Running Head: MULTI-MODAL DISCRIMINATION LEARNING

Multi-modal Discrimination Learning in Humans: Evidence for Configural Theory

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Abstract

Human contingency learning was used to compare the predictions of configural and elemental theories. In three experiments, participants were required to learn which indicators were associated with an increase in core temperature of a fictitious nuclear plant. Experiments 1 and 2 investigated the rate at which a triple-element stimulus (ABC) could be discriminated from either single-element stimuli (A, B, and C) or double-element stimuli (AB, BC, and AC). Experiment 1 used visual stimuli, whilst Experiment 2 used visual, auditory, and tactile stimuli. In both experiments the participants took longer to discriminate the triple-element stimulus from the more similar double-element stimuli than from the less similar single-element stimuli. Experiment 3 tested for summation with stimuli from either single or multiple modalities and summation was found only in the latter. Thus the pattern of results seen in Experiments 1 and 2 was not dependent on whether the stimuli were single- or multi-modal nor was it dependent on whether the stimuli could elicit summation. This pattern of results is consistent with the predictions of Pearce's (1987) configural theory.

Understanding how a stimulus is represented is fundamental to understanding how associations involving that stimulus are formed. Two influential approaches, *elemental* (e.g., Rescorla & Wagner, 1972) and *configural* (e.g. Pearce, 1987), make entirely different predictions about which parts of a stimulus enter into associations.

The *elemental* approach, utilised by several models (e.g., Gluck & Bower, 1988; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner & Brandon, 2001), suggests that each element of a compound stimulus enters into an association with the unconditioned stimulus. For example, if a light and a tone were presented simultaneously and followed by food, both elements of the compound would separately become associated with the food. If the light were subsequently presented on its own, an elemental model of associative learning would predict responding in the presence of the light due to the direct association between the light and food.

The *configural* approach (e.g., Pearce, 1987; 1994) suggests that a configural representation of the entire light/tone stimulus forms a single association with the food rather than the constituent elements forming separate associations. Configural models predict that a stimulus also indirectly acquires associative strength by generalisation from stimuli with which it shares some common elements. Therefore, if a light/tone compound was paired with food, a configural model would also predict responding to the light when presented alone, as some associative strength should generalise from the compound to the light on the basis of a shared element. Thus, even though elemental and configural models differ in their assumptions regarding which parts of a stimulus enters into associations, in this case at least they make similar predictions regarding responding to the light stimulus.

Elemental and configural models do, however, make different predictions in some situations. Consider an S+ Sø discrimination, where “S+” denotes a stimulus followed by an outcome such as food and "Sø" a stimulus followed by the absence of that outcome. Elemental models predict that, under certain circumstances, the more similar that stimuli are to each other, the easier it should be to solve a discrimination based on those stimuli. This prediction has been supported by some experimental results (e.g., Myers, Vogel, Shin & Wagner, 2001). Configural models, however, make the more intuitive prediction that the more similar that stimuli are, the more difficult it should be to discriminate between them. This prediction is also supported by experimental data (e.g., Redhead & Pearce, 1995). The goal of the present paper is to explore how it might be possible to explain these divergent results without recourse to different models of associative learning.

Both the Myers et al. (2001) and the Redhead and Pearce (1995) studies employed a discrimination of the form A+ B+ C+ AB+ BC+ AC+ ABCø. Myers et al. used a rabbit eye blink paradigm where A, B and C represented stimuli from three different modalities: visual, auditory and tactile. The "+" symbol denotes that the stimulus was followed by a puff of air into the eye of the rabbit and the "ø" symbol denotes the absence of the puff of air. Redhead and Pearce (1995) presented the same discrimination in a pigeon autoshaping paradigm. The elements A, B and C were different coloured dots presented on a television screen, and the stimuli were followed by either food (+) or the absence of food (ø). Both sets of studies found that the animals were able to learn the discrimination, responding to the single-element stimuli (e.g., A) and double-element stimuli (e.g., BC) whilst withholding responding to ABC. Both elemental and configural theories correctly predict this finding. Crucially, however, the theories differ in their predictions regarding the *rate* at which the single- and double-element stimuli should be discriminated from ABC. Elemental models (e.g., Rescorla & Wagner, 1972) predict that BC will gain associative strength faster than A. This prediction arises because, given similar salience, individual elements within a compound will gain associative strength at the same rate as an element presented on its own. Thus, each of the elements B and C will gain associative strength at the same rate as A; the overall associative strength acquired by BC – the sum of its elements – is double that of A. As a result, the BC+ ABCø discrimination should be solved more rapidly than the A+ ABCø discrimination. In other words the Rescorla-Wagner model predicts that the discrimination containing the more similar pair of stimuli should be solved more easily. This is the pattern of results that was found by Myers et al. (2001).[1]

Configural theory (e.g., Pearce, 1987, 1994), predicts that the more similar the stimuli are to each other, the more difficult it should be to discriminate between them. The theory predicts that stimuli A and BC should acquire associative strength at the same rate. In addition, associative strength should generalise from A and BC to ABC due to them sharing common elements. As a result, animals should come to respond to ABC early in training. Animals do eventually stop responding to ABC, and this finding is accommodated by the configural theory through the assumption that the ABC compound acquires inhibitory associative strength. Inhibitory associative strength in turn generalises from ABC to both A and BC. Due to the fact that BC has more elements in common with ABC than does A, more inhibitory associative strength generalises to BC than to A, and therefore the rate of acquisition of conditioned responding will be slower for BC than for A. Consequently, configural

[1] It should be noted that in order for the Rescorla -Wagner model to solve the discrimination, it is assumed that the double-element stimuli (AB/BC/AC) and triple-element stimulus ABC generate compound-unique configural cues.

theory predicts that the A+ ABCø discrimination should be solved faster than the BC+ ABCø discrimination. This pattern of results was observed by Redhead and Pearce (1995).

Predictions from a simulation based on the equations presented by Rescorla and Wagner (1972) are shown in the left panel of Figure 1, and from a simulation based on equations presented by Pearce (1994) are illustrated in the right panel of Figure 1. For these simulations the salience of the stimuli was considered to be equal (0.2 in the case of the Rescorla-Wagner model) and the value for the learning rate parameters were 0.4 on reinforced trials and 0.2 on non-reinforced trials for both models. The qualitative predictions are not parameter-driven and can be achieved with a wide range of values. It was assumed that the double-element stimuli (AB/BC/AC) and triple-element stimulus ABC generate compound-unique configural cues. The configural cue unique to the compound ABC is assumed to acquire inhibitory associative strength to counter the excitatory associative strength of its constituent elements A, B and C which have been separately paired with the reinforcer.

Myers et al. (2001) suggested that it might be possible to accommodate their results and those of Redhead and Pearce (1995) within a single theoretical framework. The authors reasoned that when stimulus elements are presented in compound, they may interact with the perception of each other, and that there may be less of this perceptual interaction between elements from separate modalities than between elements from the same modality. For example, if a clicker was added to a red light there would be less disruption to the perception of the red light than if a blue light had been added. Any difference between the perception of the red light in compound and in isolation could result in a reduction in conditioned responding due to a generalisation decrement, and hence reduce the likelihood of summation. Rescorla and Coldwell (1995) have suggested that a large generalisation decrement could explain why summation is rarely seen in pigeon autoshaping experiments using only visual stimuli (e.g., Aydin & Pearce, 1997), whilst it has often been shown in rabbit eye-blink conditioning using stimuli from different modalities (e.g., Kehoe, et al., 1994). Myers et al. suggested that the differences between Redhead and Pearce's findings and their own were simply due to differences in perceptual interactions between stimuli. A formal description of a proposed mechanism of perceptual interaction has been provided by Wagner and Brandon's (2001) Replaced Elements Model.

A study by Pearce and George (2002) went some way to addressing the question of whether the differences between the results of Myers et al. (2001) and Redhead and Pearce (1995) were due to stimuli interaction. Pearce and George presented the A+ B+ C+ AB+ BC+ AC+ ABCø discrimination to pigeons using stimuli which were from the same visual modality, but which differed along separate dimensions. A was a white triangle, B comprised 2 vertical lines and C was a red circle. Although the stimuli were all from the same modality Pearce and George assumed that it was unlikely that they would interact to produce a generalisation decrement. Nevertheless, Pearce and George (2002) found that the A/B/C+ ABCø discrimination was learnt more rapidly than the AB/BC/AC+ ABCø discrimination, the pattern of results predicted by Pearce's configural model.

The present series of experiments offers a further test of the predictions made by configural theory (Pearce, 1987; 1994) and elemental models (e.g., Rescorla & Wagner, 1972; Wagner & Brandon, 2001). The experiments set out to assess the importance of stimulus modality on human discrimination learning using the A+ B+ C+ AB+ AC+ BC+ ABCø discrimination. In Experiment 1 all of the stimulus elements were from the same modality (i.e., visual) and in Experiment 2 the elements were from different modalities (i.e., visual, auditory or tactile). Studies comparing single- and multi-modal stimuli have primarily investigated the effects of stimulus modality on attention (e.g., Arnell & Jolicouer, 1999). The proposed experiments are, however, the first in which stimulus modality has been varied within a learning paradigm.

Although Pearce and George (2002) used stimuli which were unlikely to interact when presented in compound, they did not provide evidence to show that their stimuli would produce summation. Summation of conditioned responding is critical for the pattern of results predicted by the Rescorla-Wagner model (1972) for the A+ B+ C+ AB+ AC+ BC+ ABCø discrimination. Experiment 3 provides a direct test of whether the stimuli used in Experiment 1 and 2 would produce summation when presented in compound.

The current study is not the first time that the A+ B+ C+ AB+ AC+ BC+ ABCø discrimination has been presented to human participants – Kinder and Lachnit (2003) presented the discrimination in a Pavlovian eyelid conditioning experiment. They used only single-modal stimuli and could confirm neither the configural nor elemental prediction as they found that participants learned to discriminate the single- and double-element stimuli from ABCø at the same rate. Given the contrasting results in the animal literature using single- and multi-modal stimuli, the present study offers a further test of the predictions made by configural theory (e.g., Pearce, 1987; 1994) and elemental models (e.g., Rescorla & Wagner, 1972) in human learning experiments.

Experiment 1

Participants were presented with the A+ B+ C+ AB+ AC+ BC+ ABCø discrimination. All three elements were represented by patterns of 10 dots of a specific colour (A comprised 10 red dots, B 10 white dots, and C 10 green dots) displayed on a computer screen. Participants were asked to imagine that they were in the control room of a nuclear power plant and that they had to predict whether the core temperature of the plant was going to increase or remain low by writing a rating between 0-9 next to the trial number on a score sheet. A rating of 0 indicated that the participant predicted a low temperature; a rating of 9 indicated that the participant predicted a high temperature. The participants were given feedback to indicate a high temperature following a "+" trial and a low temperature following an "ø" trial. A control room layout was presented on the computer screen in front of which the participant was seated. The control room contained three "monitors": stimuli were presented on monitor 1, information about the temperature of the core was presented on monitor 2, and procedural instructions were presented on monitor 3 (see Figure 2).

It is conceivable that participants might solve the A+ B+ C+ AB+ BC+ AC+ ABCø on the basis of numerosity – adopting a simple rule such as "one or two colours of dots on the screen are followed by a temperature increase". In studies of pigeon autoshaping (e.g. Redhead & Pearce, 1995) the control discrimination Dø Eø Fø DEø DFø EFø DEF+ has been included to exclude this possibility. Consequently, in Experiments 1 and 2, additional trials with Dø, EFø and GHI+ (D, E, F, G, H and I comprising Yellow, Light blue, Purple, Brown, Pink, and Orange dots, respectively), were presented. It is also possible that it is simply easier to learn the association between single-element stimuli and their outcome than to learn the association between double-element stimuli and their outcome. Examination of performance on the Dø, EFø and GHI + trials should also enable us to discriminate between this possibility and the predictions of configural theories. If the A/B/C+ ABCø discrimination is learnt more quickly than the AB/BC/AC+ ABCø discrimination simply because it is easier to learn the outcome following the single-element stimuli, then the ratings for Dø should decline faster than ratings for EFø. If, however, the A/B/C+ ABCø discrimination is learnt more quickly than the AB/BC/AC+ ABCø discrimination due to a process described by configural theory (Pearce, 1987; 1994) then the ratings for Dø should decline at the same rate as those for EFø.

Throughout the experiment whenever A, B or C were presented they were each represented by 10 dots. Thus, on single-element trials 10 dots were presented, on double-element trials 20 dots, and on triple-element trials 30 dots. This leads to the possibility that the participants could use a luminosity rule: the brighter the screen the more likely a rise in temperature. Both Redhead and Pearce (1995), and Kinder and Lachnit (2003) controlled for this possibility by representing A on single-element trials as 100 dots, on double-element trials as 50 dots and on triple-element trials as 33 dots. The number of dots on the screen was held constant around 100 across all trial types. One problem with this design is that it could reduce the probability of observing summation. If the 100 dots representing A on single-element trials acquire associative strength then it is possible that only a portion of that associative strength will be retained by the 50 dots representing A on the double-element trials. A consequence of this is that manipulating the number of dots might bias the experimental results against the pattern observed by Meyer et al. (2001). In order to ensure that there was a fair assessment of the predictions of elemental and configural theories, the number of dots representing A, B and C was held constant across trials in the experiments reported here. It should also be noted that in Experiment 2, where A, B and C were represented by stimuli from different modalities, the problem of luminosity was avoided.

Each stimulus was presented 10 times and the sequence of trials was arranged so that no stimulus was repeated more than twice in succession. How quickly the ratings of the single-element stimuli (A/B/C+) and the double-element stimuli (AB/AC/BC+) increased across trials in comparison to ratings of the ABCø stimulus was taken as a measure of how quickly the discriminations were learned.

Method

Participants. The participants were 20 undergraduate students at the University of Southampton who received course credits for participation in the study (14 female and 6 male; mean age = 20.3 years; age range 18-28 years)

Materials and apparatus. The experiment was conducted in a research cubicle (Length 2.4 m, width 1.3m, height 2m) containing a chair positioned in front of a 1.3 m wide work bench attached to the wall opposite the entrance to the cubicle. A 15 inch colour computer monitor and keyboard were placed on the work bench. The monitor was connected to an IBM compatible PC placed beneath the bench. The experiment was presented on the computer monitor via a Microsoft PowerPoint presentation. During training the screen displayed a scene of a control room containing 3 monitors; monitor 1 presenting the stimuli, monitor 2 presenting the feedback on the outcome of the trial and monitor 3 giving instructions to the participant (see Figure 2).

The stimuli were presented on Monitor 1, an 80mm x 50mm black oval in the centre of the computer screen. The stimuli were different coloured circular dots, 2mm in diameter. A comprised 10 red dots randomly placed on Monitor 1; B comprised 10 white dots; C comprised 10 Green dots; D comprised 10 Yellow dots; E comprised 10

Light blue dots; F comprised 10 Purple dots; G comprised 10 Brown dots; H comprised 10 Pink dots; I comprised 10 Orange dots. Double and triple compounds (e.g., AB and GHI) contained 10 dots of each colour.

Feedback following each trial was presented on Monitor 2, a 70 mm by 30 mm black rectangle on the left hand side of the computer screen. On the monitor's left side was the word "Safe" and on the right side the word "Danger". A vertical arrow would appear between the words "Safe" and "Danger". For stimuli followed by a "+" outcome (e.g., A+) the pointer fell between 50-60 mm on the continuum; for stimuli followed by a "ø" outcome (ABCø) the pointer fell between 10 and 20 mm on the continuum. Instructions such as "Press space bar to begin" were given to the participants via Monitor 3, a 40 by 60 mm black rectangle on the right hand side of the computer screen. Score sheets containing trial numbers 1-180 were placed next to the monitor for the participant to record their rating for each trial.

Procedure. Once the participants were seated in front of the PC the experimenter left the room. The participants progressed through the computer programme by pressing the space bar. They were given the following instructions on the computer screen.

> "You have been accepted to build a career in the exciting world of nuclear waste development. It is your job to predict the temperature of the core, if it gets too hot the plant will blow up. We have highly sophisticated machinery which monitors everything; your job is to work out what the dials on the machinery mean. One dial, for instance, shows different patterns of dots. After certain combinations of dots the plant's core temperature is very low but after others it is high. After each trial, write down a number between 0-9 to show if you think the plant is going to blow or not. A rating of 0 means you think the temperature will

remain cool, 9 means the temperature will increase to a dangerous level. Only put 0 or 9 when you are sure you know what the stimuli mean otherwise put a score which reflects your confidence. For example, put 5 if you have no idea; put 3 if it is most likely safe; put 7 if it is probably dangerous. After you have recorded your rating, press the space bar and you will receive feedback from the dial on the left as to whether you were correct or not. Please press the space bar when you are ready to start."

There were 180 trials in total that were presented in 10 blocks of 18 trials (1 A+ trial, 1 B+ trial, 1 C+ trial, 1 AB+ trial, 1 BC+ trial, 1 AC+ trial, 3 ABCø trials, 3 Dø trials, 3 EFø trials and 3 GHI + trials). The order of presentation was randomised within blocks. On each trial the dots were presented on Monitor 1, at the centre of the computer screen, for 5 seconds after which Monitor 1 became black and a message on Monitor 3 on the right of the computer screen instructed the participant to write down their rating for that trial and then press the space bar for feedback on the outcome of the trial. Once they had pressed the space bar an arrow on Monitor 2 on the left of the computer screen would appear along the continuum between the words Safe and Danger. After 10 seconds the arrow would disappear and the next trial would commence. At the end of the experiment a message on the screen asked the participant to inform the experimenter outside the cubicle that the experiment had been completed.

Results and Discussion

All statistical tests were evaluated with respect to an alpha value of 0.05. The results for the acquisition of the A+ B+ C+ AB+ BC+ AC+ ABCø discrimination are shown in the left panel of Figure 3. The ratings for the single-element stimuli (A/B/C) were combined and presented as a single mean score as were the ratings for the double-element stimuli (AB/BC/AC). Combining the stimuli was considered appropriate as two one-way analyses of variance (ANOVA) with stimulus as the independent variable performed on the mean ratings of the single- and double-element stimuli revealed no significant effect of stimulus either for single-element stimuli, $F(2, 38) = 1.83$ (*M*s: A+ = 6.7, B+ = 6.2, C+ = 6.4) or for double-element stimuli, $F(2, 38) = 2.04$ (*M*s: AB+ = 6.1, BC+ = 5.8 , AC+ = 6.2).

The ratings for the three trial types (single-, double- and triple-element stimuli) were initially very similar over the first two blocks of trials. After block 2 the ratings for trial type ABCø steadily declined, while ratings for the other trial types increased. Also from trial block 3 and for the remainder of the trial blocks, the mean rating for A/B/C+ trials was higher than that of AB/BC/AC+. A two-way repeated measures ANOVA performed on the mean ratings revealed a main effect of trial type (single-, double- and triple-element stimuli), $F(2, 38) = 28.19$, a main effect of trial blocks, $F(9, 171) = 3.21$, and a significant interaction between trial type and trial block, $F(18, 342) = 19.08$. Simple main effect analyses (Keppel, 1973) indicated that the responses to the three types of trials differed from trial block 3 onward, $Fs(2, 380) > 4.33$. The observation that the A/B/C+ ABCø discrimination was acquired more readily than the AB/BC/AC+ ABCø discrimination was supported by the results of Newman-Keuls tests. Mean ratings of A/B/C+ were significantly greater than ratings of ABCø following trial block 2, q^{nk} (380) > 4.28 but mean ratings of AB/AC/BC+ were only significantly higher than ratings of ABCø after trial 3, q^{nk} (380) > 3.02. In addition mean ratings of A/B/C+ were significantly higher than the mean ratings of AB/BC/AC+ on trial blocks 8 and 10, q^{nk} (380) > 2.82.

The acquisition of the Dø EFø GHI+ discrimination is shown in the right panel of Figure 3 and was analysed using a two-way repeated measures ANOVA with trial blocks and trial type as the independent variables. There was a main effect of trial type, $F(2, 38) = 51.19$, a main effect of trial blocks, $F(9, 171) = 8.94$, and the interaction between trial type and trial blocks was also significant, $F(18, 342) = 7.48$. Simple main effect analyses indicated that responses to the three types of trials differed following trial block 3, $Fs(2, 380) > 6.67$. Newman-Keuls tests confirmed that the rating of GHI+ was significantly higher than the ratings of both Dø and EFø after trial block 3, $q^{nk}(380) > 3.61$. Ratings of Dø and EFø did not differ.

The results of the Dø EFø GHI+ discrimination suggest that the results of the A+ B+ C+ AB+ BC+ AC+ ABCø discrimination can not be explained by it being easier to form an association with a single-element stimulus than double-element stimulus. The ratings of the Dø and EFø trials declined at the same rate. This pattern is in line with the predictions of the configural theory (Pearce, 1987; 1994) since there would be no difference in generalisation between Dø and GHI+ and between EFø and GHI+ as none of these stimuli share any elements in common. Given that participants were instructed give a rating of 5 if they were unsure whether the outcome of a trial was a safe or a dangerous temperature, the Rescorla-Wagner model (1972) predicts that the EFø trials should decline faster than the Dø trials. This pattern of results was not found. It must be noted that participants could have been attending to only one of the colours present on EFø trials, rendering them equivalent to single-element trials. Such a strategy would result in there being no difference in acquisition associated with Dø and EFø trials. This would appear unlikely given the participants have to attend to all elements of a stimulus in order to solve the A+ B+ C+ AB+ BC+ AC+ ABCø discrimination but it still does remain a possibility.

The Dø EFø GHI+ trials were also added in attempt to rule out the possibility that the participants could simply learn that the temperature increased on trials where relatively few stimuli were present. It has to be acknowledged that participants could still learn such a rule for the A+ B+ C+ AB+ BC+ AC+ ABCø discrimination and the opposite rule for the Dø EFø GHI+ discrimination. Even using the alternative control discrimination (Dø Eø Fø DEø DFø EFø DEF+) employed by Kinder and Lachnit (2003), the results would be open to such an interpretation. Therefore, the results must be viewed with this alternative possibility in mind.

The results from the A+ B+ C+ AB+ BC+ AC+ ABCø discrimination follow the pattern that is predicted by configural theory (Pearce, 1987; 1994). Mean ratings for the single-element stimuli A/B/C+ were significantly higher than for the double-element stimuli AB/BC/AC+ by the end of training. The results are similar to those reported by Redhead and Pearce (1995) and Pearce and George (2002) in their studies with pigeons and suggest that people solve discriminations based on configural processes.

The results do not replicate all studies which have employed this discrimination. Kinder and Lachnit (2003) presented similar visual stimuli to those used in Experiment 1 but did not find any difference in the rate at which the A/B/C+, ABCø discrimination was solved compared to the AB/BC/AC+, ABCø discrimination. Kinder and Lachnit argued that their results were best described by a modified version of Pearce's configural theory (1994) in which generalization between patterns decreases as the discriminability of their component elements increases. Kinder and Lachnit suggested that the discriminability between the stimuli they used was high and showed that the modified version configural theory could account for their results: there was no difference between responding on the A\B+\C+ and the AB\BC\AC+ trials. By setting the discriminability of stimuli to a lower value, the modified model can predict the findings of Experiment 1. One conclusion that can be drawn from the results of these simulations is that the stimuli used in Experiment 1 were less discriminable than the stimuli used by Kinder and Lachnit (2003). It is not, however, clear why this would be the case, given that Kinder and Lachnit also used coloured dots in two of their experiments.

Results reported by Myers et al. (2001) using stimuli from different modalities in a rabbit eye blink paradigm showed the opposite pattern to those in Experiment 1. Myers et al. suggested that the difference between their findings and those of Redhead and Pearce (1995) was due to the use of multi-modal stimuli. In order to investigate this possibility, Experiment 2 was conducted. Experiment 2 was exactly the same as Experiment 1 with the exception that the stimuli were drawn from three different modalities.

Experiment 2

The participants were trained on an A+ B+ C+ BC+ AB+ AC+ ABCø discrimination in which the elements A, B and C were drawn from three different modalities: visual, auditory and tactile. Based on the results of a similar study by Myers et al. (2001) it was expected that the triple-element stimulus would be differentiated from the double-element stimuli more rapidly than from the single-element stimuli as predicted by the Rescorla-Wagner model (1972).

Method

Participants. The participants were 20 undergraduate students receiving course credits for participation in the study (15 female and 5 male; mean age 19.8 years; age range 18-24 years). The participants were divided into three subgroups in order to counterbalance the modality of the filler stimuli: 6 in subgroup 1, 7 in subgroup 2 and 7 in subgroup 3. None of the participants from Experiment 1 took part in Experiment 2.

Materials and apparatus. Materials and apparatus were the same as in Experiment 1 with the exception that stimuli were presented in three different modalities. Auditory stimuli consisted of different sounds presented via the speakers of the computer at a level of 50 dB measured 30 cm in front of the centre of a computer screen. Tactile stimuli were presented via two 5 cm x 5 cm x 2 cm boxes strapped to the wrists of the participant. Each box contained a vibrating device that was controlled via a 2 cm diameter photocell connected to the box via a 30 cm wire. The photocell was attached to the bottom corner of the computer screen with adhesive tape. The photocell was triggered by a 1 cm diameter white circle which was presented via the Microsoft PowerPoint presentation. The photocell obscured the white circle so that there was no additional visual stimulus associated with the tactile stimuli. There were two stimuli created by the tactile vibrating device, a continuous vibration for 5 seconds and an intermittent vibration for 5 seconds. Over the 5 second period of the latter trial type the vibrate device was switched on at the start of seconds 1, 3 and 5 and off at the start of seconds 2, 4, and at the end of the 5th second.

For all participants, A was a constant vibration of the box on the left wrist, B was a Bell sound, C was 10 Red dots, G comprised 10 Brown dots, H was a horn sound and I was an intermittent vibration of the box on the right wrist. The participants were divided into three subgroups in order to counterbalance the modalities of the single-element stimulus D and double-element stimulus EF. For subgroup 1, D comprised 10 Yellow dots; E was a Clicker sound; and F was a constant vibration of the box on the right wrist. For subgroup 2; D was a constant vibration of the box on the right wrist; E comprised 10 Yellow dots and F was a Clicker sound. For subgroup 3, D, E and F were the Clicker, constant vibration of the box on the right wrist and 10 Yellow dots respectively.

Procedure. The details of the procedure were the same as for Experiment 1 except that before the Experimenter left the room the boxes were strapped to the participants' wrists. The computer instructions included additional information that the monitoring system produced visual, auditory and tactile signals. The participants were told that they should take all of these different signals into account when predicting the core temperature.

Results and Discussion

The results of the A+ B+ C+ AB+ BC+ AC+ ABCø discrimination presented in Experiment 2 are shown in the left panel of Figure 4. The ratings for the single-element stimuli (A/ B/ C) were combined and presented as one mean as were the ratings for the double-element stimuli (AB/BC/AC). Combining the stimuli was considered appropriate as two one-way ANOVAs with stimulus as the independent variable performed on the mean ratings of the single- and double-element stimuli revealed no effect of stimulus either for single-element stimuli, $F(2, 38) = 2.21$ (*M*s: A+ = 6.6, B+ = 6.8, C+ = 6.0) or for double-element stimuli, $F < 1$ (*M*s: AB+ = 6.1, BC+ = 6.2, AC+ = 6.2).

A one-way ANOVA with subgroup as the independent variable performed on the mean ratings revealed no main effect, $F < 1$ (*M*s: Subgroup 1 = 5.5, Subgroup 2 = 5.2, Subgroup 3 = 5.3). The results of the subgroups were subsequently combined.

Overall, the pattern of results shows that, following the first trial where the ratings for the three trial types were similar, the ratings of ABCø decreased over the course of training while the ratings of the single-element stimuli and double-element stimuli increased. For the first three blocks of trials the double-element stimuli were rated higher than the single-element stimuli. In subsequent trial blocks the single-element stimuli were rated higher than the double-element stimuli.

A two-way repeated measures ANOVA performed on the mean ratings revealed a main effect of trial type, $F(2, 38) = 38.87$, and a main effect of trial block, $F(9, 171) = 2.31$. There was also a significant interaction between trial type and trial block, $F(18, 342) = 11.68$. Simple main effect analyses (Keppel, 1973) indicated that responses to the three types of trial differed from trial block 3 onward, Fs(2, 380) > 6.81. The observation that ratings for A/B/C+ increased at a faster rate than the ratings for AB/BC/AC+ was supported by the results of Newman-Keuls tests. The mean ratings of trial types A/B/C+ were significantly higher than the mean ratings of trial types AB/BC/AC+ on trial blocks 9 and 10, $q^{nk}(380) > 2.80$. Mean ratings of trial types A/B/C+ and trial types AB/AC/BC+ were both significantly higher than ratings of trial type ABCø following trial block 2, $q^{nk}(380) > 4.41$.

The course of acquisition of the Dø EFø GHI+ discrimination is shown in the right panel of Figure 4 and was analysed using a two-way repeated measures ANOVA with blocks of trials and trial type as the independent variables. There was a main effect of trial type, $F(2, 38) = 21.56$, a main effect of trial block, $F(9, 171) = 2.43$, and the interaction of trial type and trial block was also significant, $F(18, 342) = 5.14$. Simple main effect analyses indicated that the responses to the three types of trial differed on trial 4, $F(2, 380) = 21.09$ and from trial 6 onwards, Fs(2, 380) > 4.43. Newman-Keuls test confirmed that the rating of GHI+ was significantly higher than the ratings of both Dø and EFø on trial block 4 and from trial block 6 onwards, $q^{nk}(380) > 6.21$. Ratings of Dø and EFø did not differ. The results of the Dø EFø GHI+ trials suggest that any difference in the main discrimination during the last few trials of the session can not be due to ease of learning the outcome associated with a single-element stimuli compared to a double-element stimulus.

It should be noted that there was a significant effect of trial type in the Dø EFø GHI+ discrimination after 3 trials compared to after only 2 trials in the A+, B+, C+ AB/BC/AC+, ABCø discrimination. Both configural theory (Pearce, 1987; 1994) and the Rescorla-Wagner (1972) model predict that the former discrimination should be learned more quickly than the latter. It is not clear why the results differ from both sets of predictions. It is possible that the difficulty of discriminating between two tactile stimuli in the Dø EFø GHI+ trials was responsible for this slight retardation in acquisition.

Once again, the main set of results followed the pattern predicted by configural theory (Pearce, 1987; 1994). The ratings for the single-element stimuli A/B/C+ were higher by the end of training than the double-element stimuli AB/BC/AC+. The results are opposite to those found by Myers et al. (2001) where stimuli from different modalities were used. Over the first three trial blocks of the current experiment the ratings for the double-element stimuli were higher than the single elements, though this difference was never statistically significant.

Myers et al. (2001) suggested that, because Redhead and Pearce (1995) used stimuli from a single modality, their stimuli interacted in compound resulting in a generalisation decrement (Rescorla & Coldwell, 1995). As a result, the associative strength of the double-element stimuli would have been reduced in relation to the single-element stimuli. Experiment 2 used stimuli from different modalities as did Myers et al., but still the results replicated those of Redhead and Pearce (1995). It is possible that, for the procedure and participants in the present studies, the associative strength of stimuli presented in compound does not summate in the way necessary to produce the pattern of results observed by Myers et al. (2001). It may be that there is still perceptual interaction when the stimuli are presented in compound even though the stimuli are drawn from three different modalities. An alternative way of examining how the stimuli interact in compound is by directly testing for summation. Experiment 3 was designed to assess summation using the same stimuli and general procedure used in Experiments 1 and 2.

Experiment 3

Participants were presented with the same scenario as in Experiments 1 and 2. They were asked to predict which sets of stimuli were associated with different of core temperatures. There were two groups: Group Different received training with visual, auditory and tactile stimuli; Group Same received only visual stimuli. It would have been preferable to include subgroups which had received only auditory or tactile stimuli but it was not possible to generate nine tactile stimuli that participants were able to discriminate between easily. Pilot studies indicated that participants were able to discriminate readily between the visual, auditory and tactile stimuli used in Experiments 2 and 3.

The participants were trained to associate stimuli A, B and C with a moderate rise in temperature. For Group Same, A comprised 10 red dots, B comprised 10 blue dots and C comprised 10 white dots. For Group Different, A comprised 10 red dots, B was a tone and C was the vibration of a box strapped to the participants' left wrist. The participants were then tested with compounds AB, BC and AC to test for summation. In human causality judgement experiments (e.g., Beckers, De Houwer, Pineno, & Miller, 2005) it has been necessary, in order to demonstrate summation, to include further training trials that are associated with higher outcome values than the target training trials. The training trials, therefore, consisted of A+ B+ C+ Dø E++ FGø IH++ , where "+" trials were associated with the arrow appearing midway on the Safe

Danger continuum, "++" trials toward the Danger end and "ø" toward the Safe end. Trials Dø, and FGø where included so that single-element stimuli and double-element stimuli were both associated with the arrow appearing on the Safe end of the Safe Danger continuum. For full stimulus counterbalancing it might have been considered necessary to have included further trials where the compound was associated with a medium rise in temperature (e.g., JK+, LM+, NO+). These were not included due to the limited number of discriminable tactile stimuli available. The omission of these trials was not considered to be critical to the analysis of the results as the experiment was a between-groups design. Trials were also included in which no stimulus was presented. On these trials the participants were asked to predict the temperature but no feedback regarding the outcome of the trial was given. These trials were presented to give an index of the associative strength acquired by the background context.

Method

Participants. The participants were 30 undergraduate students receiving course credits for participation (20 female and 10 male; mean age 22.1 years; age range 18-39 years). The participants were divided into two equal groups: Group Same and Group Different. The participants in Group Different were further divided into three equal subgroups. None of the participants from Experiments 1 and 2 took part in Experiment 3.

Materials and apparatus. With the exception of the following, all other details were the same as in Experiment 2. For Group Same, A comprised 10 red dots; B comprised 10 blue dots; C comprised 10 white dots; D comprised 10 green dots; E comprised 10 yellow dots; F comprised 10 orange dots; G comprised 10 brown dots; H comprised 10 light blue dots; and I comprised 10 purple dots. For Group Different: A comprised 10 red dots; B was a Bell sound; C was a 5 sec vibration in the box attached to the participants left wrist. The participants of Group Different were divided into 3 subgroups in order to counterbalance the modalities of the filler stimuli D, E, F, G, H and I. For Group Different subgroup 1, D comprised 10 blue dots; E comprised 10 white dots; F was a clicker sound; H was a horn sound; G was an intermittent vibration of the box attached to the right wrist; and I was a steady vibration of the box attached to the right wrist. For Group Different subgroup 2, D was an intermittent vibration of the right wrist box; E was a steady vibration of the box attached to the right wrist; F comprised 10 blue dots; H comprised 10 white dots; G was a clicker sound; and I was a horn sound. For Group Different subgroup 3, D was a clicker sound; E was a horn sound; F was an intermittent vibration of the right wrist box; H was a steady vibration of the box attached to the right wrist; G comprised 10 blue dots; and I comprised 10 white dots.

Procedure. The participants were presented with the same scenario as in the previous two experiments. They were presented with A+, B+, C+, Dø, E++, FGø, and IH++ trials. The "ø" Trials were followed by the arrow appearing at the safe end of the feedback monitor (Monitor 2), "+" Trials were followed by the arrow appearing in the middle of the feedback monitor, and "++" Trials were followed the arrow appearing at the danger end of the monitor. There was an additional trial in which no stimuli were presented. These trials were not followed by any feedback and it was explained to the participants, via the computer screen, that there had been an intermittent fault in the monitor. A block of trials consisted of one of each of the 8 different trial types and there were 8 blocks during a session. During block eight, the participants also received test trials with AB, BC and AC. Once again no feedback was given following these test trials.

All other details of the procedure are the same as those reported in Experiment 1 with the exception that in the instruction regarding ratings, participants were told that a rating of 5 would indicate that they thought there would be a medium increase in temperature.

Results and Discussion

A one-way ANOVA with subgroup as the independent variable was performed on the acquisition data of Group Different which revealed no main effect, $F(2, 12) = 3.08$ (*M*s: Subgroup 1 = 3.9, Subgroup 2 = 4.8, Subgroup 3 = 4.6). The results of the different subgroups were subsequently combined.

The mean ratings of trial types A/B/C+ were combined for the two groups, this was considered appropriate as a one-way ANOVA with trial type as the independent variable performed on the mean ratings of Group Same revealed no main effect, $F < 1$ (*M*s: A+ = 4.3, B+ = 4.5, C+ = 4.0). A similar analysis performed on the mean ratings of Group Different revealed no effect of trial type, $F < 1$ (*M*s: A+ = 4.5, B+ = 4.5, C+ = 4.3).

The rate of acquisition for the two groups was tested using a three-way mixed design ANOVA with groups, trial type (++, + and o) and trial blocks as independent variables. There was a significant effect of trial type, $F(2, 56) = 78.25$, but no main effect of trial block or group, $F\text{s} < 1$. There was a significant trial type by trial block interaction, $F(14, 392) = 15.62$, but none of the other interactions were significant, group by trial type, $F(2, 56) = 1.26$, group by trial block, $F(7, 196) = 1.91$, group by trial type by trial block, $F(14, 392) = 1.68$. The left panel of Figure 5 shows the acquisition data for Group Different and the central panel of Figure 5 shows the acquisition data for Group Same.

The mean ratings for the final presentations of A, B, and C combined and for the test trials of AB, AC, and BC combined are shown in the right panel of Figure 5 for the two groups. The mean rating of the elements shown separately was much lower for Group Different than the mean rating of the elements shown in compound. However, the mean rating of the two types of stimuli were very similar for Group Same. This impression was verified by a two-way mixed design ANOVA with groups (between) and trial type (within) as the independent variables. There was no main effect of group, $F(1, 28) = 1.41$. There was, however, a significant effect of trial type, $F(1, 28) = 7.68$, and a significant interaction between group and trial type, $F(1, 28) = 12.22$. Further investigation of the simple main effects revealed that there was a significant effect of trial type for group different, $F(1, 28) = 19.63$, but none for Group Same, $F < 1$. There was no difference between the groups in their mean ratings of the individual elements trial types, $F < 1$ but there was in their ratings of the compound trial types, $F(1, 56) = 7.52$.

The group mean rating scores for the context alone trials during training for Group Different and Group Same are shown in the left and central panels of Figure 5 respectively. Rating of the context by Group Different appeared to be higher than by Group Same, particularly in the first three trials. This impression was verified by a two-way mixed design ANOVA with groups (between) and trial block (repeated measures) as the independent variables. There was a main effect of group, $F(1, 28) = 4.87$. Neither the main effect of trial block nor the interaction was significant, Fs < 1.

The results of Experiment 3 follow the pattern of those found by Kehoe et al. (1994) and Myers et al. (2001). There was evidence of summation when previously trained stimuli from different modalities were presented in compound, whereas there was no summation when stimuli from the same modality were presented in compound. It would appear then that the simultaneous presentation of the multi-modal stimuli used in Experiment 2 was not likely to have resulted in a large generalisation decrement. Therefore, the difference between the results of Experiments 2 and those of Myers et al. are unlikely to be due to differences in the way the stimuli are perceived when in compound. Thus even when stimuli are used that produce summation, the pattern of results in an A+ B+ C+ AB+ BC+ AC+ ABCø discrimination follow those predicted by configural theory (Pearce, 1987; 1994).

General Discussion

The current experiments sought to test the predictions made by configural theory (e.g., Pearce, 1987, 1994) and elemental models (e.g., Rescorla & Wagner, 1972) regarding an A+ B+ C+ AB+ BC+ AC+ ABCø discrimination. It was found that presenting such a discrimination to human participants resulted in higher responding to the single-element stimuli (A/B/ C) than responding to the double-element stimuli (AB/AC/ BC) by the end of training. This finding was obtained irrespective of whether the stimuli used were single- or multi-modal, or whether summation was observed when the stimuli were presented in compound. The findings are consistent with configural theory which explains the pattern of results as follows: during acquisition of the discrimination, more inhibitory associative strength generalised from ABCø to the double-element stimuli (AB/AC/ BC) than to the single-element stimuli (A/B/ C), because the former had more elements in common with ABCø.

Experiment 1, in which the stimuli were taken from a single modality, replicated in humans the results obtained by Redhead and Pearce (1995) in pigeons. Experiment 2 used a multi-modal design similar to an experiment by Myers et al. (2001). Myers et al. found that responding to the double-element stimuli was higher than responding to the single-element stimuli by the end of training, in line with the predictions of elemental models (e.g., Rescorla & Wagner, 1972). Myers et al. (2001) suggested that the difference between Redhead and Pearce's (1995) results and their own was a consequence of their use of stimuli drawn from three different modalities. Myers et al. argued that conditioning with elements from different modalities was more likely to generate summation of the associative strengths of the separate elements in the double-element stimuli, resulting in responding to the double-element stimuli reaching asymptote more rapidly. Indeed summation is rarely seen in pigeon autoshaping experiments using only visual stimuli (e.g., Aydin & Pearce, 1997), whereas it is commonly observed in rabbit eye-blink conditioning using stimuli from different modalities (e.g., Kehoe, et al., 1994). In Experiment 2, however, we failed to replicate Myers et al.'s results despite using multi-modal stimuli. Instead, rating of the single-element stimuli was again higher than the ratings of the double-element stimuli by the end of training. These findings suggest that the difference between the stimuli used by Myers et al. (2001) and Redhead and Pearce (1995) cannot explain the differential pattern of results obtained in these two studies.

It still may have been the case, however, that combining stimulus elements used Experiment 2 did not result in the summation of associative strengths. Such summation would be necessary for responding to the double-element stimuli to exceed responding to the single-element stimuli, the pattern of responding predicted by elemental models (e.g., Rescorla & Wagner, 1972). Experiment 3 directly measured the amount of summation produced by the stimuli used in Experiments 1 and 2. Summation was not seen with the single-modal stimuli in Experiment 1 but it was observed using the multi-modal stimuli in Experiment 2. Thus, Myers et al.'s (2001) suggestion – that responding to the single-element stimuli reached asymptote more rapidly than responding to the double-element stimuli due to the absence of summation – could explain the pattern of results obtained in Experiment 1, but not those obtained in Experiment 2. Configural theory (Pearce, 1987; 1994), in contrast, predicts the pattern of results seen in both Experiments 1 and 2.

Configural theory can also predict the pattern of summation observed in Experiment 3, but only if we assume that the context was more salient in the multi-modal discrimination than it was in the single-modal discrimination. Without a salient context, configural theory has difficulty predicting summation (see Darby & Pearce, 1995). According to configural theory, only half of the associative strength of each of the stimuli A and B will generalize to the compound AB, leading to the compound having the same associative strength as the associative strength of each of as its components individually. As a result configural theory predicts that no summation should be observed when A and B are presented in compound. A more formal derivation of the predictions based on the equations specified by Pearce (1987) produces a value of λ for the net associative strength of the compound AB, where λ represents the associative strength of the stimuli A and B at asymptote. With a salient context, however, the initial training trials could be represented as AX+, BX+, Xø, where X represents the context. Stimuli AX and BX will acquire excitatory associative strength through being paired with the positive outcome. Excitatory associative strength will generalise to the context from the stimuli AX and BX. Since the context alone is never followed by the outcome, the context will acquire inhibitory strength to counteract the excitatory strength generalising from the stimuli AX and BX. The inhibitory associative strength of the context will in turn generalize to stimuli AX and BX, weakening responding to them. In order that responding can reach asymptote, AX and BX need to acquire further excitatory associative strength. It is this additional excitatory associative strength which results in summation when AX and BX are presented together as the compound ABX. Predictions based on the equations specified by Pearce (1987) produced a value of 1.33λ for the net associative strength of ABX.

In Experiment 3, evidence was found to indicate that the context for Group Different was more salient than for Group Same as the participants in Group Different rated the context alone trials higher than the participants in Group Same. Configural theory can thus explain why summation was observed in Group Different but was not observed in Group Same. This leaves the question of why the context should be more salient for participants receiving the multi-modal stimuli. It is possible that participants in Group Different, expecting stimulation from three modalities, were sensitised to danger warnings and exhibited a general tendency to overestimate danger for the context. If this were the case there should be a significant group effect for the single element stimuli, this was not found to be the case.

An alternative reason for the increase in context salience might be due to the manner in which the tactile stimuli were presented via boxes strapped to the participants' wrists. This meant that there was contact pressure on the participants' skin throughout the experimental session. The participant would thus have to detect a change in contact pressure in order to discriminate between the tactile stimuli and the background contact pressure. According to configural theory (Pearce, 1987) the more similar the stimuli are to the context the more associative strength will generalise to the context. Compare this to the visual stimuli presented against a black background where the participants merely had to detect if the visual stimuli were present or absent. Pearce, Redhead and George (2002) have similarly reported summation when they presented bright visual stimuli which displaced a similar bright background context but not when the stimuli displaced a dark background.

The pattern of results obtained in the experiments of the present paper can thus be accounted for by configural theory (Pearce, 1987; 1994). But the question remains: is it possible to explain both the findings of Myers et al. (2001) and those of the present study with a single theory? One candidate is the Replaced Elements Model (REM) (Wagner & Brandon, 2001), which can match certain predictions of both elemental and configural theories. Wagner and Brandon suggested that when a stimulus is presented it activates sets of representational elements which are either context-independent or context-dependent. For example, in the compound AB, A may be represented by both A_I (context-independent) elements, activated whenever A is presented, and A_B (context-dependent) elements, activated only when A is presented in compound with B. The ratio of context-independent to context-dependent elements that are activated by a compound stimulus is determined by the degree to which its component stimuli interact at a perceptual level, and dictates whether REM makes predictions consistent with configural or elemental models of learning. Consider a situation in which the compound AB is presented following A+ B+ training. If the compound generates a large proportion of context-dependant elements (reflecting a high level of perceptual interaction), only relatively few of the A and B elements present during training will also be activated by the compound. In this situation there would be little summation – a prediction consistent with configural theory (Pearce, 1987). If the compound generates a small proportion of context-dependant elements, and hence many of the representational elements that were conditioned during training, summation should be seen – consistent with predictions made by elemental models (Rescorla & Wagner, 1975). In a series of simulations of an A+ B+ C+ AB+ BC+ AC+ ABCø discrimination, Pearce and George (2002) systematically manipulated the ratio of the context-dependent elements to context-independent elements but were unable to find a set of values which would allow REM to predict that responding to the single-element stimuli would be higher than responding to the double-element stimuli. Wagner and Brandon's Replaced Elements Model cannot predict the results seen in Experiments 1 and 2.

Configural theory (Pearce, 1987; 1994) can predict both sets of results depending on the stage of training and the salience of the context. This prediction arises again through a consideration of the impact of the context on the discrimination. If the context (X) is considered to be an additional stimulus, the discrimination can be represented as AX+ BX+ CX+ ACX+ ABX+ BCX+ ABCXø Xø and the context will have a marked impact on the acquisition of associative strength by the compound stimuli.

Predictions from a simulation based on the equations presented by Pearce (1987) for an AX+ BX+ CX+ ACX+ ABX+ BCX+ ABCXø Xø discrimination are shown in Figure 6. The salience of the context (X) was assumed to be equal to those of the other stimuli. The associative strength of the double-element stimuli exceeded that of the single-element stimuli for 70 blocks of trials out of 100, compared to 30 in the predictions depicted in the right panel of Figure 1 where the context was assumed to have negligible salience. Pearce (2002) has previously argued that the paradigm used by Myers et al. (2001) results in the context becoming very salient as the rabbits are restrained in the apparatus with no other stimulation. Configural theory (Pearce, 1987; 1994) could, therefore, predict Myers et al.'s (2001) results if the context is considered to be very salient and testing was curtailed before responding to the stimuli had reached asymptote.

There is some evidence in the current experiments for an effect of increased context salience on an A+ B+ C+ AB+ BC+ AC+ ABCø discrimination. In

Experiment 1, where the stimuli were all from the same modality the ratings of double-element stimuli never exceeded the ratings of the single-element stimuli. In the first three trials of Experiment 2 the ratings of the double-element stimuli numerically exceeded those of the single-element stimuli. If one does assume that the context is more salient in the multi-modal discrimination, as suggested by the context alone trials of Experiment 3, then the pattern of responding in the initial trials of Experiment 2 conform to the predictions of configural theory (Pearce, 1987, 1994).

In summary, Experiments 1 and 2 found that rating of the single-element stimuli in an A+ B+, C+, AB+, BC+, AC+, ABCø discrimination were higher than rating of the double-element stimuli by the end of training. This pattern of results was obtained whether the stimuli were from a single or multiple modalities. The results of Experiment 3 demonstrate that summation is observed when the stimuli are multi-modal. This finding, taken in conjunction with the results of Experiment 2, rule out the possibility that the difference in responding to the single-element stimuli compared to the double-element stimuli was simply due to a failure to find summation when the stimuli were presented in compound. The most workable account for the present results appears to be provided by Pearce's configural model (1987; 1994), and not by elemental theories (e.g., Rescorla & Wagner, 1972; Wagner & Brandon, 2000).

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Figure Captions

Figure 1. Associative strength derived from computer simulations of the Rescorla - Wagner model (1972) (left panel) and Pearce's configural model (1987) (right panel) for the A/B/C+ (filled disks), AB/BC/AC+ (empty disks), ABCø (filled triangles) discrimination plotted as a function of blocks of trials.

Figure 2. The three monitors presented to the participants: Monitor 1 presented the visual stimuli; Monitor 2 provided feedback on the outcome of the trial; Monitor 3 presented instructions to the participants.

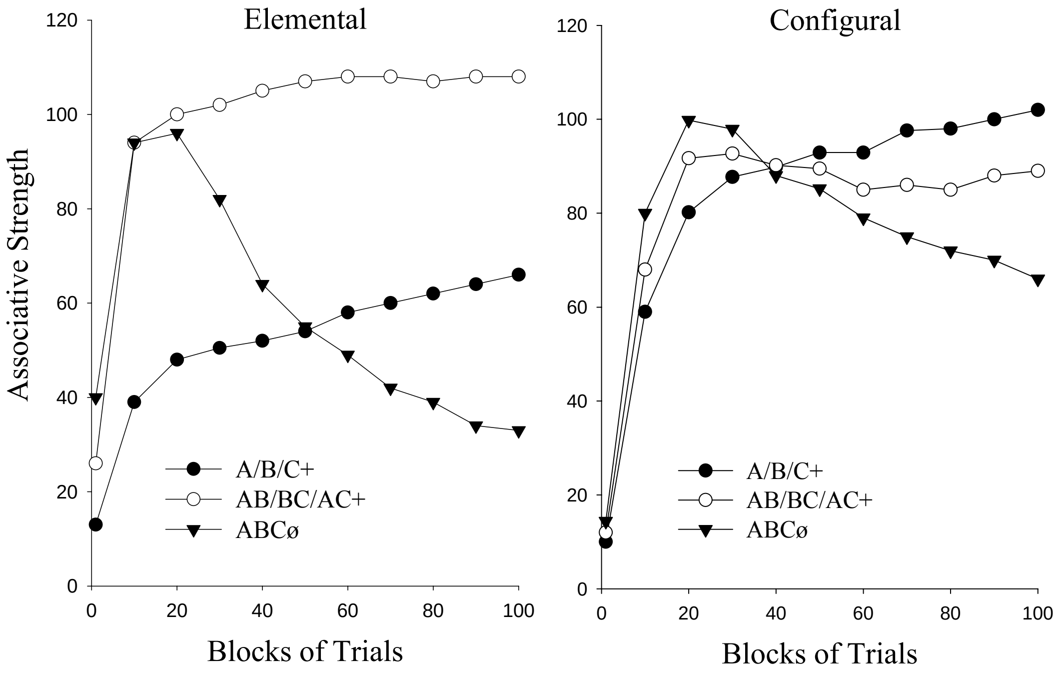
Figure 3. Mean rating scores for single, double and triple element stimuli within the A/B/C+ (filled disks), AB/BC/AC+ (empty disks), ABCø (filled triangle) discrimination across trial blocks in Experiment 1. Mean rating scores for single, double and triple element stimuli within the Dø (filled squares), EFø (empty squares), GHI+ (filled diamond) discrimination across trial blocks in Experiment 1 (right panel). The standard error bars are the standard error of the mean.

Figure 4. Mean rating scores for single, double and triple element stimuli within the A/B/C+ (filled disks), AB/BC/AC+ (empty disks), ABCø (filled triangles) discrimination across trial blocks in Experiment 2 (left panel). Mean rating scores for single, double and triple element stimuli within the Dø (filled squares), EFø (empty squares), GHI+ (filled diamond) discrimination across trial blocks in Experiment 2 (right panel).The standard error bars are the standard error of the mean.

Figure 5. Mean ratings scores for ø, +, ++ and context alone trial types during acquisition training in Experiment 3 for Group Different (filled symbols) (left panel) Mean ratings scores for ø, +, ++ and context alone trial types during acquisition training in Experiment 3 for Group Same (empty symbols) (centre panel). Mean group rating scores for single (A/B/C; black bar) and compound (AB/BC/AC; grey bar) stimuli during test trials in Experiment 3 (right panel). The standard error bars are the standard error of the mean.

Figure 6. Predicted associative strengths of stimuli within the AX/BX/CX+ (filled disks), ABX/BCX/ACX+ (empty disks), ABCXø (filled triangles), Xø (filled squares) discrimination where the context (X) is considered to be of equal salience to the stimuli from a computer simulation based on Pearce’s configural model (1987).

Figure 1


Elemental
Configural
Associative Strength
Blocks of Trials
Blocks of Trials
A/B/C+
AB/BC/AC+
ABCø
A/B/C+
AB/BC/AC+
ABCø
0
20
40
60
80
100
120
0
20
40
60
80
100

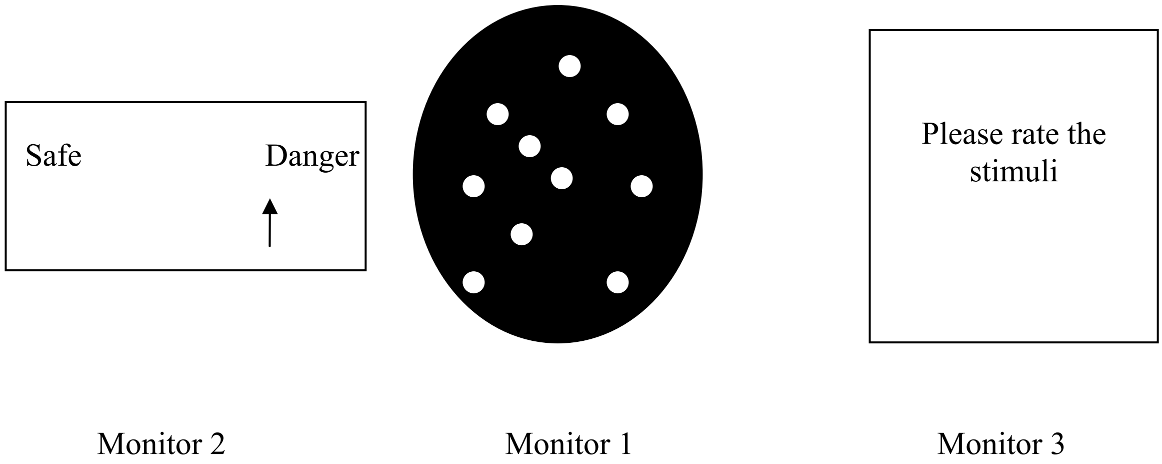

Safe
Danger
Please rate the stimuli
Monitor 2
Monitor 1
Monitor 3

Figure 2

Figure 3

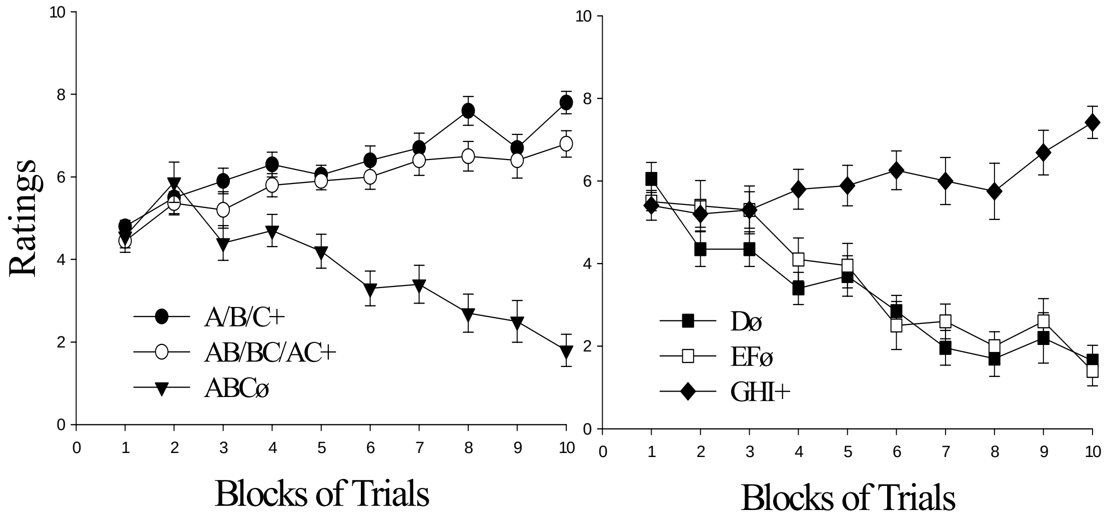

Ratings
A/B/C+
AB/BC/AC+
ABCø
Blocks of Trials
Dø
EFø
GHI+
Blocks of Trials

Figure 4

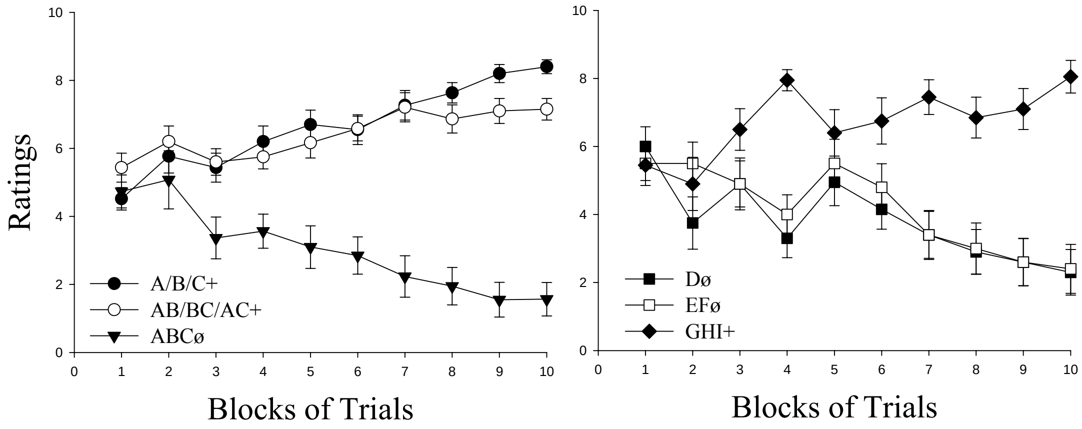

Ratings
A/B/C+
AB/BC/AC+
ABCø
Blocks of Trials
Dø
EFø
GHI+
Blocks of Trials

Figure 5

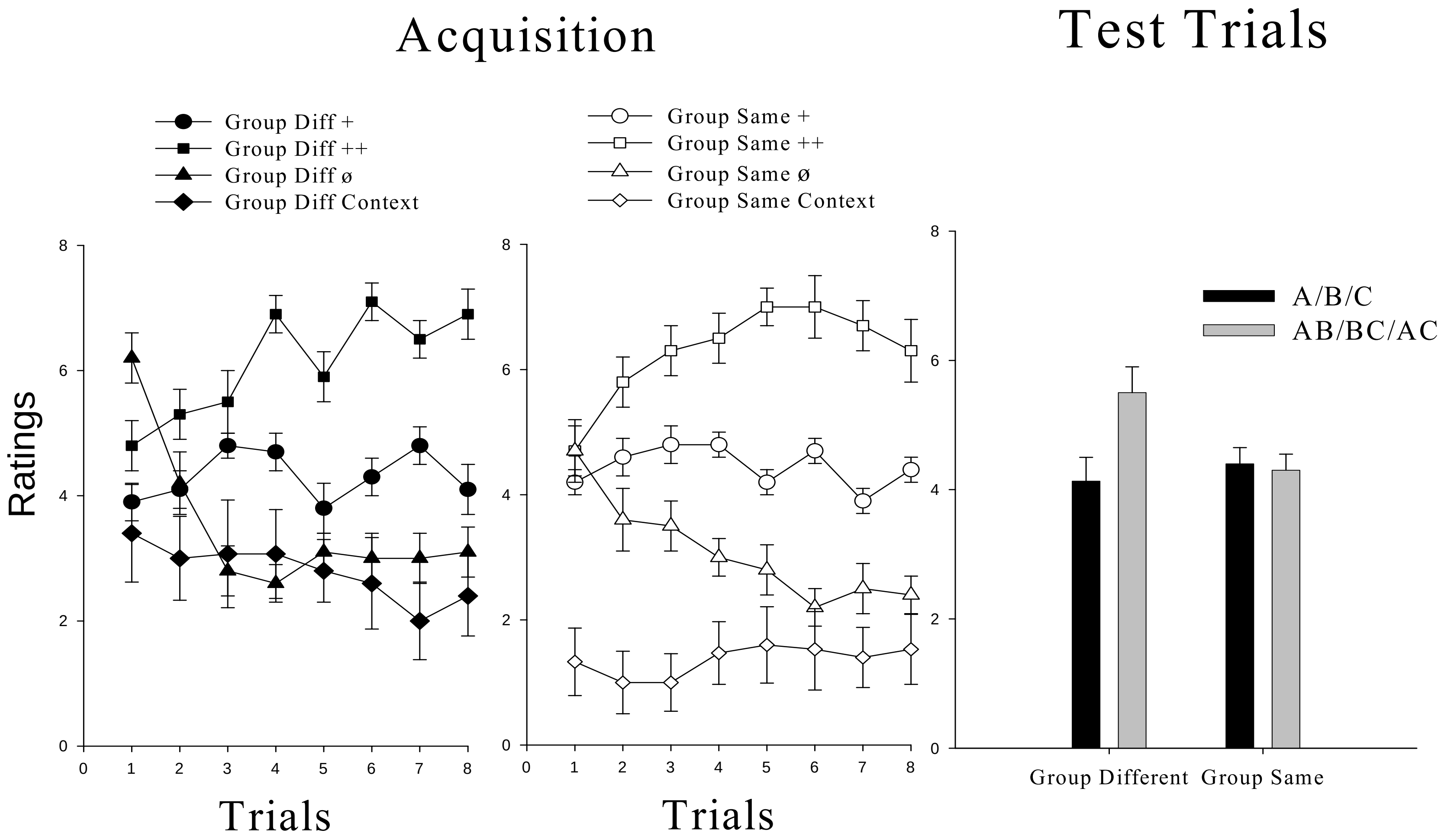
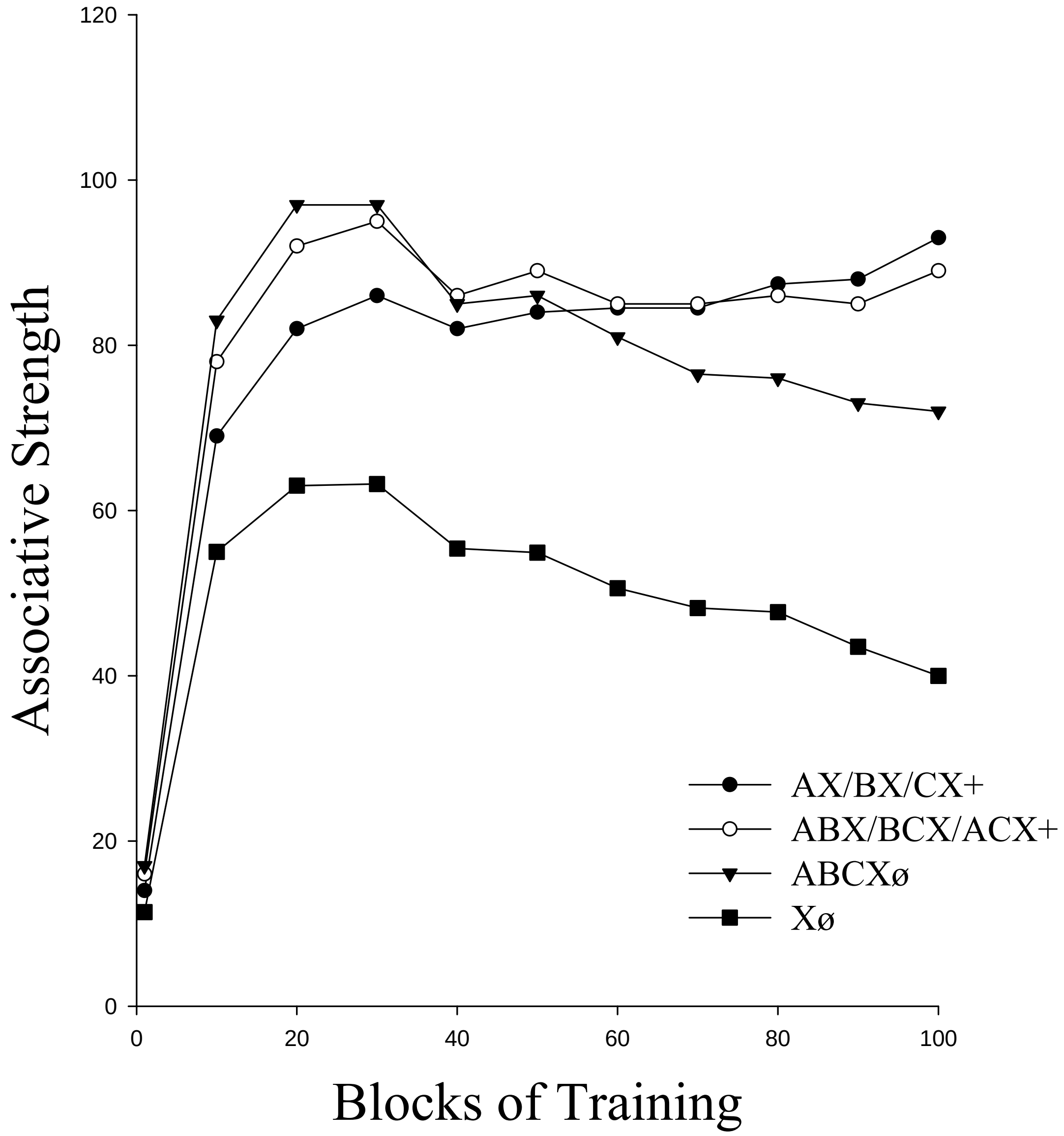

Acquisition
Test Trials
Group Diff +
Group Diff ++
Group Diff ø
Group Diff Context
Group Same +
Group Same ++
Group Same ø
Group Same Context
Ratings
Trials
Trials
A/B/C
AB/BC/AC
Group Different
Group Same

Figure 6


Associative Strength
120
100
80
60
40
20
0
0
20
40
60
80
100
Blocks of Training
AX/BX/CX+
ABX/BCX/ACX+
ABCXø
Xø