance (Tamez et al., 2008). The results of this study suggest that verbal learning and working memory are related to fluid intelligence. Therefore, it is possible that associative learning is also related to fluid intelligence and working memory because associative learning also relies on information being processes, encoded, and retrieved. The present study expanded on the findings of Tamez et al. (2008) by examining fluid intelligence and working memory with associative learning.

In a different study, Tamez et al. (2012) examined processing speed, working memory, associative learning, and fluid intelligence in the context of the cognitive cascade hypothesis which proposes that age related slowing stems from decreases in working memory abilities that cascade down to other processes. This study found that more effective learners performed better on fluid intelligence tasks. However, learning does not fully mediate the relationship between working memory and fluid intelligence. This study provides further support that these cognitive processes are closely related to one another, and it is worth further studying their relationship to understand the individual constructs and how they are related. Also, it is possible that specific learning patterns in associative learning rely on cognitive processes such as working memory, attentional control, and fluid intelligence differently and therefore, positive patterning, negative patterning, and biconditional discriminations were examined individually in the present study.

Additionally, Kaufman et al. (2009) hypothesized that associative learning may account for more of the variance in intelligence than processing speed and working memory. This study shows that there is a general associative learning ability that is related to intelligence even when controlling for working memory and attention. It was found that as learning increased, so did performance on intelligence measures. Using structural equation modeling, the researchers also found that associative learning, working memory, and processing speed affect intelligence independently and significantly. The findings of Kaufman et al. (2009) further influenced the present study to focus on specific learning patterns in relation to other cognitive processes.

As previously stated, associative learning involves pairing stimuli together while learning discriminations are the different types of associative learning patterns. The three main discriminations examined were positive patterning, negative patterning, and biconditional discriminations. Positive patterning involves two stimuli that are only reinforced together, but not when presented with any other stimuli (e.g., Ax0, yB0, AB+). Negative patterning refers to two separately presented stimuli that are reinforced when they are presented with any other stimuli except each other (e.g., Cw+, vD+, CD0). Bi-conditional discriminations, on the other hand, refer to two pairs of stimuli presented in four possible combinations that are only reinforced in particular pairs (e.g., EF+, GH+, EH0 and GF0).

Associative learning has been studied with some conflicting results. For example, Harris, Livesey, and Gharaei (2008) found that bi-conditional discriminations are harder than negative patterning discriminations in rats. Additionally, Harris and Livesey (2008) compared patterning and biconditional discriminations in humans and found that participants learned both positive and negative patterning discriminations more quickly than the biconditional discrimination. This study adds support for elemental theories which believe that biconditional discriminations are harder than negative patterning. In elemental theories stimuli are seen as separate entities as opposed to configural theories where stimuli that are presented together are seen as a pair. These two theories have been studied with conflicting results.

For example, Whitlow (2013) found that negative patterning is just as hard if not harder than biconditional discriminations, this finding is consistent with configural theories. In this study participants paired foods and beverages with good, bad, or neutral events. A positive patterning advantage was found, which is consistent with previous findings (Whitlow, 2010). A positive patterning advantage is occurs when positive patterning is found to be easier than other learning discriminations such as negative patterning or biconditional patterning. Not only did Whitlow (2013) add support to a positive patterning advantage, but also discovered that negative patterning is either learned at the same pace or a slower pace when compared to biconditional discriminations. Through further examination, Whitlow and Loatman (2015) found that negative patterning discriminations are harder than bi-conditional discriminations in humans which is in line with configural theories of causal learning. Configural theories assume that when people learn to associate stimuli together they are learning the compound as opposed to the separate elements. Whitlow, Soreth, and Kelley (2015) evaluated the effects of configural-oriented mindsets and elemental-oriented mindsets by having participants focus on either compound stimuli or individual stimuli during an associative learning task. The associative learning task used for this study had participants learn to associate hypothetical pairs of actors and actresses together. A configural-oriented mindset was targeted by having participants focused on the chemistry of the pairs, while the element-oriented mindset was targeted by having participants focused on star potential. This study found that using a configural mindset makes both negative patterning discriminations and biconditional discriminations easier. However, in both configural oriented mindsets and elemental oriented mindsets negative patterning discriminations were found to be harder than biconditional discriminations (Whitlow et al., 2015).

The present study examined three discrimination tasks: (1) Positive patterning; (2) negative patterning; and (3) bi-conditional discriminations in relation to working memory, attentional control, and fluid intelligence. First, it was hypothesized that associative learning, working memory, attentional control, and fluid intelligence are related constructs. Additionally, it was hypothesized that those who learn negative patterning would perform better on tasks involving working memory, attentional control, and fluid intelligence. Furthermore, this study aimed to add support to the notion that negative patterning is harder to learn than biconditional discriminations. This research aimed to offer a deeper understanding of learning patterns in relation to other cognitive processes with a focus on specific learning discriminations to help deepen the understanding of how specific learning patterns are related to other cognitive constructs. New stimuli are processed every day and therefore it is important to understand which patterns of stimuli are harder to learn and how they are related to other cognitive constructs.

Methods

This correlational study consisted of 40 Rutgers University students from the student research pool. Participants were recruited through the Rutgers Camden Experimetrix online sign-in and received class credit for their participation. This study was held on campus at Rutgers University, Camden in the Memory and Cognition Lab and took approximately two hours.

Measures

Learning Task. A shorter version of the associative learning task from Whitlow et al. (2015) was used in the present study. Three discrimination tasks, consisting of positive patterning, negative patterning, biconditional, were used in this learning task. Participants viewed one actor name and one actress name at a time and decide whether the pair has good performance chemistry or no performance chemistry. Participants viewed new and repeated pairings distributed across 10 blocks, each with 20 displays. Participants had no prior knowledge of the information presented in the task and were expected to learn the different patterns throughout the task. At first participants were presented with pairings and guessed whether they had good chemistry to no chemistry. Participants pressed one for good chemistry and two for no chemistry on the keyboard. Feedback was provided to inform participants whether their response was correct or incorrect, and stated whether the pair had chemistry or no chemistry. Feedback was provided to offer information about the pairs that the participants could use to learn the patterns. The feedback was used to reinforce pairs that have good chemistry together and facilitate learning. It was important to use novel stimuli so the participants had no prior knowledge or pre-existing associations.

For negative patterning, one actor and one actress, when paired together, have no performance chemistry, but when they are paired with anyone else, they do have performance chemistry (i.e., Aw+, xB+, AB0). Here, + indicates a reinforced pair in terms of performance chemistry while 0 indicates a non-reinforced pair with no performance chemistry. Additionally, the capitalized letters represent reoccurring stimuli while the lowercase letters represent novel stimuli. For positive patterning, an actor and an actress have performance chemistry together, but not with anyone else (i.e., Cy0, zD0, CD+). In biconditional patterning, two actors and two actresses were paired in four possible combinations. Each actor has performance chemistry when paired with one of the actresses, but not the other (i.e., EF+, GH+, EH0 and GF0).

Working Memory Tasks. The present study used a working memory battery consisting of four task developed by Stephen Lewandowsky (Lewandowsky, 2011). All tasks were run in Matlab using the Psychophysics toolbox. These tasks include a working memory updating task (WMU), an operation span task (OS), a sentence span task (SS), and a spatial short-term memory task (SSTM). Each task takes approximately 10 minutes to complete.

WMU. Participants mentally stored digits and updated those digits based on arithmetic operations presented corresponding to their specific location and were then prompted to recall the updated digits (Lewandowsky, 2011). Upon the start of this task participants were presented with the to-be-remembered numbers one at a time for 1 sec each. Then arithmetic cues were presented one at a time for 1.3 sec each with a 250-msec blank interval and in the same locations that the previous numbers appeared, such as “+2” or “-5”. Participants had to mentally perform the operation and were then prompted to type in the updated number for that location. There was no time constraint for recall and participants were not given any feedback for this or any of the other tasks. The operations did not exceed “-7” or “+7” and answered ranged only from 1-9. The set size varied from 3-5 items across trials. There were two practice trials plus an additional 15 trials.

OSpan. This task involved evaluating presented arithmetic equations as true or false and remembering a series of letters presented one at a time after each equation is displayed (Lewandowsky, 2011). A fixation cross was positioned in the center of the screen for 1.5 sec. Then participants saw a mathematical operation such as “3+2=5” for no more than 3 sec and indicated whether the operation was correct by pressing “/” for yes and “z” for no. After the operation went away, a consonant was presented in the center of the screen for 1 sec. Then there was 100-msec blank interval followed by the next question. Set sizes ranged from 4-8 items. At the completion of the sequence participants were prompted to recall the letters in the order that they saw them. The screen displayed a question mark with a blinking underscore until participants entered in the letters. Again, there was no time constraint for recall. There was an inter-trial interval of 500-msec and after every three trials there was a self-paced break. There were 15 trials total. An example of this task is shown in Figure 1.

SSpan. This task is the same as the OSpan task except the SSpan task uses sentences instead of arithmetic equations (Lewandowsky, 2011). A fixation cross was positioned in the center of the screen for 1.5 sec. Then participants read simple sentences and had to decide whether the sentences made sense by pressing “/” for yes and “z” for no, like in the OSpan task. For example, a sentence could say “The sun is a star” or “All humans have tails” and the participant will indicate if the sentence makes sense or not by indicating “yes” or “no”. After each sentence a consonant was presented for 1sec. Then there was 100-msec blank interval followed by the next question. Set sizes ranged from 4-8 items for 15 trials with three additional practice trials. An example of this task is shown in Figure 2.

SSTM. This task involves remembering the location of dots presented in a 10 x 10 grid (Lewandowsky, 2011). A fixation cross was presented in the center of the screen for 1sec. The 10 x 10 grid was shown and a series of dots appeared one by one, each in individual cells for 900msec each with a 100msec pause in between each dot. Participants were presented with sequences ranging from 2-6 dots. After each sequence a black grid was shown and participants were instructed to click on the grids where the dots had been shown. They did not have to enter the dots in the correct order that they had seen them, they only needed to indicated where on the grid they saw the dots. Clicking on a dot twice made it disappear, so participants could edit their response. Again, there was no time constraint for recall. When participants were satisfied with their answer they clicked on the “Next” button on the bottom of the screen. There were 30 trials, six for each set size. An example of this task is shown in Figure 3.

Attentional Control Tasks. (Unsworth & Spillers, 2009)

Arrow flankers. For this task, participants looked at a fixation point for 400msec. Then an arrow appeared directly above the fixation point for 1700msec. Participants were instructed to correctly and quickly indicate which direction the arrow is pointing by pressing the appropriate key (“f” for left pointing arrows and “j” for right pointing arrows). Fifty of the presented trials have distractor arrows pointing in the same direction as the fixation arrow, also known as a congruent trial, while another 50 of the trials have distractor arrows pointing in the opposite direction of the fixation arrow, known as an incongruent trial. Additionally, another 50 trials were neutral, featuring only an arrow pointing either left or right with horizontal lines as the flankers on the sides instead of arrows. All of the trials were randomly mixed. The outcome measure for this task was the reaction time difference between congruent and incongruent trials. This task is a measure of constrained attention which is the ability to focus on a target amongst distractors.

Fluid Intelligence Task.

Raven's Advanced Progressive Matrices (RAPM). This task measures visuospatial or nonverbal reasoning skills (Raven, Raven, and Court, 1998). Only odd numbers of sets one and two were used to shorten the task to adhere to the two hour time. Altogether, 24 items of progressive difficulty were tested. The range of possible scores for this task is 0-24. Each item consists of a 3 x 3 matrices display of geometric patterns with the right bottom pattern missing. The participants had to choose from eight possible answers to complete the pattern and were given as much time as needed to complete the problems. This measure was scored by the total number of correct solutions. This test is a measure of abstract reasoning. An example of this task is shown in Figure 4.

Procedures

Participants arrived at the memory and cognition lab on campus at Rutgers University, Camden and signed in to receive credit towards their class. The informed consent was administered at the beginning of the session. Participants were given as much time as they needed to thoroughly read the information. Then participants were asked if they understood the content and if they had any questions. One copy was collected and another copy was offered if participants wanted one for their records. Minors were not included in this study. Age was recorded on the informed consent and those under 18 (i.e., minors) were not included in the study. To control for demand characteristics, participants were not presented with the specific details of the hypothesis being tested. Instead, the study was described as “A study concerned with perception, memory, judgment or some combination of these three processes.” This description allows participants to understand what is being asked of them without giving away the direct goal of the study.

After the informed consent was signed and returned, participants were seated comfortably at a personal computer. This study was partially counterbalanced to control for fatigue effects so, half of the participants began with the learning task and the other half began with the executive functioning tasks of working memory, attentional control, and fluid intelligence. Participants completed the tasks within two hours. Participants’ confidentiality was ensured by keeping informed consent documents in a locked file cabinet. The only cognitive test to be administered on paper was Raven’s Advanced Progressive Matrices which was also kept in the file cabinet. Only the participant’s non-identifying subject number was used on the test. All computer data has been stored electronically by a non-identifying subject number and kept on a password protected computer. This study posed minimal risk to participants, no more than encountered in everyday life. Furthermore, data analysis consisted of simple discriminations between the constructs and structural equation modeling.

Results

All data from the different constructs measured were processed individually before comparison. For the associative learning patterns, a mean percent correct discrimination responses were recorded for each participant for each of the three learning discriminations. This is the percent correct for reinforced pairs minus non-reinforced errors. Scores for positive patterning ranged from -.11-1.00, negative patterning from -.56-.61, and biconditional discriminations from -.33-.78. The working memory battery was analyzed using a script for SPSS developed by Lewandowsky (2010), which produced the mean percent correct values for each of the four working memory tasks separately for each participant. Additionally, a total mean value for all four of the working memory tasks combined together was used to create an overall working memory mean score for each participant with scores ranging from .30-.80 Attentional control was analyzed using the difference between reaction time on incongruent and congruent trials. The difference was then divided by the mean reaction time measures of the congruent, incongruent, and neutral trials combined to normalize the result with scores ranged from -.05-.39. Lastly, RAPM was measured by the total number of correct responses with scores ranging from 5-23. Furthermore, overall means from the data of all participants were calculated for each of the tasks as shown in Table 2.

Data analysis included simple correlations between all of the constructs to test for significance (Table 3). We found that associative learning, working memory, attentional control, and fluid intelligence yielded significant correlations. First, there was a significant correlation between working memory capacity and fluid intelligence, $r(40)=$.(43), $p < .01$, which replicated the results of previous studies (Tamez et al., 2008; Tamez et al., 2012; Unsworth et al., 2009; Unsworth & Spillers, 2010). This supports the claim that working memory and fluid intelligence are related constructs. However, there was not a significant correlation between the measures of attentional control and fluid intelligence or working memory and attentional control used in this study.

As shown in Figure 5, negative patterning was the hardest learning pattern for participants compared to biconditional discriminations and positive patterning when comparing the mean scores for each learning pattern (Negative patterning M= 0, SD= .28; Biconditional M= .25, SD= .27; Positive patterning M= .38, SD= .28). This is consistent with previous studies and supports the hypothesis that negative patterning is harder to learn than biconiditional discriminations and positive patterning (Whitlow, 2013; Whitlow & Loatman, 2015; Whitlow, Soreth, & Kelley, 2015). This is consistent with configural theories in associative learning which suggest that negative patterning is harder to learn than positive patterning or biconditional discriminations (Whitlow 2015). However, these findings conflict with the findings of Harris, Livesey, and Gharaei (2008) and Harris and Livesey (2008), which suggests that biconditional discriminations are harder to learn than negative patterning.

It was further hypothesized that negative patterning would be related to higher scores in working memory, attentional control, and fluid intelligence. This hypothesis was supported by a moderate correlation between negative patterning and working memory capacity as a whole, $r(40)= .35$, $p < .05$. However, when looking at the each of the four working memory tasks separately, only the OSpan task yielded a significant result with negative patterning, $r(40)= .38$, $p < .05$. Moreover, there was a significant correlation between negative patterning and fluid intelligence, $r(40)= .33$, $p <$

.05. However, there was not a significant correlation between negative patterning and attentional control.

Positive patterning was found to be the easiest task for participants to learn and was not significantly correlated to any of the constructs measured in this study. This is consistent with configual theories in associative learning which suggest a positive patterning advantage (Whitow 2015). Also, this replicates the findings of a positive patterning advantage in previous studies (Whitlow 2013; Whitlow 2015). Biconditional discriminations were significantly correlated with attentional control $r(40)= -.39$, $p < .05$. The correlation between biconditional discriminations and attentional control is negative because attentional control was measured by the difference in response time of incongruent and congruent trials. A lower response time means they were faster to respond. This suggests that biconditional discriminations rely on attentional control and response inhibition. However, biconditional discriminations were not significantly correlated with working memory capacity or fluid intelligence.

Additionally, structural equation modeling (Figure 6) was used to show the relationship between working memory as a latent variable and the other observed constructs of the individual working memory tasks, attentional control, fluid intelligence, and each of the learning patterns. The paths from the latent variable to the observed variable show standardized factor loadings. Factor loadings closer to either negative one or positive one indicate that the factor strongly affects the variable. First, this model shows similar loadings, with the exception of the SSTM task, to Lewandowsky (2011), which examined the strength of the relationship between each of the working memory tasks as observed variables and working memory as a latent variable. This adds support that the working memory task used in this study yields reliable results. However, further examination of the reliability for the SSTM task is encouraged in future studies. Also, this analysis is consistent with the correlations reported in Table 3 as negative patterning had the greatest associative strength with working memory with a factor loading of .44, while positive patterning had the lowest associative strength with a factor loading of .17. Additionally, this model shows strong associative strength with working memory and fluid intelligence with a factor loading of .67, which replicates the findings of previous studies (Lewandowsky, 2011; Unsworth et al., 2009).

Discussion

This study adds support to configural theories which propose that negative patterning is harder to learn than biconditional discriminations. Additionally, the present study adds support to a positive patterning advantage as positive patterning was the easiest learning pattern for participants to master. Results of this study suggest that there is a difference in cognitive ability in those who learn negative patterning. Negative patterning has shown to be more difficult to learn in multiple studies and seems to rely more heavily on working memory and fluid intelligence compared to biconditional discriminations and positive patterning. Previous research has stated that inhibitory control is related to negative patterning (Whitlow, 2013). The present study adds support to that statement as negative patterning was significantly correlated with working memory, which requires some level of inhibitory control to correctly respond to tasks. However, no significant result was found for the attentional control task, which directly relates to inhibitory control, and negative patterning. On the other hand, the biconditional discriminations were significantly correlated with attentional control, suggesting that inhibitory control is important for performance in biconditional discriminations. It is recommended that future research examines inhibitory control in relation to negative patterning and biconditional patterning more closely to determine if there is a fundamental difference in how people process these two discriminations.

As previously stated, working memory and fluid intelligence have shown to be related in numerous studies (Tamez et al., 2008; Tamez et al., 2012; Unsworth et al., 2009; Unsworth & Spillers, 2010). Working memory involves processing and manipulating new information while fluid intelligence is the ability to solve novel problems and therefore, involves the processing and manipulation of new information to solve the problem. Therefore, the significant correlation adds support to the hypothesis that these are related constructs. However, there were no significant correlations with working memory and attentional control for fluid intelligence and attentional control which does not support the hypothesis that these processes are related.

Moreover, it was hypothesized that working memory, attentional control, and fluid intelligence would be related to negative patterning. Working memory and associative learning both rely on processing new and previously stored information, therefore learning a more difficult pattern of presented stimuli, such as negative patterning, is related to an increased ability to process and manipulate information in working memory. Additionally, associative learning and fluid intelligence rely on configuring patterns together and discerning relationships between stimuli, therefore learning a more complex associative learning pattern, such as negative patterning, is related to better performance on fluid intelligence. In other words, when a learning pattern is harder to master, like negative patterning, it is likely to rely on working memory and fluid intelligence more so than easier learning patterns. This study adds support to this notion as higher ability in negative patterning is related to increases in working memory and fluid intelligence scores. It can be seen as an advantage to be able to learn negative patterning as it is related to more efficient functioning of important processes such as working memory and fluid intelligence.

One limitation of this study was the small sample size. It is recommended that future studies on this subject use a larger sample size to examine these findings more closely. Additionally, only one measure was used for attentional control and fluid intelligence. Using additional measures of these constructs would increase construct validity and serve to better represent the relationship between associative learning, attentional control, working memory, and fluid intelligence. Moreover, this was a relatively long study, taking approximately two hours, and may be subject to fatigue effects. Although this study was partially counterbalanced, it may be beneficial to use a Latin square counterbalancing design where each of the four tasks occurs first throughout a sequence. Another way to control for fatigue effects would be to have participants come to the lab on two separate days to complete the tasks.

This is the first study to our knowledge to look at specific associative learning patterns with working memory, attentional control, and fluid intelligence together. The results of the present study suggest that there is a relationship between our abilities to learn complex patterns of stimuli and other cognitive processes such as working memory and fluid intelligence. The findings of this study have implications for how people learn to associate stimuli together. This has practical importance as people learn to associate stimuli together every day. This can be particularly important when learning to avoid something, such as a food that one is allergic to. Future studies may find it interesting to focus on those who perform well on negative patterning and learn more about why some people are better able to utilize their cognitive resources. Also, this study could have implications for future studies on cognitive training. Because negative patterning has shown to be related to other cognitive constructs, it is possible that cognitive training with associative learning patterns may increase performance in working memory or fluid intelligence ability. Overall, this study adds support to previous research showing relationships between different cognitive processes and extends on those studies by examining specific associative learning patterns. However, more research is needed to explore the differences between specific associative learning patterns and other cognitive processes.

Table 1

Learning Discrimination Task Examples			
Positive Patterning:			
Mary -	Kate -	**Mary +**	
John -	**Mark -**	**Mark +**	
Negative Patterning:			
Joe +	Brad +	**Joe -**	
Lisa +	**Tiffany +**	**Tiffany -**	
Biconditional Discriminations:			
Tom +	**Jenna +**	**Tom -**	**Ashley -**
Ashley +	**Dave +**	**Jenna -**	**Dave -**

Note. Items in bold represent reoccurring stimuli. Names with a plus sign represent a reinforced pair while names with a minus sign represent non-reinforced pairs. Therefore, pairs with plus signs had good chemistry in the learning task while pairs with minus signs had bad chemistry.

Table 2

Descriptive Statistics	M	SD
Neg	.00	.28
Pos	.38	.27
Bicon	.24	.28
WM	.55	.12
MU	.35	.19
Ospan	.55	.19
SSpan	.50	.21
SSTM	.80	.07
AC	.16	.10
gF	14.18	4.35

Note. Neg = Negative Patterning; Pos = Positive Patterning; Bicon = Biconditional Discriminations; WM = Working Memory; MU = Memory Updating; Ospan = Operation Span; SSpan = Sentence Span; SSTM = Spatial Short Term Memory; AC = Attentional Control; gF = Fluid Intelligence.

Table 3

Correlations	**1.**	**2.**	**3.**
1. WM	---	---	---
2. AC	-.20	---	---
3. gF	.43**	-.26	---
4. Negative	.35*	-.08	.33*
5. Positive	.18	-.07	.01
6. Bicon	.13	-.39*	.21

Note. WM = Working memory; AC = Attentional control; gF = Fluid intelligence; Negative = Negative patterning; Positive = Positive patterning; Bicon = Biconditional discriminations

*p<.05; **p<.01.

Appendix

Acknowledgment of Informed Consent

I have agreed to take part in a study concerned with perception, memory, judgment or some combination of these three processes. In this experiment I expect to be presented with words, word-like displays, or pictures, and I will be asked to remember or make simple judgments about the information I have been shown. The duration of this study will be from 1½ to 2 hours, as specified on the sign-up sheet.

I understand that my participation in this experiment is voluntary, that I could choose to satisfy my course requirement by other means, such as writing an approved paper, that there will be no risks to me by participating in the study, and that I may discontinue my participation at any time. I also understand that the primary benefits of my participation are to advance general understanding of psychological processes and to help me understand the nature of psychological research. I may be shown my individual data but I will not receive a copy of my data nor will I be told how my performance compares to other participants in this research.

I also understand my data will be kept confidential, being released only as anonymous results in reports of scientific research. "Confidential" means that the research records will include some information about me and this information will be stored in such a manner that some linkage between my identity and my responses in the research exists. Information collected about me includes my name, gender, age, and date of my participation. The researchers will keep this information confidential by limiting access to the research data and keeping it in a secure location. The research team and the Institutional Review Board at Rutgers University are the only parties that will be allowed to see the data, except as may be required by law. If a report of this study is published, or the results are presented at a professional conference, only group results will be stated. All study data will be kept for at least 3 years.

If I have any questions about the research, I understand that I can contact Brianna Soreth of the Psychology Department, 311 N. Fifth Street, Camden, NJ 08102, by phone at 609-204-4629 or by email at briannasoreth@gmail.com. I can also contact Dr. J.W. Whitlow, Jr. of the Psychology Department at (856) 225-6334 or by email at bwhitlow@camden.rutgers.edu; I also understand that should I have any questions about my rights as a research subject, I can contact Institutional Review Board:
Rutgers University, the State University of New Jersey
Liberty Plaza/Suite 3200
335 George Street, 3rd Floor
New Brunswick, NJ 08901
Tel: 732-235-9806 Email: humansubjects@orsp.rutgers.edu

Participant
Date:____________ Age:______ Signature: ______________________________

Investigator
Date:____________ Signature: ______________________________

Figure 1

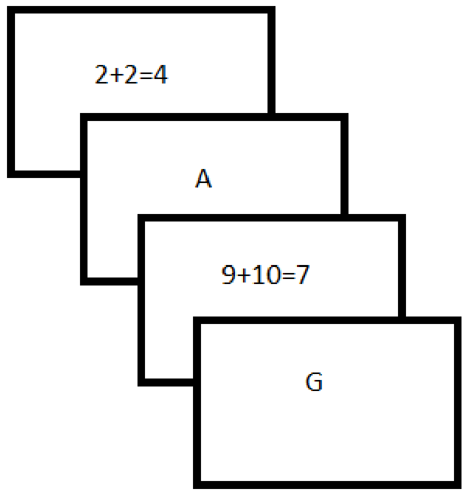

Figure 1. Operation Span Task

Figure 2

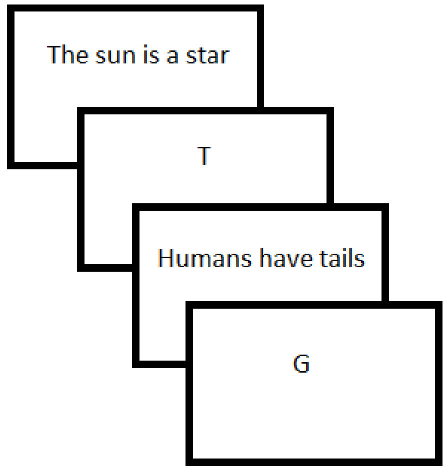

Figure 2. Sentence Span Task

Figure 3

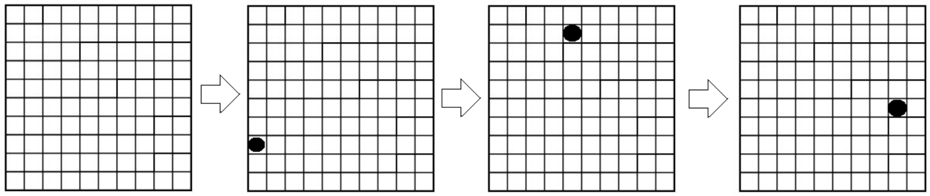

Figure 3. Spatial Short Term Memory Task

Figure 4

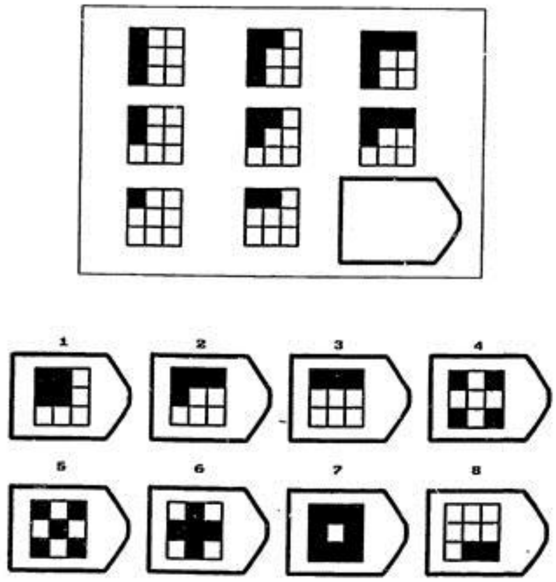

Figure 4. Raven's Advanced Progressive Matrices

Figure 5

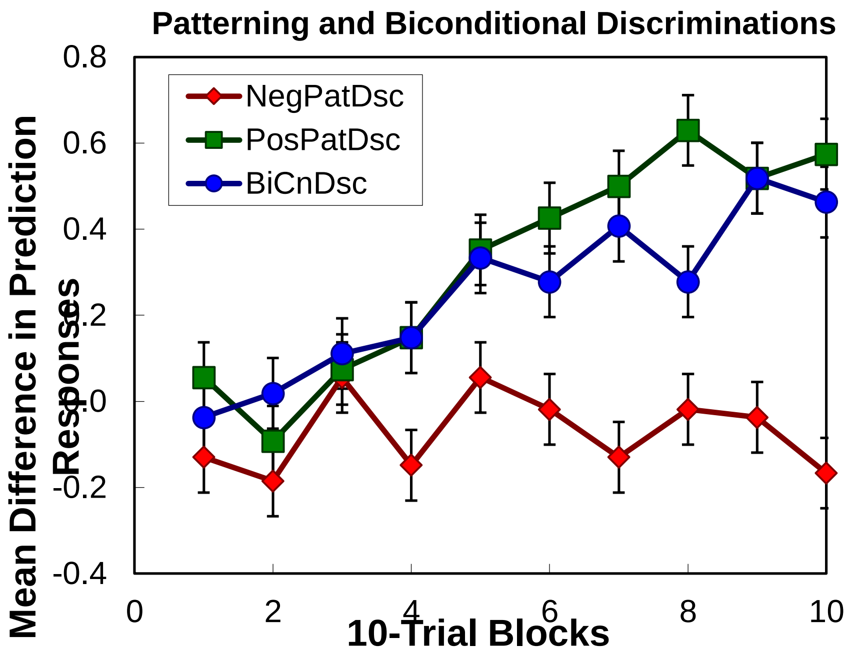

Figure 5. Graph showing how well participants performed in each of the different learning tasks across trials. This adds support that negative pattering is harder to learn than positive patterning or biconditional discriminations.

Figure 6

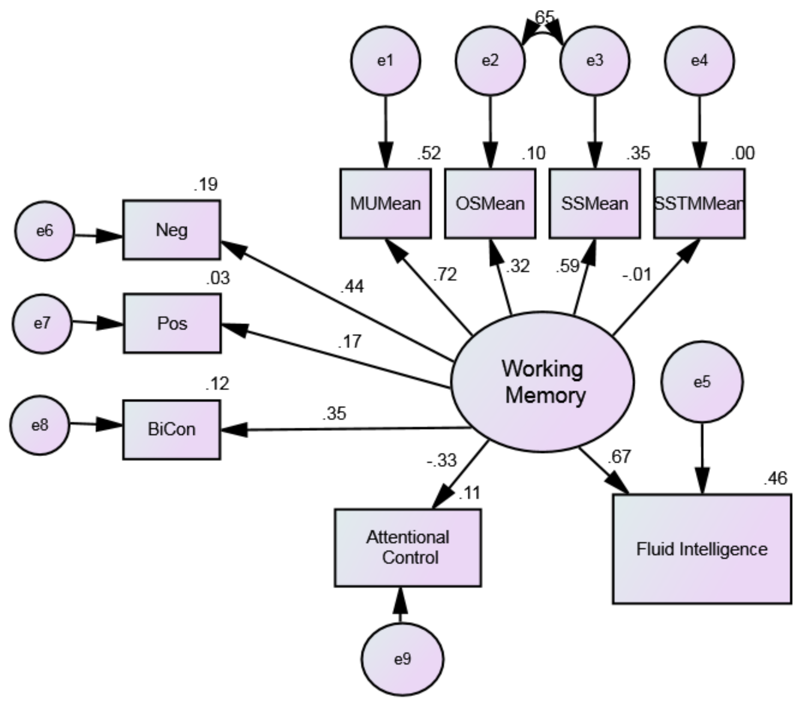

Figure 6. Structural equation model with working memory as a latent variable in relation to specific associative learning patterns, attentional control, and fluid intelligence. Paths connecting the latent variable to the observed variables represent the loadings of each task onto the latent variable. MU, memory updating; OS, operation span; SS, sentence span; SSTM, spatial short term memory; Neg, negative patterning; Pos, positive patterning; BiCon, biconditional discriminations.

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