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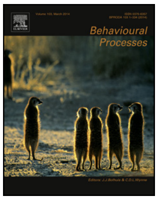

Full length article

Elemental, configural, and occasion setting mechanisms in biconditional and patterning discriminations

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ABSTRACT

Three experiments explored the utility of considering mechanisms of occasion setting for understanding patterning and biconditional discriminations – two more complex conditional discriminations in which the stimulus-outcome relations of occasion setting are embedded. In Experiment 1, rats were trained in an appetitive conditioning task with either a biconditional or a patterning discrimination using relatively brief CSs (10 s) and differential outcomes as USs. In this study, rats learned the positive patterning task before they had learned negative patterning, and the biconditional task was the most difficult. However, a detailed examination of the results suggested that rats trained in the biconditional task responded to the stimulus compounds mainly on the basis of individual stimulus-outcome associations. Different conditioned response (CR) topographies as a function of reinforcer type complicated interpretation of these results. Experiment 2 confirmed that the biconditional task, with the parameters used here, was not learned, regardless of whether training involved differential or non-differential outcomes. In Experiment 3 the CS duration was increased to 30 s and two different USs were used that each supported similar CR topographies. Under these conditions, we observed that whereas the positive patterning task was learned most rapidly, the biconditional discrimination was learned faster than the negative patterning task. Considered in relation to other findings on patterning and biconditional discriminations, the results suggest that elemental, configural, and/or modulatory occasion setting mechanisms may play different roles in these complex conditional discrimination tasks especially as a function of stimulus duration and differential outcome training.

1. Introduction

Occasion setting has been a remarkable stimulant for both empirical and theoretical work on the nature of associative learning, generating an extensive literature in the past 30 plus years that has substantially broadened the way we think of conditioning paradigms. Here we examine the potential involvement of occasion setting mechanisms in certain kinds of complex discrimination learning tasks and ask whether we can gain insight into the mechanisms by which those complex discriminations are solved.

Our investigation starts from the recognition that the feature positive/feature negative discriminations used to demonstrate occasion setting can be thought of as the simplest of a nested set of conditional discriminations that increase in complexity. The basic idea is illustrated in Table 1, which shows arrangements of these conditional discrimination tasks (feature positive/feature negative, positive and negative patterning, ambiguous feature positive/feature negative, and biconditional discriminations) that emphasize the way the simpler discriminations are embedded in the more complex ones.

Consideration of the relations among different complex discriminations has become a matter of recent theoretical interest for distinguishing among theoretical accounts of associative learning. The importance of comparing these tasks was initially highlighted in the contemporary literature by two papers published in 2008 by Justin Harris and his colleagues. Harris and Livesey (2008) showed with human subjects and Harris et al., (2008) showed with rat subjects that biconditional discriminations were more difficult to learn than were positive and negative patterning tasks. These findings were particularly notable because they were the first to test directly a prediction made by the Rescorla-Wagner theory (1972),

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Table 1
Comparisons among feature positive/negative, positive/negative patterning, ambiguous occasion setting, and biconditional discriminations.

Feature Negative:	B+, AB-	
Feature Positive:		D-, CD+
Negative Patterning:	A+, B+, AB-	
Positive Patterning:		C-, D-, CD+
Ambiguous Occasion Setting:	A*C*+, *C*-, B+, AB-	*A*C-, *A*+, D-, CD+,
Biconditional:	A*C*+, *CD*-, B*D*+, AB-	*A*C-, *AB*+, *B*D-, CD+

among others, that the biconditional task should be more easily learned than the negative patterning task. As will be described below, the predicted advantage of the biconditional over negative patterning reflects the assumption in the Rescorla-Wagner model that these discriminations are learned through associations to configural cues. Consequently, the failure to confirm the prediction was taken by Harris and Livesey (2008) and Harris et al. (2008) as evidence that configural cues did *not* play a role in learning the discriminations. Because the idea that occasion setting might reflect the contribution of configural cues (e.g., Wilson and Pearce, 1989; Brandon and Wagner, 1998; Wagner and Brandon, 2001) rather than the operation of other "modulatory" mechanisms (e.g., Bonardi, 1998; Bouton and Nelson, 1998; Delamater, 2012; Holland, 1985; Rescorla, 1985; Schmajuk et al., 1998), we think it is important for the understanding of occasion setting to have a clear idea of how to interpret procedures that purport to show the role of configural cues.

1.1. *Configural cues in complex discriminations*

According to the Rescorla-Wagner theory, both the negative patterning and the biconditional tasks usually require the involvement of configural cues for successful solution of the discriminations. This problem is readily seen in the case of the biconditional, with 4 trial types represented as AC+, BD+, AB- and CD-. Each component stimulus, A–D, is equally often reinforced (+) and non-reinforced (−), and all stimuli appear in compounds. Thus, the only way to differentiate between reinforced and the non-reinforced compounds is to identify the specific stimulus configurations. In the case of negative patterning, with 3 trial types represented as A+, B+, and AB-, the component stimuli are also equally often reinforced and nonreinforced, and successful discrimination requires learning to suppress responding to the compound despite consistent reinforcement of the component stimuli.

The prediction of the Rescorla-Wagner theory (Rescorla and Wagner, 1972) that biconditional discriminations should be easier than negative patterning arises from the different demands of the two tasks. In the biconditional task, differential responding will occur as soon as the configural cues for the reinforced compounds have more excitatory strength than the configural cues for the non-reinforced compounds; the strengths of the component stimuli are essentially neutralized. In the negative patterning task, however, correct differential responding will occur only after the configural cue has acquired sufficient inhibitory strength to outweigh the combined excitatory strengths of the component stimuli. Since that inhibitory strength will only be established after excitatory strength develops to the component stimuli, this learning will proceed relatively slowly.

1.2. *Elemental processes in complex discriminations*

Harris and his colleagues have emphasized an alternative way to conceptualize the nature of the stimulus components in complex discriminations. Specifically, they have followed Estes' (1950) approach in stimulus sampling theory and represented stimuli as collections of hypothetical microstimulus elements from which samples are drawn on different occasions. Whereas Estes treated all microstimuli as interchangeable, later theorizing has found it useful to distinguish among at least four classes, namely, common elements (e.g., Rescorla and Wagner, 1972; McLaren and Macintosh, 2002), distinctive elements (Wagner, 2003), suppressed (or replaced) elements (e.g., Harris, 2006; Wagner, 2003), and configural elements (e.g., Wagner and Brandon, 2001; Pearce, 1994). One notable consequence of this conceptualization was the idea that some microstimulus elements might be suppressed when a stimulus was presented in compound with another stimulus. Furthermore, this possibility provided a way to solve the negative patterning task without needing to invoke configural elements at all. Elements that were available when a stimulus was presented alone but were suppressed when it was presented in compound could provide the foundation for learning a patterning discrimination. Moreover, with this alternative approach to characterizing stimuli, a simple prediction was that negative patterning should be easier than the biconditional task, which was in fact the result that Harris and his colleagues found. This prediction stems from the fact that because stimuli are always presented in compounds in the biconditional task, only the salient elements of each stimulus would be active on all trials. For learning to occur in this situation, then, a compound unique pattern of suppression would need to occur in order for a different constellation of elements to be present on the different trial types.

The available literature that allows comparisons among the 4 tasks in Table 1 is not large, and it is also somewhat inconsistent. For example, among studies that make comparisons directly, negative patterning is sometimes harder (Whitlow and Loatman, 2015) and sometimes easier (Harris and Livesey, 2008; Harris et al., 2008) than the biconditional. One noteworthy difference between these two contrasting findings is that Whitlow and Loatman (2015) used a procedure with humans in which the elements of the patterning task were combined with a separate novel stimulus on every reinforced trial. In this way, the negative patterning task was trained under more similar conditions to the biconditional in that each stimulus was always presented within a stimulus compound. Under these conditions, Harris's (2006) model would predict that the negative patterning task would be especially difficult to learn because only the strongest microstimuli of each stimulus would tend to be activated on both reinforced and non-reinforced trials, and so there would be no strong basis for learning the discrimination. In contrast, Harris and his colleagues showed with humans (Harris and Livesey, 2008) and rats (Harris et al., 2008) superior learning of the negative patterning task than the biconditional when using the more typical procedure of presenting stimuli in isolation on reinforced trials in the negative patterning task.

Another complex discrimination problem is the so-called ambiguous occasion setting task (e.g., Holland, 1991). This close cousin of the biconditional task takes the form: AC+, AB−, C−, B+. The only difference between the two is whether C− and B+ occur on their own or as part of CD− and BD+ stimulus compounds. Holland and Reeve (1991) compared learning both the positive (AC+, C−) and negative (AB−, B+) occasion setting components of this task to learning (in different groups of rats) positive and negative patterning discriminations. They found that negative patterning is sometimes no different from learning the feature negative occasion setting component of the ambiguous occasion setting task (Holland and Reeve, 1991; Exp. 1), and sometimes a little easier (Holland and Reeve, 1991; Exp. 2).

1.3. *Differential outcomes in complex discriminations*

Delamater et al., (2010) studied the impact of a differential outcomes treatment on rats learning ambiguous occasion setting and biconditional discriminations. They found that both the biconditional and ambiguous occasion setting tasks were learned much more rapidly and successfully when each reinforced stimulus was rewarded with a distinctive US, and that animals trained with non-differential outcomes failed to learn either the positive or negative occasion setting components of the ambiguous occasion setting task. These results suggest that the course of learning is strongly affected by whether a differential or non-differential outcomes treatment is used. However, Delamater et al. (2010) did not assess learning in patterning discriminations.

Given this somewhat mixed set of findings, we thought it important to examine how rapidly biconditional and patterning discriminations are learned in rats trained with differential outcomes. Given Delamater et al.'s (2010) finding that biconditional discriminations were learned faster with differential than with non-differential outcomes, we asked whether training with differential outcomes would change the relative difficulty of patterning and biconditional discriminations.

There are at least two reasons why this might matter. First, the Rescorla-Wagner model anticipates that the biconditional task could be solved without recourse to configural cues when training with differential outcomes. This follows from the fact that each element of each reinforced compound bears an excitatory relationship to one US and an inhibitory relationship to the other US. This could render the biconditional task easier to solve than the negative patterning. Second, Delamater (2012) interpreted the differential outcome effects in the Delamater et al. (2010) biconditional and ambiguous occasion setting tasks in terms of an acquired distinctiveness of cues effect, whereby training with differential outcomes enabled the animals to perceptually distinguish more effectively between the two auditory cues and also between the two visual cues in their tasks. This mechanism would allow for a more rapid solution to the biconditional problem, but whether such learning would be more rapid than in the negative patterning task is not known.

2. Experiment 1

The present study examines the relative rates of learning Pavlovian biconditional, positive patterning, and negative patterning tasks when combined with a differential outcomes treatment. In these tasks we used two different auditory (A1, A2) and visual (V1, V2) stimuli and two qualitatively distinct unconditioned stimuli (US1, US2). The form of these discriminations is: A1V1-US1, A1V2-, A2V1-, A2V2-US2 (for the biconditional task), A1V1-US1, A1-, V1- (positive patterning), and A2-US2, V2-US2, A2V2- (negative patterning). These procedures are very similar to those used by Harris et al. (2008) except we employed two USs here, instead of just one. Their experiment was unique in that the total number of reinforced trials was matched between groups given the biconditional and patterning discrimination procedures, and because the patterning procedures were trained using a within-subject method in which the different audio-visual stimulus sets used in the biconditional group were also used for each type of patterning problem. We see these design features as an advantage and used them here as well. In short, the present study asked if the pattern of findings reported by Harris et al. (2008) would also occur when using a differential outcome procedure.

2.1. Method

2.1.1. Subjects

Subjects were 16, experimentally naïve, male (8) and female (8) Long-Evans rats bred at Brooklyn College, but derived from Charles River laboratories. The free feeding body weights varied between 358 and 421 g for the males and between 225 and 271 g for the females at the beginning of the experiment. The rats were housed in groups of 2–4 animals in plastic tub cages with wood chip bedding (17 × 8.5 × 8 in, l × w × h) in a colony room that was on a 14 h light/10 h dark cycle, and they were maintained at 85% of their free feeding body weights by daily supplemental feedings (given following the experimental session each day). Experimental sessions occurred during the light phase of their light/dark cycle, approximately 6 h after light onset.

2.1.2. Apparatus

The apparatus consisted of a set of eight identical standard conditioning chambers (BRS Foringer RC series), each of which was housed in a custom made sound- and light-resistant shell. The conditioning chambers measured 30.5 cm × 24.0 cm × 25.0 cm. Two end walls were constructed of aluminum, and the sidewalls and ceiling were made from clear Plexiglas. The floor consisted of 0.60 cm diameter stainless steel rods spaced 2.0 cm apart. In the center of one end wall 1.2 cm above the grid floor was a recessed food magazine measuring 3.0 × 3.6 × 2.0 cm (length × width × depth). The reinforcers were 2, 45-mg pellets supplied by TestDiet (MLab rodent grain pellets) and a 0.1 ml droplet of a 20% sucrose solution. The sucrose reward was delivered via a gravity-feed valve (ASCO Red-Hat valve) to one of two wells positioned at the entrance of the food magazine, and the food pellets were dropped onto the floor of the same food magazine. On the inner walls of the recessed magazine were an infrared detector and emitter enabling the automatic recording of head movements inside the magazine. These were located 0.9 cm above the magazine floor and 0.8 cm recessed from the front wall. Located 3.0 cm to the right and left of the magazine and 8.0 cm above the floor were different response levers (4 cm in width). These levers protruded into the chamber at all times, but separate sheet metal coverings prevented access to both levers at all times throughout the experiment. A 6-W light bulb, located above the experimental chamber and towards the top portion of the rear wall of the sound attenuating outer chamber, flashed (F), with equal on/off periods, at a rate of approximately 2 cycles/s when activated. Another 6-W light bulb, located towards the bottom right corner of the rear wall of the outer chamber, emitted light continuously (L) when activated. Approximately 22 cm behind the end wall of the chamber (behind the food magazine) were two audio speakers. One speaker, when activated, emitted a 1500-Hz pure tone generated by a computer and amplified by a Radio Shack amplifier. The other speaker emitted white noise produced by a Grason-Stadler white-noise generator. The pure tone (T) measured 4 dB and the white noise stimulus (N) 12 dB above a background noise level of 78 dB (measured by a Radio Shack Sound Level Meter, C weighting (Cat #33-2050)). The chamber remained dark during trials except during presentations of the visual stimuli. Fans mounted to the outer shells of the chambers supplied cross ventilation and produced the background noise. All experimental events were controlled and recorded automatically by a Pentium-based PC and interfacing equipment (Alpha Products) located in the same room.

2.1.3. Procedure

The rats were initially magazine trained with the two reward types. On each of two days, one magazine training session with one outcome was followed immediately by a second session with the other outcome. The order in which magazine training sessions occurred with the two outcomes was counterbalanced across days. In each session, 20 rewards of one kind were delivered according to a random time 60 s schedule.

2.1.3.1. Biconditional discrimination training. Over the next 56 sessions half of the rats (4 male, 4 female) were trained on a biconditional discrimination task using procedures similar to those described by Harris et al. (2008), with exceptions noted below. In each session there were 8 presentations of each of 4 trial types. These trial types consisted of 4 distinct audio-visual compound stimuli (FN, FT, LN, LT), where two were reinforced with different outcomes and the other two were non-reinforced. Specifically, FN was reinforced (at stimulus offset) with pellets and LT with sucrose. In this study the specific stimulus compound-reinforcer type assignments were not counterbalanced because our primary interest was to compare learning of this biconditional task to learning different patterning discriminations, and the F and N stimuli in that task (see below) were also trained with pellets while L and T were trained with sucrose. All stimuli were 10 s in duration and the trial types were pseudo-randomly presented in each session in 4, 8-trial blocks with the constraint that each trial type occurred twice in each block. There were 8 different running sequences used irregularly across days. The inter-trial interval averaged 2 min, with a range from 1 to 3 min.

On Day 57, the four individual stimuli were tested on non-reinforced probe trials that were irregularly interleaved with normal compound training trials. Each stimulus was tested 4 times throughout the session (once in each block), and each compound was presented 4 times.

2.1.3.2. Patterning discrimination training. The remaining rats (randomly chosen) were trained for 56 sessions on a patterning task using similar parameters as those described above. One set of stimuli (F, N) was used with the pellet reward and the other (L, T) with the sucrose reward, but the patterning task (positive, negative) was counterbalanced across these stimulus sets (i.e., FN-pel, F-, N-, L-sucr, T-sucr, LT- for one subset of rats and FN-, F-pel, N-pel, L-, T-, LT-sucr for the other subset). Each session consisted of 4, 8-trial blocks where each compound stimulus occurred twice and each element once in each block. Following Harris et al. (2008) this procedure equates the overall number of reinforcers in each session to the biconditional discrimination group.

2.1.3.3. Statistical analysis. The rate and duration of magazine entry responding was assessed during each stimulus presentation as well as in 10 s pre stimulus periods. Elevation scores were then calculated by subtracting pre stimulus responding from that occurring during the stimuli. A discrimination score was also calculated in which these elevation scores during non-reinforced stimuli were subtracted from that seen during reinforced stimuli. Positive scores reflect greater responding to reinforced than non-reinforced stimuli.

The data was then analyzed using analysis of variance (ANOVA) techniques recommended by Rodger (1974, 1975); see Appendix A for details). Briefly, these methods entail reconceptualizing factorial designs (e.g., with I and J factors) in terms of a one-way design (e.g., with I × J levels). When a given one-way ANOVA test achieves significance, then interesting interactions among the conditions and groups are uncovered through post-hoc analysis. The outcome of these post-hoc tests are then used to construct a quantitatively precise statement about the effect sizes observed. One measure of effect size this method produces is an estimate of the non-centrality parameter of the non-central F distribution, Δ, which states how much overall variation exists among the means that comprise the F score. In the present study, we report these values for each significant F test. Since Rodger's method is a decision-based post-hoc testing approach, type I error rate is defined in terms of the expected proportion of true null contrast rejections (out of a set of $\nu 1$ mutually orthogonal and linearly independent contrasts) and is assessed against Rodger's table of critical F scores (Rodger, 1974). In the present studies our type I error rate was set to 0.05. Moreover, our sample sizes were chosen in order to achieve a reasonably high rate (0.85) of detecting moderately sized effects when they exist.

This method was chosen over others because the method avoids any ambiguity regarding statistical decisions concerning all of the data to be evaluated and because it is among the most powerful presently available ANOVA techniques at detecting true effects (see also Rodger and Roberts, 2013).

2.2. Results

2.2.1. Positive versus negative patterning discrimination learning

Fig. 1 displays the course of acquisition of the patterning and biconditional discriminations. The mean% time spent in the magazine during the reinforced and non-reinforced stimuli (expressed as elevation scores) is shown over 8-session blocks. It is clear that the positive patterning discrimination was learned more rapidly than the negative patterning discrimination, and that the negative patterning task was somewhat superior to the biconditional discrimination task. Pre CS responding did not differ among trial types or between groups throughout training. The mean% time (and SEM) averaged across training blocks in Group Patterning and Group Biconditional, respectively, was 27.5 (6.5) and 26.2 (5.1).

Group Patterning's data was first analyzed by performing a repeated measures ANOVA across the reinforced and non-reinforced stimuli and blocks. This analysis revealed significant differences across these conditions, $F(27,189) = 2.82$, $MSE = 279.681$, $\Delta = 48.4$. Subsequent post-hoc tests revealed that differences in responding to the reinforced stimulus compound and non-reinforced stimulus elements in the positive patterning task first started to emerge in block 2 of training, and persisted throughout the 7 blocks. In contrast, responding to the reinforced elements was greater than to the non-reinforced compound in the negative patterning task only in blocks 5, 6, and 7. Thus, the positive patterning task was learned more rapidly than the negative patterning task.

2.2.2. Negative patterning versus biconditional discrimination learning

Since Group Biconditional also appeared to have learned their discrimination to some degree, a separate repeated measures ANOVA was performed on this group to determine where in training their discrimination emerged. This analysis revealed that differences in responding across the reinforced and non-reinforced trials did, indeed, emerge over training, $F(13,91) = 3.24$, $MSE = 81.859$, $\Delta = 28.2$. Subsequent post-hoc tests revealed that differences in responding between reinforced and non-reinforced trials emerged in blocks 5, 6, and 7. There were no differences in responding during pre stimulus periods throughout training.

In order to examine whether the negative patterning task was more successfully learned than the biconditional discrimination task a further analysis was performed on these data after first constructing a discrimination score. This index was a difference score between reinforced and non-reinforced stimuli. The data are presented in Fig. 2. As was observed by Harris et al. (2008) the negative patterning task initially produced somewhat greater responding to the non-reinforced compound compared to the reinforced elements (revealed by small negative difference scores), but then greater discriminative responding, relative to that seen in Group Biconditional, emerged across training.

These data were analyzed by performing repeated measures ANOVAs on each group, based on a common error term ($MSE = 66.231$) as well as a between group main effects test. The groups did not differ, overall, from one another, but each group displayed significant differences across training although there was substantially greater variation across training in Group Patterning, $F(6,84) = 25.17$ and $\Delta = 141.4$ than in Group Biconditional, $F(6,84) = 2.63$ and $\Delta = 9.4$. Post-hoc analyses confirmed that the negative patterning discrimination score was initially less than that

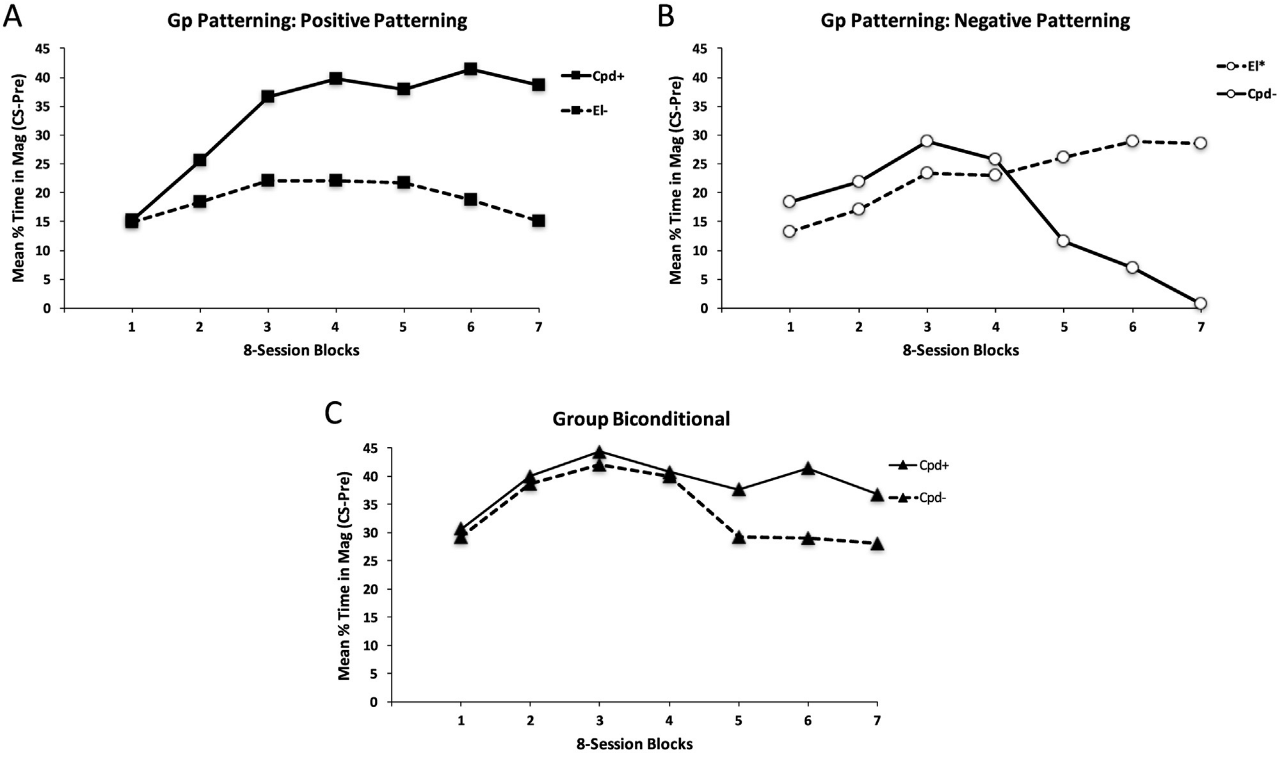

Fig. 1. Mean% time in the magazine elevation scores (CS–Pre) on reinforced and non-reinforced trials across 8-session blocks of Experiment 1 for Group Patterning on the positive (A) and negative (B) patterning tasks and for Group Biconditional (C). Responding is shown in Group Patterning for reinforced (+) and non-reinforced (−) compound (Cpd) and Element trials (El), and for reinforced and non-reinforced compound trials in Group Biconditional.

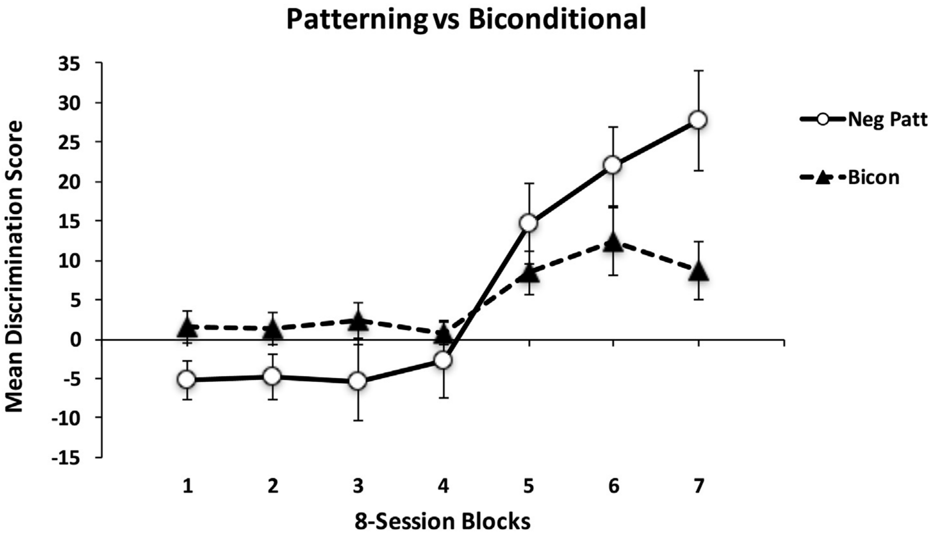

Fig. 2. Mean (+/− SEM) discrimination scores for the negative patterning (Neg Patt) task in Group Patterning and the biconditional (Bicon) task in Group Biconditional over 8-session blocks in Experiment 1. The discrimination score reflects a difference in elevation scores (see Fig. 1) on reinforced and non-reinforced trials. Larger numbers indicate greater levels of conditioned responding on reinforced than non-reinforced trials.

of the biconditional group, but then exceeded the biconditional discrimination by the end of training. The small, but significant, increase in discriminative responding over training seen in Group Biconditional suggests that this group did learn the task albeit to a lesser degree. However, a further analysis of the data helps identify the nature of the learning seen in this group.

The discrimination data in Group Biconditional was broken down in terms of responding seen to the stimulus compounds reinforced with pellets, with sucrose, or not reinforced. The mean response rate and mean% time data across 8-session blocks are depicted in Fig. 3. It is clear that this group responded with different topographies in the presence of the pellet- and sucrose-paired stimuli, by responding with a high rate of magazine entries in the presence of the pellet-paired compound, and with a high% of time spent in the magazine in the presence of the sucrose-paired compound. Each of these stimuli greatly exceeded responding during the non-reinforced compounds, but only with one of the response measures.

The data were analyzed by conducting separate repeated measures ANOVAs on the data from the final two blocks of training for

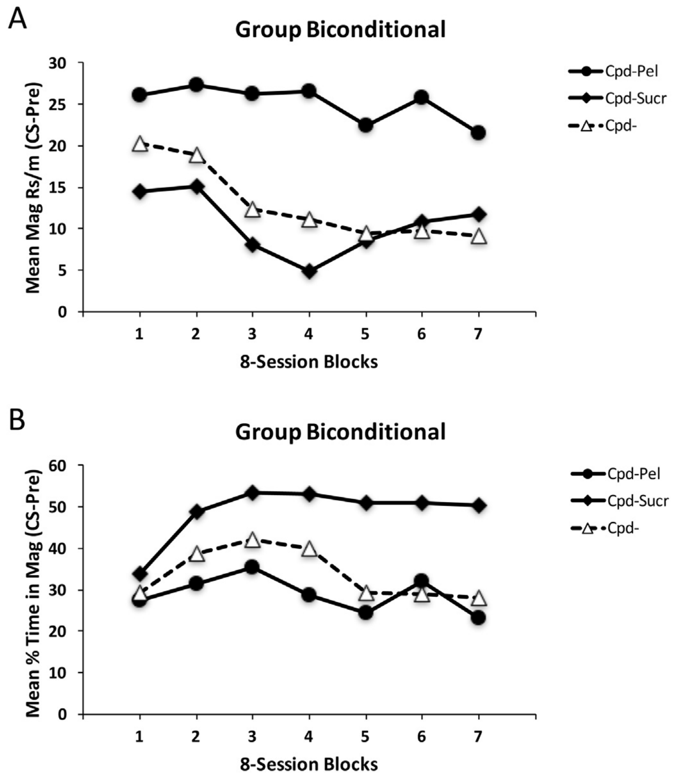

Fig. 3. Mean elevation scores (CS-Pre) in Group Biconditional on trials in which the compound stimulus was paired with the pellet US (Cpd-Pel), the sucrose US (Cpd-Sucr), or was non-reinforced in Experiment 1. The data in panel A displays responding in terms of mean responses per minute, while panel B shows responding in terms of% time in the food magazine.

the two response measures. Significant differences emerged across the three stimuli in these blocks with both the response rate measure, F(5,35) = 1.50, MSE = 265.365, Δ = 2.0, and the% time measure, F(5,35) = 8.94, MSE = 129.12, Δ = 37.1. Post-hoc tests confirmed that with the response rate measure the pellet-paired stimulus was greater than the sucrose-paired and unpaired stimuli, which did not differ, but that the sucrose-paired stimulus was greater than the pellet-paired and unpaired stimuli, which did not differ, with the% time measure. Thus, although overall responding to the reinforced stimulus compounds was greater than to the non-reinforced compounds in the biconditional task, response topography differences to pellet and sucrose reinforced stimuli need to be taken into consideration.

The data for Group Patterning was similarly examined, but because of the small sample sizes per sub-group a composite patterning score was created by combining across both positive and negative components for the problem trained with the pellet versus sucrose USs. By the end of training both measures revealed higher response levels in the presence of reinforced than non-reinforced stimuli; however, the magnitude of this difference with each response measure differed as a function of reinforcer type (as might be anticipated from the data in Group Biconditional). In particular, the difference in response rate to reinforced and non-reinforced stimuli was greater with the pellet US versus sucrose US (reinforced and non-reinforced responding: 20.3, 2.0 for pellet and 6.8, 1.7 for sucrose). Conversely, the difference in% time to reinforced and non-reinforced stimuli was greater with the sucrose than pellet US (46.6, 7.5 for sucrose and 22.1, 13.3 for pellet). Thus, these data generally mirror what was found with these two response measures in Group Biconditional; however, it is important to note that successful discriminative responding, in particular, on the negative patterning task cannot be described in terms of a simple summation of response tendencies conditioned to each separate element.

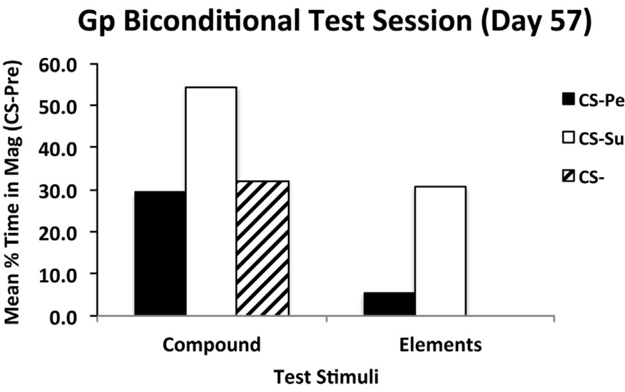

Fig. 4. Mean% time in the magazine, expressed as elevation scores (CS-Pre), in Group Biconditional during compound and element test trials on session 57 for Group Biconditional in Experiment 1. The data are shown separately for the conditioned stimuli that had been with the pellet US (CS-Pel), the sucrose US (CS-Sucr), and the non-reinforced stimulus (CS-).

One final analysis was performed on the element test session data for Group Biconditional on day 57 of the experiment. Because there were no reliable differences among the various compounds or elements with the response rate data, only the% time data are presented. The compound stimuli paired with pellets, with sucrose, or non-reinforced are shown in Fig. 4, as is responding to the elements paired with pellets or sucrose. Responding to the stimuli paired with sucrose (compounds or elements) evoked a higher level of magazine responding than the stimuli (compounds or elements) paired with pellets. In addition, overall responding was higher to the compounds than the elements. Pre stimulus responding did not differ between these two trial types. The mean (SEM) % time scores for compound and element trials, respectively, were 23.5 (6.9) and 28.2 (7.7).

A one-way repeated measures ANOVA was performed on these data and revealed a significant difference among these conditions, F(4,28) = 10.87, MSE = 221.373, Δ = 36.4. Subsequent post-hoc tests revealed that responding to the compound stimulus paired with sucrose was significantly greater than to the compound paired with pellets, the element paired with sucrose, and the non-reinforced compound. In addition, responding to the elements paired with pellets was lower than to all other test stimuli.

2.3. Discussion

The main findings of the present study were that (1) a positive patterning task was more easily learned than a negative patterning task, and (2) that a negative patterning task was more successfully learned than a biconditional task in which the same set of visual and auditory stimuli were presented and the number of reinforcements was equated. These results are largely consistent with those reported by Harris et al. (2008), but under circumstances in which a differential outcome manipulation was employed. One complication introduced by this manipulation was that different response topographies developed in the presence of the stimulus compounds reinforced by pellets and sucrose. In particular, the animals displayed a high rate of magazine entries in the presence of the pellet-paired stimulus compound, but a higher% of time spent in the magazine in the presence of the sucrose-paired stimulus compound. Perhaps Group Biconditional subjects merely learned to associate each individual stimulus with its paired reinforcer, and did not actually solve the biconditional problem by utilizing complex representational strategies. For example, responding to the sucrose-reinforced stimulus compound could merely reflect an additive sum of response tendencies to the two stimuli since these two stimuli were only paired with sucrose. In contrast, the non-reinforced stimulus compounds consisted of one stimulus paired with pellets and one with sucrose, and since only the sucrose stimulus evoked a high% of time spent in the magazine the total level of responding to these compounds was less than to the sucrose-reinforced compound. This analysis was supported by the tests with individual elements on day 57 of the experiment. In this test, the sucrose-paired stimuli evoked a higher% time spent in the magazine than the pellet-paired stimuli when tested individually. Further, the effect was reduced compared to when stimulus compounds were tested. This pattern of results is what would be expected if the separate tendencies to enter the magazine in the presence of the individual stimuli additively contributed to responding. Thus, although responding was greater to the reinforced than non-reinforced compounds, overall, it is not so clear whether this reflects control by anything other than learning to individual stimulus elements. It remains to be determined, therefore, whether rats could learn the biconditional discrimination at all when these differential response tendencies controlled by the individual stimuli is eliminated. The next experiment examined this further.

3. Experiment 2

The present experiment compared two groups of rats trained on biconditional discrimination tasks. One group was trained using a differential outcomes procedure similar to that used in Experiment 1. However, a second group of rats was trained using a non-differential outcomes procedure in which each reinforced stimulus compound was reinforced half the time with pellets and half the time with sucrose. Thus, in this group each individual stimulus would have been reinforced on some trials with pellets and on other trials with sucrose. If the rats are capable of learning the biconditional task then they should learn to respond more to reinforced than non-reinforced compounds, and the fact that pellets and sucrose support different response topographies should be without any effect. However, if rats given the differential outcome treatment learn to respond more to reinforced than non-reinforced stimulus compounds because they respond in different ways to pellet- and sucrose-paired stimuli, then the non-differential rats may not be capable of acquiring the discrimination. Harris et al. (2008) trained their rats using pellets only, and observed that rats could slowly learn the biconditional discrimination task. However, the present study re-examines this using the present set of procedures that involves training with multiple reinforcer types. The results will better help us interpret the findings of Experiment 1 in which only a relatively subtle difference in learning biconditional and negative patterning tasks was found.

3.1. Method

3.1.1. Subjects

Subjects were 16, experimentally naïve, male Sprague-Dawley rats purchased from Charles River laboratories. Their free feeding body weights varied between 354 and 406 g at the beginning of the experiment. The rats were housed individually in wire mesh cages in a colony room that was on a 14 h light/10 h dark cycle, and they were maintained and performed in the study as in Experiment 1.

3.1.2. Apparatus

The apparatus the same at that used in Experiment 1.

3.1.3. Procedure

The rats were initially magazine trained with the two reward types as described above. On each of two days, one magazine training session with one outcome was followed immediately by a second session with the other outcome. The order in which magazine training sessions occurred with the two outcomes was counterbalanced across days. In each session, 20 rewards of one kind were delivered according to a random time 60 s schedule.

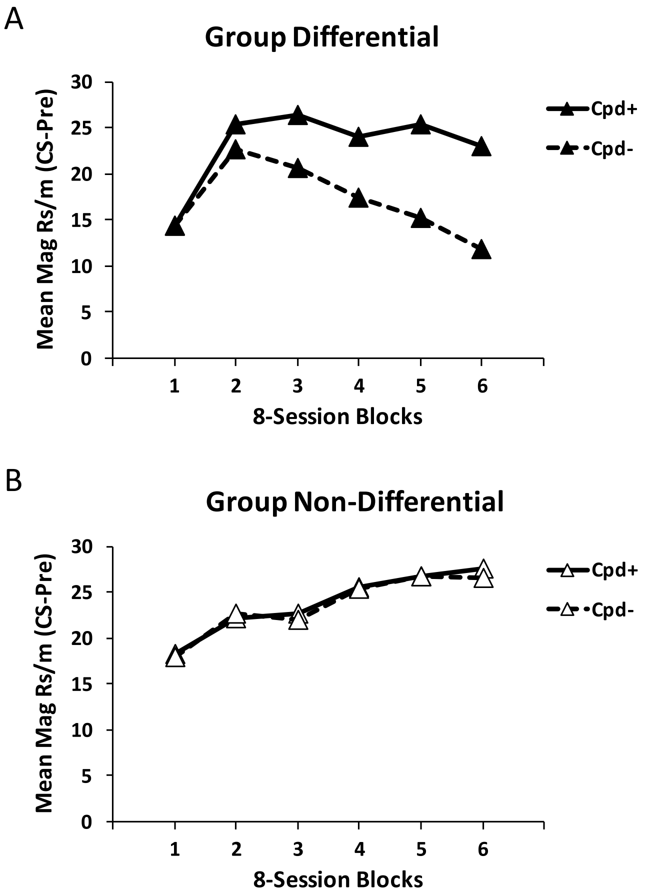

Fig. 5. Mean magazine responses per minute on reinforced and non-reinforced compound trials (Cpd+, Cpd−) across 8-session blocks in the biconditional discrimination task in Experiment 2 for groups trained with differential (A) or non-differential outcomes (B) on reinforced trials.

3.1.3.1. Biconditional discrimination training. Over the next 48 sessions the rats were trained on a biconditional discrimination task using procedures similar to Experiment 1, except that there were 10 trials of each type per session and the inter-trial interval averaged 60 s (ranging from 30 to 90 s). One group of rats (n = 8) was trained with differential outcomes associated with FN and LT (with reinforcer type counterbalanced), and a second group was trained with non-differential outcomes. In this group FN and LT were paired with pellets on half of their trials and with sucrose on the remaining trials within each session.

3.2. Results

Mean magazine responding in 8-session blocks is shown for Groups Differential and Non-Differential in Fig. 5. Responding is shown separately for the two reinforced compounds pooled together (Cpd+) and the two non-reinforced compounds (Cpd-), and these data are expressed as CS – Pre CS difference scores. It is clear that Group Differential gradually acquired the discrimination whereas Group Non-Differential failed to learn the discrimination. The data from the final two blocks of training were analyzed by performing repeated measures ANOVAs on each group, using a pooled error term (MSE = 83.321), as well as by performing a between group main effect test. Differences between reinforced and non-reinforced stimulus compounds were observed only in Group Differential, F(3,42) = 3.91, Δ = 8.2, and overall responding did not differ between the groups. Pre stimulus responding did not differ between trial types within each group or between groups in these sessions. The mean pre stimulus response rates (SEM) in Groups Differential and NonDifferential, respectively, were 5.2 (.5) and 7.6 (1.5).

Fig. 6 shows mean magazine response rate and% time data for each group broken down by whether the stimulus compound was paired with pellet or sucrose rewards. Note that for Group Non-Differential each reinforced compound was reinforced with both outcomes, so for this group the stimuli were arbitrarily assigned to different categories as it was in Group Differential. As in Experiment 1 only the stimulus compound paired with pellets in Group Differential evoked a higher rate of magazine responding than the non-reinforced compounds, whereas with the% time measure only the stimulus compound paired with sucrose evoked higher levels than in the non-reinforced compounds. Group Non-Differential did not differ with either measure in responding to the various stimuli.

Repeated measures ANOVAs performed on the data from the final two blocks in each group revealed differences among the stimuli only in Group Differential, F(5,70) = 5.45, MSE = 166.147, Δ = 21.5 for the response rate measure and F(5,70) = 21.40, MSE = 85.088, Δ = 99.0 for the% time measure. Subsequent post-hoc tests performed on the response rate data revealed that responding to the pellet-reinforced compound was higher than to the sucrose-reinforced and non-reinforced compounds, which did not differ. Post-hoc tests on the% time data revealed that the sucrose-reinforced and pellet-reinforced compounds, respectively, were higher than and lower than the non-reinforced compounds. The overall level of responding in the groups did not differ.

3.3. Discussion

The results of the present study replicated the findings in Experiment 1 that rats trained with a differential outcome treatment learned to respond discriminatively in a biconditional task (at least partially), but largely because they developed different response topographies to sucrose- and pellet-paired stimuli. In contrast, by eliminating the ability of the rats to develop different response topographies in the presence of different stimuli in a non-differential outcome version of the task, the rats completely failed to learn the discrimination. Thus, it appears as though the rats found our biconditional tasks extremely difficult to learn, and only gave the appearance of learning the task when the different individual stimuli were reinforced with different outcomes. Such a procedure, though, is best described as resulting in stimulus control by individual stimulus elements, a strategy that did not lead to a complete solution to the biconditional discrimination problem.

4. Experiment 3

The results of Experiments 1 and 2 suggest that our rats had an easier time learning a positive than negative patterning task, but that they could not effectively master a biconditional discrimination task. While this overall pattern of results is similar to those reported by Harris et al. (2008), our rats strikingly failed to completely learn the biconditional task after a large number of training sessions. One perhaps noteworthy difference is that the stimulus duration used here was relatively short (i.e., 10 vs 30 s). Why would stimulus duration matter for learning a biconditional discrimination? One possibility is that perhaps more time is required for the development of configural cue representations. Kehoe and Graham (1988) found in rabbit eyeblink conditioning that negative patterning discrimination was not possible unless stimuli were 1300–1800 ms in duration, even though reliable excitatory conditioning and excitatory summation could be seen with stimuli that were only 300 ms in duration. Deisig et al. (2007) have also argued that more post-trial processing time is required for configural cues than for isolable stimuli, based on the fact that a negative patterning discrimination in honey bees only appears with longer ITIs. These results certainly offer suggestive support for the idea that processing configural cues may require longer periods of time than processing simple excitatory cues. However, both of these experiments studied configural processes in negative patterning tasks rather than biconditional discriminations, and therefore are subject to the question of whether the discrimination actually involves configural cues. As noted above, the analysis provided by Harris (2006) could, in principle, explain successful negative patterning learning without recourse to configural cues. Thus, it is of additional interest to assess the relative ease of learning the various discriminations studied here under conditions that might better support control by configural cues in a biconditional task. While the Harris et al. (2008) study can be construed as providing this assessment, we examined whether their findings would also apply to a situation in which training occurs with differential outcomes. As noted above, this procedure may enhance even further the rate of biconditional discrimination learning, but how this might compare to the rate of negative patterning learning is unknown. Experiment 3, therefore, examined the course of positive, negative, and biconditional discrimination learning when the duration of the stimuli was increased from 10 to 30 s. One further change that we implemented in the present study was the use of two distinctively flavored food pellets. We expected that different flavored food pellets would not likely produce different CR topographies, as would liquid sucrose and food pellet USs. This would enable us to more clearly determine if a differential outcome manipulation affected the course of biconditional discrimination learning.

4.1. Method

4.1.1. Subjects

Subjects were 16, experimentally naïve, male Long-Evans rats bred in the laboratory and of descent from Charles River laboratories. Their free feeding body weights varied between 255 and 298 g (females) and between 391 and 618 g (males) at the beginning of the experiment. The rats were housed and maintained as in Experiment 1.

4.1.2. Apparatus

The apparatus was similar to that used in Experiment 1, with some notable exceptions. Another set of 8 experimental chambers was used and these had the same interior dimensions as those used in Experiments 1 and 2. These chambers allowed for the delivery of two distinctively flavored food pellets: TestDiet MLab rodent grain pellets and BioServ Purified rodent pellets. The BioServ pellet contains significant amount of sugars and is therefore considerably sweeter. Prior work in our lab revealed that the rats can readily distinguish between these two pellet types. Each US delivery consisted of a presentation of a single food pellet. The four stimuli used in the present study were all 30 s duration and included a white noise, a 4500 Hz sonalert (Med Associates), a flashing houselight, and steady panel lights. Three 28 V panel lights were positioned on the front panel in a horizontal plane above the food magazine.

4.1.3. Procedure

The same general procedures were employed as in Experiment 1, except (1) that the stimuli were always presented for 30 s duration (instead of 10 s as in Experiment 1), (2) the ITI was 2.5 min

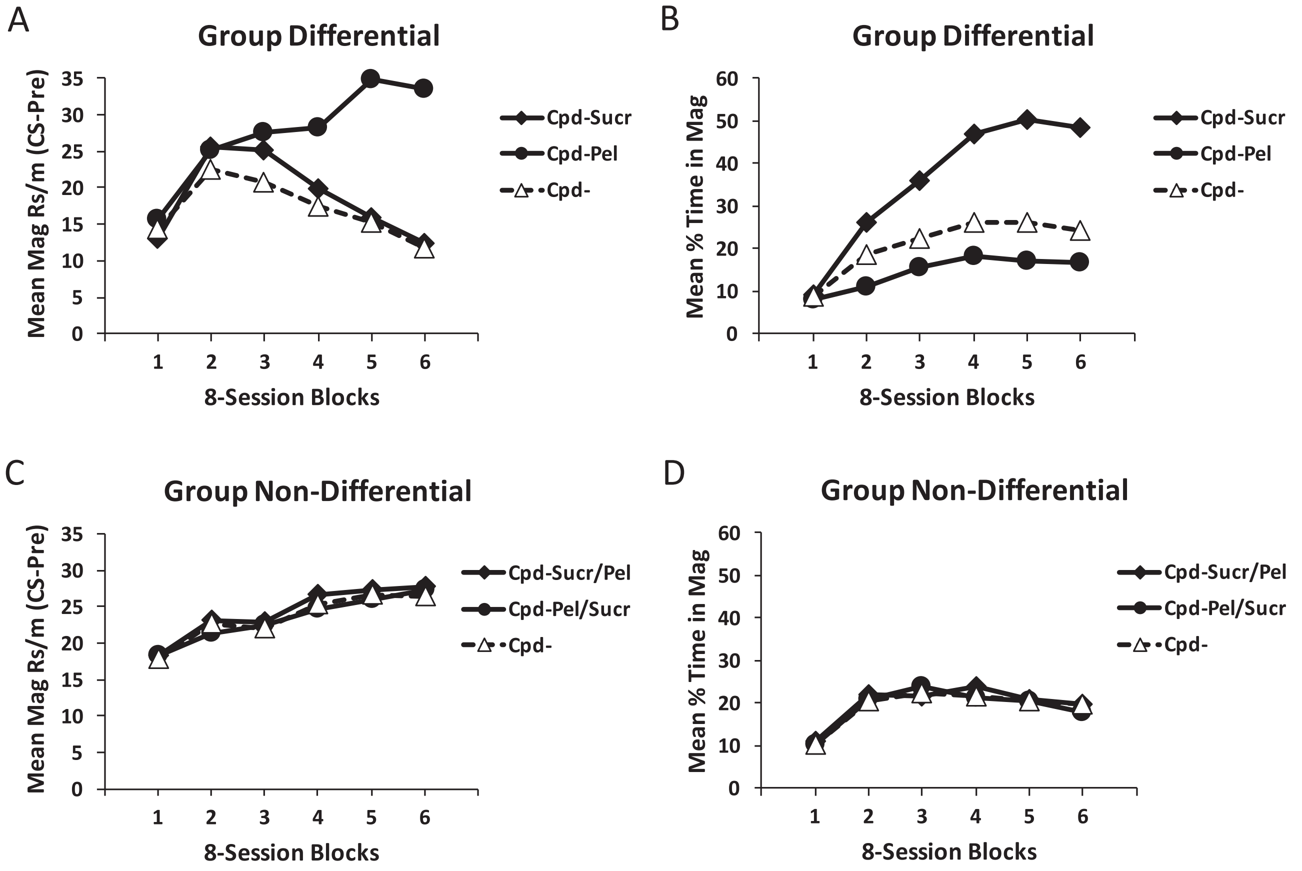

Fig. 6. Mean magazine responses per minute (A, C) and% time in the magazine (B, D) expressed as elevation scores (CS-Pre) across 8-session blocks on compound trials reinforced with sucrose (Cpd-Sucr), with pellets (Cpd-Pel), or non-reinforced (Cpd−) for Groups Differential and Non-Differential in Experiment 2. Each reinforced compound was reinforced equally often with sucrose and pellet USs (Sucr/Pel or Pel/Sucr) for Group Non-Differential.

(instead of 2 min in order to partially compensate for the increased stimulus duration), and (3) each reinforced trial ended in the delivery of a single food pellet (rather than 2). Conditioning in the two groups (Biconditional, Patterning) was carried out for 72 sessions during which time response rates were measured. Two additional training sessions were given during which the% time measure was recorded.

4.2. Results

Mean magazine responding in 8-session blocks is shown for Groups Patterning and Biconditional in Fig. 7. Responding in Group Patterning (panel A) is shown separately for the stimulus compounds and the (pooled) elements of the positive (Cpd+, El-) and the negative (Cpd-, El*) patterning tasks. Responding in Group Biconditional (panel B) is shown collapsed across the two reinforced compounds (Cpd+) and the two nonreinforced compounds (Cpd-). As before, these data are expressed as CS – Pre CS difference scores. There were no appreciable differences in Pre CS response levels in the two groups (overall means = 6.1 and 5.3 r/m, respectively, for Groups Patterning and Biconditional). It is clear that in Group Patterning the positive patterning task was learned more rapidly and more successfully than the negative patterning task. Group Biconditional also learned their discrimination, but in this experiment they did so at a rate that was intermediate between the two patterning tasks. These differences are made more obvious by considering the discrimination score data (panel C). These data reflect a difference in response rates to reinforced and non-reinforced stimuli that make up each discrimination problem. The rats showed steady improvements in all three tasks, but learned the positive patterning task faster than the biconditional task which was superior to the negative patterning task.

The data was analyzed by first comparing responding in Group Patterning on the positive and negative patterning tasks. A repeated measures ANOVA revealed differences in responding across training, F(17,119) = 12.39, MSE = 27.093, Δ = 190.1. Subsequent post-hoc tests revealed that discriminative performance of the positive patterning task was superior to the negative patterning task at every block of training. An additional test was conducted comparing the rates of learning the biconditional and negative patterning tasks. For this analysis the two groups were compared at each block of training using a pooled error term (MSE = 25.946) and Satterthwaite's degrees of freedom correction. These analyses revealed that Group Biconditional was superior to Group Patterning (on the negative patterning task) in block 2, F(1,35) = 4.51, Δ = 3.3, and in block 3, F(1,35) = 6.68, Δ = 5.3. Moreover, overall, the two groups showed increases over training, F(8,112) = 16.09, MSE = 10.89, Δ = 118.5. These analyses reveal that both groups had learned their tasks, but Group Biconditional was better earlier in training.

One additional analysis was conducted. During the final two training sessions we recorded the% time the rats spent with their heads in the food magazine during the various stimuli. In Experiment 1 Group Biconditional rats displayed sharp differences in CR topography depending upon whether the CSs were paired with pellet or liquid sucrose USs. In the present study two distinctively-flavored pellet USs were used. Nonetheless, we determined if any differences were found as a function of pellet type. The% time data, overall, was very similar to the response rate data and there were no differences as a function of pellet type in Group Patterning. In

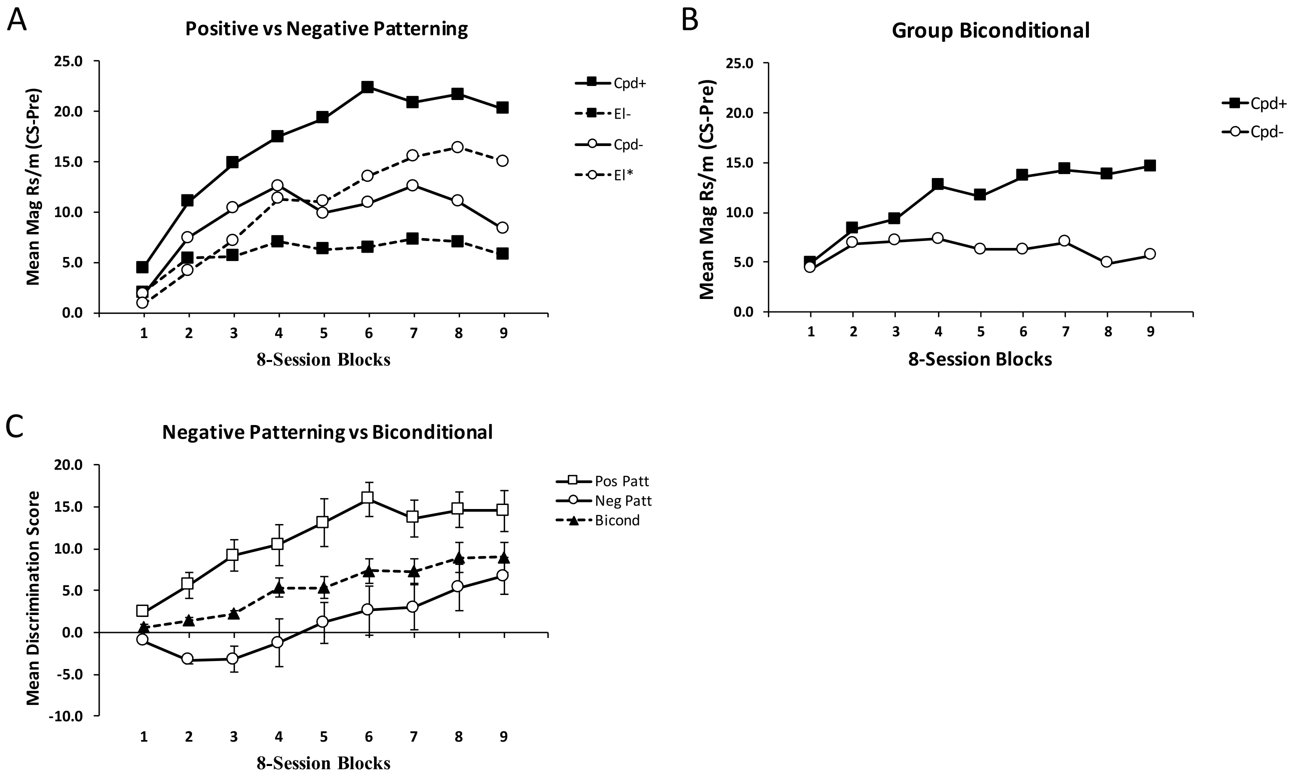

Fig. 7. Mean magazine responses per minute (A, B) expressed as elevation scores (CS-Pre) across 8-session blocks on reinforced and non-reinforced compound trials (Cpd+, Cpd−) and on reinforced or non-reinforced element alone trials (El*, El-) for the patterning and biconditional tasks in Experiment 3. Panel C shows mean discrimination scores (+/− SEM) for the positive and negative patterning tasks (Pos Patt, Neg Patt) as well as for Group Biconditional (Bicond).

Group Biconditional, responding to both of the reinforced stimulus compounds was higher than to the nonreinforced compounds with both response rate and% time measures. However, the stimulus compound paired with the sweet (BioServ) pellet produced a higher% time in the magazine than the stimulus compound paired with the grain pellet (means = 32.1, 21.0, 11.6, respectively, for the Cpd + BioServ, Cpd + grain, Cpd−).

4.3. Discussion

The results of the present study differed from those seen in Experiment 1. Importantly, increasing the CS duration from 10 to 30 s resulted in rats still learning the positive patterning task most rapidly. However, Group Biconditional rats solved their problem more rapidly than Group Patterning rats solved the negative patterning component of their task. Apparently, increasing the CS duration and/or training with two distinctively flavored food pellets made it easier for rats trained with a biconditional task to either (1) construct and utilize configural cues in solving their discrimination problem, or (2) learn simple excitatory and inhibitory binary associations with the different USs that could support rapid learning of the task. It is also true, of course, that the present study introduced other procedural differences that may have played a role. For instance, because a different set of chambers was used than in Experiment 1 a somewhat different set of stimuli was used in the present study (i.e., 4500 Hz tone instead of 1500 Hz, and a steady panel light instead of a more diffuse steady light). In addition, a single pellet was delivered with each US delivery (instead of 2). Nonetheless, the present data clearly indicate that learning a negative patterning task is not always superior to a biconditional task, and, indeed, sometimes the reverse is true. The implications of these findings will be discussed in the General Discussion section.

5. General discussion

The present experiments compared patterning and biconditional discriminations when training involved differential outcomes in an effort to identify the contributions of elemental, configural, and, possibly, modulatory mechanisms in learning complex discriminations that contain occasion setting contingencies. We hypothesized that training with a differential outcomes procedure might make the biconditional task easier to learn than the negative patterning problem employed here. The results showed that the relative difficulty of these discriminations depended on stimulus duration and/or on whether or not the outcomes were differentiated as well as whether they produced similar or different conditioned response topographies. These findings, in turn, offer new perspectives on both occasion setting and complex discriminations that contain occasion setting contingencies. In this general discussion, we consider our results in relation to prior empirical work and also in relation to various theoretical approaches.

The results of Experiment 1, more specifically, showed that rats acquired a positive more rapidly than a negative patterning discrimination, but learned both of these tasks more quickly and/or successfully than other rats trained with a biconditional discrimination. Further, in Experiment 2 we observed that rats failed to learn a biconditional task with a non-differential outcome procedure. These results are generally consistent with the findings of Harris et al. (2008) and Harris and Livesey (2008) and with theorizing that emphasizes the importance of salience interactions among stimulus elements (e.g, Harris, 2006). Elemental (Rescorla and Wagner, 1972) and configural (Pearce, 1994) processes predict that biconditional tasks should be learned more quickly than the negative patterning task used here. However, we may note that Pearce's configural theory (Pearce, 1994) could explain these findings if we assume that the two auditory stimuli used here shared a common feature and the two visual stimuli also shared a different common feature. On the other hand, when we increased the stimulus durations and eliminated any gross differences between the conditioned response topographies produced by our different USs in Experiment 3, we once again observed rapid positive patterning learning but also that the biconditional discrimination was easier to learn than the negative patterning task. These data support those of Whitlow and Loatman (2015) that were collected under very different circumstances, and run counter to the findings of Harris and his colleagues. There are several different ways in which we might understand these different sets of findings, each of which suggest additional avenues for research.

First, as noted in the general introduction, training with differential outcomes makes the biconditional task solvable without recourse to configural cues, according to the Rescorla-Wagner model. Specifically, if A1 and V1 both formed excitatory associations with US1 and inhibitory associations with US2 (while A2 and V2 learned the opposite), then A1 should suppress V2's excitatory effect on US2 (while V2 should suppress A1's excitatory effect on US1) on non-reinforced A1V2 trials. This could help explain why the biconditional task can be learned more rapidly than negative patterning. It is not clear why this same mechanism should not have applied to the results of Experiment 1; however, we may note that since the stimuli trained with pellet and sucrose USs evoked very different response topographies it is difficult to compare the relative speeds of biconditional and negative patterning in that experiment. More generally, though, the implications for how learning about different outcomes may affect the course of learning in the kinds of complex discrimination procedures employed here have not been extensively explored. The present data, though, point to a surprisingly simple elemental solution to a problem that has traditionally defied analyses based on elemental processes alone (see also Harris, 2006).

Second, of the several differences between Experiments 1 and 2, on the one hand, and Experiment 3, on the other, the difference in stimulus duration is an obvious target for consideration. As noted in the introduction to Experiment 3, there is clear evidence that negative patterning discrimination learning requires longer stimulus durations than simple excitatory conditioning (e.g., Kehoe and Graham, 1988). If configural cues were used to solve negative patterning in the Kehoe and Graham task, that would suggest that biconditional discriminations might also require longer stimulus durations, in essence, because longer durations would be required in order to construct those configural cues that could foster successful biconditional discrimination learning. Accordingly, the Rescorla-Wagner model anticipates more rapid biconditional learning for the reasons specified in the general introduction. Why this was not also found in the Harris et al. (2008) study may have to do with peculiarities of the specific stimuli used in each experiment, as well as the use of one versus two USs in our respective studies. Consequently, configural cues in our study may have been more salient than in the Harris et al. (2008) study. We should also note, however, that because there were other important differences between our Experiments 1 and 3 (e.g., pellet vs. liquid sucrose USs or different flavored pellet USs), the importance of stimulus duration, per se, for biconditional learning will need to be explored further because this mechanism alone cannot explain both our findings and those of Harris and his colleagues.

A third possibility is based on Delamater's (2012) suggestion that training with differential outcomes might render the stimuli more perceptually distinctive (e.g., through an acquired distinctiveness effect). In the biconditional task this means that the two stimuli paired with US1 (e.g., A1, V1) should become more distinctive from those paired with US2 (e.g., A2, V2). If these sets of stimuli are more distinctive from one another then it should be easier to learn a biconditional discrimination that requires subjects to distinguish among these 4 stimuli. Futhermore, the reason why this manipulation may not benefit the negative patterning task can be appreciated by considering Delamater's (2012) explanation of negative patterning learning. That account stipulates that in order for negative patterning problems to be solved, animals must construct a representation of the stimulus compound that is distinct from its elements. Delamater (2012) suggested that this could be accomplished if the internal representation of each individual element tended to inhibit the internal representation of the other element. In order for this to occur, however, it would be required that the two elements of the negative patterning task, themselves, become more distinctive from one another. In the present studies, both elements of the negative patterning task were each associated with the same US type (not different ones), and this should tend to produce an acquired equivalence effect that would present difficulties for negative patterning problems solved in this manner. In the Harris et al. (2008) procedure, where a single US was used, perhaps the tendency for an acquired equivalence effect to occur would interfere more with solving the biconditional than the negative patterning task.[1]

Fourth, an alternative framework for thinking about biconditional and patterning discriminations is in terms of modulatory occasion setting processes (e.g., Bonardi, 1998; Bouton and Nelson, 1998; Delamater, 2012; Holland, 1985; Rescorla, 1985; Schmajuk et al., 1998). Delamater (2012) suggested that a multi-layer connectionist framework can be used to think about complex conditional discrimination learning tasks in these terms. In particular, a negative patterning task can be thought of in terms of each element serving as a negative occasion setter for the other. If each element on its own has its own pathway through the "hidden layer" of a multi-layer network to the US unit, then it is not difficult to see how one element might disrupt the other element's pathway. This is one way of implementing Holland's (1985) notion that occasion setters operate on CS-US links (see also Schmajuk et al., 1998). Similarly, in the biconditional task the elements of each reinforced compound (e.g., A1V1-US1, A2V2-US2) can serve as positive occasion setters for one another and negative occasion setters for the other element with which they are compounded on non-reinforced trials (e.g., A1V2-, A2V1-). What Delamater's (2012) simulations showed is that these positive and negative occasion setting relations within the biconditional task are more easily segregated within a multi-layer network when each reinforced compound is reinforced with different USs than when reinforced with the same US. Perhaps for this reason the present finding of relatively faster biconditional than negative patterning learning can be understood, whereas in the Harris et al. (2008) experiment where only a single US was used the opposite pattern was obtained. Other research has shown that occasion setting may work in US-specific ways (Bonardi et al., 2012), but the full implications of that fact has not been fully appreciated. We may also note that our differential outcome occasion setting explanation does not address why stimulus duration should have played an especially important role, as it appears to have done in the present studies. However, the results of Experiment 1 were difficult to interpret because each US produced such different response topographies, and this may have interfered with normal acquisition or expression processes in these tasks. A within-experiment comparison of stimulus duration with the different flavored food pellets used in Experiment 3 would be required to more fully assess this issue.

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[1] This acquired distinctiveness mechanism might also have applied to the results of Experiment 1 where pellet and liquid sucrose USs were used. However, in that experiment the outcomes conditioned very different response topographies and this fact complicates any interpretation we may offer in terms of acquired distinctiveness.

Aside from attempting to explain our findings in relation to those of others, we may also point out that an interesting feature of the present studies is that all of our stimulus compounds were simultaneously trained. We are here claiming that modulatory occasion setting mechanisms may well have been involved, whereas other research has shown that occasion setting mechanisms are more likely to play a role in training procedures where the elements of stimulus compounds are presented sequentially but not simultaneously (e.g., Holland, 1985). Perhaps in situations where solutions to the learning tasks can be made on the basis of acquiring simple CS-US associations, modulatory occasion setting mechanisms will be less likely to play a role. However, in other situations where solutions cannot easily be made on the basis of simple associative relations, such as negative patterning and biconditional tasks (at least with non-differential outcomes), modulatory mechanisms may be more likely to play a role even when simultaneous compounds are trained. Clearly, additional work would be required to examine the involvement of such processes in a wider variety of tasks than those used to study standard positive or negative occasion setting.

In sum, our main conclusion is that multiple mechanisms may be engaged by the sorts of complex tasks employed here. What remains to be identified is a clear statement of when occasion setting, patterning, and biconditional learning tasks are solved using predominantly CS processing (e.g., Harris, 2006), elemental (e.g., Rescorla and Wagner, 1972), configural (e.g., Pearce, 1994), and/or modulatory (e.g., Bonardi, 1998; Bouton and Nelson, 1998; Delamater, 2012; Holland, 1985; Rescorla, 1985; Schmajuk et al., 1998) mechanisms. In magazine approach conditioning studies with rats, for example, it appears as though training with a single US results in more rapid negative patterning than biconditional learning (Harris et al., 2008), and this would point to non-configural learning solutions in this paradigm. However, when training with differential US types the biconditional task is more rapidly learned which might suggest a role for configural cues, but could also reflect the contribution of other non-configural processes. We suggest that stimulus duration, training with differential or non-differential outcomes, and the relative salience of configural cues may all play significant roles, but future research will be required to further elaborate these claims.

Acknowledgements

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Appendix A.

Given that an overall one-way ANOVA reveals differences among the various conditions of interest, Rodger's method (e.g., Rodger, 1974, 1975) entails constructing a mutually orthogonal linearly independent set of contrasts (with $\nu 1$ contrasts), post-hoc, for statistical evaluation in order to assess the locus of any differences. Rejected contrasts are assigned a non-zero value expressed in σ units, $\delta = g\ \sigma\ \sqrt{\Sigma c^2}$ (c refers to the contrast coefficients), whereas non-rejected contrasts are assigned a value of $\delta = 0$. These values are eighted by a factor, g (conceptually similar to Cohen's d), that is scaled by the observed size of effect, $g = \sqrt{(\nu_1\ F_h/N)}$ (where F_h is the obtained contrast F). These statistical decisions for contrasts within a set can then be used to deduce a quantitative description of the relative positions among the population means through Rodger's implication formula:

$$_{\mu j} - \mu. \ = {}_{1\delta h}({}_{h}C_{jj}C_{h}{}^{T})^{-1}{}_{h}C_{j} \tag{1}$$

Each contrast set (${}_{h}C_{j}$) with its own set of statistical decisions (i.e., ${}_{1\delta h}$ values) gives rise to one quantitatively unique set of implied population means (expressing, in σ units, the difference between each implied population mean from the overall grand mean, ${}_{\mu j} - \mu.$), and reflects a quantitatively precise and clear statement as to the nature of the differences in the data set.

Furthermore, once these implied means are computed, then an estimate of the overall effect size, i.e., the amount of variation among the implied population means, can be calculated as:

$$\Delta \ = \ N\Sigma({}_{\mu j} - \mu.)^2/{}^{\sigma 2} \tag{2}$$

This computed value, Δ, is an estimate of the non-centrality parameter that defines the non-central F distribution when the null hypothesis is false. Perlman and Rasmussen (1975) discovered a uniformly minimum variance unbiased estimator of this non-centrality parameter and the implied means calculated by Eq. (1) above were rescaled to conform to PPerlman and Rasmussen's (1975) estimate of this non-centrality parameter. In addition to reporting F scores produced by this statistical analysis, this measure of effect size, Δ, will also be reported for all rejected F tests.

This approach conceives of type I error in terms of an expected rate of rejecting true null contrasts, where Rodger's table of critical F values (Rodger, 1974) are the basis of these statistical decisions. It is, therefore, a decision-based definition of type I error, and, in the present study this rate was set to equal 0.05. Using these techniques, the present sample sizes ($n = 8$) were chosen to ensure that moderately large sized effects (Rodger's $g = 1$) would be detected with a power level of at least 0.85.

All of the statistical techniques used here can be performed with a publically available software package, *Simple Powerful Statistics* (see also Roberts, 2011), downloadable from the following website: https://sites.google.com/site/spsprogram/home.

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