An Associative Analysis of Compound Predictor Processing in Contingency Judgments

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Abstract

Three experiments test the processing of compound predictors in contingency judgments. Participants judged the relation between compound predictors and an outcome, as well as the relation between their constituent elements and the outcome, under different predictor-outcome contingencies. In Experiment 1, the contingency of an AB compound predictor was judged as independent of the contingencies of its elements A and B. In Experiment 2, judgments of a compound predictor (ABC) remained similarly unaffected by changes in the contingencies of its elements, even though the similarity between the compound predictor and one of its constituent elements (AC) was high. In Experiment 3, compound predictors were perceived as unique, although the rate of acquisition of an A+, AB- discrimination did not differ from that of an AC+, ABC- discrimination, contrary to the prediction of Pearce's (1994) configural model. Overall, the elemental associative view is rejected in favor of a modified, low generalization, configural model.

Associative or connectionist models make predictions consistent with empirically observed judgments of the contingency between single predictors and an outcome (Allan, 1993; Siegel & Allan, 1996). According to these models, learning the contingency between a predictor and an outcome is a byproduct of associations formed between these events, and judgments are presumed to have a monotonic relation with the strength of these associations. Associative models differ, however, in their analyses of how a predictor composed of multiple elements and an outcome become associated.

Two classes of associative models may be identified that are relevant to compound predictor processing: elemental and configural. Both classes relate the change of associative strength between a predictor and an outcome with experience, and describe interaction effects among predictors all associated with the same outcome. However, the two classes describe different processes by which a compound predictor becomes associated with an outcome, and how associative strength is generalized between a compound predictor and the individual predictors that compose it.

According to the Rescorla-Wagner (1972) model, (see also, Mackintosh, 1975; Pearce-Hall, 1980), when a compound predictor is paired with an outcome, an association will develop between each element of the compound and the outcome, as well as between the compound as a configural cue and the outcome (Rescorla, 1973; Rescorla, Grau, & Durlach, 1985). The response to a compound predictor will be the sum of the associative strengths of the configural predictor and the individual predictors that compose it. The individual predictors are seen to contribute 100% of their respective associative strengths to the response to the compound predictor. In general, the salience of the configural cue is thought to be small relative to the salience of its constituents, and the response to the compound is largely related to the sum of the associative strengths of its constituent predictors (Rescorla, 1997, Wagner & Rescorla, 1972).

Pearce (1987; 1994) developed a configural model to account for findings from animal research that appear incompatible with an elemental view of associative processing (Pearce & Redhead, 1993; Wilson & Pearce, 1992). According to Pearce (1987), when a compound of several predictors is paired with an outcome, the only association that will develop is that between the compound cue and the outcome. Any change in the constituent elements of a compound will result in an association between a new configural predictor and the outcome. The response to a compound will be the sum of the associative strength of the configural cue and the associative strength generalized to it from other predictors as a function of their similarity. The similarity between two predictors is proportional to the number of elements they have in common (Pearce, 1994). Thus, whereas elemental models predict that the generalization of associative strength between a compound and its elements is complete, Pearce's (1987; 1994) model predicts that generalization is somewhat less than complete and related to the similarity between the predictors.

A modified feature-negative discrimination paradigm was implemented in three studies to assess elemental and configural cues in contingency judgments, and contrast the two classes of associative models.

Experiment 1

We assessed if judgments of the relation between a compound predictor composed of two elements and an outcome are mediated by the relation between its constituent elements and the outcome, in a modified feature-negative discrimination paradigm. The contingency (Δp) between the three possible predictors and the outcome (O) was calculated as the difference between the two independent

conditional probabilities, P(O|predictor) and P(O|~predictor) (Allan, 1980; Jenkins & Ward, 1965).

In the classic feature-negative discrimination paradigm animals are presented with A+ , AB- discrimination (+ indicates the presence of the outcome and - its absence). The outcome occurs every time A is presented alone but never when it is presented in compound with B. In this experiment, participants were presented with A, B, and AB trials. The contingencies between the three predictors and the outcome were presented in a 2 X 2 factorial design. The four conditions each involved two contingencies between A and the outcome, and two contingencies between B and the outcome. The contingency between A and the outcome was either .6 [P(O|A) = .8, P(O|~A) = .2], or .3 [P(O|A) = .65, P(O|~A) = .35]. The contingency between B and the outcome was either 0 [P(O|B) = .5, P(O|~B) = .5], or -.5 [P(O|B) = .25, P(O|~B) = .75]. The contingency between the AB compound and the outcome remained constant at -.34 across conditions [P(O|AB) = .2, P(O|~AB) = .54]. The contingencies for each predictor by experiment and condition are presented in Table 1.

The different conditions of predictor-outcome relatedness were implemented within a fictitious medical context where participants were asked to make judgments of the relation between taking different medications (predictors) for a given disease and the occurrence of a facial rash (outcome).

Method

Participants Twenty-four undergraduate students (22 females, 2 males; mean age = 26 years) were recruited at the University of Ottawa to serve as participants for this experiment. After 24 participants were tested, one person was chosen randomly and awarded a $50 prize.

Apparatus Three IBM compatible microcomputers, located in individual testing rooms, served to administer the tasks and collect data for this experiment. Each computer was equipped with a keyboard, a mouse, and a 14 in VGA color monitor. The computer program used for task presentation and data collection was developed using Microsoft Visual Basic Professional 4.0.

Table 1: Predictor contingencies by experiment (Exp.) and condition (Cond.).

		Predictors (Δp)					
Exp.	Cond.	A	B	C	AB	AC	ABC
1	1	.6	0		-.34		
	2	.3	0		-.34		
	3	.6	-.5		-.34		
	4	.3	-.5		-.34		
2	1	.55	0	-.34		.6	-.34
	2	-.34	0	.55		.6	-.34
	3	.52	0	-.36		.3	-.34
	4	-.36	0	.52		.3	-.34
3	1	.6	0		-.34		
	2	.3	0		-.34		
	3		0			.6	-.34
	4		0			.3	-.34

Stimuli All stimuli were presented sequentially in a discrete trial procedure to participants on 10 cm by 15 cm graphical windows centered in the middle of the computer screen. Within each experimental condition, a graphical window represented the medical file of one patient who participated in the clinical trial for a given fictitious disease. The left hand portion of the graphical window displayed the treatment(s) administered to the patient, while the right hand portion displayed the treatment outcome (i.e., facial rash, or no facial rash). The treatments were represented with oval-shaped medication pills, one red and one green. Each medication pill measured approximately .9 cm vertically and .5 cm horizontally. The outcome was represented with a round yellow icon depicting a face, which measured approximately 1.2 cm in diameter. The presence of rash on the face was indicated with red spots. The display of each medical file remained visible on the computer screen for 3 sec, with a 1 sec inter-trial interval.

Procedure The participants were first presented with task instructions on the computer screen. They were told to imagine they had access to the files of patients who took part in a clinical trial to assess the effectiveness of certain medications for treating a disease. It was explained that the patients were all ill with the disease, that one possible symptom of the disease was facial rash, and that the medications given could affect the likelihood with which the patients get facial rash. It was emphasized that their task was to judge the effect of the medications on the likelihood of the facial rash. It was explained that they would be asked to make these judgments in the context of five different clinical trials, each for a different fictitious disease. The first clinical trial was a practice during which they could request the clarification of task instructions.

Following the initial instructions, participants were shown the graphical components that represented patient files, possible medications (i.e., red pill alone, green pill alone, and red and green pill together), and possible outcomes (i.e., facial rash, and no facial rash). They were told a treatment could either increase, decrease, or leave the likelihood of facial rash unchanged relative to the absence of the treatment under consideration. It was emphasized that the relations between the various medications and the facial rash remained constant within a clinical trial, but varied between clinical trials.

Each clinical trial consisted of 40 individual trials (patient files), and participants were asked to judge the relations between each medication treatment and the facial rash after every 4 trials for a total of 10 judgements per medication. Judgments were made on a response screen that presented each possible treatment with its respective icon on a different line. Responses were recorded by manipulating a horizontal scroll bar placed to the right of each medication treatment with a mouse. Manipulations of the scroll bar were reflected with a number in a data input box placed between the treatment icons and the scroll bars. Possible responses ranged from -100 to + 100, in increments of 1. The location of the slider on the horizontal scroll bar was reset to 0 for each new judgment screen, so that participants

did not have access to their previous responses. Since judgments were made after every 4 trials, it was emphasized that judgments should be based on all the files seen up to the current response screen for a given disease.

After the initial task instructions, participants completed a practice clinical trial. The practice was identical to the experimental clinical trials except for the normative contingencies between the predictors and the outcome. In the practice trial, the contingency for A was .5 [P(O|A) = .75, P(O|~A) = .25], the contingency for B was -.5 [P(O|B) = .25, P(O|~B) = .75], and the contingency for the AB compound was 0 [P(O|AB) = .5, P(O|~AB) = .5]. The names of the fictitious diseases (Laparosis, Oxyopathy, Hypermegia, Anoperosis, Dendropathy) were displayed at the top of the computer screen for each clinical trial. Within each experimental condition, the order of trial presentation was randomized with one constraint. At least one of the first four trials contained the presentation of a compound treatment, thereby exposing participants to all the individual pills prior to the first judgment screen. This was to ensure that even the early judgments were based on a minimum of empirical information. The order of presentation of experimental conditions was counterbalanced between participants, according to the 24 possible permutations of four objects. The assignment of pill color to contingency was counterbalanced between conditions and between subjects. Between each condition participants were presented with a screen explaining that a new clinical trial was beginning, and instructed to disregard all they had seen previously and start their evaluations afresh. The frequency of the outcome (20) was kept constant across conditions as judgments have been reported to vary with frequency (Dickinson, Shanks, & Evenden, 1984).

Results and Discussion

A within-subject analysis of variance, with individual judgments as the dependent variable, was used to examine the variables of contingency of A (Δp = .6 or .3), contingency of B (Δp = .5 or 0), stimulus judged (A alone, B alone, AB compound), and judgments (1 to 10). Planned comparisons were protected with the Bonferroni procedure. A Type I error rate of .05 was used.

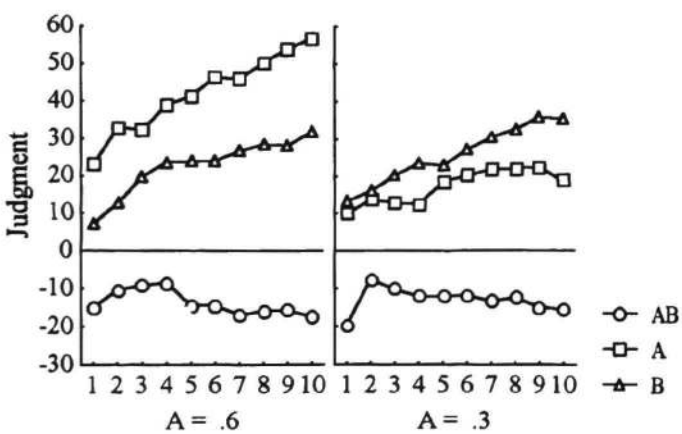

Figure 1. Judgments of predictors by the contingency for A.

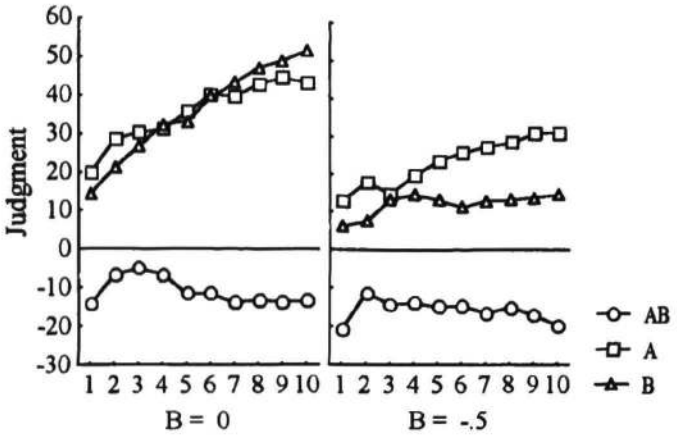

Figure 2. Judgments of predictors by the contingency for B.

This analysis revealed main effects of A ($F_{1,23}$ = 7.80, *MSE* = 4600.88), B ($F_{1,23}$ = 36.57, *MSE* = 3812.71), stimuli ($F_{2,46}$ = 33.58, *MSE* = 15704.37), and judgment ($F_{9,207}$ = 21.62, *MSE* = 294.54); two-way interactions between A and stimuli ($F_{2,46}$ = 4.93, *MSE* = 11777.39), B and judgment ($F_{9,207}$ = 2.89, *MSE* = 356.86), and stimuli and judgment ($F_{18,414}$ = 5.41, *MSE* = 476.64); and , three-way interactions between A, stimuli, and judgment ($F_{18,414}$ = 1.87, *MSE* = 316.6), and between B, stimuli, and judgment ($F_{18,414}$ = 2.79, *MSE* = 364.24).

Planned comparisons were used to examine the three-way interactions. In the three-way interaction between A, stimuli, and judgment, participants discriminated between the two A contingencies ($F_{1,23}$ = 14.08, *MSE* = 10633.2), but varying the contingency between pill A and the outcome did not affect judgments of either B or the AB compound (Figure 1). In the three-way interaction between B, stimuli, and judgment, participants discriminated between the two B contingencies ($F_{1,23}$ = 11.45, *MSE* = 12277.8), but varying the contingency between pill B and the outcome did not affect judgments of either A or AB (Figure 2).

The results of Experiment 1 are consistent with a configural model. Varying the contingency of any elemental treatment had no affect on judgments of the other elemental treatment or of the compound. Judgments of the relation between the AB compound and the outcome remained constant across conditions, never approaching the sum of the normative contingencies between its constituent elements and the outcome, which varied systematically from .6 to -.2 among conditions.

Experiment 2

Associative accounts specify that generalization from the constituent elements should affect responding to the compound. Although no evidence for such generalization was found in Experiment 1, it could be because the elements were very different from one another. In Experiment 2, a common element C was added to create the AC+, ABC- discrimination. The addition of C increases the similarity between the two predictors, and the likelihood that changing the AC contingency will influence judgments of ABC through generalization. Also, although the contingency between B and the outcome in Experiment 1 was either 0 or

-.5, judgments remained consistently positive with mean terminal judgments of approximately .34. The current experiment addresses the extent to which this finding is related to a limitation of the experimental task used.

The five different predictors in this experiment were: ABC, AC, A, B, and C. The contingencies between these predictors and the outcome were presented in a 2 X 2 factorial design, with AC and A the only treatments varying systematically across conditions (Table 1). The contingency between AC and the outcome was either .6 [P(O|AC) = .8, P(O|~AC) = .2], or .3 [P(O|AC) = .65, P(O|~AC) = .35]. The contingency between A and the outcome was yoked with the contingency between C and the outcome as follows: when Δp for A was -.34 [P(O|A) = .46, P(O|~A) = .8] Δp for C was .55 [P(O|C) = .76, P(O|~C) = .21], when Δp for A was -.36 [P(O|A) = .42, P(O|~A) = .78] Δp for C was .52 [P(O|C) = .71, P(O|~C) = .19], when Δp for A was .55 [P(O|A) = .76, P(O|~A) = .21] Δp for C was -.34 [P(O|C) = .46, P(O|~C) = .8], when Δp for A was .52 [P(O|A) = .71, P(O|~A) = .19] Δp for C was -.36 [P(O|C) = .42, P(O|~C) = .78]. The two levels of the positive and of the negative contingencies for both A and C were considered equivalent for purposes of statistical analysis and interpretation, thus yielding one level of A at .54 (with C at -.35), and another level of A at -.35 (with C at .54). The contingency between ABC and the outcome remained constant at -.34 [P(O|ABC) = .2, P(O|~ABC) = .54], and the contingency between B and the outcome remained constant at 0 [P(O|B) = .5, P(O|~B) = .5], across conditions.

Method

Participants Twenty-four undergraduate students (21 females, 3 males; mean age = 24 years) were recruited at the University of Ottawa. After 24 participants were tested, one person was chosen randomly and awarded a $50 prize.

Apparatus and Stimuli The apparatus and stimuli were the same as in Experiment 1, except for the addition of a blue pill.

Procedure The procedure used in Experiment 1 was

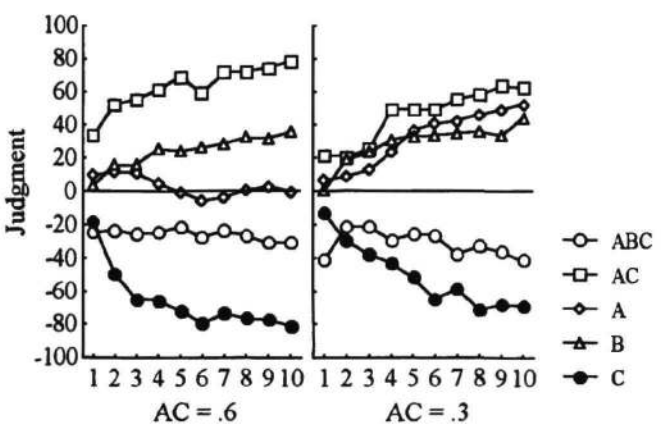

Figure 3. Judgments of predictors by the contingency for AC, when the contingency for A was .54.

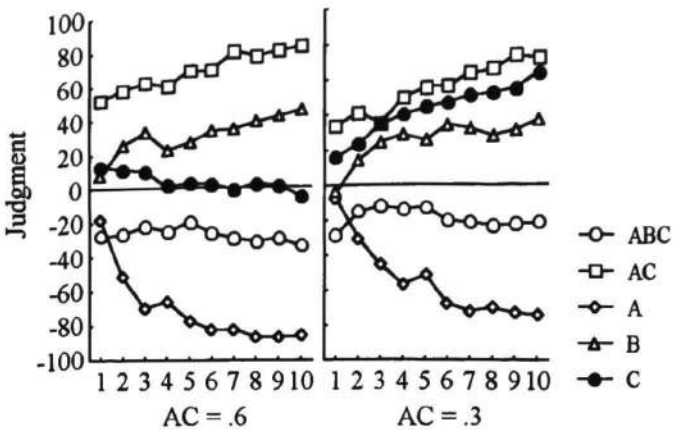

Figure 4. Judgments of predictors by the contingency for AC, when the contingency for C was .54.

modified to accommodate five predictors on the response screen. During the instruction phase, participants were shown the icons for five possible treatments (red alone, green alone, blue alone, red and blue together, and red, green, and blue together). Trials did not include treatments for which participants were not asked to make judgments. For example, BC was not a possible treatment type. In the practice trial, the contingency for A was .5 [P(O|A) = .75, P(O|~A) = .25], the contingency for B was -.5 [P(O|B) = .25, P(O|~B) = .75], the contingency for C was .5 [P(O|C) = .75, P(O|~C) = .25], the contingency for the AC compound was .5 [P(O|AC) = .75, P(O|~AC) = .25], and the contingency for the ABC compound was 0 [P(O|ABC) = .5, P(O|~ABC) = .5].

Results and Discussion

The judgments were analyzed according to a within-subject factorial analysis of variance with the contingency of AC (Δp = .6 or .3), the contingency of A (Δp = -.35 or .54), stimulus judged (A, B, C, AC, ABC), and judgment (1 to 10) as sources. There were main effects of AC ($F_{1,23}$ = 6.92, MSE = 8156.59), and stimuli ($F_{4,92}$ = 60.69, MSE = 21605.39). The analysis also revealed interactions between AC and judgment ($F_{9,207}$ = 6.56, MSE = 533.25), AC and stimuli ($F_{4,92}$ = 10.75, MSE = 6861.58), A and stimuli ($F_{4,92}$ = 75.95, MSE = 10280.18), and judgment and stimuli ($F_{36,828}$ = 14.51, MSE = 673.92). Three-way interactions were found between AC, judgment, and stimuli ($F_{36,828}$ = 1.44, MSE = 638.77), and between A, judgment, and stimuli ($F_{36,828}$ = 11.65, MSE = 671.08). Finally, the four-way interaction between the variables was reliable ($F_{36,828}$ = 2.81, MSE = 640.4).

Planned comparisons with Bonferroni correction were used to examine the four-way interaction. Varying the contingency between AC and the outcome from .6 to .3 did not affect judgments of ABC (p > .8). Similarly, changes in the contingency between A and the outcome from -.35 to .54 did not affect judgments of ABC (p > .3). Changes in Δp for AC affected judgments of A in conditions when A was involved in a positive contingency with the outcome ($F_{1,23}$ = 13.72, MSE = 8736.4), such that judgments of A were lower when Δp for AC was .6 than when Δp for AC was .3 (Figure

3). Similarly, changes in Δp for AC affected judgments of C in conditions when C was involved in a positive contingency with the outcome ($F_{1,23}$ = 22.72, *MSE* = 7556.6), such that judgments of C were lower when Δp for AC was .6 than when Δp for AC was .3 (Figure 4).

The results of Experiment 2 are again more consistent with a configural model. Although participants reliably discriminated the two levels of contingency between AC and the outcome, judgments of ABC remained constant across conditions. Similarly, varying the contingency between A and the outcome had no affect on judgments of ABC. Further, in the presence of a compound predictor with a moderate positive contingency with the outcome (i.e., AC, Δp = .6), judgments of a slightly weaker one-element predictor (i.e., either A or C, Δp = .54) were reliably suppressed. This result is suggestive of a form of overshadowing (Baker, Mercier, Vallée-Tourangeau, Frank, & Pan, 1993). Finally, the negative judgments obtained in this experiment preclude the possibility that participants completing the experimental task fail to use the negative portion of the response scale.

Experiment 3

In this experiment, participants were asked to make judgments of predictor-outcome contingency in the context of a feature-negative discrimination under two degrees of similarity. In a condition with relatively low similarity, participants judged a compound predictor with two elements (AB), as well as its constituent elements (A and B), at two levels of A. The contingency between A and the outcome was either .6 [P(O|A) = .8, P(O|~A) = .2], or .3 [P(O|A) = .65, P(O|~A) = .35]. The contingency between AB and the outcome remained constant at -.34 [P(O|AB) = .2, P(O|~AB) = .54] across levels of A. In a condition with higher similarity, participants made judgments of a three element compound predictor (ABC), a two element compound (AC), and a single predictor (B), at two levels of AC. The contingency for AC was either .6 [P(O|AC) = .8, P(O|~AC) = .2], or .3 [P(O|AC) = .65, P(O|~AC) = .35]. The contingency for ABC remained constant at -.34 [P(O|ABC) = .2, P(O|~ABC) = .54] across levels of AC. The contingency for B remained constant at 0 [P(O|B) = .5, P(O|~B) = .5)] across all four experimental conditions (Table 1). Pearce's configural model (1994) predicts that an AC+, ABC- discrimination will be acquired at a slower rate than an A+, AB- discrimination because the amount of generalization is directly proportional to the similarity between predictors. Conversely, an elemental model predicts a faster discrimination of AC+ ABC- because AC+ trials will result in a net gain in associative strength greater than that on A+ trials.

Method

Participants Twenty-four undergraduate students (19 females, 5 males; mean age = 21 years) participated. After 24 participants were tested, one person was chosen randomly and awarded a $50 prize.

Apparatus and Stimuli The apparatus and stimuli were the same as in Experiment 2.

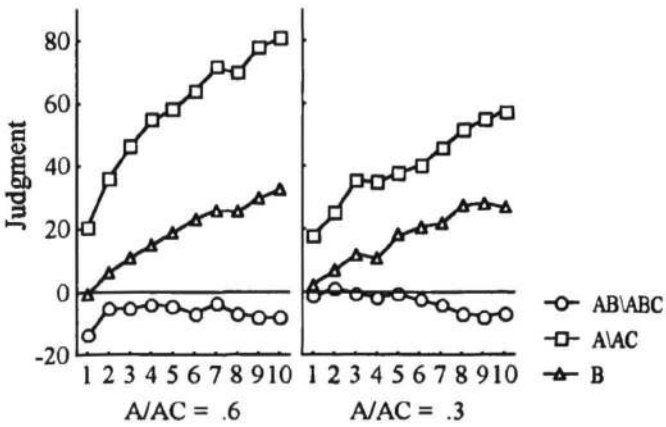

Figure 5. Judgments of predictors by the contingency for A/AC

Procedure The procedure was generally the same as in Experiment 2, except that in two conditions, treatments consisted of either a red, a green, or red and green pills together whereas in the other two conditions, treatments consisted of either red and blue pills together, red, green and blue pills together, or a green pill. One practice of each type was administered, always beginning with low similarity. In the low similarity practice trial, the contingency for A was .5 [P(O|A) = .75, P(O|~A) = .25], the contingency for B was -.5 [P(O|B) = .25, P(O|~B) = .75], the contingency for the AB compound was 0 [P(O|AB) = .5, P(O|~AB) = .5]. In the high similarity practice trial, the contingency for the AC compound was .5 [P(O|AC) = .75, P(O|~AC) = .25], the contingency for B was -.5 [P(O|B) = .25, P(O|~B) = .75], and the contingency for the ABC compound was 0 [P(O|ABC) = .5, P(O|~ABC) = .5].

Results and Discussion

A within-subject analysis of variance with factors of similarity (low, high), contingency for constituent A/AC (Δp = .6, or .3), stimulus judged (A/AC, B, and AB/ABC), and judgment (1 to 10) revealed main effects of stimuli ($F_{2,46}$ = 35.37, *MSE* = 19717.89), and judgment ($F_{9,207}$ = 33.97, *MSE* = 576.36). The analysis also revealed two-way interactions between A/AC and stimuli ($F_{2,46}$ = 23.68, *MSE* = 1308.68), A/AC and judgment ($F_{9,207}$ = 4.59, *MSE* = 307.4), and stimuli and judgment ($F_{18,414}$ = 16.38, *MSE* = 430.25). Contrary to the predictions of Pearce's (1987; 1994) configural model, there was no effect involving similarity.

Planned comparisons with Bonferroni correction revealed that participants discriminated between the levels of A/AC ($F_{1,23}$ = 28.1, *MSE* = 2780.43), and that changing Δp for A/AC had no effect on judgments of any other predictors (Figure 5). These results are consistent with a configural view of stimuli. However, they are not entirely consistent with Pearce's (1994) configural model because the lack of effect of similarity can only occur if generalization of associative strength among predictors is negligible.

General Discussion

The results of three experiments strongly indicate that people process compound predictors as unique cues, independent of the elements that constitute them. This is consistent with a configural associative model such as Pearce's (1994). Pearce's model also considers generalization among predictors to contribute significantly to discriminations thus predicting slower acquisition when discriminative stimuli are more similar to one another. This reasonably intuitive prediction was not verified here, implying that, at a minimum, the extension of Pearce's model to contingency judgments requires the abandonment of the high generalization assumption. The lack of differential discrimination speed associated with similarity among stimuli could be accounted for by an elemental associative model with the assumption that the salience of a compound predictor is significantly larger than the salience of the individual predictors of which it is composed. This assumption is partly supported by the results of Experiment 2 indicating overshadowing by a compound predictor of one of its elements. However, the elemental view is so strongly contradicted by our core finding, the three times reproduced demonstration of the uniqueness of configural cues, that we must reject it in favor of a modified, low generalization, configural associative model.

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