AUDITORY OR VISUAL? AN EXAMINATION OF MULTIPLE SENSORY CUES IN CAUSAL LEARNING

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THESIS ABSTRACT

Auditory or Visual? An Examination of Multiple Sensory Cues in Causal Learning

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Current literature regarding visual and auditory associative learning provides conflicting results. Some literature suggests audio-visual stimuli can facilitate learning, while other literature suggests it can interfere with learning. The present study aimed to investigate learning differences between conditions that combine visual and visual stimuli and conditions that combine visual and auditory stimuli. Mean accuracy scores for different discrimination tasks were analyzed to determine patterns of learning in the two conditions. The findings of this study provide support for the notion that audio-visual is much more difficult to learn than visual-visual stimuli in discrimination tasks.

Introduction

How do we learn? Why do we associate items? If I do x, then what is y? Is this relationship constant or variable? Whether it is teaching a toddler a simple task of stacking blocks or teaching a college student an array of information, associations consume our daily lives. We are constantly conducting our own individual experiments, testing the limits that defy our understanding of our everyday life. Distinguishing cause and effect is a concept thoroughly researched in psychology, but the research regarding multisensory processing in causal learning provides conflicting results and implications. Because multisensory processing is found in every facet of human life, it is reasonable to believe multisensory processing would always work congruently, but some research indicates this may not always be true. The literature review below dives into the research surrounding auditory and visual learning and provides a framework for the study conducted.

Literature Review

Causal reasoning and associative learning represent rule-based relationships between events (Willis, 2005, p. 41). This type of learning relies heavily on the transfer of information between one sequence of events and another (Baker, Murphy, Mehta, & Baetu as cited in Willis, 2005, p. 12). Prominent models of associative learning include the Pearce model and the Rescorla-Wagner model. The Pearce model uses a configural approach to causal learning which assumes individual stimuli, when shown in compounds, are processed collectively as an association (Pearce, 1987). Using this model as a reference, individual stimuli shown as an individual or in a compound should have their own amount of learned information. Learned information from an individual stimulus should never be summed together when shown in a compound and there should be no summation effect. Additionally, this model assumes there would be a decreased response to individual cues when trained on compounds and a decreased response to compounds when trained on individual cues.

The Rescorla-Wagner model uses an elemental approach to causal learning which suggests that individual stimuli, whether shown as a single cue or in compounds, produce a unique association to that particular stimulus (Rescorla & Wagner, 1972). Elemental approaches to causal learning use microelements to develop an association, specifically shared elements, distinctive elements, configural elements, and suppressed elements. Shared elements, or common elements, are elements that share features (Mclaren & Mackintosh, 2000), and distinctive elements are elements that are always present and are not influenced by other stimuli (Wagner, 2003). Suppressed elements are experienced when stimuli are presented alone, but suppressed when in a compound (Harris, 2006) and configural elements depend on the co-occurrence of other stimuli (Wagner & Brandon, 2001). Using this model as a reference, there should be a summation effect as there would be an increased response to compound cues than the individual cues. While these two theories make similar predictions, they differ greatly on how the predictions are achieved. Using these models for multisensory associative learning could provide valuable insight into how two different senses process, bind, and associate information congruently.

Multisensory Learning

Multisensory learning is found throughout cognitive processing, but an especially important example is that of auditory and visual processing. This is evident in classroom learning styles using both lecture and visual presentations, in human conversation with spoken words and facial expressions, and in casual, everyday television watching. But, how the two processes of audio and visual information work congruently, and more specifically bind information during memory tasks, is a facet of behavior that is still debated. It has often been debated how multisensory stimuli influence working memory capacity and if visual and auditory information act in an additive fashion or interferes (Quak, London, & Talsma, 2015). While little information is understood about multisensory learning rates in discrimination tasks, there is information in other fields of cognition that can help frame this concept.

Several studies regarding multisensory processing have indicated multiple sensory inputs, specifically auditory and visual information, have an additive feature. In a visual motion detection task, Seitz, Kim and Shams (2006) had participants view two displays, one an array of directional signals, one was just noise. Some participants only experienced the visual condition while other participants listened to white-noise in varying levels between ears to induce a perception of motion while viewing the displays. Participants would then indicate which frame was the directional signal and the perceived direction of motion. Seitz et al. (2006) found the audio-visual condition learned more efficiently and suggested auditory sound facilitates learning.

A study conducted by Fifer, Barutchu, Shivdasani, and Crewther (2013) used visual shapes and auditory pseudowords during a paired associative learning matching task and found similar results to Seitz et al. (2006). During this study, participants were presented with novel sounds and black line shapes (the novel-AV condition), pseudoword and back line shapes (the verbal-AV condition), and novel red filled shapes and black line shapes (shape-VV condition). Participants would then learn the association between the stimuli. Barutchu et al. (2013) found the verbal-AV condition performed with greater accuracy than the other two conditions. The novel-AV condition performed better than the shape-AV condition. On the surface, this data makes sense to our everyday experiences. Classroom learning is designed to take advantage of this additive feature of auditory-visual learning. However, if this data was painting a complete picture, why would some studies indicate there is no significant advantage from a duel modality in learning?

Morey and Cowan (2004) explored the effect of visual and verbal memories on a working memory task. Participants were issued an auditory memory instruction of 2 or 7 digits, the phrase "your phone number", or the phrase "nothing to say." Participants then viewed an array of 4, 6, or 8 squares, a blank screen, another array of 4, 6, or 8 squares, and were asked to indicate if the array was different or the same and then recall the auditory memory. This study found visual working memory performance significantly decreased when asked to remember the 7 random digits, when compared to the easier auditory memory tasks. Additionally, Morey and Cowan (2004) found an interference of audio and visual information when the task was difficult, such as high load (7 digits) and visual array performance. The implications of these results suggest audio-visual processing can interfere with learning when the task is extremely difficult.

In a study conducted by Tanabe, Honda, and Sadato (2005), two-dimensional shapeless texture patterns and white noise sound waves were used in an audio-visual or visual-visual paired-association learning task. Participants identified audio-visual pairs or visual-visual pairs depending on the task. This study found no significant difference in learning speeds between the audio-visual and visual-visual condition, and no significant differences between the testing phases for accuracy or reaction times. This suggests audio-visual learning may not produce an additive effect in learning tasks.

Generalization in Discrimination Tasks

The associative learning theories of Pearce (1987) and Rescorla-Wagner (1972) make different predictions about generalization and summation as a measure of learning. Summation is expressed in learning tasks when the amount of learning associated to each of two or more individual cues appears to be added together when the cues are presented with one another. The summation effect implies that when individual cues are presented as a compound, they still retain the learning associated with each. According to the Rescorla-Wagner model, summations should always occur. According to Pearce's model, there should actually be a generalization decrement when adding one cue to another or removing a cue from a compound, because the cues presented by themselves are a different pattern, or configuration, than the cues presented as a compound.

Evidence showing a summation effect was reported in a study conducted by Soto, Vogel, Castillo, and Wagner (2009). They used three food-allergy prediction experiments to measure the summation effect when using unspecified magnitude (allergy vs. no allergy) or submaximal magnitude (likelihood of allergy on a scale of 0-20 points). Participants were shown a stimulus (e.g., A or B), or a pair of stimuli (e.g., EF), of possible foods that would develop an allergy and were prompted to give their prediction. At the end of the study, participants were instructed to measure the likelihood of a food allergy and the intensity of an allergic reaction to the presented cue. Participants responded higher for the novel compound AB than for either the trained individual cues

(A, B) or the trained compound (EF). In a follow-up experiment, participants gave higher ratings for novel compounds (AB, AD, BC, CD) than for the individual elements (A, B, C, D) or the trained compounds (AC, BD). Both experiments found support for a summation effect that does not align with Pearce's generalization decrement theory. Pearce's theory would have expected to find a similar response rate for the novel compounds (AB) as for the individual cues (A, B, C, D). Soto et al. (2009) concluded that finding a summation effect in a human study is more likely when people use a submaximal rating scale.

Other studies using human subjects often find difficulty providing evidence for a summation effect. For example, Young, Wasserman, Johnson, and Jones (2000) conducted two experiments which included both a positive and negative patterning component. To operationalize this study, Young et al. (2000) had participants pretend they were pathologists and were given substance cues to determine if the cues were causing an illness within the body. Participants in the positive patterning condition consistently responded faster to compounds than elements in the training trials. These findings would be predicted by both the Pearce and Rescorla-Wagner models. However, although participants in the negative patterning condition initially responded slower to compounds than elements in the training trials, at the end of training, reaction times were faster for compounds than elements (Yong et al., 2000). These results do not suggest a summation effect as an increased response to the compounds should have been experienced early in training.

Summation effects have been found in studies with non-human animals. For example, Harris, Livesey, and Gharaei (2008) trained two groups of rats on a biconditional discrimination task and a patterning discrimination task (including both negative and positive patterning) by using light and sound with food as reinforcement. By comparing the learning rate between the two groups of rats, this study found rats solved negative and positive patterning more easily than biconditional discriminations. These results are consistent with other literature using non-human animal studies indicating negative patterning is usually more easily solved. However, this study also found an early summation effect on patterning conditions as rats responded more to the compound than the single stimuli early in training. The apparent disparity in finding a summation effect in non-human animal but not in human studies could be due to the fact that animal studies often use multiple modalities whereas human studies use unimodal modalities. The possible role of multi-sensory stimuli in producing a summation effect is suggested by results from a study conducted by Thorwart, Uengoer, Livesey, and Harris (2016). In this study, the summation effect in humans was explored using a goal-tracking procedure that used a computer like game to facilitate learning. Participants would catch fish in a river by clicking on the individual fish. Participants would then experience visual or auditory cues, which would have to be learned. The visual or auditory cue would indicate that participants needed to feed a pig that appeared in a cave. This unique paradigm, used negative and positive patterning to measure a positive patterning advantage and summation effect. This study found positive patterning was learned faster, and more accurately. This study also found a summation effect in the negative pattern condition, which could be because of the use of audio-visual cues (Thorwart et al, 2016).

The studies reviewed thus far have built a foundation of information for the present study conducted. Previous research has indicated multisensory learning can have an additive effect, (Seitz et al., 2006; Fifer et al., 2013), during simple, but not during difficult tasks (Morey & Cowan, 2004; Tanabe et al., 2005). Research on generalization in discrimination tasks suggest summation can be experienced in human studies, but is often difficult to produce (Soto et al., 2009; Young et al., 2000; Beckman & Young, 2007), whereas it is often found in non-human animal studies (Harris et al., 2008). Multisensory learning research suggests audio-visual tasks can produce generalization in human studies (Thwart et al., 2016) and that the disparities between human and non-human animal studies and summation could be due to the varying modalities that are used (Soto et al., 2014). This information indicates there could be a difference in learning styles between visual-visual conditions and auditory-visual tasks in associate learning tasks, especially with humans.

Recent Research

A study conducted by Whitlow and Otero (2018) aimed to measure the individual roles of distinctive, suppressed, common, and configural elements in associative learning. Additionally, this study investigated the role of novelty in associative learning and explored how novel stimuli are represented in microelements. This study found that the weights of distinctive, suppressed, common, and configural elements depended on the training schedule for individual training cues. These results suggest the salience of each element whether in compounds or individual stimuli is partly dependent on the pattern in which stimuli are presented. Additionally, this study found support for Pearce's model (1987) indicating generalization decrement when adding or removing a cue in the testing condition. These findings are particularly interesting because previous research suggests eliminating a cue would result in reduced generalization more than adding a cue

(Brandon et al., 2000). The findings of this study have been used as groundwork for the present study because the present study wants to know if learning will be influenced differently between tasks when the stimulus combinations are auditory and visual rather than just visual.

Present Study

The present study will expand on previous literature by using multiple sensory channel cues during a discrimination task. This study is important because there is limited information available regarding multi-sensory processing with causal reasoning in humans. This study will specifically focus on configural and suppressed elements that are often used in discrimination tasks. Additionally, this study will also focus on the role of novelty in discrimination tasks. It was hypothesized that using multiple sensory channels (i.e. auditory stimuli and visual stimuli) during a discrimination task will be associated with a decreased role for suppressed elements and a decreased ability to process configural elements. It was therefore expected that learning discriminations that rely on configural cues would be difficult to solve. Additionally, it was hypothesized auditory-visual compounds will be more difficult than visual-visual compounds to learn during a discrimination task. The results of the study will be used to help build a platform of information for how varying stimuli are processed in discrimination tasks.

Method

Experiment 1

Participants

Twenty-three total students from the Rutgers University – Camden subject pool participated in Experiment 1. This convenience sample was used because students of Rutgers University – Camden represent a diverse demographic with adult cognitive ability. Students received partial fulfillment of a class requirement for their participation. Socio-demographic characteristics varied and were not recorded.

Materials and Measures

A total of 200 words from Battig and Montague's (1969) published list of category norms were used as word cues. Battig and Montague's (1969) category norms were used because they have established reliability and validity, have been widely used in previous research, and have been cited more than 1,600 times (Van Overschelde, Rawson, & Dunlosky, 2004). Participants were presented materials and made responses in the visual-visual condition on desktop computers.

Design

Experiment 1 consisted of 3 different training conditions simple discrimination, compound discrimination, and simple discrimination with irrelevant novel cues. Simple discriminations (A+,B+, C-, D-) were individual stimuli positively reinforced, such as elicited brain seizure activity and negatively reinforced, did not elicited brain seizure activity, (i.e. Newt+, Herring+, Dog-, Fox-). Compound discriminations were compound stimuli (EF+, GH-) positively reinforced and negatively reinforced (i.e. Newt & Herring+, Dog & Fox-). Simple discrimination with irrelevant novel cue (In+, nK+, Jn-, nL-) were constant cues that were consistently presented with an irrelevant novel cue (Newt & Novel+, Novel & Herring +, Dog & Novel-, Novel & Fox-). In this discrimination, the learned information would come from the constant cue as this cue would always be the predictor of brain seizure activity, (i.e. Newt, Herring) and the novel cue would be irrelevant to the condition. The design of experiment 1 is illustrated in Table 1. After completing the training conditions, participants were then instructed to complete the associative strength test. Here, participants were shown each individual cue and asked to rate on a scale of 0-100 the strength of each cue. Using a compound cue as an example, (Newt & Herring) participants would be asked to rate the strength of Newt, Herring, and Newt & Herring.

Type of Discrimination	**Cues**
Simple Discrimination	A+, B+, C-, D-
Compound Discrimination	EF+, GH-
Simple Discrimination with Irrelevant Novel Cue	In+, nK+, Jn-, nL-

Table 1. Design of Experiment 1

The task was written in GWBASIC in MSDOS. Participants completed 6 total trial blocks, with 20 trials in each block. Eight trials involved 4 pairs of simple discriminations (e.g., A+, B-), four trials involved two pairs of a compound discrimination (e.g., EF+, GH), and eight trials involved 4 pairs of simple discriminations with novel irrelevant cues (In+, Jn-). Words were randomly assigned to conditions at the start of the session for each participant, and the order of trials was randomized at the start of each trial block. The particular design was chosen to use as it is a variation of an experiment previously conducted (Whitlow & Otero, 2018).

Procedure

Participants were recruited from Experimentrix for partial completion of a class requirement. Participants were compensated with one credit towards their required three credits of experimental participation as an undergraduate student; however, students were not required to participate, and could fulfil their required credits by completing an alternative assignment for their respective classes. Participants chose from available time frames posted on Experimentrix and were given instructions on the location of the lab.

Upon arrival, students were asked to sign in and were issued a printed set of instructions and an informed consent form. The instructions informed participants they would be participating in a study interested in perception, judgment, and memory, or a combination of all three. Participants were informed they would play the role of a psychologist working with a patient who has mild brain seizures. Their role within the study was to predict whether a one word thought or a combination of one word thoughts would cause a mild brain seizure in the patient. After completing several trials, participants were informed they would then complete a rating task on the previously presented thoughts or pair of thoughts. After reading these instructions, participants were asked if they have any questions, if they felt comfortable continuing, and then the signed informed consent was collected. Participants were then instructed to follow the prompts on their computer.

On each trial, participants were presented with a visual display of a word or a pair of words expressing thoughts the patient was having. Participants were then prompted to judge whether the presented thought/thoughts would or would not cause a brain seizure. Participants indicated their prediction by typing "1" for mild brain seizure activity or "2" for no brain seizure activity. After their judgment, participants would be informed if their judgment was correct or incorrect. Participants completed 20 trials in each of the 6 learning blocks in the learning phase of this study. After this phase, participants were then asked to complete an associative strength rating test. Here, participants were shown each word or pair of words they were previously trained on and asked to indicate the strength of association between the particular cue and a brain seizure. They were also tested on single words and word combinations derived from the study conditions. Participants were asked to rate the strength on a scale between 0-100, where 0 indicated no association between the thought and brain seizures and 100 indicated a very strong association between the thought and brain seizures.

Experiment 2

Participants

Experiment 2 recruited 26 total participants from the same subject pool as Experiment 1. Participants received partial credit for a course requirement.

Materials and Measures

Experiment 2 used the same word cues as experiment 1; however, in this condition half of the words were presented in an auditory format and half in a visual format. Participants were presented with and responded using HP desktop computers. Auditory stimuli were delivered through on-ear headphones at 60 decibels.

Design

Experiment 2 consisted of 5 different training conditions including positive patterning, negative patterning, biconditional, irrelevant cue, and simple discrimination with irrelevant novel cues. Positive patterning (AW-, BX-, AB+) elicited a brain seizure when paired together, but not when paired with other cues (i.e. Newt, & Herring-, Dog & Fox-, Newt & Dog+). Negative patterning (CY+, DZ+, CD-) elicited a brain seizure when paired with other cues, but not when paired together (i.e. Newt & Herring+, Dog & Fox+, Newt & Dog-). Biconditional (EF+, GH+, EG-, FH-) elicited a brain seizure when two cues are paired together, but not when they are switched (Newt & Herring+, Dog & Fox+, Newt &Dog-, Herring & Fox-). Irrelevant cue (IK+, IL+, JK-, JL-) elicited brain seizure activity when paired with a constant cue (Mulberry& Drum+, Mulberry & Fir+, Chestnut & Drum-, Chestnut & Fir-) Here, Mulberry and Chestnut are the constant cues determining the prediction and Drum and Fir act as irrelevant cues. Simple discrimination with irrelevant novel cue (Mn+, nO+, Pn-, nQ-) also used constant and irrelevant cues (Newt & novel+, novel & Hearing+, Dog & novel-, novel & Fox-) Here, the novel cue, which was always a new cue, acted as the irrelevant cue because it provided no predictive information to the participants. The design of this experiment is illustrated in Table 2. Participants completed 12 total trial blocks, with 22 trials in each block. Cues were randomly assigned to each trial for each participant.

Type of Discrimination	Cues
Positive Patterning	AW-, BX-, AB+
Negative Patterning	CY+, DZ+, CD-
Biconditional Patterning	EF+, GH+, EG-, FH-
Irrelevant Cue	IK+, IL+, JK-, JL-
Simple Discrimination with Irrelevant Novel Cue	Mn+, nO+, Pn-, nQ-

Table 2. Design of Experiment 2

Procedure

The procedure of Experiment 2 was similar to that of Experiment 1, except as noted. Participants were presented with one visual word and one auditory word. Participants were then prompted to judge whether the presented thought/thoughts would or would not cause a brain seizure and indicated their prediction by typing “1” for mild brain seizure activity or “2” for no brain seizure activity. After their judgment, participants were informed if their judgment was correct or incorrect. Participants completed 22 trials in each of the 12 learning blocks in the learning phase of this study. After completing this phase, participants were thanked for their participation. There was no final associative rating task.

Results

The focus of this study was to examine learning rates between visual and auditory conditions during discrimination tasks. Each experiment was analyzed separately.

Experiment 1: Visual-Visual Training

Participants uniquely learned each of the simple, novel, and complex discrimination tasks during 6 trial blocks. A repeated measures ANOVA with factors of trial (6), discrimination type (simple, novel, and compound) and reinforcement (reinforced or no reinforced) was conducted. The difference between the means of discrimination task and trial was statistically significant: $F(10, 220) = 1.905$, $p = .046$. There was also a significant interaction between trials and reinforcement, $F(5, 110) = 11.346$, $p < .01$, which reflects a clear, distinct learning pattern between discriminations. Figure 1 illustrates mean proportion of predictions of brain seizures across 6 learning trials by discrimination type.

Mean discrimination scores were collected and calculated into discrimination accuracy by task type and trial. To calculate discrimination accuracy, the proportion of brain seizure responses on non-reinforced trials (false alarms) were subtracted from the proportion of brain-seizure responses on reinforced trials (hits). Further analysis showed simple discriminations (A+/C-) significantly received more correct responses than irrelevant novel cue discriminations, $t(22) = 4.44$, $p = < .01$. Compound discriminations also significantly received more correct responses than irrelevant novel cue discriminations $t(22) = 2.86$, $p = <.01$. Simple and compound discriminations did not significantly differ, $t(22) = .59$, $p > .05$. Mean discrimination accuracy scores are shown in Figure 2.

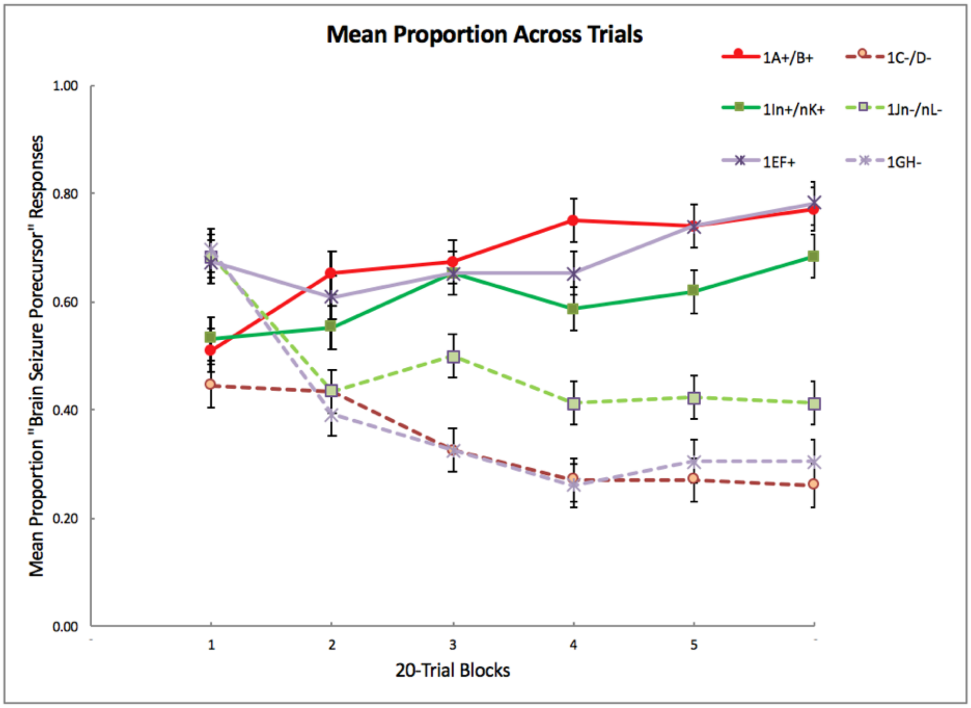

Figure 1. Mean accuracy across 6 training blocks for Experiment 1. Simple discrimination reinforced and non reinforced, simple discrimination with irrelevant novel cue reinforced and non reinforced, and compound discrimination reinforced and non reinforced. Standard errors are represented in the figure.

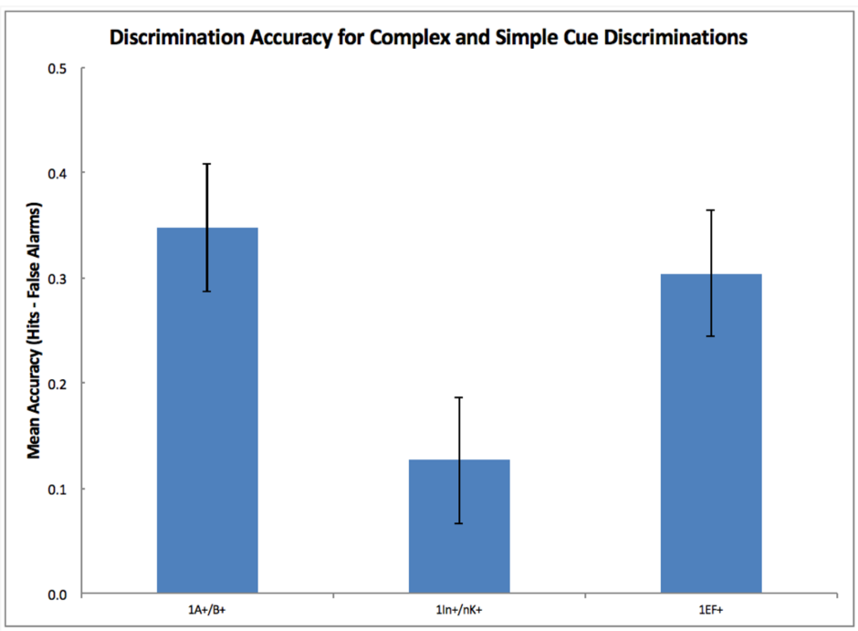

Figure 2. Mean accuracy across trials in Experiment 1 for discrimination task (simple, irrelevant cue, and compound discriminations), Standard errors are represented in the figure.

Experiment 1: Associative Strength Ratings Test

Associative ratings were measured on a scale of 0-100. Mean ratings across conditions are illustrated in Table 3. Results showed no significant effects between mean associative ratings when trained on an individual cue A+. When trained on the compound (AB+) and tested on the compound (*M* = 71.5), tested on the individual cue (*M* = 55.2), and tested on the novel compound (*M* = 53), a significant learning decrement was experienced, $t(22) = 2.2$, p = .03; $t(22) = 2.9$, p = < .01. Additionally, when trained on the irrelevant novel cue compound, there was no significant differences between An+ (*M* = 53) and A+, indicating novelty did not influence learning, but, when adding a cue to make compound (AB+), there was a significant difference between A+ and AB+, indicating a possible summation effect in the irrelevant novel condition, only, $t(22) = 2.6$, p = < .01

	AB(+)	**A(+)**	**An(+)**
A+/B-	78.4	71.2	61.9
AB+/CD-	71.5	55.2	52.9
An+/Bn-	66.3	44.4	53.0

Table 3. Mean associative rating scores.

Experiment 2: Auditory-Visual Condition

Mean discrimination scores were collected and calculated into discrimination accuracy by task type and trial. To calculate discrimination accuracy, the proportion of non-reinforced responses (false alarms) were subtracted from reinforced responses (hits). Mean discrimination accuracy scores are shown in Figure 3.

Contrary to previous research, participants generally found negative and biconditional patterning easier than positive patterning. Interestingly, the irrelevant cue condition experienced much higher accuracy in discrimination than the complex tasks, such as negative patterning and biconditional discriminations, which were about equally as difficult to discriminate.

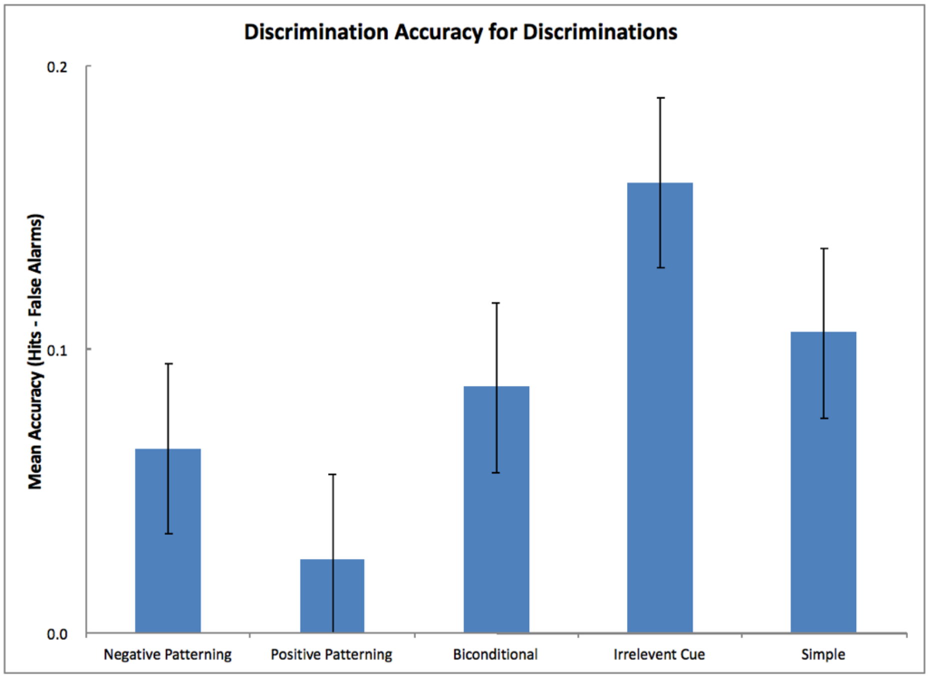

Figure 3. Mean accuracy across trials in Experiment 2 for discrimination task negative patterning, positive patterning, biconditional, irrelevant cue, and simple discrimination with irrelevant novel cue). Standard errors are represented in the figure.

Participants also learned the discrimination tasks at a much slower rate than in corresponding visual-visual conditions from other studies in our lab. Initial analysis was conducted using a repeated measures ANOVA with factors of trial types (negative patterning, positive patterning, biconditional, irrelevant cue, and simple discrimination with irrelevant novel cue). For Experiment 2, the repeated measures ANOVA did not find significant effects between discrimination types, $F(4,100) = 2.189$, $p = .07$. However, this seemed to reflect a longer period during which participants were not showing reliable discriminations than has been true in past research in our laboratory. Restricting attention to the last 7 trials only, there was a significant effect of discrimination type, $F(4, 100) = 3.052$, $p < .05$. This indicates participants would require a much larger amount of trials to learn the individual discriminations. Further analysis of discrimination tasks indicates when compared to the irrelevant cue task, participants learned all tasks poorly. Irrelevant cue discrimination received more correct responses than negative patterning, $t(25)=2.86$, $p=.01$, positive patterning $t(25)=2.49$, $p = .02$, biconditional $t(25) = 2.10$, $p = .05$, and novel irrelevant cue discrimination $t(25) = 2.10$, $p = .05$. Figure 4 illustrates mean proportion of predictions of brain seizures across 12 learning trials by discrimination type.

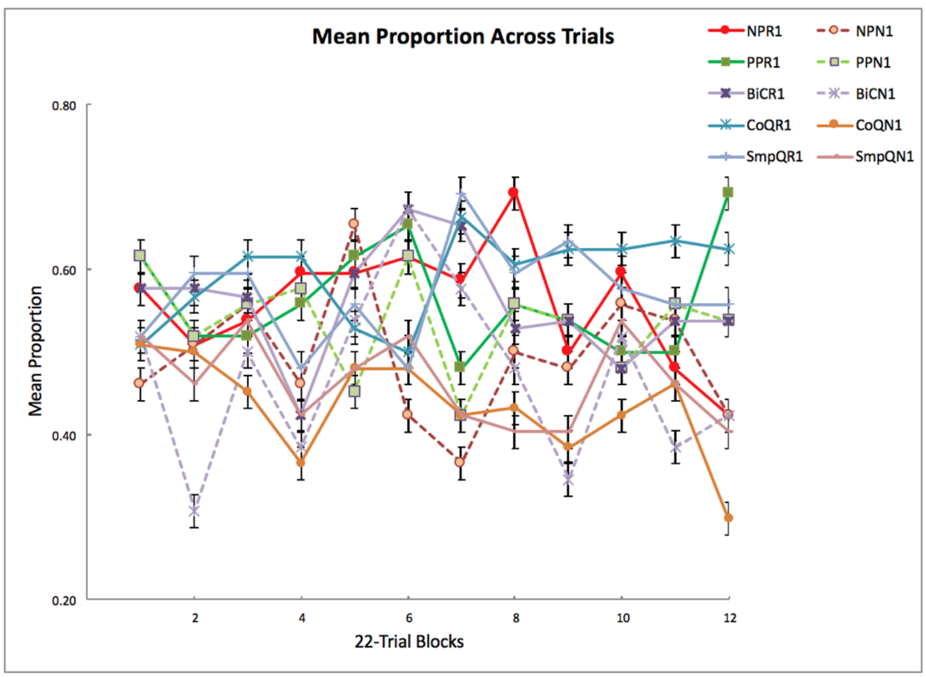

Figure 4. Mean accuracy across 6 training blocks for Experiment 2. Negative patterning reinforced and non reinforced, positive patterning reinforced and non reinforced, biconditional reinforced and non reinforced, irrelevant cue reinforced and non reinforced, and simple discrimination with irrelevant cue reinforced and non reinforced. Standard errors are represented in the figure.

Direct Comparison Analysis of Visual-Visual and Visual-Auditory Processing of Irrelevant Novel Cue Discriminations

Both experiment 1 and experiment 2 measured participants' learning on a simple discrimination with an irrelevant novel cue component. In experiment 1, participants learned a novel irrelevant cue discrimination M =.13 In experiment 2, participants learned the same cue discrimination in the simple discrimination task in the first six trials, M =.05, and the last 6 trials, M =.16. Albeit, not significantly different between the first 6 trials, $t(48)=1.23$, $p > .05$. However, further analysis of the last half of trials of experiment 1 (trials 4, 5, and 6) and the same trials in experiment 2, there was a significant difference between the experiments and learned discriminations, $t(48)= 5.97$, $p < .01$.

Discussion

The aim of this study was to compare learning rates between a visual-visual discrimination task and a visual-auditory discrimination task. It was hypothesized that when using multiple sensory channels (i.e. auditory stimuli and visual stimuli), auditory-visual compounds will be more difficult than visual-visual compounds to learn during a discrimination task. Overall, findings support visual-visual discrimination that require configural cues were more quickly learned than auditory-visual discrimination tasks. This is consistent with a view that there is less configural information in initial multi-sensory information processing.

The visual-visual condition was learned across 6 trial blocks, with 20 trials in each block. Overall, the results indicate when trained on an individual cue (A/B+) or a compound cue (EF+) similar mean accuracies were achieved. This indicates individual and compound cues are treated similarly in the salience of each cue. The associative rating measure showed when trained on an individual cue, (A+) and tested on a compound, (AB+), no significant differences were experienced. Thus, no summation effect was experienced and findings were consistent with Pearce's model of associative learning. When trained on the compound (AB) and tested on the individual cue (A) or the novel compound (An), A and An had similar means which were significantly less than the compound mean. These results show support for a generalization decrement which would be predicted in both Pearce's model and in the Rescrola-Wagner model. These findings are consistent with previous research that indicates that adding cue N does not influence learning (Whitlow & Otero, 2018), but, does show support for generalization between cues. However, results indicated there is a possible summation affect in the irrelevant novel condition. Participants tested on the novel compound (An) and the single cue (A) treated these cues as similar conditions. When adding a cue to make AB, participants rated this compound with a higher mean associative rating than An or A. This could indicate a summation effect in the novel condition, only.

The auditory-visual task was comprised of 12 trials blocks and 22 trials in each block. Participants struggled to learn each of discrimination tasks adequately as there were no significant differences between discrimination tasks. However, further analysis showed that participants required several training blocks before a significant effect could be determined. This was evident in comparing all 12 training blocks to the last 7 training blocks.

Comparing the visual-visual and auditory-visual experiments on the novel irrelevant cue discrimination task showed a clear, distinct learning rate by trial. Participants in the visual-visual condition required only 6 learning blocks to distinctly learn the novel irrelevant cue. However, participants in the first 6 learning blocks of the auditory-visual condition indicated minimal learning, whereas the last 6 learning blocks, learning was comparable to the visual-visual condition.

Previous research on discrimination tasks indicate negative patterning should be more difficult to learn than positive patterning and biconditional (Delamater, Garr, Lawrence, & Whitlow, 2016). In a traditional model of learning, negative patterning and biconditional should be most difficult to learn because it relies on configural cues to distinguish the pattern of information. Positive patterning might be easier to learn because it does not need to rely on configural cues, leading to a positive pattern advantage (Thorwart et al., 2016). However, in this study there were no significant differences between these discrimination tasks and did not reflect this traditional pattern of learning. These results indicate multi-sensory cue compounds are much more difficult to discriminate when compared to a single sensory cue. Using novel cues as a measure, this study showed a clear deficit between learning rates in single sensory and multi-sensory discrimination tasks. These results, when compared to previous research in our lab on visual-visual cues, indicate auditory-visual cues require a much larger amount of trials to be sufficiently learned. It would be expected that over more trials, a larger distinction between tasks would be experienced.

In the case of this study, results could be interpreted as the irrelevant cue discrimination was treated as a novel condition, much like the simple discrimination. The results within this study would be consistent with previous research in that novelty was treated as a feature in these particular tasks and developed higher associations than the reinforced stimuli (Beckman & Young, 2007).

The overall difficultly of the task could be due to similarity of the cues. Previous research on the similarity of cues indicates cues can interfere in some circumstances, particularly in extremely difficult tasks (Morey & Cowan, 2004). The results of this study could support this motion. Additionally, very few studies on associative learning and discrimination tasks use auditory-visual word cues, but several studies have indicated other types of learning benefit from audio-visual stimuli (Seitz et al., 2006). It could be that it could take longer to draw a similar sensory associative memory when compared to other forms of memory, but additional studies would need to be conducted to explore this comparison further. Significant differences in learning rates were experienced between 4 of the discrimination tasks (negative, positive, biconditional, and simple) and irrelevant cue. Previous research on discrimination tasks would predict positive patterning and irrelevant cue should be easier to learn than negative and biconditional patterning (Delamater et al., 2016). Because the auditory-visual task was difficult to learn, this could be why anticipated results were not experienced.

Overall, this study indicates a clear distinction between discrimination pattern learning using visual and auditory cues. Auditory-visual discrimination task learning required more trials than the visual-visual task. The results of this study indicate in associative learning tasks, auditory-visual cues require more trials to adequately learn. This study yields support to the notion that a multisensory advantage could be context dependent. Additionally, the comparison between audiovisual-visual visual condition shows support that while audio-visual learning required more trials to adequately learn, after training trials are completed, the audio-visual condition may have started to have an increased performance. This could imply audio-visual may have an additive effect after several learning trials.

Appendices A1:

Acknowledgment of Informed Consent

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 approximately 1 hour, as specified on the sign-up sheet. This study is part of a research program that will enroll approximately **45** participants.

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 unidentifiable 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, 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 Dr. J.W. Whitlow, Jr. of the Psychology Department, 311 N. Fifth Street, Camden, NJ 08102, by phone at (856) 225-6334 or by email at bwhitlow@camden.rutgers.edu; I can also contact Ms. Jackie Dunn of the Psychology Department at (856) 225-6520. I also understand that should I have any questions about my rights as a research subject, I can contact:

Institutional Review Board

Rutgers, The State University of New Jersey

Liberty Plaza/ Suite 3200

335 George Street, 3rd Floor

New Brunswick, NJ 08901-8559

Tel: 732-235-2866 Email: human-subjects@ored.rutgers.edu

Participant

Date: ____________________ Signature: ________________________

Investigator

Date: __________________________ Signature: ________________________

This informed consent form was approved by the Rutgers Institutional Review Board for the Protection of Human Subjects on 10/24/18.

A2: Instructions

Clinical Judgment Studies – Imagery and Seizures (CAUSAL 860+)

Dear Participant:

This experiment is part of a research project that seeks to understand how we learn about the thought processes of others. One source of information about the thinking of others can be found in the thoughts they express and in the way they combine different thoughts. Obviously, deciding how to think about people based on the particular thoughts they express is a complex process in which we often have to learn how to interpret the various thoughts and thought patterns that someone describes. Nonetheless, despite its difficulty, the problem is one we encounter frequently in our day-to-day lives, whether we consider our families, our friends, our co-workers, or simply a group of people at a gathering. It is also a problem that clinicians encounter in their professional practice.

Because we are social creatures, we presumably know how to arrive at reasonable interpretations much of the time. However, the details of how people make this kind of judgment and the factors that make such judgments easier or harder are not well understood. This research is designed to help us understand the process better. The duration of this study will be approximately 1 hour.

We appreciate your participation in this study.

Instructions

1. In this experiment you will be playing the role of a psychologist working with young clients. For example, one client is a boy named Jimmy and another client is a girl named Jenny. Jimmy and Jenny (and their parents) have agreed to be part of a study of brain activity. Specifically, the study is designed to see if certain thoughts or thought combinations predict a particular pattern of brain activity that signals the onset of mild seizures. These seizures can be seen in brain activity but are below conscious awareness, so a person will not know they are occurring. However, the seizures can still affect thought, feelings and behavior, and they often give rise to full blown seizures that are very disruptive. Your goal is to learn which thoughts or thought patterns predict these mild seizures, so you can instruct your client in how to take anticipatory action to prevent a full blown seizure.

2. You will be presented with a series of displays or sounds in which a pair of objects is named, which means that the child is thinking about those two objects. Your task is to learn whether those thoughts predict mild unconscious seizures for the child. Thus, you will see or hear a pair of nouns, and you will be asked to predict whether the child will have a seizure. After you make your prediction, you will receive feedback about the outcome: whether the child had a mild seizure or not. For example, you might see a display or hear a pair of words for Jimmy like this:

Ostrich

Cantaloupe

This would mean that Jimmy is thinking about an ostrich and a cantaloupe. Your task is to predict whether having one or both of those thoughts signal the onset of a mild seizure. After your prediction, the actual outcome will be shown. For example, if thoughts of either of the two objects were a precursor of a seizure, you would see the message:

"Outcome of these thoughts was MILD BRAIN SEIZURE ACTIVITY!"

If neither of the thoughts signaled a seizure, you would see the message

"Outcome of these thoughts was no change in brain activity."

After a short pause, you will be presented with a new series of displays or sounds. You will see or hear names of two more objects and have to make the same kind of prediction: whether thoughts about one or both of the objects signal the onset of mild brain seizure activity. This process will continue for a block of 22 trials, after which you will be informed about your average score of correct predictions before you start another block of prediction trials.

3. After the first block is completed, you may see or hear some of the same thoughts as well as some new thoughts; however, your task remains the same, which is trying to learn which thoughts predict seizures and which do not. In some cases, only one particular thought may signal the onset of seizures regardless of what the other thought is; in other cases, two thoughts may signal a seizure when they occur together but not when they each occur as a new pair with another thought.

4. You will be tested at various points as you go through the examples. These tests are intended to provide us with information about what you have learned, and it is important that you provide this information as accurately as you can.

5. You will be asked to make two separate types of judgments about seizure activity signals:

One type of judgment you will be asked to make is to predict whether particular thoughts or thought combinations signal seizure activity.

For this judgment, respond with "1" to indicate " mild seizure activity",
"2" to indicate "no seizure activity"

Note that you will be asked to make these judgments right at the beginning of the experiment, so at first you will have to guess what thoughts or thought combinations predict seizures, because you won't know. As you get more experience, you will start to learn which thoughts and thought combinations signal seizure activity and will not need to guess.

From time to time, the end of a series of prediction judgments will be followed by a series of judgments of a different type. For this other type of judgment, you will be asked to make to judge the strength of the association between a thought or pair of thoughts and mild seizure activity. To make these judgments, **use a scale of 0 to 100**, as shown at the top of the next page.

Use the number to express your sense of the strength of the relation to seizure activity, where *0* means that there is no relation to seizure activity and *100* means there is an extremely strong association with seizure activity.

For example, if your sense was that a particular thought or pair of thoughts had a strong association with seizure activity, you might enter ‘75' or ‘80’, whereas if your sense was that the thought or the pair of thoughts had a weak association with seizure activity, you might enter ‘15’ or ‘20’. If the association was extremely strong, you might enter ‘100’, and if you thought the association was extremely weak (or not even present), you might ‘0’.

Note that for this task you have to think back over all the prediction trials you saw earlier.

5. Please use the *number keys* at the top of the keyboard to enter your responses to each question type. Use the *backspace key* if you make a mistake or accidentally enter a number you did not intend.
6. At the end of the experiment, you will see a message stating

This experiment is over. Thank you.

7. Please contact the experimenter, who will ask you some questions about your experience during the task. The experimenter will also be happy to answer any questions you may have.

8. Strength of Signal for Seizure Activity Scale

100	80	60	40	20	0
Very Strong	Strong	Moderately Strong	Moderately Weak	Weak	Very Weak

References

Battig, W.F. & Montague, W.E. (1969). Category norms for verbal items in 56 categories: An experiment and extension of the Connecticut norms. *Journal of Experimental Psychology, 80*, 1-46.

Beckmann, J., & Young, M. (2007). The feature positive effect in the face of variability: Novelty as a feature. *Journal of Experimental Psychology: Animal Behavior Processes, 33(1)*, 72-77. doi:10.1037/0097-7403.33.1.72

Brandon, S. E., Vogel, E. H., & Wagner, A. R. (2000). A componential view of configural cues in generalization and discrimination in Pavlovian conditioning. *Behavioural Brain Research, 110,* 67-72.

Delamater, Andrew R., Garr, Eric, Lawrence, Samantha, Whitlow, Jesse W. (2017) Elemental, configural, and occasion setting mechanisms in biconditional and patterning discriminations. *Behavioural Processes*, 137, 40-52. doi:10.1016/j.beproc.2016.10.013

Fifer, J. M., Barutchu, A., Shivdasani, M. N., & Crewther, S. G. (2013). Verbal and novel multisensory associative learning in adults. *F1000Research, 2*, 34. doi:10.12688/f1000research.2-34.v2

Harris, J. A. (2006). Elemental representations of stimuli in associative learning. *Psychological Review, 113(3),* 584-605.

Harris, J. A., Livesey, E. J., Gharaei, S., & Westbrook, R. F. (2008). Negative patternin is easier than a biconditional discrimination. *Journal of Experimental Psychology-Animal Behavior Processes, 34*(4), 494-500.

Kim, R., Seitz, A., & Shams, L., (2008). Benefits of Stimulus Congruency for multisensory Facilitation of Visual Learning (Multisensory Learning). *PLoS ONE*, *3*(1), e1532. https://doi.org/10.1371/journal.pone.0001532

Mclaren, I. P. L., & Mackintosh, N. J. (2002). Associative learning and elemental representation: II. Generalization and discrimination. *Animal Learning & Behavior, 30,* 177–200. http://dx.doi.org/10.3758/BF03192828

Morey, C. C., & Cowan, N. (2004). When visual and verbal memories compete: Evidence of cross-domain limits in working memory. *Psychonomic Bulletin & Review, 11*(2), 296-301. doi:10.3758/bf03196573

Pearce, J. (1987). A model for stimulus generalization in Pavlovian conditioning. *Psychological Review, 94*(1), 61-73.

Quak, M., London, R., Talsma, D., & Quak, M. (2015). A multisensory perspective of working memory. *Frontiers in Human Neuroscience*, *9*, 197–197. https://doi.org/10.3389/fnhum.2015.00197

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. K. Prokasy (Eds*.), Classical conditioning II* (pp. 64–99). New York, NY: Appleton-Century-Crofts.

Seitz, A. R., Kim, R., & Shams, L. (2006). Sound Facilitates Visual Learning. *Current Biology, 16*(14), 1422-1427. doi:10.1016/j.cub.2006.05.048

Shams, L., & Seitz, A. (2008). Benefits of multisensory learning. *Trends in Cognitive Sciences*, *12*(11), 411–417. https://doi.org/10.1016/j.tics.2008.07.006

Soto, F. A., Gershman, S. J., & Niv, Y. (2014). Explaining compound generalization in associative and causal learning through rational principles of dimensional generalization. *Psychological Review, 121*(3), 526-558. doi:10.1037/a0037018

Soto, F., Vogel, E., Castillo, R., & Wagner, A. (2009). Generality of the summation effect in human causal learning. *Quarterly Journal of Experimental Psychology, 62(5),* 877-889. doi:10.1080/17470210802373688

Tanabe, H. C. (2005). Functionally segregated neural substrates for arbitrary audiovisual Paired-Association Learning. *Journal of Neuroscience, 25*(27), 6409-6418. doi:10.1523/jneurosci.0636-05.2005

Thorwart, A., Uengoer, M., Livesey, E.J., Harris, J.A. (2016) Summation effects in human learning: evidence from patterning discriminations in goal-tracking. *The Experimental Psychology Society, 70*, 1366-1379.

Van Overschelde, J.P., Rawson, K., & Dunlosky, J. (2004). *Category norms: An updated and expanded version of the Battig and Montague (1969) norms.* Journal of Memory and Language 50, 289–335. doi:10.1016/j.jml.2003.10.003

Wagner, A. R. (2003). Context-sensitive elemental theory. *The Quarterly Journal of Experimental Psychology, 56*, 7–29.

Wagner, A. R., & Brandon, S. E. (2001). A componential theory of Pavlovian conditioning. In R.R. Mowrer & S. B. Klein (Eds.), *Handbook of contemporary learning theories* (pp. 23–64). Mahwah, NJ: Erlbaum.

Whitlow, J.W. & Otero, K. (2018, March) *A study of novelty and microelements in associative learning.* Poster presented at 2018 Annual Meeting of the Eastern Psychological Association, Philadelphia, PA.

Wills, A. J. (2005). *New Directions in Human Associative Learning*. New York: Lawrence Erlbaum.

Young, M. E., Wasserman, E. A., Johnson, J. L., & Jones, F. L. (2000). Positive and negative patterning in human causal learning. *The Quarterly Journal of Experimental Psychology B: Comparative and Physiological Psychology, 53*, 121–138. http://dx.doi.org/10.1080/713932723