COMPARING NEGATIVE PATTERNING AND BICONDITIONAL DISCRIMINATION IN A
SIMULATED FORAGING TASK

by

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A thesis submitted to the

Graduate School-Camden

Rutgers, The State University of New Jersey

in partial fulfillment of the requirements

for the degree of Master of Arts

Graduate Program in Psychology

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Camden, New Jersey [January 2013]

ABSTRACT OF THE THESIS

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How humans solve patterning and biconditional discrimination is a topic of continued theoretical debate. Some theories assume that solving negative patterning of A+, B+, AB0 is contingent upon learning to associate outcomes with individual stimuli, whereas others assume the addition of a unique configuration of the compound is needed to solve it. Research in humans has found evidence to support both theories. However, a problem with human associative learning experiments is the use of arbitrary reinforcement stimuli, which may cause humans to use rule-based learning rather than associative learning. This paper reports a study of patterning and biconditional discrimination that uses a novel simulated foraging task in which all trials involve stimulus compounds to provide a clearer test of the competing theories.

Comparing Negative Patterning and Biconditional Discrimination in a Simulated Foraging Task

If given a pair of eyes, a nose, and a mouth, any normally functioning human being will see a face. But what exactly constitutes a face? And why do we no longer observe the eyes, nose, and mouth in isolation when they are presented simultaneously? Is the product of a face embedded into each individual facial feature, and is only conceptualized after a certain sum of individual facial features reaches a threshold? Or do we treat faces as unique stimuli, as something completely distinct from individual facial features? Faces can be thought of as representations from a pattern of information. Take away the pair of eyes or the mouth, and a face will likely not be readily observable. So, how does the brain create configurations, such as a face, from a pattern of otherwise isolated stimuli? The answer may lie in how humans associate outcomes with individual stimuli versus stimuli in compound.

A challenge to associative learning researchers is to explain how animals solve negative patterning and biconditional discriminations (Pavlov, 1927; Rescorla, 1972; Saavedra, 1975; Whitlow & Wagner, 1972; McLaren & Macintosh, 2002; Harris & Livesey, 2008). Because each discrimination cannot be solved by linear properties they are particularly unique. In patterning discriminations, individual stimuli and their compound are each paired with outcomes. In positive patterning, the individual stimuli are not reinforced, whereas the compound of the same stimuli is reinforced (A0, B0, AB+). In negative patterning, the individual stimuli are reinforced, whereas the compound is not reinforced (A+, B+, AB0). In a biconditional discrimination, four stimuli are presented in compound in such a way that each individual stimulus is both

reinforced and non-reinforced (CD+, EF+, CE0, DF0). A stimulus is anything that represents a detectable change in the environment, which influences or causes a temporary increase of physiological activity or response. In experiments involving non-human animals, auditory and visual cues are normally used as stimuli. For example, researches designate cue A as an auditory stimulus (usually a specific tone), and cue B as a visual stimulus (a light), creating a fundamental modal distinction between each stimulus. The compound AB occurs when the auditory and visual stimulus are given simultaneously. It has long been documented since Spence (1937) that when a stimulus is paired with reinforcement, the animal will learn to respond more to that same stimulus in the future. In the example above, a rat will learn to respond more to the light if it is paired with reinforcement (A+), than if the light was paired with non-reinforcement (A0). Thus, reinforced stimuli are said to develop excitatory strength, whereas non-reinforced stimuli develop inhibitory strength.

The non-linear property of patterning and biconditional discriminations reflects the fact that they cannot be solved by a process that distributes excitatory and inhibitory associative strength according to a simpler linear combination rule to the stimuli as a whole. According to such a rule, for example, in negative patterning (A+, B+, AB0), the compound AB should acquire the summed excitatory strengths of both A+ and B+, in which case, the animal should not be able to learn not to respond to the non-reinforced compound AB0. Similarly in the biconditional discrimination (CD+, EF+, CE0, DF0), because each individual stimuli is paired with both a reinforced and non-reinforced outcome, the animal should never be able to solve this discrimination if excitatory and inhibitory strengths are combined in a linear fashion. Most

vertebrates can solve these discriminations, however, which have lead researchers to develop associative learning models that have components mich can combine excitatory or inhibitory associative strength in non-linear modes (Rescorla & Wagner, 1972; Pearce 1994; McLaren & Macintosh, 2002; Harris, 2006).

The components that animals use to solve complex discriminations are adopted from stimulus sampling theory (Estes, 1950), which treat stimuli as a large, but finite number of stimulus elements. To illustrate this point, when we see a digital picture we believe we are seeing a complete representation of that picture (figure 1), but instead what we are seeing is a series of pixels that make up that representation (figure 2).

Figure 1: Digital representation of a persimmon

Figure 2: Pixelated representation of a persimmon

In this analogy, stimulus elements are represented by pixels, whereas the stimulus as a whole is represented by of the digital picture. In this theory, it is the stimulus elements that can develop excitatory or inhibitory strength when the stimulus is paired with an outcome. These elements have been classified into four classes, namely, common elements (McLaren & Macintosh, 2000), replaced elements (Wagner, 2003), distinctive elements (Wagner, 2003), and configural elements (Pearce, 1994). How these elements are used in solving negative patterning and biconditional discriminations has been a topic of debatethat has divided researchers into opposing

camp: Researchers that model learning with the use of configural elements, and researchers who do not.

A popular solution to solving negative patterning and biconditional discrimination, described first by Spence (1952), asserts that the presentation of two stimuli together constitute more than the sum of its parts. Two stimuli in compound represent a new unique configural pattern in addition to other stimulus elements. A stimulus element that exists in compound, but not in individual stimuli is noted as a configural element. In using lights and tones as an example, it is reasonable to assume that there are some properties that exist only in compound. For example, a compound represents a sense of “twoness” that is absent in individual stimuli, because the compound represents a pair whereas the individual stimuli do not. There are also examples of configural learning in comparisons between global and local processing (Wills, A. J., Graham, S., Koh, Z., McLaren, I. P., & Rolland, M. D. (2011). Eyes, a nose, a mouth are all features that can be singled out using local processing, but when observing all of these features at once, on a global scale, a face emerges. There is no sense of a face when observing eyes or a nose individually, but it becomes observable when we view these features in a compound. Whatever the configural element may be, theories that use configural cues to solve negative patterning assume that an animal must learn to develop an inhibitory association with the configural element to offset the summed excitatory strength of the compound. Thus, negative patterning can be conceptualized as $(A+, B+ ABx0)$, in which “x” represents the configural element. Using our example of faces and their individual features, suppose stimulus A is a mouth and stimulus B is a nose. You receive reinforcement when the mouth is

presented (A+), and then receive reinforcement when a nose is presented (B+). After these features are presented individually, you receive them in combination with no reinforcement (AB0). The compound AB reveals the “face,” which was not present in “nose” or “mouth” individually. Configural theory argues that in order to learn not to respond to ‘AB0’ the configural element (face) needs to develop enough inhibitory associative strength to offset the summed excitatory strength of the individual reinforced features nose (A+) and mouth (B+). In the biconditional discrimination (CD+, EF+, CE0, DF0), because each stimulus is in compound, there are essentially four configural elements attached to each. The configural elements that are paired with the reinforced compounds become offset by the configural elements paired with non-reinforced compounds. Thus, the biconditional discrimination can be conceptualized as (CDx+, EFx+, CEx0, DFx0), in which, again, “x” indicates the configural element. This leads the biconditional discrimination to be solved much more quickly than the negative patterning discrimination.

Elemental theories rely on the assumption that configural cues are not necessary to solve negative patterning. Because of this assumption, they make drastically different predictions about complex discrimination learning difficulty. Elemental theories propose that compound stimuli are represented solely by its stimulus elements. Using the facial features example, negative patterning is solved solely by learning associations between the individual features (nose and mouth). The concept of a face is not needed to solve the discrimination. An elemental theory proposed by McLaren and Macintosh (2002), assumes that stimuli are made up of distinctive and common elements. In this particular model, McLaren and Macintosh

argue that stimuli can share at least 50% of their features in common. A nose and a mouth, then, share at least 50% of their features. These common features may be the fact that they are distinguishing features that make up a face, they are close to each other in proximity, or they are both orifices. Negative patterning can be solved if common elements acquire excitatory strength and distinctive elements acquire inhibitory strength. Recently, Harris and his colleagues developed a new model which asserts common, distinctive, and suppressed or replaced elements to solve negative patterning and biconditional discriminations (Harris & Livesey, 2008; Harris, Livesey, Gharaei, & Westbrook, 2008; Harris & Livesey, 2010). In this model, elements compete directly for attention. This competition designates elements as winner and losers, in which winning elements become more salient and losing elements become weak. Access to attention is an all or nothing system, and the attention network changes between compound and individual trials. Compound trials create a greater number of stimulus elements, which produces more competition for attention. In the non-reinforced negative patterning compound, the nose and mouth are battling for attention, with more salient elements entering the “attention buffer,” and weaker elements becoming suppressed. Negative patterning can then be solved by the weaker suppressed elements in the compound developing inhibitory strength, and the more salient elements acquiring excitatory strength. Harris & Livesey (2012), use a normalizing model of attention (Reynolds & Heeger, 2009), in which gain control plays an important role in determining element salience. Under this model the biconditional discrimination should be much harder to learn than negative patterning; a prediction that is congruent with other elemental models (McLaren and

Macintosh, 2002), but not with models that invoke configural elements (Pearce, 1994).

Comparing Negative Patterning and Biconditional Discriminations

In Harris and Livesey (2008), human participants were presented with positive patterning, negative patterning, and biconditional discrimination in a task in which a hangover served as reinforcement. They were asked to make predictions about which specific wine bottle was causing a fictitious person a hangover. For the negative patterning discriminations, participants received the names of individual wine bottles which were reinforced with a hangover (A+, B+), and then showed the combination which was non-reinforced with no hangover (AB0). The biconditional discrimination was presented in all compounds with each stimuli being both reinforced and non-reinforced depending on the trial (CD+, EF+, CE0, DF0). In this study, Harris and Livesey found that negative patterning was easier to learn than the biconditional discrimination, results that are consistent with their model and other models that offer complex discrimination solutions without the use of a configural element.

A problem with this comparison is that all stimuli in biconditional discriminations are stimulus compounds, whereas stimuli in patterning discriminations involve a contrast between individual stimuli and their compound. As discussed above, elements may operate differently in compound as opposed to when they are in isolation. Thus, drawing a comparison between negative patterning and biconditional discrimination may be complicated by this discrepancy.

The present study incorporates a novel design which uses compounded stimuli in all patterning discriminations. The procedure uses two stimuli on every trial, corresponding to two inputs for a logical dyad. In positive and negative patterning, the stimuli of interest are compounded with novel stimuli on each trial. Negative patterning, for example, can then be conceptualized as $Aw+$, $By+$, $AB0$, where the italicized lower case letters represents novel stimuli and the capitalized letters (A and B) represent the stimuli of interest. With this new conceptualization, the features of negative patterning are retained, while the novel stimuli represent benign features that do not disrupt the associative strengths of the pattern. This particular design also simulates an experience in which participants must extract features from the environment, forcing them to tease out novel stimuli with the stimuli that are causing a particular outcome.

Implicit vs. Explicit Learning and Discrimination Learning

Learning to categorize and associate stimuli with certain outcomes is an important learning mechanism because organisms need to make predictions about their environment in order to survive. Organisms must be able to identify mates or within group members. Some environments harbor dangerous predators, whereas others are abundant with healthy good. Following a specific direction may lead to plentiful food and water, or a safe place to raise young, whereas other directions might lead to inhabitable land with scarce resources. Organisms that are able to rapidly learn the consequences of specific environmental outcomes will ultimately be better able to adapt to their environment and survive longer than those that cannot. Because of these reasons, categorization learning has played an important role in the

evolution of animals, and has been a focal point in animal and human learning (Ashby & Maddox, 2011; Nosofsky, 1987; Lazareva & Wasserman, 2010; Pearce, 1994).

In human learning, researchers have found two levels of categorization learning (Smith, Berg, Cook, Murphy, Crossley, Bomer, Spiering, Beran, Church, Ashby, & Grace, 2012; Reber, Kassin, Lewis, & Cantor, 1980). Implicit learning allows organisms to make generalizations about environmental features by the use of associative learning. This system is useful for extracting features of the environment and processing them into configural representations. Explicit learning appreciates stimuli using sharply focused attention on the features of a stimulus. This system is assumed to rely heavily on working memory and executive functions. Using facial examples, implicit learning uses an exemplary approach when observing a face, in which it views it holistically. In this example, implicit categorization learning will readily identify a face rather than its component parts such as nose and eyes. In explicit learning, the nose and eyes will be the central focus of the observation, and the structure that configures to a face will not readily available. Some researchers suggest there are individual differences in the use of implicit vs. explicit learning in humans (Byrom & Murphy, in press), and which one of these approaches they use is contingent upon the nature of the task. The present study requires participants to make predictions based upon combinations of stimuli, which may encourage them to use a more holistic approach in making their predictions.

Deliberative and Non-Deliberative Processes

Cognitive scientists have also found it useful to distinguish between two different classes of learning, namely, deliberative and non-deliberative cognitive

processes (McLaren, Green, & Mackintosh, 1994; Brooks, 1978; Kahneman, 2003).

Deliberative processing consists of the ability to learn structures or rules that govern phenomenon in the world. On the other hand, non-deliberative processing is an exemplary based system that is said to rely on associative learning because the rules governing a given system are not readily observable (Wills, Graham, Koh, McLaren, & Rolland, 2011). A non-deliberative system is helpful when there are not apparent rules governing a system because it allows us to make predictions based upon associations between stimuli and their outcomes. If milk and cheese makes one feel sick, but not chicken or pasta, then it is likely that this particular person will begin avoiding milk and cheese. This type of learning is caused by simple associations between milk and cheese (the stimuli) with the outcome of feeling sick. However, it might not be readily apparent what is causing the sickness feeling to occur, or if the quantity or time of day is causing the sickness. It may be the case that one slice of cheese does not cause an upset stomach, but two slices does. Or perhaps whole milk causes an upset stomach, but skim milk does not. Trial and error in an exemplary based system like that described above will eventually allow the sick victim to have a working knowledge of which foods to avoid and which to eat. However, perhaps before he feels any symptoms, a doctor indicates that he lacks a lactase gene and is lactose intolerant. The doctor advises him to avoid all dairy products, including milk and cheese. Now, there is a deliberative rule in place that governs his eating habits: avoid all dairy. This rule allows him to make predictions about food without making associations between food and outcomes.

An interesting feature of Harris and Livesey (2008) is, as mentioned before, they used a study test paradigm which had both individual and compound stimuli. The problem with this arrangement is that a rule now governs the patterning discriminations. This rule is known as the *opposites rule* (Young, Wasserman, Johnson, & Jones, 2000). Human participants can deliberately learn that in order to solve the patterning discriminations, one needs only to understand that the outcome for the individual stimuli (reinforced or non-reinforced) will always be the opposite outcome of the compound. If this is the case, Harris and Livesey (2008) are not accurately testing associative learning, non-deliberative processing, but instead are testing how well participants can learn an opposite rules vs. the biconditional discrimination. Under these conditions, negative patterning will be much easier to learn than the biconditional discrimination because the biconditional discrimination cannot be learned by an opposites rule. By compounding all stimuli, the present study ensures that human participants will always use a non-deliberative, associative learning process because the patterning discriminations cannot be solved by an opposites rule, or any other rule based learning system.

Comparing Human and Non-Human Animals

Most theoretical models of associative learning assume vertebrates, including humans, have generally the same learning processes, and researchers should find a great deal of consistency across species (Rescorla & Wagner, 1972; Harris & Livesey, 2008). However, in the laboratory, different methodologies need to be used to accommodate different species for ethical and practical purposes. For example, laboratory procedures for rats involve using foods as a stimulus reward or

foot shock as punishment. These deliveries last for several days, with the rat confined to a cage for the duration of the experiment. In human associative learning experiments, participants engage in computer simulating task for about an hour, and receive some form of arbitrary award for participation. For example, Harris and Livesey (2008) used a hangover/no hangover reinforcement schedule for participants. Whitlow and Loatman (in preparation) had participants judge actor and actress performance chemistry, with “good chemistry” outcomes used as reinforcement, and “no chemistry outcomes” used as non-reinforcement. These human experiments are fundamentally different from experiments with non-human animals. Most non-human animal discrimination learning experiments use study tests that tap into the critical elements of survival, such as food, fear, and motivation. In a sense, the animal’s survival becomes contingent upon what it learns throughout the duration of the experiment. A wrong answer may elicit a powerful foot shock or a withdrawal of food, whereas a correct answer may yield a food pellet and a safe environment free of electrical shocks or the presentation of predators. When an animal understands that its survival is dependent upon correct and incorrect response, it is likely that it will treat stimuli differently than a human participant in a computer simulation with arbitrary tasks. It is reasonable to assume, then, that the human participant does not receive the same parasympathetic reaction to the computer stimulated responses when compared to experiments with rats.

To help engage participants, the present study asked to play the role of a survivalist lost in a foreign territory. They had to learn which foods were safe to eat

and which were poisonous. They were also given a health-bar that monitored their health throughout the experiment, which served as a function of their prediction accuracy. With this implementation, the experiment functioned much like a video game. Video games that are goal driven generate increases in arousal (Fleming & Rickwood, 2001), and can enhance visual and attention skills (Dye et. al., 2009). Under these conditions, by shaping the experiment in the form of a video game, participants may be more motivated and engaged in this task than previous experiments on humans.

IRB Submission

The Institutional Review Board at Rutgers University, New Brunswick, accepted this proposal on February 28th, 2012. The IRB documents are attached at the end of this document.

1. Experiment 1

Experiment 1 provided a comparison of negative patterning, positive patterning, and biconditional discriminations using a task that ascribes a novel stimulus to the stimuli of interest. The display on each trial showed a pair of plant pairs, with the arrangement of pairs following the design shown in Table 1. The two primary questions of interest was whether the positive patterning discrimination would be easier than the negative patterning discrimination (Whitlow, 2010) and whether the biconditional discrimination would be easier to learn than negative patterning, as predicted by the Rescorla and Wagner (1972) model and by the Pearce (1980) model, or would be harder to learn, as predicted by Harris (2006, 2012). The present study incorporated a similar methodology in Whitlow and Loatman (in preparation), but used a task that simulated foraging behavior and included a

secondary reinforce (health bar). It was hypothesized that the results from this study will be consistent with theories that invoke a configural cue to learn the negative patterning condition.

1. Method

Participants: Approximately 25-30 students from the introductory psychology classes will participate in a session of about 55 minutes as partial fulfillment of a course requirement.

Stimulus Materials: A set of approximately 300 plants were constructed from various wilderness survival guides. E-Prime, a product from Psychology Software Tools will be used for testing. Stimuli will be presented as text only. Participants will be tested on dell computers. Names of the plant pairings will be presented as individual items and compounds, with one name above the other. Across subjects, stimuli will be assigned to conditions to ensure that each will be used in positive patterning, negative patterning, and biconditional discrimination in both the poisonous and non-poisonous outcomes.

Study Design: The design of the experiment is shown in table 2. Three discrimination tasks comprising negative patterning, positive patterning, and biconditional discriminations were presented to every participant in a block of 20 displays. Each display contained a pair of plants, and the participants' task was to judge whether the pair in the display was poisonous or non-poisonous. Participants viewed a total of 340 pairings, distributed across 18 blocks, and 8 displays served as baseline pairs, which were non-reinforced novel stimuli. These pairs are designated *mn0*, *op0*, *st0*, *uv0* in table 1.

For the negative patterning pairs, two plant foods were selected to be poisonous whenever they were paired with newly introduced names, but never when they were paired

with each other. These pairs can be conceptualized as Az+, By+, AB0 with the lowercase z and y referring to the novel stimuli, and A and B referring to the discrimination stimuli.

For the positive patterning items, two plant foods were selected to be poisonous only when they were paired with each other but never when they were paired with novel stimuli. These pairs are designated Cw-, Dx-, CD+ with the lower case w and x referring to the novel stimuli, and C and D referring to the discrimination stimuli.

For the biconditional discrimination, four plants were selected and paired in four possible combinations. Two pairs are reinforced, whereas two pairs are non-reinforced. These pairs are designated as EF+, GH+, EH- and GF-. It is important to note that the biconditional discrimination does not contain novel stimuli.

Procedure: At the start of the session, participants were seated comfortably in front of a computer screen in a laboratory, and given an instruction booklet explaining the nature of the tasks they were to perform. After participants read the instructions, the experimenter reviewed the task and answered any question before beginning.

Participants proceeded through a sequence of 17 study blocks. The study began immediately following the instructions. Participants were asked to play the role of survivalist lost in a foreign territory. They were told that in order to survive, they must learn which wild plant food pairings were poisonous and which were not poisonous. Participants received 17 blocks of 20 plant names. Each display showed two plant names, and they were asked to predict the outcome of the pairing, with “1= poisonous” and “2= not poisonous.” After their predictions, they were given feedback about the pairing. After 20 displays, the study block ended and a new study block began. The next block began after a delay of 4000 milliseconds. See Table 1.

Health Bar

On the feedback display, participants received a health level that was presented in terms of a percentage. The health percentage was a function of their accuracy across all 17 trials. This health percentage served as a secondary reinforcer, and ensured that the reinforced and non-reinforced outcomes were fundamentally different. In order to make the health homogeneous with the study task, participants were instructed that a poisonous or nonpoisonous prediction was an agreement to either ingest or not ingest the plant. For example, if the participant predicted that a plant was nonpoisonous, then they agreed to ingest the plant. If the prediction was wrong, and the plant was poisonous, then ingestion of plant would yield a health decrease. All participants were instructed that an 80% level of health, which corresponds to an 80% accuracy rate, was necessary to survive. The health bar was displayed on the feedback screen, below the information given about whether or not the previous display was a correct or incorrect prediction.

2. Results

Figure 3 show discrimination differences between reinforced and non-reinforced pairs for negative patterning, positive patterning, and the biconditional discrimination across all 18 trial blocks. Mean scores begin at chance level during trial block 1 at a score of 0, then diverged, with predictions for non-reinforced pairs decreasing towards -1.0 and reinforced pairs increasing towards +1.0. Mean discrimination scores was calculated for each of the three tasks by taking the

difference in predictions for reinforced compared to non-reinforced pairs.

According to the discrimination scores, negative patterning was much more difficult to learn than positive patterning and biconditional discrimination. Positive patterning and biconditional discrimination were learned at similar rates, with a separation of reinforced and non-reinforced trials by Trial Block 5. Negative patterning did not show consistent discrimination between reinforced and non-reinforced trials until Trial Block 15. These results replicate those found in Whitlow and Loatman (manuscript in preparation).

The mean discrimination scores were analyzed in a 4x18 within subject repeated measures ANOVA that had factors of discrimination task (negative patterning, positive patterning, and biconditional discrimination) and Trial Block. The ANOVA showed significant main effects for each factor. The effect of Trial Block yielded $F(17, 152) = 16.204, p < .01$, reflecting the increase in discrimination scores across trials. The Discrimination Task Yielded $F(2, 2) 30.073, p < .01$, reflecting the

poor discrimination score for negative patterning compared to the other two tasks.

There was also an interaction effect between Trial Block with Discrimination Task, $F(34, 594) = 1.548, p < .05$, reflecting the divergence over trials on negative patterning compared to the other two tasks.

To help illustrate the rate of learning in terms of reinforced and non-reinforced predictions, Figure 4 depicts prediction responses for reinforced and non-reinforced outcomes for each discrimination task. In this graph, chance performance is around a score of 1.5. Participants learned to discriminate between reinforced and non-reinforced stimuli more quickly in the biconditional and positive patterning discriminations than negative patterning.

3. Discussion

Experiment 1 compared negative patterning, positive patterning, and biconditional discriminations in which all stimuli were compounded with novel stimuli. Under these conditions, positive patterning and biconditional discrimination were substantially easier than negative patterning, as predicted by configural cue theories like Pearce (1994) and Rescorla and Wagner (1972). This finding is problematic for models such as McLaren and Macintosh (2002) and Harris and Livesey (2010), which either omit or minimize the role of configural elements. Figure 5, 6, and 7 Pearce's (1994) configural model, the Rescorla and Wagner (1972) model, and Harris's (2006) model in which all stimuli are compounded with novel stimuli. These model simulations were used from Alt Sim 3.7 (Thorwart, Schultheis, König, & Lachnit, 2009), which is a MATLAB program that simulates human associative models of Rescorla & Wagner (1972), Wagner (2003), Harris (2006), and Pearce (1994). ALTSim has been used by a number of researchers as a tool to provide a comparison between associative learning theories. It is not readily adaptable to the protocol used here, however, because the program did not allow novel stimuli to be introduced on every trial. To remedy this problem, the simulations treated the stimuli compounded with novel items as single events. It is assumed in associative learning that reinforced stimuli are more salient than non-reinforced stimuli, so a beta value of 0.8 was given for reinforced stimuli and .05 was given to non-reinforced stimuli. These beta values also have the benefit of being used as parameters in other studies using ALTSim 3.7 (Harris & Livesey, 2008). All other parameters, such as

connectedness and shared elements, for example in the Harris (2006) model simulation, were set to their default values, thus allowing consistency across each model being tested.

Figure 5: Pearce configural model simulated predictions when all stimuli are compounded

As can be seen by Pearce's (1994) model, discrimination between reinforced and non-reinforced stimuli in negative patterning is relatively poor when compared with positive patterning and biconditional discrimination. The present study shows the same discrimination prediction divergence as Pearce's simulations, which further adds to our confidence that configural cues are essential to solving negative patterning.

Figure 6: Rescorla & Wagner (1972)
model simulated predictions when all
stimuli are compounded

Results from the Rescorla & Wagner (1972) model show that negative patterning is extremely difficult to learn, with essentially no divergence of reinforced and non-reinforced stimuli by the end of the experiment. These results do not depict the present study's results as accurately as Pearce (1994), but it still makes the prediction that negative patterning is much more difficult to learn than positive patterning and biconditional discrimination. Another notable feature of this simulation is that the biconditional discrimination is learned as readily, if not more readily, as the positive patterning discrimination. The present study found positive patterning and biconditional discrimination were learned equally. Harris & Livesey (2008) did not find a positive patterning advantage.

Figure 7: Harris (2006) model simulated predictions when all stimuli are compounded

Harris (2006) shows negative patterning learning difficulty, but the biconditional discrimination is much more difficult to learn than the negative patterning and positive patterning discrimination, results that are inconsistent with the findings from the present study.

The results of this experiment are the first to show an advantage for biconditional discriminations compared to negative patterning, when all patterning discriminations are compounded with novel stimuli. The present finding presents a better discrimination comparison than Harris and Livesey (2008), who did not use patterning discrimination compounds as stimuli. It also helps mitigate the use of an opposites rule, which can make the patterning discriminations substantially easier to learn, but not by the use of associative processes.

It may be the case that Harris and Livesey (2008) study test allowed participants to potentially use an opposites rule. Although they asked participants if

they used an opposite's rule in a post-experiment questionnaire and found no differences between those who said they used an opposite's rule versus those who said they did not, it may have been the case that participants who indicated that they were not using an opposite's did not explicitly know that they were using an opposite rule, but in actuality, there were using the rule. The present study allowed for an exemplary study test which disallowed rule based learning to take precedent over associative learning. It did not allow any discrepancies involving whether or not participants were using an opposite's rule or not. Future studies on associative or conditioning learning should be mindful of the growing literature on the distinctiveness of implicit versus explicit learning (Smith, et. al., 2012). By implementing a design that allows for retaining the intrinsic features of positive and negative patterning, while mitigating explicit learning, I was able to control for cognitive processes that are not associative in nature. This provided an excellent baseline comparison between patterning discriminations and biconditional discriminations.

It could also be the case that study test of the present study allowed participants to make predictions about reinforced and non-reinforced combinations in a more holistic, global approach. Global processing is an approach used to identify configural information in the environment. In order to understand the concept of a face, one needs to use a global approach to encompass all of the features of a face as one singular whole. Conversely, a local processing approach is more technical and tedious, as it allows for extraction of micro-features that may or may not be a part of a whole. The novel stimuli presented on every trial in combination with the patterning

trials may have encouraged participants to treat the stimuli as a whole rather than tediously extracting the reinforced stimuli from the novel stimuli. Harris and Livesey (2008), by using a study test which contrasted isolated stimuli with compound stimuli, may have encouraged participants to use a local processing approach in their predictions. Byrom & Murphy (in press) have found that there are individual differences in global and local processing amongst humans. Along this spectrum, in solving a problem with both local and global features, certain individuals are more sensitive to using global processing, whereas others are more sensitive to using local processing. Although there is no report of an instance in which a task can manipulate or encourage either global or local processing, it may be the case that the fluidity of the system would allow for such a phenomenon. Although this has not been tested, future studies analyzing local and global processing in learning should address this issue.

In conclusion, the present study used a novel study test design that compounded all trials with novel stimuli to provide a baseline comparison between negative patterning and biconditional discrimination. Negative patterning was found to be much more difficult to learn than negative patterning when compared to positive patterning and biconditional discriminations, results that conflict with theories that do not invoke configural cues in solving the negative patterning discrimination. Historically, negative patterning has been found to be difficult in prior studies of patterning discriminations that did not assess biconditional discriminations. Some experiments measuring negative patterning compared to positive patterning in non-human animals indicate that negative patterning cannot be solved within the time

frame of the experiment (Bellingham, Gillette-Billingham, & Kehoe, 1985; Komische, Sandoz, Lachnit, & Giurfa, 2003).

By ridding the potential of participants using explicit learning rules to solve the negative patterning discrimination, the present study was able to ensure that participants used implicit associative learning processes in their predictions about stimuli and their outcomes. This prohibited participants from using an opposites rule, and allowed for a more direct test of associative learning processes in patterning and biconditional discrimination learning. Additionally, the health bar implemented in the feedback display provided participants with an indication of their performance after each individual display, which allowed participants to understand the consequences of each of their predictions. This feature controlled for the possibility that participants were treating reinforced and non-reinforced outcomes as arbitrary, encouraging them to pay specific attention to the reinforcement history of each stimuli.

Researchers using learning models that attempt to understand learning across species should enable these features in humans to help control for explicit learning processes (Harris & Livesey, 2008; Rescorla & Wagner, 1972; McLaren & Macintosh, 2002). This would allow for a more direct comparison between the human and rat associative learning literature, giving researchers a better understanding of this basic mechanism that has been shown to exist in organisms from paramecium to humans. (Pearce, 2008).

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