CARDIFF UNIVERSITY

Attention in the Pigeon

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A thesis submitted for the degree of

Doctor of Philosophy

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CONTENTS **Page**

CONTENTS

CONTENTS

iii

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ACKNOWLEDGEMENTS

I firstly owe a debt of gratitude to my supervisor, Professor John M. Pearce, for his endless support and guidance. I will be forever thankful that I was fortunate enough to be supervised by John, for his continual positive attitude and sense of humour in the face of failure. I will be sure to let him know if the completion of my PhD really has made me a better person.

I would also like to thank Dr Jemma Dopson whose guidance was again invaluable, always willing to offer help and advice no matter how busy she was or how often I had already asked!

I would additionally like to thank all the staff in the Behavioural Neuroscience laboratory and all the technical staff, without whom the completion of my PhD would not have been possible.

Finally I would like to thank my family and friends for all their support, in particular Christian Williams for always trying to make me see the bright side and Roz Lambe for her never-ending pigeon jokes.

SUMMARY

Using methodology devised by Pearce, Esber, George and Haselgrove (2008), the role of attention in discrimination learning in pigeons was investigated. In Chapter 1 a review of literature revealed several unanswered questions

Experiments 1 and 2 explored whether attention is paid to entire dimensions or to individual stimuli. In a test, pigeons learnt a discrimination based upon previously relevant stimuli more rapidly than they did a discrimination based on previously irrelevant stimuli. This was evident when discriminations were based on colours that were close or far apart on the spectrum.

Experiment 3 attempted to detect latent inhibition in pigeons. No effect was observed; findings were attributed to the amount of attention paid to a stimulus being determined by the degree of responding to it. In Experiment 4 compounds in which components were superimposed on the other eliminated the effects seen in Experiment 3.

Experiment 5 explored whether more attention is paid to reliable or unreliable predictors of outcome. No evidence was found of greater attention paid to partially-reinforced stimuli. Experiment 6 found pigeons learnt more rapidly about previously reinforced stimuli when accompanied by stimuli with low associative strength than with stimuli with high associative strength.

Experiment 7 explored whether attention increased to previously non-reinforced stimuli from a discrimination. No evidence was found. Experiment 8 asked the same question but paired previously non-reinforced and previously irrelevant stimuli during Stage 2. The discrimination based upon non-reinforced stimuli was learnt more rapidly than the discrimination based upon irrelevant stimuli.

From the findings presented it seems attentional changes were masked by the amount of time a pigeon spent pecking at a stimulus. The exception was the final experiment. It seems attentional changes as envisaged by Mackintosh (1975a) may occur, but are only apparent when the effect of the amount of pecking is reduced.

1.   General Introduction

A fundamental assumption of theories of associative learning is that the rate at which an association develops between a stimulus and a reinforcer is determined by the salience of the former and the magnitude of the latter (e.g. Rescorla & Wagner 1972; Pearce, 1994). In addition, the rate of such learning has been said to be affected by the amount of attention paid to the stimulus, which can vary according to prior experience. In fact, it has been proposed that two rather different kinds of experience might influence the attention that is paid to a stimulus. According to certain authors (e.g. Lawrence 1949, 1950; Sutherland & Mackintosh 1971; Mackintosh 1975a) attention is determined by stimulus relevance. That is, more attention will be paid to stimuli that in the past have been relevant rather than irrelevant to the occurrence of reward. Pearce and Hall (1980) on the other hand, argued that attention is guided by predictive accuracy. Stimuli that have been followed by unpredictable events are assumed to receive more attention than those that have been followed by predictable events. In this introductory chapter I shall start by briefly introducing theories that represent these contrasting views of attention. During the course of this discussion, a number of issues will be identified that have yet to be fully resolved. The remaining chapters will then report a series of experiments that are intended to shed more light on these issues in order to enhance our understanding of the relationship between attention and associative learning.

1.1 Attention and stimulus relevance

Some of the earliest evidence for the suggestion that animals may pay more attention to stimuli that are relevant rather than irrelevant to the occurrence of reward comes from experiments using what is known as intradimensional-extradimensional shift (IDS-EDS) design. In these experiments subjects are first presented with a discrimination featuring compound stimuli of which all relevant components belong to a single dimension and all irrelevant components to another dimension. The IDS group will then face a subsequent discrimination between compound stimuli featuring novel relevant stimuli from the previously relevant dimension and novel irrelevant stimuli from the previously irrelevant dimension. The EDS group will face a new discrimination in which novel stimuli from the previously irrelevant dimension are now relevant and novel stimuli from the previously relevant dimension are now irrelevant.

Take, for example, the stimuli shown in Figure 1.1. During stage one for the IDS group colours are always relevant, with red always signalling food and blue always signalling the absence of food. Patterns are always irrelevant with both forward sloping lines and backward sloping lines equally predicting both the absence and presence of food. For the EDS group patterns are the relevant dimension with forward sloping lines signalling the presence of food and backwards sloping lines signalling the absence of food. Colours are the irrelevant dimension with both red and blue equally signalling the presence and absence of food. In the second stage, both groups receive the same discrimination, novel colours are the relevant dimension with green and yellow signalling the presence and absence of food respectively. Novel patterns make up the irrelevant dimension with both horizontal and vertical lines signalling the presence and absence of food equally. The second stage represents an

intradimensional shift for the IDS group and an extradimensional shift for the EDS group.
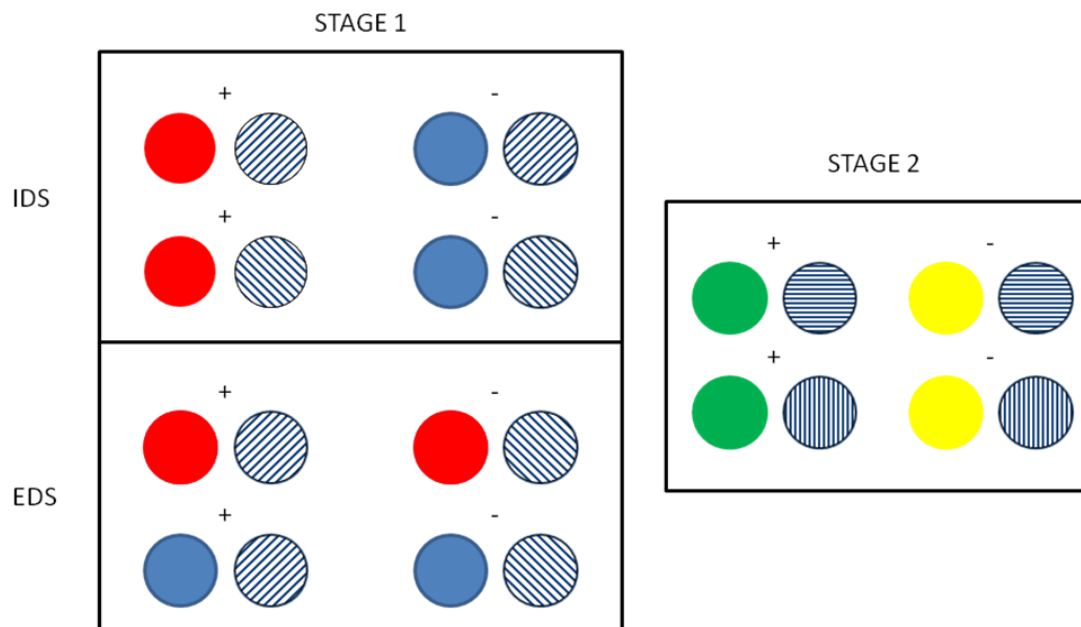
Figure 1.1. Example stimuli for an IDS/EDS experiment. + represents reinforcement and − represents non-reinforcement.

Many studies using this experimental design have shown that subjects in the IDS group learn the test discrimination significantly faster than subjects in the EDS group. Mackintosh and Little (1969) used a design very similar to that shown in Figure 1.1 and were able to demonstrate that pigeons given a subsequent discrimination that constituted an IDS shift solved it more rapidly than those pigeons given a subsequent discrimination based upon an EDS shift. These findings were replicated by George and Pearce (1999), again using a design similar to that shown in Figure 1.1. Pigeons were presented with a square on a television screen, half the square was made up of

one of two solid colours and the other half of black and white lines oriented in one of

two orientations. For half of the subjects colour was the relevant dimension with food

following presentation of one of the two colours and for the remaining half line

orientation was the dominant dimension with food following presentation of one of

the two line orientations. This training was followed by presentation of a new

discrimination featuring two novel colours and two novel line orientations. For half of

pigeons the relevant dimension remained constant and for half the relevant dimension

changed for the second discrimination. It was shown that pigeons subjected to an IDS

solved the second discrimination significantly more rapidly than pigeons subjected to

an EDS shift. However not all attempts to demonstrate the IDS/EDS effect in pigeons

has proved successful. Couvillon, Tennant and Bitterman (1976) sought to replicate

the findings of Mackintosh and Little (1969); in an experiment using equivalent

stimuli they failed to find any difference in the subsequent acquisition of an IDS and

EDS discrimination. Hall and Channell (1985), in an effort to reconcile these

apposing accounts in pigeons, again using stimuli very similar to those used by

Mackintosh and Little (1969), was unable to demonstrate any difference in the

acquisition of a subsequent IDS and EDS discrimination pigeons. The findings of

IDS/EDS experiments using rats are equally as mixed, Shepp and Eimas (1964) used

discriminations in which either the shape of the stimulus or the direction of stripes

was relevant. They demonstrated that in a subsequent test discrimination, rats were

able to solve a discrimination based upon the previously relevant dimension more

quickly than a discrimination based upon the previously irrelevant dimension.

Conversely, Sutherland and Andelman (1969) were unable to demonstrate such an

effect. They trained rats to in a discrimination in which either brightness or orientation

was relevant but did not witness any difference in the acquisition of an IDS and EDS

discrimination. Evidence for the IDS/EDS effect in marmosets was provided by Dias, Robbins and Roberts (1996) but as will be discussed in Chapter 2, methodological criticisms leave the way open for alternative conclusions to be drawn from their findings. As we shall now see those findings which offer evidence for the IDS/EDS effect have been taken as evidence that more attention is paid to relevant than irrelevant stimuli during conditioning (Sutherland & Mackintosh 1971; Mackintosh 1975a).

1.2 Sutherland and Mackintosh (1971)

One of the most influential of the early theories of attention and learning was proposed by Sutherland and Mackintosh (1971). This is a two-stage model where animals must first attend to a stimulus and then learn to respond to it correctly. The response is said to be controlled by the switching on or off of analysers with each analyser responsible for detecting a single dimension such as colour or shape. Animals must first learn to attend to the correct dimension (switch in the correct analyser) and then learn to respond according to whether a stimulus is reinforced or non-reinforced. Responses made will form attachments to the relevant analyser and will be strengthened when this response is reinforced and weakened when a response is not reinforced. Prior to the start of conditioning, all analysers will have different strengths and these strengths will differ among species, for example the analyser for colour may have a high base strength in pigeons as this dimension is often important for identifying food. The theory states that the sum output of all analysers' activity is a constant; therefore an increase in the strength of one analyser, as a result of reinforcement to a response, will result in a corresponding decrease in the strength of one or more of the other analysers, an assumption known as the Inverse Hypothesis. If

5

no analyser is able to make consistent predictions about the response required to stimuli presented then all analyser strengths will revert to their base strengths.

While more than one analyser can be switched on at the same time, one analyser will likely have more strength and it is the strength of the response attachment of this analyser which will therefore control the response made by the animal. This said, if the strength of any other analyser is close in strength to the strongest analyser, this analyser can too play a role in the response made by the animal.

Referring again to the experimental design shown on Figure 1.1, Sutherland and Mackintosh (1971) would explain the findings of such IDS/EDS experiments by claiming that animals first learn to attend to the relevant stimuli in stage one by switching in the relevant analyser; colour for group IDS and patterns for group EDS. The inverse hypothesis would ensure while attention to the relevant dimension remained high, the attention to the irrelevant dimension remained low. Subsequently the IDS group would find the discrimination in stage two relatively easy as the correct analyser was already switched in and they were attending to colours and not patterns. Conversely, for the EDS group patterns had been relevant during the first stage and so the analyser for patterns had been switched in. The Inverse Hypothesis states while attention to patterns is high, attention to colours will be low and therefore when presented with the discrimination in the second task, animals will be attending to patterns rather than colours and will therefore find the discrimination difficult to solve.

1.3 Mackintosh (1975a)

In keeping with Sutherland and Mackintosh (1971), Mackintosh (1975a) proposed that animals will pay more attention to relevant than irrelevant stimuli. He rejected their proposal however, that the amount of attention paid to one stimulus is inversely proportional to the amount paid to any others that accompany it. One justification for this change of mind can be found in the phenomenon known as blocking. Blocking is said to have occurred when prior learning about a stimulus restricts learning about an additional stimulus when the two are paired to form a compound stimulus (Kamin 1968). Mackintosh (1975b) however, found evidence to suggest that blocking does not occur on the first compound trial, which has important implications for his views on attention. For simplicity I will detail only part of his experiment but it should be noted that counterbalancing and control groups were implemented.

Two groups of thirsty rats first received eight trials during which a tone signalled a shock, delivered through the floor of the conditioning chamber. The tone was presented while the rats were drinking from a tube and the effectiveness of conditioning was measured as the extent to which this activity was suppressed during presentation of the conditioned stimulus (CS). One group was then subjected to eight compound trials in which the tone together with a light now signalled the shock, the other group was presented with a single trial of the same compound. A single trial of just the light was then presented to both groups. The group that received eight compound trials exhibited little conditioned suppression during the light when it was subsequently presented on its own. Certainly this group exhibited less suppression to the light than a control group which received the same conditioning with the compound, but no pre-training with the tone. Consistent with the claims of Sutherland

and Mackintosh (1971), earlier learning about the tone would have resulted in the corresponding analyser gaining in strength to the detriment of other analysers. Therefore when the compound trials were presented little would be learned about the light as the analyser for this stimulus would be suppressed by the mere action of the analyser for tone. It is in the group to whom only a single compound trial was given however, that we see the most important result. This group received the same eight trials with the tone but was then given only one compound trial. When the group was then presented with a trial containing just the light, they showed equivalent evidence of suppression, to a control group, thus demonstrating no blocking as a consequence of the first compound trial. This significant effect of conditioning with the light on the first compound trial cannot be easily explained by the Sutherland and Mackintosh (1971) Inverse Hypothesis. An increase in strength of the analyser responsible for learning about the tone should prevent learning about the second element of the compound trial from the first trial onwards.

On the back of these findings, Mackintosh (1975a) proposed a theory which differed from Southerland and Mackintosh (1971) in several important ways. Firstly and perhaps most crucially, he rejected the Inverse Hypothesis; arguing against the claim that an animal has a limit to its information processing capacity and that an increase in attention to one stimulus must necessarily result in attention to other stimuli being reduced. Mackintosh suggested it is unlikely that attention would be limited in this way, especially when a stimulus may be quite intense and presented for a considerable amount of time. Instead of referring to analysers, a learning rate parameter α is used to determine the associability of a stimulus, which in turn can be said to reflect the amount of attention paid to the stimulus. The value of α increases to

a maximum of 1 when the stimulus is a good predictor of reinforcement and decreases towards its base level when a stimulus is no better at predicting reinforcement than any other stimulus present.

So it follows that the value of α of a stimulus, A, will increase when

$$(\lambda - V_A) < (\lambda - V_X) \tag{1}$$

Where λ represents the asymptotic value of the unconditioned stimulus (US) predicted by A, V_A represents the current associative strength of A, and V_X represents the current associative value of all other stimuli present. Conversely α_A will decrease when,

$$(\lambda - V_A) \geq (\lambda - V_X) \tag{2}$$

Mackintosh stipulated that the change in associative strength of stimulus, A, ΔV_A, on any trial is influenced by its associability according to Equation 1, where β is a learning rate parameter with a value between 0 and 1 that is determined by properties of the US.

$$\Delta V_A = \alpha_A \beta (\lambda - V_A) \tag{3}$$

It follows that animals will learn no more about the association between A and the outcome when the associative strength of A is equal to the asymptotic associative strength of the outcome predicted by it. Crucially, and in line with Mackintosh's (1975a) rejection of the Inverse Hypothesis, it is assumed that the presence of other stimuli will have no influence on the capacity of A to elicit a response.

The principles of Mackintosh's theory can be applied to a simple discrimination, such as AX+/ BX-, in the following way. During the initial AX+ trials, A and X will each gain in associative strength, some of which will be lost by X

on the BX- trials. As a consequence, A will soon become a better predictor of the US than X and subsequent AX trials, according to the principles outlined above, will result in attention increasing to A and falling off to X. Mackintosh's theory is less clear however, on how the same principles apply to non-reinforced stimuli. Little by way of explanation is given other than stating that attention will be greater towards relevant than irrelevant stimuli which necessarily includes relevant non-reinforced stimuli. The only real reference to how these changes in attention will occur to non-reinforced stimuli comes from the statement 'The simple assumption that the value of λ for non-reinforcement is either zero or some negative number will permit appropriate changes in α on non-reinforced trials' (Mackintosh 1975a, p. 288). From this, it would seem that after a number of BX- trials it will become apparent that B is a better predictor for the absence of the US than X which will result in attention falling again to X, but increasing to B. It is thus follows from the theory that attention to X will be less than to A and B, after an AX+ BX- discrimination.

The last significant difference between this theory and that of Sutherland and Mackintosh (1971) is that with the loss of analysers associated with specific dimensions, it follows that attention is stimulus specific rather than dimension specific. For example, if a red light signalled food to pigeons, their attention to red, and not colours in general, will increase. To explain the IDE/ EDS effect however, Mackintosh (1975a) proposed that changes in attention to individual stimuli generalise to other, similar stimuli, in much the same way as associative strength generalises from one stimulus to another. Since it is reasonable to suppose that changes in attention will generalise more readily between stimuli from the same rather than different dimensions, it follows that more attention will be paid to the relevant cues of the test discrimination after an ID shift than an ED shift. Such a difference in

attention should then result in the discrimination based upon the ID shift being acquired more readily than the one based upon an ED shift.

An attractive feature of Mackintosh's (1975a) theory is that it is able to account for a wide range of phenomena. Take, for example, an effect that is referred to as selective association. This term refers to the finding that it is easier to acquire some CS-US associations more readily than others, even when account is taken of differences in stimulus salience and reinforcer magnitude. Thus, Garcia and Koelling (1966) demonstrated that rats associate tastes with illnesses with ease, and tastes with pain with difficulty (see also Shapiro, Jacobs & LoLordo, 1980). While evolution may well result in animals being predisposed form birth to learn about some relationships more readily than others, Mackintosh (1973) argued that changes in attention brought about through prior experience might be responsible, at least in part, for selective association. To support his argument he conducted the following experiment. Rats were presented with a random sequence of tones and shocks, which was intended to reduce attention to the tone as it was no better than the surrounding context as a predictor of shock. Support for this claim came from the test stage, during which it was found that rats learned slowly that the tone was a signal for shock when they were repeatedly paired together. A control group for whom the tone and shock were both novel at the start of the second stage learnt the association significantly faster. A third group, containing thirsty rats was also included for which during the initial stage the tone was presented randomly with respect to the delivery of water. The tone was then paired with the shock during the test stage. Interestingly, previous presentation of the CS (tone) did not significantly hinder learning of the subsequent tone-shock association.

Mackintosh (1973) explained these findings by stating that a CS which has been a poor predictor of a specific outcome will come to be ignored and will therefore hinder subsequent learning when the CS is changed to be a good predictor of the same outcome. He referred to this effect as learned irrelevance. However, if the previously unreliable CS is later paired with a different outcome, attention will be restored and learning about the new association will occur. The implications of these results for selective association should be clear. During daily foraging animals are likely to find that the experience of different flavours is uncorrelated with the experience of pain. Such learned irrelevance training will then make it difficult to associate flavours with painful events if they should be repeatedly paired together. An important implication of this analysis of selective association, and of the results of Mackintosh (1973), is that changes in attention are reinforcer specific.

Mackintosh's (1975a) theory can also offer an explanation for the findings of the blocking experiment detailed earlier. During the first stage, in which both groups were exposed to eight trials with a tone signalling a shock, attention to the tone will increase as it is the most reliable predictor of the shock. When both groups were exposed to the first compound trial, attention to the tone would remain high as it previously signalled a shock and attention to the light would also be high as it is a novel stimulus. Thus for the group which only received a single compound trial, no evidence of blocking would be observed. The group which received eight compound trials however, while attending to the light during the first compound trial, would learn that it is less able to predict the shock than the pre-trained component (tone), to which they are already attending and so attention to the light would decline and very little learning about the light would take place.

Furthermore, Mackintosh (1975a) also offers an explanation for latent inhibition whereby non-reinforced pre-exposure to a stimulus hinders subsequent conditioning to that stimulus. An experiment by Channel and Hall (1983) demonstrates this effect well. A group of rats was exposed to a light repeatedly over a series of trials while another group was placed in the test chamber for equivalent sessions but without the presentation of any stimulus. Both groups were then subject to test trials during which the light was paired with food. The group which had experienced pre-exposure to the light learned the subsequent association between light and food at a slower rate than the control group did. Mackintosh's (1975a) theory explains these findings easily. During the first stage, rats exposed to the light learn that the light is no better at predicting the outcome that follows it – nothing - than the context and so little attention is paid to it. When the light is then paired with the food, little attention is being paid to it and so learning progresses slowly. Conversely the group for which the light is novel in the second stage will attend to it and thus learn rapidly that it is a signal for the US.

Overall, Mackintosh's (1975a) theory has become highly influential with much experimental evidence shown to support the claims he made. However, several years after Mackintosh (1975a) proposed his theory, an alternative account of the relationship between learning and attention was put forward by Pearce and Hall (1980). The theory has its roots in the result of an experiment initially conducted in order to lend support to the theory of Mackintosh (1975a). Instead, the experiment revealed findings incompatible with this theory by demonstrating an effect which has come to be known as 'Hall-Pearce negative-transfer'. A group of rats conditioned to associate a tone with a small shock was then given trials in which the tone was paired with a large shock. According to Mackintosh (1975a) the training given to rats in the

first stage should result in the tone becoming a good predictor for the shock and thus

attention to this stimulus should be high. On this basis conditioning should progress

rapidly in the second stage when the tone is paired with the large shock. In fact,

learning about the relationship between the tone and the large shock progressed

slowly. Learning occurred more rapidly when a novel CS was paired with the large

shock. This led Pearce and Hall (1980) to propose a theory which differs radically

from the one put forward by Mackintosh and which shall now be discussed.

1.4 Pearce and Hall (1980)

There are initial similarities between the theories of Pearce and Hall (1980)

and Mackintosh (1975a). Both assume the amount of attention paid to a stimulus is

reflected by the value of a learning rate parameter, α. The two theories differ however

in what is claimed to control changes to the value of this parameter. Pearce and Hall

(1980) claim an animal will attend to a stimulus only long enough to learn about the

associated consequence; a CS will be attended to until the animal has learnt the

association with the corresponding US. Once the animal has learnt this association

and conditioning has reached asymptote, attention to the CS can cease at least as far

as learning about its significance is concerned. Obviously the stimulus must still be

paid attention in order to be detected, and thereby influence behaviour, but this was

assumed by Pearce and Hall (1980) to occur through automatic, non-attentional

processes. Thus during the learning of a single CS-US association the learning rate

parameter, α, will be high during the initial trials because the CS will be a poor

predictor of the US, but as the CS becomes a progressively more accurate predictor of

the US then the value of α will start to decline. If a stimulus should be an inconsistent

predictor of an outcome, perhaps through equal reinforcement and non-reinforcement, it will continue to attract attention because the CS will never serve as an accurate predictor of the event that follows it. This account can be more formally expressed using Equation 2.

$$\alpha_{n = (\lambda_{n-1} - V_{n-1})} \tag{4}$$

In this equation, α_n represents the attention paid to a given stimulus on trial n. λ_{n-1} represents the strength of the reinforcer or US on the immediately preceding trial, and V_{n-1} represents the associative strength of all other stimuli associated with the reinforce or US on the immediately preceding trial. The change of associative strength on a given trial is then determined by Equation 3, where S is determined by the salience of the stimulus.

$$\Delta V = \alpha \cdot S \cdot \lambda \tag{5}$$

As each trial of training with a continuous reinforcement schedule passes, the value of V will increase according to Equation 3, and the value of α will decrease according to Equation 2. Conditioning will cease when the associative strength of the CS is equal to λ and the value of α will be zero.

While the experiment by Hall and Pearce (1979) described above lends little support to Mackintosh (1975a), it is consistent with the claims of the Pearce and Hall (1980) theory. Once the CS associated with a weak shock has been shown to be a reliable predictor, attention to it will be reduced. When the same CS is paired with a strong shock in subsequent trials, learning will be hindered by the lack of attention paid to the CS. In contrast, a novel CS paired with a strong shock is yet to be shown to be a reliable predictor and so attention will be high and conditioning will progress rapidly

In addition to offering an explanation for Hall-Pearce Negative Transfer, the Pearce and Hall (1980) theory can explain many of the phenomena which lend support to Mackintosh (1975a). The results of blocking experiment (Mackintosh 1975b) outlined above can also be predicted by the Pearce Hall (1980) theory. During the first stage of the experiment, the theory predicts that rats will attend to the tone while learning about its association with the shock. Once this association is learnt, attention towards the tone will be reduced and the suppression reaction occurring upon hearing it will become automatic. The group of rats which subsequently receive eight compound trials of the tone combined with a light will discover that the light-tone compound is followed by a shock that is already predicted by the tone. Attention to the light will therefore decline as it is followed by accurately predicted consequences. However, on the first trial with the compound, the light will be novel and the attention it is therefore paid ensures it enters into a normal association with the shock. It is only after this trial that attention to the light will be reduced which prevents further gains in its associative strength.

Experiments on latent inhibition also lend support to the claims of Pearce and Hall (1980). The findings by Channell and Hall (1983) detailed earlier can be understood by reasoning that during the first stage, the rats presented with the light come to learn that it reliably signals no change in circumstance and thus attention to the light decreases. During the second stage, attention to the light would initially be low and so when it was then paired with the US, learning would be impaired. Conversely, the group for whom the light was a novel CS during Stage 2 would attend to the CS enabling conditioning to progress rapidly.

So far the Pearce and Hall (1980) theory has easily accounted for the described phenomena; on the surface the theory cannot so easily predict the findings

observed in experiments looking at learned irrelevance. Using this time the example of the experiment by Mackintosh (1973), at first sight, the Pearce and Hall theory would appear to predict high attention would be paid by the experimental group to the tone during the first stage by virtue of its unreliably predicting the presentation of the shock. Therefore, during the test phase when the tone and shock were paired, conditioning should progress rapidly due to the high attention paid to the CS. However, when considering this kind of finding Pearce and Kaye (1985, p. 419) pointed out that learned irrelevance training normally results in the CS and US being paired together rarely, and that the events that follow the CS are reasonably constant from trial to trial. In these circumstances, attention to the CS is predicted to decline quite rapidly.

Lastly it remains to be discussed whether the Pearce and Hall (1980) theory can account for the findings observed in IDS/EDS experiments. Referring again to the example design shown in Figure 1.1, during the first stage of the experiment Pearce and Hall would predict that initially attention will be high to all stimuli as they are all novel. As training progresses each colour-pattern compound will eventually signal the outcome that follows it and, according to the theory, attention to all the components of all the compounds will decline. In Stage 2 Pearce and Hall would accordingly predict that those animals facing an EDS discrimination would learn the discrimination at the same rate as those facing an IDS discrimination.

The failure to find support for this prediction creates a real problem for the theory. So it would seem that neither Mackintosh (1975a) nor Pearce and Hall (1980) are able to give a complete explanation for attention and learning; the former is unable to explain the Hall-Pearce effect, the latter the EDS/IDS effect. Perhaps instead a combination of the theories is needed, and indeed several hybrid theories have been

17

put forward. LePelley (2004, see also Pearce & Mackintosh 2010) proposed a theory which combined elements of Mackintosh (1975a) and Pearce and Hall (1980).

Alternatively it has been suggested that features of the design of IDS/EDS experiments leave open the possibility that this effect is not a consequence of attentional processes. If this was the case then it is possible that the Pearce and Hall (1980) theory could provide a comprehensive explanation of all the phenomena that have been said to reflect the influence of attentional processes. One such methodological criticism of traditional IDS/EDS experiments was put forward by Hall (1991). He suggested that the observed IDS/ EDS effects of such studies may not be due to changes in attention; rather, the principles of acquired equivalence and distinctiveness could be responsible. In a typical discrimination used in the first stage of an IDS/EDS experiment, e.g. AX+/BX- AY+/BY-, where A and B signal reinforcement and non-reinforcement respectively and X and Y are irrelevant, it could be argued that A and B will acquire distinctiveness given that A alone signals reinforcement and B non-reinforcement. Conversely X and Y have both signalled the same thing, equal reinforcement and non-reinforcement and thus may be regarded as being equivalent. These changes would then make it easier for subjects subsequently to discriminate between A and B, than between X and Y. If it is further assumed that acquired distinctiveness and equivalence can generalise from the stimuli used in stage 1 of an IDS/ EDS experiment to those in stage 2, then it would follow that the test discrimination after an IDS will be acquired more readily than after an EDS. So with Pearce and Hall (1980) able to explain blocking and latent inhibition and with the explanation for learned irrelevance put forward by Pearce and Kaye (1985) it seems plausible, given the suggestion that IDS/EDS effects may not be due to changes in attention, that the theory is an adequate account of attention in associative learning.

With this in mind, recent experiments by Pearce, Esber, George and Haselgrove (2008) and Dopson, Esber and Pearce (2010) take on particular significance as their findings challenge the explanation offered by Hall (1991) for the IDS/ EDS effect. A summary of the design of one of the experiments by Dopson et al. (2010a) can be seen in Table 1.1.Two groups of pigeons were trained using four colours (A to D) and four patterns (W to Z) for a set of discriminations of the form AX+ BX-. During Stage 1 for the Colour-relevant Group, colours were relevant and patterns irrelevant and for the Pattern-relevant Group patterns relevant and colour irrelevant. During Stage 2, both groups were given the discrimination AW+/AX-/BW-. Dopson et al found that the component of the test discrimination based upon patterns (AW+/AX-) was solved more quickly by the Pattern-relevant than the Colour-relevant Group and the component based upon colours (AW+/BW-) was solved more quickly by the Colour-relevant than the Pattern-relevant Group. These findings lend support for Mackintosh (1975a); if animals attend to stimuli which are relevant then during Stage 1, the Pattern-relevant Group would have attended to patterns and ignored colours and the Colour-relevant Group would have attended to colours and ignored patterns. It would then follow during Stage 2 that the Pattern-relevant Group would continue to attend to patterns, facilitating the learning of the component of the test discriminations based upon patterns and ignore colours, hindering their learning of the component of the discrimination based upon colours. The converse is true for the Colour-relevant Group who, during Stage 2, would continue to attend to colours facilitating the component based upon colours and hindering the learning of the component based upon patterns.

19

Group	Stage 1	Stage 2
Colour Relevant	Aw+ Cw- Ax+ Cx- Bw+ Dw- Bx+ Dx- Ay+ Cy- Az+Cz- By+ Dy- Bz+ Dz-	AW+ AX- BW-
Pattern Relevant	aW+ aY- bW+ bY- aX+ aZ-bX+ bZ- cW+ cY- dW+ dY- cX+ cZ- dX+ dZ-	

Table 1.1. Discriminations used during Experiment 1 of Dopson et al (2010a). For Stage 1, upper-case letters denote relevant stimuli and lower-case irrelevant stimuli.

As previously noted, the study by Dopson et al (2010a) is of interest because its findings challenge Hall's (1991) acquired equivalence and distinctiveness explanation for the EDS/IDS effect. During Stage 1 for the colour-relevant group, A and B were both followed by food and, according to Hall's proposals they should have been regarded as being equivalent which would then hamper any discrimination between them. In fact the training in Stage 1 was found to promote the discrimination between A and B. This finding implies that even though A and B initially signalled the same event they did not lose distinctiveness. Rather, in keeping with the theory of Mackintosh (1975a), this training appears to have facilitated the discrimination between A and B in Stage 2 by increasing the attention paid to each of them.

The results of the experiment by Dopson et al. (2010a) are also of interest because they pose a problem for what is generally regarded as the standard theory of associative learning, that proposed by Rescorla and Wagner (1972 see also Wagner & Rescorla, 1972). According to this theory, conditioning results in the formation of associations between a conditioned and unconditioned stimulus (CS and US), the strength of which determines the strength of the conditioned response. To be specific, the increase in the associative strength of CS A, ΔV_A is given by Equation 6 where α and β are learning rate parameters with values between 0 and 1, λ is the asymptote of conditioning set by the magnitude of the US, and V_Σ is the sum of the associative strengths present on a trial.

$$\Delta V_A = \alpha . \beta (\lambda - V_\Sigma) \qquad\qquad 6$$

When this equation is applied to the Stage-1 training of the design summarised in Table 1.1 it predicts that a cue signalling the occurrence of food, say A, will gain considerable positive associative strength, an irrelevant cue, say X, will gain a modest amount of associative strength, and a cue signalling the absence of food will gain negative associative strength. The theory also predicts that by the end of Stage 1 the overall associative strength of all the compounds signalling food will be λ. It then follows from Equation 6 that when Stage 2 is introduced, extinction with the two non-reinforced compounds will take place at the same rate. The failure to confirm this prediction led Dopson et al. (2010a) to conclude that their results could not be explained by the Rescorla-Wagner (1972) theory. Instead, as we have just seen, the results were taken as evidence that the course of discrimination can be influenced by the amount of attention that is paid to stimuli.

21

There are therefore good reasons for thinking that changes in attention take place during conditioning, and that these changes are governed by two different processes. This does not mean, however, that the last word has been said on the role of attention in learning. In fact, a number of important issues remain to be resolved before we have a complete understanding of how attention influences learning in animals.

One issue, which has already been raised, concerns the claim by Sutherland and Mackintosh (1971) that changes in attention take place to entire dimensions of stimuli, whereas Mackintosh (1975a) maintains they take place to individual stimuli. In fact, Mackintosh did not cite any evidence to support this claim and the purpose of Chapter 2 is to look closely at the important question of whether changes in attention take place to stimuli or dimensions. It turns out that the methodology summarised in Table 1.1 provides a valuable new tool for assessing whether changes in attention are to dimensions or stimuli.

A second issue concerns the generality of latent inhibition across species. In Chapter 3 I shall show there are numerous demonstrations of this effect with a variety of mammals, but virtually none with birds, despite many attempts using pigeons. A similar state of affairs is true for the Hall-Pearce (1979) negative transfer effect. While this effect has been shown with mammals, there are no successful demonstrations of the effect with birds. Of course, the absence of latent inhibition and the Hall-Pearce effect in pigeons may have occurred because the correct experiments remain to be conducted. The methodology summarised in Table 1.1 provides a novel opportunity to look carefully at whether latent inhibition and the Hall-Pearce effect can be found in a non-mammalian species. The results from a series of experiments based upon this methodology are discussed in Chapters 3 and 4.

A third and final issue concerning the relationship between attention and associative learning is raised by the results reported by Dopson et al (2010a), and Pearce et al (2008). They revealed that during the course of an AX+/ BX-discrimination, more attention is paid to a cue that signals the occurrence of food, A, than to one that is irrelevant to the occurrence of food, X. But what about B? This stimulus is relevant by virtue of signalling the absence of food and, according to Mackintosh (1975a), attention to it will increase. A brief review of the relevant literature in chapter 5 indicates that there is no evidence to support this prediction, and the two experiments that are reported were conducted with this shortcoming in mind.

Overall therefore, the purpose of my thesis is to make use of the methodology summarised in Table 1.1 in order to address some outstanding, fundamentally important issues concerning the role of selective attention in learning.

2.   Do Changes in Attention Occur to Dimensions or to Specific Stimuli?

2.1.   Introduction

As previously discussed, IDS/EDS experiments have provided support for the claim that animals attend to relevant over irrelevant stimuli. However it is not possible to ascertain from the same findings whether the claims of Mackintosh (1975a), that attention is stimulus specific, or of Sutherland and Mackintosh (1971), that attention is dimension specific, are supported. Using again the IDS/EDS example in Figure 1.1, according to Sutherland and Mackintosh (1971) different colours belong to a single dimension, and line orientations to another. If one stimulus from a given dimension is made relevant, or irrelevant, to a discrimination, then attention to the entire dimension to which that stimulus belongs is thought to be modified. Thus in the above example the initial training will result in the IDS group paying more attention to lines of any orientation than to colours of any hue. This group should then acquire the test discrimination, which is based on novel line orientations, readily. As the EDS group was initially trained with colours as relevant and orientations as irrelevant, at the outset of the test discrimination more attention should be paid to the dimension of colour than line orientation, hindering the acquisition of the test discrimination.

As an alternative to this account, Mackintosh (1975a) proposed that the initial training given during an IDS/EDS experiment will result in more attention being paid to the individual stimuli that are relevant to the solution of the discrimination, than to those that are irrelevant. He further proposed that these changes in attention will generalise to similar stimuli. As stimuli from the same dimension are likely to be more similar to one another than stimuli from different dimensions, the IDS group will pay more attention to the novel orientations presented on test than to the novel

24

colours, and the discrimination will be acquired readily. In contrast the EDS group will pay more attention to the colours than the orientation of the lines, and acquire the test discrimination slowly.

Thus it is difficult to infer from the results of this experiment, and other IDS/EDS experiments that have used similar stimuli (e.g. Mackintosh & Little 1969; George & Pearce, 1999), whether animals pay attention to dimensions or to individual stimuli. The results from IDS/EDS experiments that have used rather different stimuli are also ambiguous in this respect. Dias, Robbins and Roberts (1996) trained marmosets with compounds that consisted of a black line superimposed on a blue polygon. Either the shape of the blue polygon or the shape of the black line was relevant to the trial outcome. The subsequent IDS/EDS effect that was observed could then be explained in terms of learning to attend to specific exemplars from a single dimension (different shapes), in line with Mackintosh's (1975a) account, or to complex dimensions that represent combinations of colour and shape (the 'blue polygon' dimension, or the 'black line' dimension). Although the existence of such complex dimensions is not strictly in keeping with the idea of a dimension as defined by Sutherland and Mackintosh (1971), it remains a possibility that subjects acquired the discriminations in this way.

An experiment by Trobalon, Miguelez, McLaren and Mackintosh (2003) using spatial learning sought to tease apart these two varying accounts. Rats were trained to discriminate between two arms of a maze with either tactile cues serving as the relevant stimuli and arm position irrelevant (EDS) or arm position serving as the relevant stimuli and tactile cues irrelevant (IDS). A subsequent test discrimination in which arm position was relevant for both groups revealed the previously described IDS/EDS effect. However a second similar experiment failed to replicate these

findings, showing little difference between the IDS and EDS groups rate of learning. The explanation proposed for this was that, contrary to the first experiment, the position of the arms in the test stage of Experiment 2 were placed in regions which were previously irrelevant. If the position of the arms can be said to form a single dimension then these findings lend support for Mackintosh (1975a) rather than Sutherland and Mackintosh (1971) i.e. that attention was paid to individual relevant cues within the same dimension. However, it could be said that the different landmarks used to navigate to the relevant arms of the maze could in themselves form different dimensions and so it could be argued that the discrimination was solved as a result of attention to dimensions rather than individual stimuli. An obvious problem with interpreting the last two experiments is that of identifying what constitutes a dimension. To return to the study by Dias et al. (1996), until a means can be found for specifying if animals treat black lines of various shapes as belonging to a single dimension, it will be impossible to say with confidence whether or not their findings support the proposals of Sutherland and Mackintosh (1971).

2.2   Experiment 1

In view of the problem with using relatively complex stimuli to understand how changes in attention take place the present experiments adopted a rather different strategy for assessing whether changes in attention occur to individual stimuli, or to dimensions. Pigeons were initially trained with a set of discriminations of the form AX+ CX-, where A and C were relevant and X was irrelevant to the trial outcome. All of the stimuli, however, were from the same dimension, say colour. If changes in attention take place to individual stimuli then ultimately more attention should be paid to A and C than X. But if such changes occur to entire dimensions, then the amount of

26

attention paid to the three stimuli should be similar, irrespective of whether they are relevant or irrelevant. In order to evaluate these predictions, the ease with which these stimuli were learned about during a new discrimination was assessed with the technique first used by Pearce, Esber, George and Haselgrove (2008, see also Dopson, Esber, & Pearce, 2010).

The design of the experiment can be seen in Table 2.1. During Stage 1, a single group received four discriminations based on the AX+ CX- format, with all stimuli from the same dimension, before progressing to the test stage. Each compound in the test discrimination was composed of one element that signalled food during Stage 1, A or B, and another element that was irrelevant for the Stage-1 discriminations, Y or Z. One component of the test discrimination was based on two stimuli that had been relevant during training (AZ+ BZ-), and the other was based on two stimuli that had been irrelevant (AZ+ AY-). The amount of exposure to each of the four stimuli presented during the test stage was the same during Stage 1. Thus if acquisition of the test discrimination was determined purely by the overall associative strengths of the three test compounds, and by a subject's familiarity with their components, the discrimination between AZ+ and BZ- should be acquired at the same rate as that between AZ+ and AY-. This prediction is not made by Mackintosh's (1975a) theory. It follows from this account that the Stage-1 training will result in the relevant cues A and B being paid more attention than the irrelevant cues Y and Z, even though each of these cues belongs to the same dimension. As a consequence, considerable attention will be paid to A and B during the test stage, and the discrimination between AZ+ and BZ-, for which A and B are the distinctive cues, will be acquired rapidly. On the other hand, the discrimination between AZ+ AY- will be acquired slowly because, at least initially, rather little attention will be paid to the

27

distinctive cues, Z and Y. If this prediction is confirmed then during the test phase, responding to BZ will decline more rapidly than to AY. Alternatively, if any changes in attention occurring during Stage 1 were to affect dimensions of stimuli, rather than individual stimuli, then the attention paid to A, B, Z, and Y will be similar – because they all belong to the same dimension – and a similar rate of responding should be observed during BZ and AY throughout the test phase.

Training Discriminations (Stage 1)	Test Discrimination (Stage 2)
AX+ CX-	AZ+ BZ- AY-
AY+ CY-	
BZ+ CZ-	
BX+ CX-	

Table 2.1. Discriminations presented during Stage 1 and 2 of Experiment.

In order to assess the generality of my results, the experiment contained two groups, one trained entirely with six colours: red, orange, yellow, green, cyan and blue; the other trained entirely with six patterns: lines of four different orientations, black dots against a white background, and concentric black and white rings. While it might be reasonable to regard the six colours as belonging to a single dimension, it is more debatable whether the same is true of the six patterns that we selected. With this doubt in mind, the four patterns comprising line orientations were assigned to the roles of A, B, Y and Z (the stimuli presented on test), as it seems reasonable to suppose that these, at least, belong to a single dimension (Sutherland and Mackintosh, 1971).

Method

Subjects. The subjects were 32 naïve adult homing pigeons (*Columba livia*). They were housed in pairs and had free access to food and water. They were gradually reduced to 80% of their free-feeding weights and maintained at this weight by restricted feeding following each experimental session. The pigeons were maintained in a light-proof room in which the lights remained on for 14.5 hours per day. They were tested at the same time on successive days during periods when the lights were on in their holding room. At the start of the experiment the subjects were randomly assigned to one of two groups, with each group containing 16 subjects.

Apparatus. The experimental apparatus consisted of eight pigeon test chambers (30.0 x 33.0 x 35.0 cm). Each contained an 8.3-cm-high x 6.3-cm-wide clear acrylic panel, which was hinged at the top. Pecks on the panel were detected by a reed relay that was operated whenever a magnet attached to its lower edge was displaced by a distance greater than 1 mm. The midpoint of the panel was 24 cm above the floor of the chamber. A colour thin film transistor TV with a 15.5 x 8.7-cm screen was located 2.0 cm behind the acrylic panel. Food was delivered by operating a grain feeder with an opening that measured 4.6 cm x 5.4 cm located in the same wall as the response key. The midpoint of the opening was 9.0 cm above the chamber floor and 7.0 cm to the left of the midline of the wall. The feeder was illuminated whenever grain was made available. The chambers were permanently lit during all experimental sessions by a 2.8-W bulb, operated at 24 V, located in the centre of the ceiling of the chamber. Risc PC microcomputers, which were programmed in Arachnid, were used for the control of events, recording of responses, and generation of stimuli on the TV screens.

Stimuli. The stimuli were presented on the TV screen, which was otherwise black. The stimuli consisted of 2 horizontally adjacent circles, each 2.4 cm in diameter. The point at which the circles joined was located at the centre of the TV screen. For 16 subjects, the Colour Group, each of the circles was filled with one of six plain colours: red, orange, yellow, green, cyan or blue. The remaining 16 birds formed the Pattern Group, for which each of the circles was filled with one of six patterns. Four of the patterns were created from three black bars, each 3 mm wide, separated by white bars of the same width. For each of these patterns the orientation of the bars with respect to the top of the TV was different; either 0º, 45º, 90º or -45º. Two black and white patterns were used in addition to these four stimuli. One of these consisted of three concentric white circular bands, each with a width of 2 mm. The outermost edge of the outermost band formed a circle with diameter 2.4 cm. Each band was separated by black circular bands of the same width. In the centre of the stimulus was a black circle (diameter 4 mm). The other 'spotted' pattern consisted of a white circle containing 7 black circles, each with diameter 0.64 cm.

The stimuli were counterbalanced in the following way. For half of the subjects in the Colour Group A, B and C represented red, orange and yellow respectively, and X, Y, and Z represented green, blue and cyan. For the other half, A, B and C represented blue, cyan and green respectively, and X, Y and Z represented yellow, red and orange. In both cases the colours A, B and C served as relevant cues, with A and B consistently signalling food, and C consistently signalling the absence of food. The colours X, Y and Z served as irrelevant cues, signalling the presence and absence of food equally.

For half of the subjects in the Pattern Group A, B and C represented, respectively, striped patterns tilted at -45º and +45º and the concentric circle pattern.

X, Y and Z represented the spotted pattern and striped patterns tilted at 0º and 90º. For the other half, A, B and C represented striped patterns tilted at 0º and 90º and the spotted pattern. X, Y and Z represented the concentric circle pattern and striped patterns tilted at -45º and +45º. Stimuli used can be seen in Table 2.2.

Each trial type consisted of a relevant and irrelevant stimulus in adjacent circles. On half of presentations, the relevant stimulus appeared in the left-hand circle, and on the other half it appeared in the right-hand circle.

Procedure. The subjects first received 8 sessions in which they were trained to eat food whenever it was presented by the hopper. They were then given 5 sessions of autoshaping in which a white circle with a diameter of 2.4 cm was presented in the middle of the TV screen for 10 s. There were 45 trials in a session, the mean interval between the start of each trial was 60 s (range = 40-80 s), and food was made available in the hopper for 4 s whenever the white circle was removed from the TV screen. Subjects were then randomly assigned to either the Colour or Pattern Group, with 16 birds in each.

Session 1 of Stage 1 began on the day after the final session of autoshaping. During each of the 24 sessions of training, the two groups received discrimination training with the eight trial types given in Table 2.1. There were 48 trials in each session: each trial type was presented three times with the relevant stimulus on the left, and three times with the relevant stimulus on the right. The following details applied to all stages of the experiment. Each stimulus was presented for 10 s, and the mean inter-trial interval was 60 s (range = 40-80 s). The trial types were presented in a random order with the constraint that no more than two reinforced or two non-reinforced trials could occur in succession.

Table 2.2. Stimuli used in Stages 1 and 2 of Experiment 1. Half of each group received the discriminations on the left and half the discriminations on the right of each of the Stage 1 and Stage 2 panels.

On the day following Session 24 of training, both groups received the first session of the test discrimination. There were 10 sessions in this stage of the experiment, during which all animals received a discrimination involving three trial types that had been reinforced during training: AZ+ BZ- AY-. There were 40 trials in each session, consisting of 20 reinforced presentations of AZ, 10 non-reinforced presentations of BZ and 10 non-reinforced presentations of AY. The procedural details that have been omitted were the same as for the previous stage.

Results.

A Type-1 error rate of $p < .05$ was adopted for all of the statistical tests in all experiments. Tests of simple main effects were conducted with a pooled error term (Kirk, 1968).

The rate of pecking at the Perspex panel in front of the TV screen was recorded on every trial. Figure 2.1 shows the mean rate of responding during reinforced trials, and that during non-reinforced trials, for the two groups on each session of Stage 1. From this figure it appears that the colour group acquired the discriminations more readily than the pattern group, and that the latter responded at a higher rate in the presence of both reinforced and non-reinforced trials throughout Stage 1.
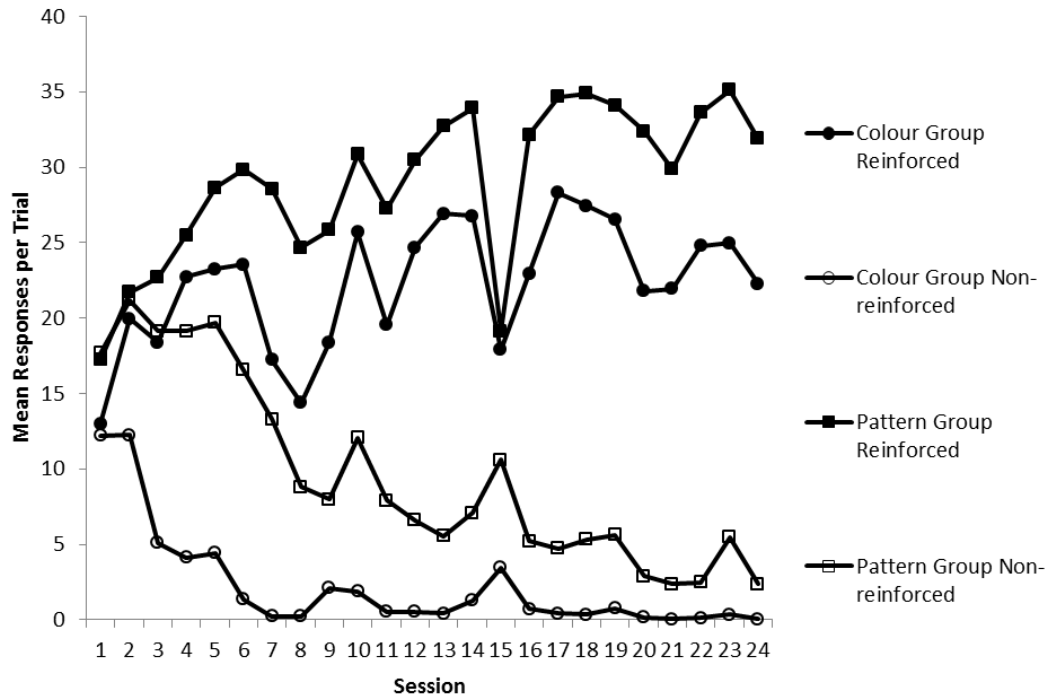
Figure 2.1. The mean rates of responding during the reinforced (CS+) and non-reinforced (CS-) trials throughout Stage 1 for the Colour and Pattern groupsof Experiment 1.

A three-way ANOVA of individual mean rates of responding during each of the 24 sessions was carried out and revealed a significant effect of session, $F(23, 690) = 8.09$, MSE = 28.33, stimulus, $F(1, 30) = 191.79$, MSE = 780.99 and group, $F(1, 30) = 16.32$, MSE = 1187.87. A significant two-way Group x Session interaction, $F(23, 690) = 2.38$, MSE = 28.33, was found, as was a significant Stimulus x Session interaction, $F(23, 690) = 59.54$, MSE = 17.79. The interaction of Group x Stimulus $F(1, 30) <1$ was not significant. The Group x Stimulus x Session interaction was significant $F(23, 690) = 7.73$, MSE = 17.79.

Tests of simple main effects were conducted in order to explore the three-way interaction. These revealed a significant Stimulus x Session interaction for the Colour Group, $F(23, 690) = 18.98$, MSE = 17.79, and for the Pattern Group, $F(23, 690) = 48.29$, MSE = 17.79, which confirms that both groups solved the discrimination. Further tests revealed that the rate of responding during the reinforced stimuli was significantly faster than during the non-reinforced stimuli from Session 2 onwards for the Colour Group, $Fs(1, 720) > 9.62$, MSE> 477.56, and from Session 4 onwards for the Pattern Group, $Fs(1, 720) > 6.54$, MSE> 324.36. A further finding from the simple main effects analysis was that the Group x Session interactions were significant for both the reinforced, $F(23, 1380) = 2.61$, MSE = 23.06, and the non-reinforced stimuli, $F(23, 1380) = 6.28$, MS= 23.06. Tests of simple effects then revealed that responding was significantly faster during the Pattern than the Colour Group for the reinforced stimuli on Sessions 6-24, excluding Sessions 10 and 15, $Fs(1, 1440) > 5.00$, MSE> 315.70, and for the non-reinforced stimuli on Sessions 2-15, excluding 13, $Fs(1, 1440) > 4.27$, MSE> 640.64.

During the ten sessions of the test stage, both groups responded at a consistently high rate to the reinforced compound, AZ, as can be seen in Figure 2.2. A two-way ANOVA of the individual mean response rates for each of the ten sessions revealed that the effect of group was not significant, $F(1, 30) = 3.10$, MSE = 36989.50. The effect of session was significant, $F(9, 270) = 3.44$, MSE = 610.14, and the Group x Session interaction, $F(9, 270) = 1.92$, MSE = 610.14, just reached significance. Subsequent tests of simple main effects revealed that the groups differed in the rate at which they responded to AZ on Sessions 1 and 2 of the test phase, $Fs(1, 300) > 4.69$, MSE = 4248.08.
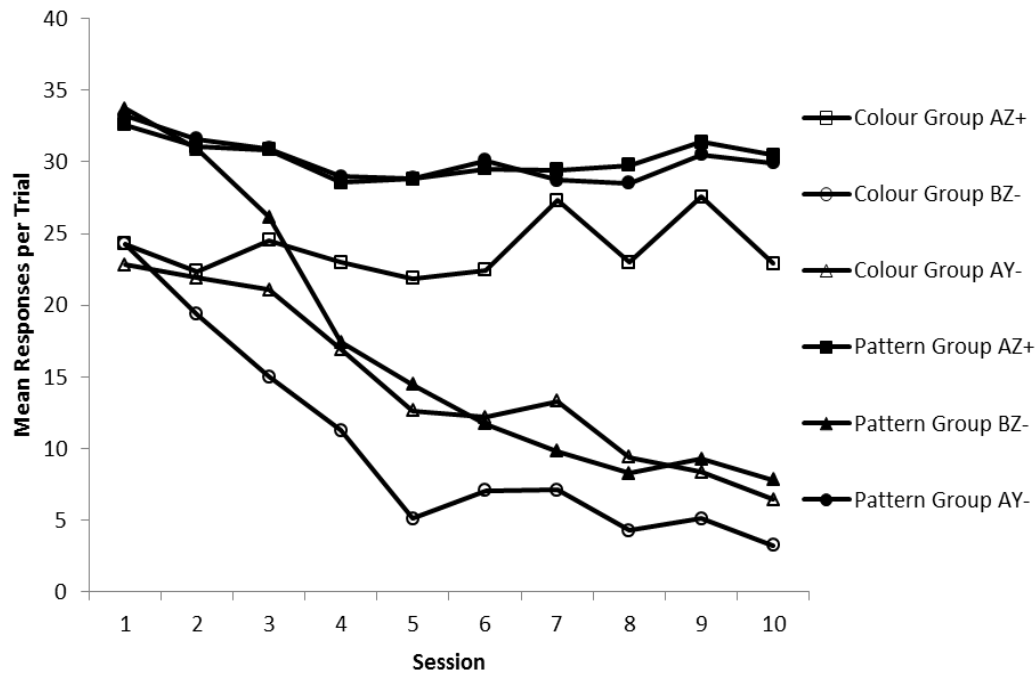
Figure 2.2. The mean rates of responding during the three compound trials throughout Stage 2 of Experiment 1 for both groups.

In order to compare the performance of the groups during the non-reinforced compounds, discrimination ratios were calculated for individual subjects for each session. The ratios were of the form $S^-/(S^- + S^+)$, where S^- is the rate of responding during a non-reinforced compound (BZ or AY) and S^+ is the rate of responding during the reinforced compound (AZ). A value of .5 with this ratio indicates that the rate of responding during a non-reinforced compound is no different to that during the reinforced compound, and 0 indicates some responding during the reinforced compound, and none during the non-reinforced compound.

Figure 2.3 shows the mean discrimination ratios for the two groups for each of the 10 test sessions during the discrimination for which the distinctive cues were irrelevant during Stage 1 (AZ+ AY-), and for the discrimination for which the

distinctive cues were relevant during the original training (AZ+ BZ-). From this figure it is evident that both groups acquired the discrimination for which the distinctive cues had been relevant during Stage 1 more readily than that for which the distinctive cues had previously been irrelevant. The difference between the two discriminations was much more pronounced for the Pattern Group, which had not solved the discrimination based on previously irrelevant cues by the end of the test stage.
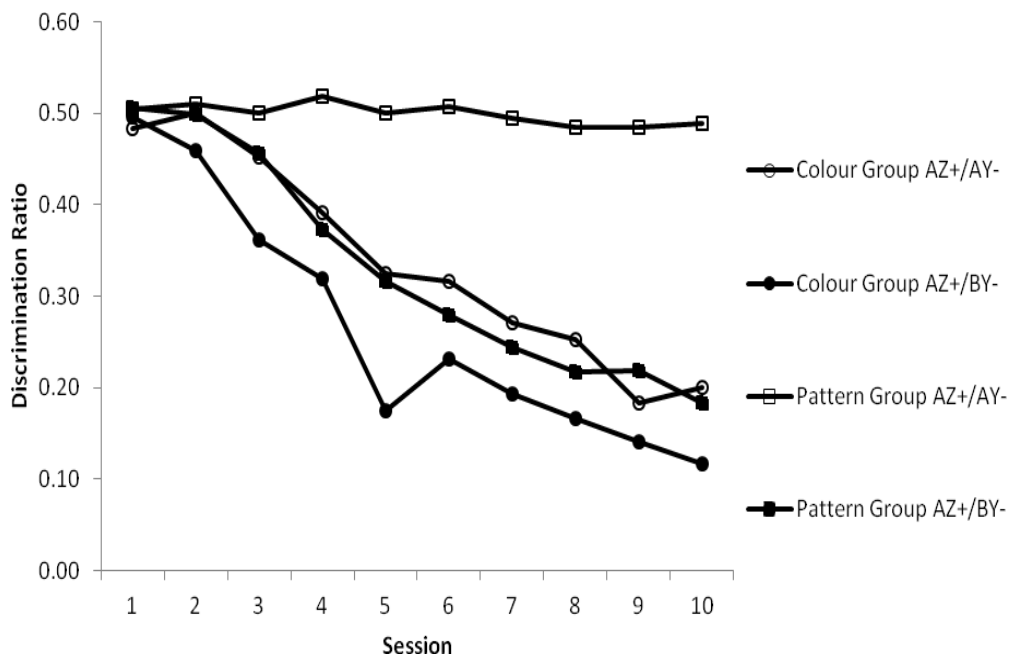
Figure 2.3. Discrimination ratios for the AZ+/ AY- and AZ+/BZ- discriminations for the Colour and Pattern groups during Stage 2 of Experiment 1.

A three-way ANOVA of individual ratios from the two components of the test discrimination, for each of the ten sessions, revealed significant effects of group, $F(1, 30) = 18.94$, MSE = 0.11, discrimination, $F(1,30) = 33.32$, MSE = 0.07, and session, $F(9, 270) = 54.66$, MSE = 0.01. The Group x Discrimination, $F(1, 30) = 5.59$, MSE = 0.07, Group x Session, $F(9, 270) = 5.66$, MSE = 0.01, Discrimination x Session, $F(9,$

270) = 10.64, MSE = 0.01, and Group x Discrimination x Session, $F(9, 270) = 5.84$, MSE = 0.01, interactions were all significant. Further analysis to explore the three-way interaction revealed that the Discrimination x Session interaction was significant for both the Colour Group, $F(9,270) = 1.96$, MSE = 0.01, and the Pattern Group, $F(9,270) = 14.53$, MSE = 0.01. Subsequent tests of simple main effects tests then revealed that the ratios for the discrimination based on previously relevant cues (AZ+ BZ-) were significantly lower than for the discrimination based on previously irrelevant cues (AZ+ AY-) on Sessions 3, 5, 6, 8 and 10 in the Colour Group, Fs(1, 300) > 4.05, MSE = 0.01, and on Sessions 4 to 10 in the Pattern Group, Fs(1, 300) > 12.62, MSE = 0.01. From Figure 2.3, it appears that the difference in the rate at which the AZ+/BZ- and AZ+/AY- discriminations were acquired was greater in the Pattern Group than in the Colour Group. Further analysis of the three-way interaction revealed a significant Group x Discrimination interaction from Session 6 onwards, Fs(1, 300) > 6.25, MSE = 0.01.

Discussion

The results from both groups show that the acquisition of an AZ+/BZ-/AY- discrimination, for which all four stimuli belonged to one stimulus dimension, was influenced by prior discrimination training with these stimuli. The component of the subsequent test discrimination based on the previously relevant stimuli A and B (AZ+/BZ-) was found to be acquired more readily than that based on the previously irrelevant stimuli Z and Y (AZ+/AY-). This result was found whether A, B, Y and Z belonged to the dimension of colour or line orientation, although the effect was more pronounced for the latter.

During Stage 1, the rate of responding during both the reinforced and non-reinforced trials was more rapid in the colour than the pattern group. Moreover, this difference between the groups carried over to the initial sessions of the test stage during the reinforced AZ trials. The possibility must be considered therefore that the difference between the test results of the two groups was a consequence of a general tendency of the pattern group to respond more vigorously than the colour group. While it is not possible to refute this explanation completely, it is weakened by the observation that the differences between the two groups were at their greatest towards the end of the test stage, when the difference between the rates of responding during AZ was no longer significant. In any case, the main purpose of the experiment was not to compare the effects of training with colours and patterns, which were used principally to confirm the generality of our results. Rather, the main purpose of the experiment was to demonstrate that different degrees of attention can be paid to stimuli belonging to the same dimension according to whether they have previously been relevant or irrelevant for a discrimination. Experiment 1 showed this to be the case for both colours and patterns, and this conclusion is not affected at all by differences in the rates at which the two groups responded.

I argued in the Introduction that the present outcome of the experiment would be more consistent with the view that changes in attention took place to individual stimuli during the Stage 1 training (e.g. Mackintosh, 1975a), rather than to dimensions of stimuli (e.g. Sutherland & Mackintosh, 1971). It is, however, possible to explain the results with the second of these alternatives by revising how a dimension is conceptualised. Thus far we have assumed that all colours belong to one dimension and all orientations of lines belong to a different dimension. However it is possible that rather than there being an overarching dimension of colour, pigeons treated red,

orange and yellow (colours from one end of the colour spectrum) as belonging to one dimension, and green, cyan and blue (colours from the other end of the spectrum) as belonging to another. In keeping with the proposals of Sutherland and Mackintosh (1971), the results from Experiment 1 could then be explained in terms of increased attention to all stimuli from the relevant dimension at the expense of those from the irrelevant dimension. Turning to the pattern group, it might be assumed that vertical and horizontal lines belong to one dimension and lines tilted at $\pm\,45^{o}$ belong to a different dimension. Although this assumption seems unlikely, it is nevertheless difficult to reject categorically. Accordingly, Experiment 2 was designed with this explanation for the outcome of Experiment 1 in mind.

2.3. Experiment 2

The design of the second experiment was identical to that of the first, except that the assignment of the stimuli to the relevant and irrelevant roles was different. Assuming that the orientations 0° and 90° belong to a separate dimension to the orientations 45° and -45°, and red and orange belong to a separate dimension to cyan and blue, in Experiment 2 one stimulus from each of these dimensions was relevant during Stage 1 and the other was irrelevant. By way of example, for one of the colour subgroups in Experiment 2 red was the relevant cue A, and orange the irrelevant cue Y. Similarly cyan was the relevant cue B and blue the irrelevant cue Z. If changes in attention affect all the stimuli belonging to a dimension equally, then similar amounts of attention should be paid to all four of these stimuli as a result of the Stage 1 training. In this case, the AZ+ BZ- component of the test discrimination should be acquired at that same rate as the AZ+ AY- component. However, if changes in attention take place to individual stimuli, then the AZ+ BZ- discrimination, which is

based on two previously relevant stimuli, should be acquired more readily than the AZ+ AY- discrimination, which is based on two previously irrelevant stimuli.

Method

Subjects. The subjects were 32 experimentally naïve adult homing pigeons. The pigeons were fed and maintained in the same manner as for Experiment 1. The pigeons were assigned at random in equal numbers to the two groups at the start of the experiment. One pigeon died during Stage 1 training, and thus the data reported are for 16 birds in the Colour Group and 15 in the Pattern Group.

Apparatus. The apparatus was the same as for Experiment 1.

Stimuli. The same stimuli as Experiment 1 were used. For half of the subjects in the Colour Group the relevant cues A, B and C represented cyan, red and yellow respectively, and the irrelevant cues X, Y, and Z represented green, blue and orange. For the other half, A, B and C represented orange, blue and green respectively, and X, Y and Z represented yellow, red and cyan. For half of the subjects in the Pattern Group A, B and C represented, respectively, striped patterns tilted at 90º and 45º and the concentric circle pattern. X, Y and Z represented the spotted pattern and striped patterns tilted at 0º and -45º. For the other half, A, B and C represented striped patterns tilted at -45º and 0º and the spotted pattern. X, Y and Z represented the concentric circle pattern and striped patterns tilted at 45º and 90º. The stimuli used can be seen in Table 2.3.

Table 2.3. Stimuli used in Stages 1 and 2 of Experiment 2. Half of each group received the discriminations on the left and half the discriminations on the right.

Procedure. Magazine training and preliminary autoshaping proceeded in the same manner as in Experiment 1. Stage 1 training proceeded as in Experiment 1, with the exception that there were 18 sessions. The first of 8 test sessions began on the day following the final session of Stage 1. Each of these sessions contained the same trial types as those given in each session of the test phase in Experiment 1. Procedural details that have been omitted from either stage of the experiment were the same as for Experiment 1.

Results

Figure 2.4 shows the mean rate of responding during reinforced trials, and that during non-reinforced trials, for the two groups on each session of Stage 1. From this figure it appears that, as in Experiment 1, the Colour Group acquired the discriminations more readily than the Pattern Group, and that the latter responded at a higher rate in the presence of both reinforced and non-reinforced trials throughout Stage 1.
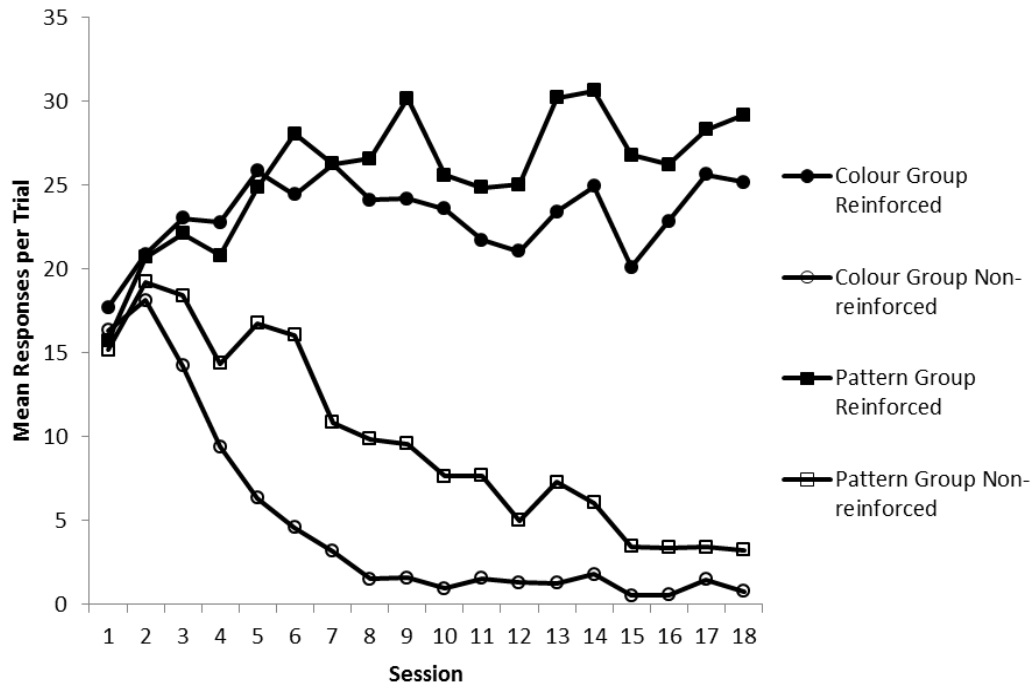
Figure 2.4. The mean rates of responding during the reinforced (CS+) and non-reinforced (CS-) trials for the Colour and Pattern groups throughout Stage 1 of Experiment 2.

A three-way ANOVA of individual mean rates of responding during each of the 18 sessions was carried out and revealed a significant effect of session, $F(17, 493)$ = 7.16, MSE = 30.30, stimulus, $F(1, 29)$ = 218.93, MSE = 389.35, and group, $F(1, 29)$ = 4.35, MSE = 1082.08. A significant two-way Group x Session interaction, $F(17, 493)$ = 3.47, MSE = 105.00, was found as was a significant Stimulus x Session interaction, $F(17, 493)$ = 61.25, MSE = 931.99. The interaction of Group x Stimulus F <1 was not significant. The Group x Stimulus x Session interaction was significant $F(17, 493)$ = 5.63, MSE = 85.60.

Tests of simple main effects were conducted in order to explore the three-way interaction. These revealed a significant Stimulus x Session interaction for the Colour

Group, $F(17, 493) = 25.65$, MSE = 15.22, and for the Pattern Group, $F(17, 493) = 41.23$, MSE = 15.22, which confirms that both groups solved the discrimination. Further tests revealed that the rate of responding during the reinforced stimuli was significantly faster than during the non-reinforced stimuli from Session 3 onwards for the Colour Group, $Fs(1, 522) > 16.70$, MSE = 36.00, and from Session 4 onwards for the Pattern Group, $Fs(1, 522) > 9.45$, MSE = 36.00. A further finding from the simple main effects analysis was that the Group x Session interactions were significant for both the reinforced, $F(17, 986) = 3.76$, MSE = 22.76, and the non-reinforced stimuli, $F(17, 986) = 4.61$, MSE = 22.76. Tests of simple effects then revealed that responding was significantly faster in the Pattern than the Colour Group for the reinforced stimuli on Sessions 5-11 and 13, $Fs(1, 1044) > 12.73$, MSE = 62.37 , and for the non-reinforced stimuli on Sessions 9, 12-15 and 18, $Fs(1, 1044) > 4.71$, MSE = 62.37.

During the eight sessions of the test stage, both groups responded at a consistently high rate to the reinforced compound, AZ as can be seen in Figure 2.5, however the Pattern Group responded at a higher rate than the Colour Group. A two-way ANOVA of the individual mean response rates for each of the eight sessions revealed that the effect of group was not significant, $F(1, 29) = 1.41$, MSE = 812.85. The effect of session was significant, $F(7, 203) = 5.30$, MSE = 17.40, as was the Group x Session interaction, $F(7, 203) = 2.78$, MSE = 17.40. Subsequent tests of simple main effects revealed that the groups differed only in the rate at which they responded to AZ on Session 1 of the test phase, $F(1, 232) = 4.04$, MSE = 116.83.
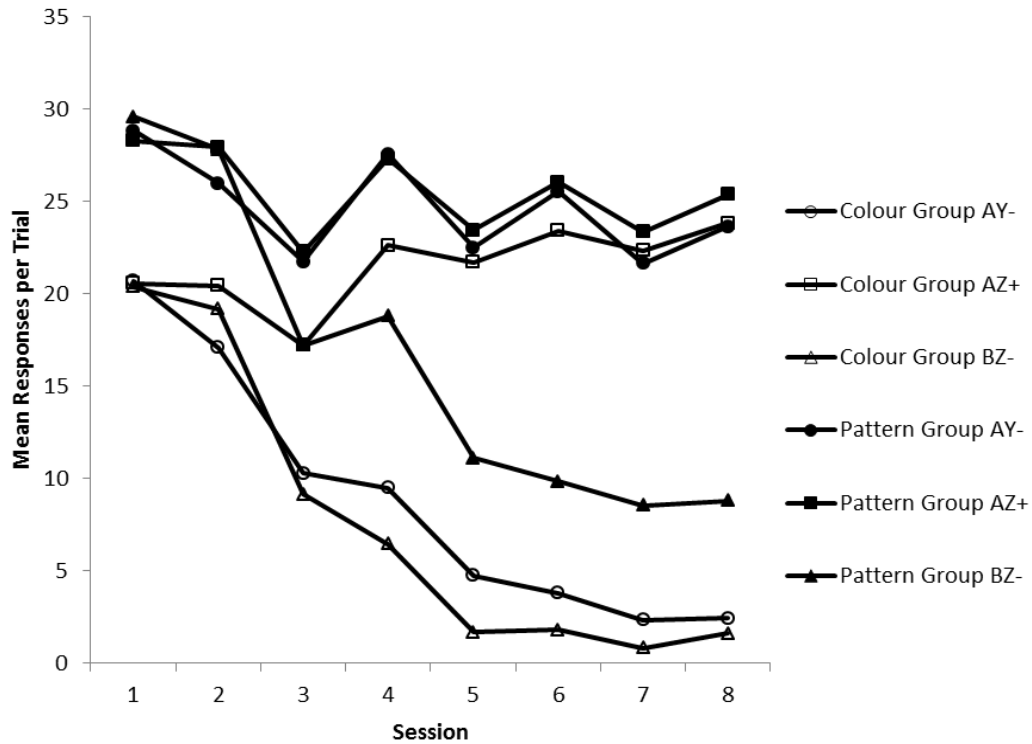
Figure 2.5. The mean rates of responding during the three compound trials throughout Stage 2 of Experiment 2 for both groups.

In order to compare the performance of the groups during the non-reinforced compounds, discrimination ratios were calculated for individual subjects in the same manner as in Experiment 1. Figure 2.6 shows the mean discrimination ratios for the two groups for each of the eight test sessions during the discrimination for which the distinctive cues were irrelevant during Stage 1 (AZ+ AY-), and for the discrimination for which the distinctive cues were relevant during the original training (AZ+ BZ-). As in Experiment 1, both groups acquired the discrimination for which the distinctive cues had been relevant during Stage 1 more readily than that for which the distinctive cues had previously been irrelevant. Again, the difference between the two discriminations was much more pronounced for the Pattern Group.

46
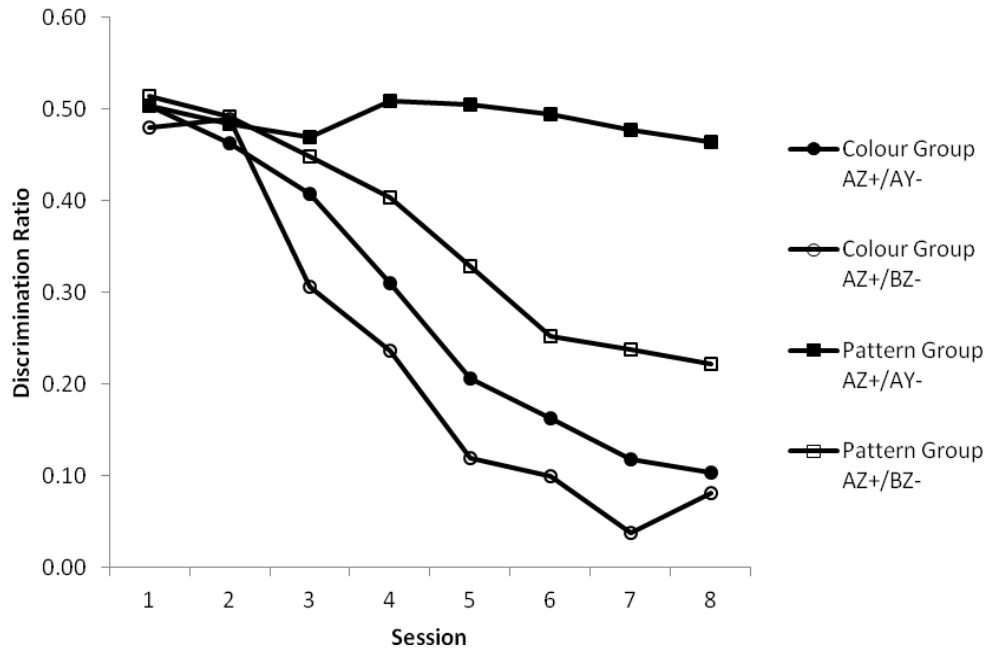
Figure 2.6. Discrimination ratios for the AZ+/ AY- and AZ+/BZ- discriminations for the Colour and Pattern groups during Stage 2 of Experiment 2.

A three-way ANOVA of individual ratios from the two components of the test discrimination, for each of the eight sessions, revealed significant effects of group, $F(1, 29) = 31.53$, MSE = 0.11, discrimination, $F(1,29) = 24.47$, MSE = 0.04, and session, $F(7, 203) = 49.63$, MSE = 0.02. The Group x Discrimination was not significant, $F(1, 29) = 3.99$, MSE = 0.04, but the Group x Session, $F(7, 203) = 11.11$, MSE = 0.02, Discrimination x Session, $F(7, 203) = 10.46$, MSE = 0.01, and Group x Discrimination x Session, $F(7, 203) = 6.62$, MSE = 0.01, interactions were all significant. Further analysis to explore the three-way interaction revealed that the Discrimination x Session interaction was significant for both the Colour Group, $F(7, 203) = 2.11$, MSE = 0.01, and the Pattern Group, $F(7, 203) = 14.97$, MSE = 0.01. Subsequent tests of simple main effects tests then revealed that the ratios for the

47

discrimination based on previously relevant cues (AZ+ BZ-) were significantly lower than for the discrimination based on previously irrelevant cues (AZ+ AY-) on Sessions 3, 4, 5 and 7 in the Colour Group, Fs(1, 232) > 4.03, MSE = 0.01, and on Sessions 4 to 8 in the Pattern Group, Fs(1, 232) > 7.93, MSE = 0.01. Inspection of Figure 4 suggests that, as in Experiment 1, the difference in the rate at which the AZ+ BZ- and AZ+ AY- discriminations were acquired was greater in the Pattern Group than in the Colour Group. In this case, further analysis of the Group x Discrimination interaction confirmed that the difference was significant on Sessions 6 to 8, Fs(1, 232) > 8.89, MSE = 0.01.

Discussion.

Despite changes to the way in which stimuli were assigned to their roles as relevant and irrelevant cues in Stage 1, the outcome of Experiment 2 was remarkably similar to the outcome of Experiment 1. As similar stimuli functioned as relevant and irrelevant cues during Stage 1 of Experiment 2, the relevant stimuli could not be regarded as belonging to a separate dimension to the irrelevant stimuli. It therefore appears that the superior acquisition of the AZ+/ BZ- component of the test discrimination compared to the AZ+/ AY- component occurred as a result of more attention being paid to the individual relevant stimuli A and B than to the irrelevant cues Z and Y during Stage 1 training.

2.4   General Discussion

The results from both experiments show that after training with several discriminations based on the AZ+ BZ- format, subjects learned more readily about the stimuli that were originally relevant rather than irrelevant when they were used in a

new discrimination. This outcome has been attributed to subjects ultimately paying more attention to relevant than irrelevant stimuli. The present findings confirm those from previous studies using a similar design (e.g. Dopson et al., 2010a; Pearce et al., 2008). They also extend the generality of these earlier studies by showing for the first time that the same results can be obtained when the relevant and irrelevant stimuli are from the same dimension, rather than different dimensions. I have argued that the findings are more compatible with the theoretical proposals of Mackintosh (1975a) than Sutherland and Mackintosh (1971) by indicating that changes in attention occur to individual stimuli rather than to dimensions of stimuli.

In the experiments reported here previous difficulties in interpreting the data were avoided by using relevant and irrelevant cues from a single dimension during the Stage 1 training. In the case of Experiment 1, this claim is acceptable only if it is allowed that all colours belong to a single dimension, and lines of all orientations belong to a single dimension. It was acknowledged in Experiment 2 that dimensions may be not be this broad and encompass, instead, only a restricted range of colours or orientations. Experiment 2 took account of this possibility by assigning similar stimuli to the roles of relevant and irrelevant stimuli. In the case of colours, for example, red was relevant and orange irrelevant for some subjects. As these two colours fall close together at one end of the spectrum, it would seem reasonable to regard them as belonging to the same dimension and, if changes in attention take place to entire dimensions, then the same amount of attention should be paid to red and orange. If all cues that were initially relevant received the same amount of attention as those that were initially irrelevant, both components of the test discrimination should be acquired at the same rate. The outcome of the experiment failed to confirm this prediction.

49

It might now be argued that all of the test stimuli in both experiments were from different dimensions encompassing a small range of values. For example, red stimuli might belong to one dimension and orange stimuli to another dimension. If dimensions are restricted in this way, then the outcome of the present experiments could have been a consequence of a shift in attention to entire dimensions of stimuli. While this conclusion remains tenable logically, it does not fit comfortably with the proposals of Mackintosh and Sutherland (1971, see page 33) who talked about more global dimensions of brightness and orientation. Moreover, once a dimension is restricted to a small range of values, such as those defined by redness, or even certain shades of red, then the theory must explain how an increase in attention to one colour will enhance attention to another. For example, the IDS/EDS experiments mentioned earlier have shown that if a stimulus is trained as relevant to a discrimination, subsequent learning about other, similar stimuli can be facilitated. By assuming that attention changes to individual stimuli, and that this change can generalise to other stimuli, Mackintosh's (1975a) theory is ideally suited to overcome these obstacles and thus appears to provide the most plausible explanation for our findings. As a final comment on this topic, by showing that changes in attention take place to individual stimuli, the present results raise the question of whether it is meaningful, or helpful, to regard sets of related stimuli as belonging to dimensions.

It follows from the theories of attention considered thus far that the changes in attention to relevant and irrelevant stimuli observed here take place once those stimuli have been perceived. However, it is possible that the mechanism underlying these changes is a more peripheral one. According to Spence (1952), discrimination training may reinforce orienting responses that result in animals directing their eyes towards stimuli that signal reward at the expense of those that signal no reward. In the case of

the present experiments, during Stage 1 pigeons would be expected to learn to direct their gaze towards the relevant stimuli A and B, which are consistently followed by food, at the expense of the irrelevant stimuli, Y and Z, which are followed intermittently by food. As a result, subjects would learn more rapidly about the former than the latter when they were involved in the subsequent test discrimination. For the present, it is simply worth noting that the present experiments demonstrate that the changes envisaged by Spence must take place to individual stimuli, rather than to dimensions of stimuli.

A possible challenge to the above explanation for the results from the test stage of Experiments 1 and 2 is that during Stage 1 of both experiments responding during the reinforced trials was substantially faster for the pattern than the colour group. According to the preceding interpretation, this finding implies that the pattern groups paid more overt attention to the reinforced relevant cues than the colour groups, and that responding during the non-reinforced test trials with BZ should therefore have declined more rapidly for the pattern than the colour group. In both experiments, however, the opposite outcome was observed.

The experiments reported here provide, for the first time, a direct test of whether changes in attention are established to individual stimuli or to entire stimulus dimensions. The results provide support for a mechanism that results in more attention being paid to individual stimuli that are relevant than those that are irrelevant (Mackintosh, 1975a), rather than to all values of the dimension to which relevant stimuli belong (Sutherland & Mackintosh, 1971). This finding not only provides support for Mackintosh's (1975a) theory, but also for more recent hybrid theories of learning that incorporate a similar principle (e.g. Le Pelley, 2004; Pearce, George & Redhead, 1998; Pearce & Mackintosh, 2010).

3. Stimulus Pre-exposure and Changes in Associability

3.1 Introduction

It was discussed during Chapter 1 that latent inhibition is observed when an animal is pre-exposed to a stimulus prior to conditioning with that stimulus. One of the aforementioned outstanding issues concerning the role of selective attention in learning relates to the lack of evidence for the occurrence of latent inhibition in pigeons. To date there are many accounts of such an effect occurring in mammals (e.g. Lubow & Moore 1959; Lubow 1973) and in honeybees (Abramson & Bitterman 1986; Chandra, Wright & Smith 2010) but evidence for its occurrence in pigeons is poor. One such attempt was undertaken by Mackintosh (1973). Effects of blocking were also investigated but of concern here are two of the four experimental groups. One group of pigeons was placed in a conditioning chamber and exposed to a light repeatedly without any reinforcement. Another group was placed for equal time in the experimental chamber but was not exposed to any additional stimuli. Both groups were then tested over eight sessions with the light now signalling the presence of food. If latent inhibition had occurred then conditioning to the light in the group pre-exposed to the light would be significantly retarded in comparison to the control group for whom the light was novel in the second stage. This was observed during the first two test sessions only and so at best only a weak effect was demonstrated.

A more successful demonstration of latent inhibition was carried out by Tranberg and Rilling (1978); using the same initial design as Mackintosh (1973), during the four subsequent conditioning sessions, pigeons which had received non-reinforced pre-exposure to the light required a greater number of trials before beginning to respond and responded at a slower rate throughout compared to the

pigeons for whom the light was novel during the test stage. Tranberg and Rilling attributed their success to an increase in the ITI during pre-exposure and an increase in the number of stimulus pre-exposures subjects received. However, there is another possible explanation for them observing latent inhibition in pigeons where others have failed. Rather than subsequent conditioning being retarded as a result of pigeons simply being pre-exposed to a stimulus, it could be that the stimulus became a conditioned inhibitor during pre-exposure. The pigeons were first magazine trained using food in the same chamber later used for testing which could have resulted in the context entering into an excitatory relationship with this US. When the light was later presented within a context with which the pigeons had come to expect food, it may be that the light gained inhibitory properties by virtue of signalling the absence of food and in fact acted as a conditioned inhibitor. Subsequent retardation of conditioning to the light would thus occur as a result of this conditioned inhibition to the light rather than simply as a result of pre-exposure

It was with this in mind that Swan (1987, unpublished PhD thesis) developed a methodology using pigeons, designed to prevent the pre-exposed stimulus entering in to an inhibitory relationship with food. During magazine training a tone was played immediately before presentation of food occurred in an attempt to overshadow the context and prevent it entering into an excitatory relationship with the food, when a light was subsequently presented in the absence of food it was expected that the context would be associatively neutral. One group of pigeons was pre-exposed to a light over several sessions and another group was placed in the test chamber without any additional stimuli. Both groups were then subjected to a number of test sessions during which trials of the pre-exposed light followed immediately by a novel light signalled the absence of food were interspersed with trials of the novel light on its

own signalling the presence of food. Subjects therefore had to learn that the presence of the pre-exposed light resulted in the absence of food following a stimulus, which would otherwise signal the presence of food. If latent inhibition had occurred the group pre-exposed to the light should learn the subsequent discrimination more slowly than the group for whom both lights were novel at the start of the test session. If the pre-exposure training resulted in the light acquiring conditioned rather than latent inhibition, the opposite pattern of results should have been seen. Thus any retardation in the learning of the test discrimination in the pre-exposed group could be attributed to latent inhibition rather than to conditioned inhibition. However, Swan (1987, unpublished PhD thesis) found no significant effect of pre-exposure to the light on subsequent inhibitory conditioning to the same light; latent inhibition was not observed.

As also stated by Tranberg and Rilling (1978), the final problem associated with experiments testing for latent inhibition in pigeons is that of the pre-exposure technique itself. Mackintosh (1973) highlighted that during pre-exposure to a stimulus in a test chamber, pigeons may simply take the opportunity to choose a corner and go to sleep. Thus they avoid pre-exposure altogether and experience the same novelty of stimulus during the test phase as a control group placed in the test chamber in the absence of a non-reinforced stimulus.

3.2   Experiment 3

The present experiment sought to detect latent inhibition using a novel test. In addition, steps were taken to reduce the likelihood that pigeons would fail to detect the pre-exposed stimulus during the initial phase of training. For this initial training, one group of pigeons, Group Pre-exposed, received the discrimination A+ B+ C- D-

and another, Group Novel, received A+ B+ E- F-, where food was signalled by A and B, but not by C, D, E, and F. The stimuli used in both stages can be seen in Table 3.1. By inter-mixing the non-reinforced pre-exposed stimuli among reinforced trials with A and B, it was hoped that the birds would continue to pay attention to the screen on which the stimuli were presented throughout this phase of the experiment. It would thus be difficult to attribute any failure to detect latent inhibition to the possibility that the birds were not interested in the screen and failed to notice the non-reinforced stimuli. All pigeons were then presented with a test discrimination of the form AC+/AD-/BC-. Group Pre-exposed, which had been previously pre-exposed to C and D should find the discrimination AC+/AD- more difficult than the AC+/BC- discrimination if latent inhibition has occurred to C and D. Conversely, Group Novel, for which C and D are novel in Stage 2, should solve both discriminations at a similar rate given that attention would be expected to be high to the previously reinforced stimuli and to the novel stimuli.

Group	Stage 1	Stage 2
Pre-exposed	A+ B+ C- D-	AC+ BC- AD-
Novel	A+ B+ E- F-	AC+ BC- AD-

Table 3.1. Discriminations presented during Stage 1 and Stage 2 of Experiment 3

Method

Subjects. The subjects were 22 naïve adult homing pigeons (*Columba livia*), maintained in the same manner as in Experiment 1. At the start of the experiment the subjects were randomly assigned to one of 2 groups with each group containing 11

subjects. At the end of Stage 1, two birds form Group 1 and one bird from Group 2 had failed to respond at a higher rate to any of the stimuli than 1 response per minute and therefore were excluded from the experiment.

Apparatus. All apparatus used was identical to that used in Experiment 1.

Stimuli. The stimuli were presented on the TV screen, which was otherwise black. During Stage 1, the stimuli consisted of one circle, 2.4 cm in diameter located at the centre of the TV screen. During Stage 2, the stimuli consisted of 2 horizontally adjacent circles, each 2.4 cm in diameter. The point at which the circles joined was located at the centre of the TV screen. For all subjects in all groups the stimuli were the same four black and white patterns used in Experiment 1 and 2 with the addition of two new patterns; a black star in a white circle, with each of the five points of the star touching the edge of the circle, and a circle divided into 12 even segments emanating from the centre point, alternately coloured black and white.

The stimuli were counterbalanced in the following way. For half of the subjects in both groups A, B, C, D, E and F represented the spotted pattern, the concentric circle pattern, striped patterns tilted at -45º, striped patterns tilted at 45º, the star pattern and the segmented pattern respectively. For the remaining half A, B, C, D, E and F represented striped patterns tilted at -45º, striped patterns tilted at 45º, the spotted pattern, the concentric circle pattern, the star pattern and the segmented pattern respectively. In both cases A and B consistently signalled food, and C, D, E, and F consistently signalled the absence of food; each group was presented with the two reinforced stimuli and two of the four non-reinforced stimuli. The patterned stimuli used can be seen in Table 3.2.

Table 3.2. Stimuli used in Stages 1 and 2 of Experiment 3. Half of each group received the top discriminations and half the bottom discriminations.

During stage two, for Group Pre-exposed, each trial type consisted of one previously reinforced and one previously non-reinforced stimulus in adjacent circles. For Group Novel, each trial type consisted of one previously reinforced stimulus and one novel stimulus. On half of the presentations, the relevant stimulus appeared in the left-hand circle, and on the other half it appeared in the right-hand circle.

Procedure. The subjects first received 8 sessions in which they were trained to eat food whenever it was presented by the hopper. They were then given 5 sessions of autoshaping in which a white circle with a diameter of 2.4 cm was presented in the middle of the TV screen for 10 s. There were 45 trials in a session, the mean interval between the start of each trial was 60 s (range = 40-80 s), and food was made available in the hopper for 4 s whenever the white circle was removed from the TV screen. Subjects were then randomly assigned to Group Pre-exposed or Group Novel. Session 1 of Stage 1 began on the day after the final session of autoshaping. During each of the 16 sessions of training, both groups received discrimination training with the four trial types given in Table 3.1. There were 40 trials in each session: each trial type was presented ten times. The following details applied to all stages of the experiment. Each stimulus was presented for 10 s, and the mean inter-trial interval was 60 s (range = 40-80 s). The trial types were presented in a random order with the constraint that no more than two reinforced or two non-reinforced trials could occur in succession.

On the day following Session 16 of training, both groups received the first session of the test discrimination. There were 10 sessions in this stage of the experiment, during which all animals received the discrimination AC+ BC- AD-. There were 40 trials in each session, consisting of 20 reinforced presentations of AC,

10 non-reinforced presentations of BC and 10 non-reinforced presentations of AD.

The procedural details that have been omitted were the same as for the previous

experiment.

Results

Figure 3.1 shows the mean rate of responding during reinforced trials, and that

during non-reinforced trials, for the three groups on each session of Stage 1. From this

figure it appears that the all groups acquired the discriminations at a similar rate.
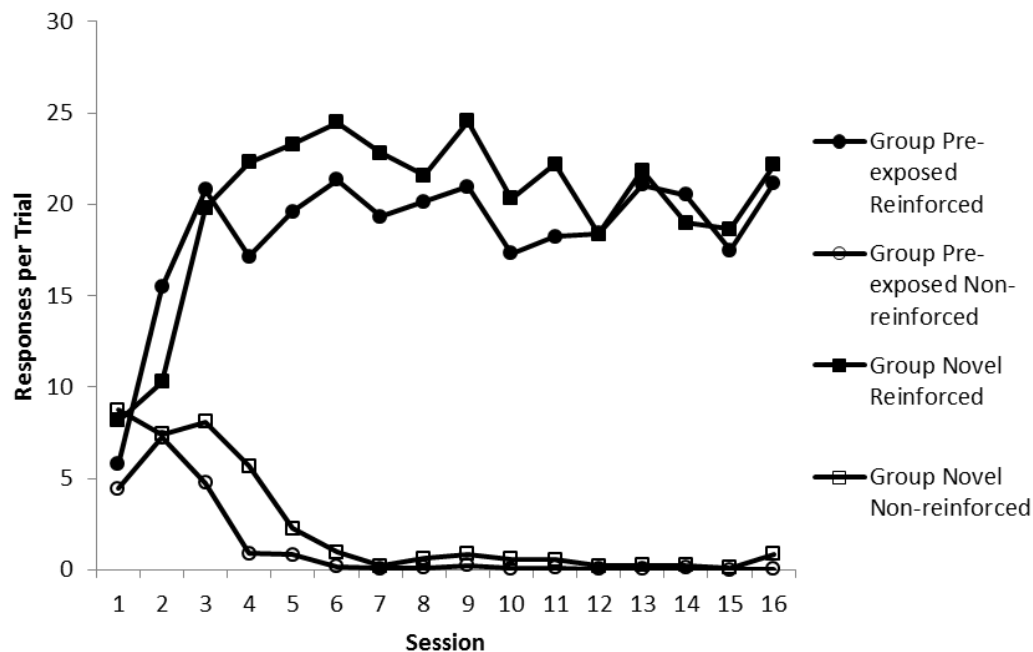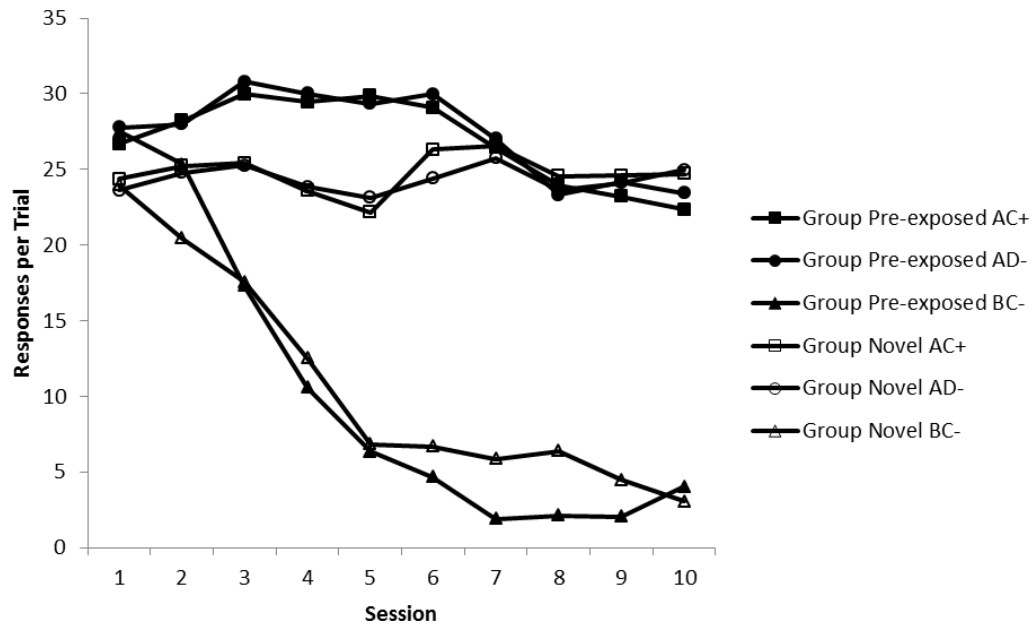

Figure 3.1. The mean rates of responding during the reinforced (CS+) and non-

reinforced (CS-) trials for both groups throughout Stage 1 of Experiment 3.

A three-way ANOVA of individual mean rates of responding during each of

the 16 sessions was carried out and revealed a significant effect of session, $F(15, 390)$

$= 5.00$, MSE $= 29.02$, and of stimulus, $F(1, 26) = 144.94$, MSE $= 672.16$. No effect of

group was found, $F < 1$. A significant Stimulus x Session interaction, $F(15, 390) = 32.20$, MSE $= 22.45$, was found. The interaction of Group x Stimulus and Group x Session, $Fs < 1$ was not significant. The Group x Stimulus x Session interaction was not significant $F < 1$.

Tests of simple main effects were conducted in order to explore the two way interaction of Stimulus x Session. These revealed a significant effect of Session for the reinforced stimuli, $F(15, 780) = 24.26$, MSE $= 25.73$, and for the non-reinforced stimuli, $F(15, 780) = 9.46$, MSE $= 25.73$. Further tests revealed that the rate of responding during the reinforced stimuli was significantly faster than during the non-reinforced stimuli for both groups from Session 2 onwards, $Fs(1, 416) > 11.50$, MSE $= 63.05$.

Figure 3.2 shows the mean rate of responding during the ten sessions of the test stage was consistently high to the reinforced compound, AC, by both Group Pre-exposed and Group Novel. A two-way ANOVA of the individual mean response rates during AC, for each of the ten sessions, revealed that the effect of group was not significant, $F(1, 17) = 1.66$, MSE $= 908.29$, nor was the effect of session, $F(9,153) = 1.67$, MSE $= 23.91$. The Group x Session interaction was significant, $F(9,153) = 2.20$, MSE $= 23.91$. Subsequent tests of simple main effects revealed that the effect of Session was significant for Group Pre-exposed, $F(9, 153) = 3.32$, MSE $= 23.91$, but not for Group Novel, $F < 1$. The groups significantly differed in the rate at which they responded to AC on Session 5, $F(1, 170) = 5.38$, MSE $= 112.35$, only.

F**igure 3.2.** The mean rates of responding during the three compound trials for both groups throughout Stage 2 of Experiment 3.

In order to compare the performance of the groups during the non-reinforced compounds, discrimination ratios were calculated for individual subjects in the same manner as in Experiment 1. Figure 3.3 shows the mean discrimination ratios for the two groups for each of the ten test sessions during the discrimination for which the distinctive cues were reinforced during Stage 1 (AC+ BC-), and for the discrimination for which the distinctive cues were non-reinforced during the original training (AC+ AD-). Both groups acquired the discrimination for which the distinctive cues had been reinforced during Stage 1 more readily than that for which the distinctive cues had previously been non-reinforced.
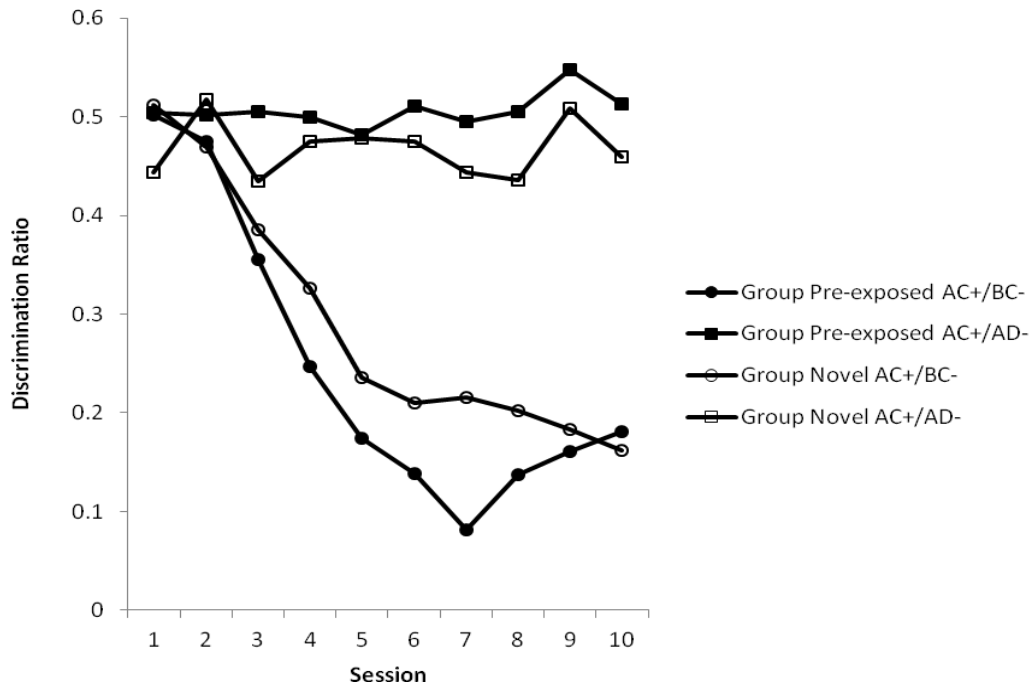
Figure 3.3. Discrimination ratios for the AC+/BC- and AC+/AD- discriminations for Group 1 and 2 during Stage 2 of Experiment 3.

A three-way ANOVA of individual ratios from the two components of the test discrimination, for each of the ten sessions, revealed significant effects of, discrimination, $F(1,17) = 68.84$, MSE = 0.10 and session, $F(9, 153) = 12.86$, MSE = 0.02. No significant effect of group, $F < 1$, was found. The interactions of Group x Discrimination, $F(1, 17) = 2.56$, MSE = 0.07, and Group x Session, $F < 1$ were not significant but the Discrimination x Session interaction, $F(9, 153) = 16.89$, MSE = 0.01, was. The Group x Discrimination x Session interaction, $F < 1$ was not significant. Further analysis to explore the two-way interaction between discrimination and session revealed that the effect of session was significant for the AC+/BC- discrimination only $F(9, 306) = 28.65$, MSE = 0.01. Subsequent tests of

simple main effects tests then revealed that there was a significant effect of discrimination from Session 3 onwards $Fs(1, 170) > 5.76$, MSE = 0.02.

Discussion.

Groups Pre-exposed and Novel both solved the AC+/BC- discrimination significantly more rapidly than the AC+/AD- discrimination. If latent inhibition had occurred then these findings would be expected from Group Pre-exposed however, it was expected that Group Novel would solve both discriminations at an equal rate. On the one hand, given that the relevant elements of the AC+/BC- discrimination had been relevant during Stage 1, and should therefore receive a high level of attention, it was expected that this discrimination would be acquired rapidly. On the other hand, given that the AC+/AD- discrimination initially contained novel stimuli as the relevant elements it was expected that this discrimination, too, would be acquired rapidly. The failure to confirm this prediction makes it hard to argue that latent inhibition was responsible for the more rapid acquisition of the AC+/AB- than AC+/AD- discrimination in Group Pre-exposed. Instead, the similar pattern of results in both groups implies that some factor other than latent inhibition was responsible for the relatively slow acquisition of the AC+/AD- discrimination and the relatively rapid acquisition of the AC+/BC- discrimination that both displayed.

While it was expected to find the most interesting results in Group Pre-exposed, it is perhaps the results of Group Novel that are the more intriguing, as they were not expected. One explanation for the results from Group Novel, and indeed, Group Pre-exposed is that the amount of attention to paid to an individual stimulus from the AC+/BC-/AD- discrimination is determined by its associative strength. In the case of Group Novel, for example, on test trials with AD, the initial training will

result in A eliciting a high rate of responding, and D a low rate. If a bird should look at the stimulus it is pecking, then it would follow that more attention will be paid to A than D, and that animals will fail to learn about the significance of the distinctive stimulus D as a cue for the absence of food. A similar line of reasoning would lead to the conclusion that on trials with BC, considerably more attention will be paid to B than C and thus, the significance of the former as a signal for the absence of food will be learned rapidly. On this basis, therefore, the AC+/BC- discrimination would be expected to be acquired more readily than the AC+/AD- discrimination.

Although the foregoing explanation for the present results is not of great interest theoretically, as it assumes that the rate of pecking a stimulus determines the attention it is paid, the explanation is of considerable significance when it comes to interpreting the results from experiments of similar design to the present one. In Experiment 1 of my thesis, for example, I showed that the subsequent test discrimination based on previously relevant stimuli was found to be acquired more readily than that based on the previously irrelevant stimuli. I argued this outcome was a consequence of different degrees of attention being paid to stimuli belonging to the same dimension according to whether they have previously been relevant or irrelevant for a discrimination, consistent with the views of Mackintosh (1975a).

In the light of the present results, however, an alternative explanation for the result of that study is that rather than altering the degree of attention paid to a stimulus as a result of its relevance, pigeons only learn about the stimulus to which they are pecking at. Thus in subsequent discriminations, attention will be focused on previously relevant stimuli only. A similar explanation can also be developed to account for the results of Pearce et al. (2008), as those authors note, and Dopson et al. (2010a).

The explanation that has just been developed clearly has considerable implications for our understanding of how pigeons react to the test stage of the relatively new method of assessing changes in attention that I have chosen to study. Accordingly, the experiment to be described next was intended to provide a direct test of this explanation.

3.3   Experiment 4

In order to test further the possibility that the rate of responding at a stimulus determines the amount of attention it is paid, Experiment 4 replicated the design used for Group Pre-exposed in Experiment 3 but with colours instead of patterns. Two groups of pigeons were first taught to discriminate between four stimuli A+, B+, C- and D-, of which A and B signalled the presence of food and C and D signalled the absence of food. During Stage 2, subjects were faced with a discrimination of the form AC+/BC-/AD-, again the same design as that for the Group Pre-exposed of Experiment 3. However for one of the two groups, the two colours which constituted each stimulus in Stage 2 where not presented in separate circles but rather combined so that both circles contained stripes of the two colours. Thus for one of the two groups it was not possible for the pigeons to only look and peck at one of the two stimuli making up the compound stimulus.

If the proposal that attention is only paid to the stimulus to which the pigeon is looking and pecking at, as an explanation for the findings of Experiment 3, is to have merit then it would be expected that the group for whom the compound stimuli in Stage 2 are shown as separate colours would solve the discriminations in a similar manner to Group Pre-exposed in Experiment 3. The discrimination based upon previously reinforced stimuli (AC+/BC-) should be solved significantly faster than the

discrimination based upon previously pre-exposed stimuli (AC+/AD-). This is because, again, during Stage 2, subjects will orient towards the stimuli which has previously been relevant to the detriment of other stimuli thus hindering their learning of the AC+/AD- discrimination. Conversely the group for whom the stimuli constituting the compound stimuli in Stage 2 are combined should solve both discriminations at an equal rate given that they are unable to orient towards one part of the compound stimuli and away from the other part. Thus attention will be paid to all stimuli and the discriminations learnt at an equally rapid rate given that attention to all stimuli will be high.

Method

Subjects. The subjects were 32 naïve adult homing pigeons (*Columba livia*), maintained in the same manner as in Experiment 1. At the start of the experiment the subjects were randomly assigned to one of two groups, Group Separate and Group Combined, with each group containing 16 subjects.

Apparatus. All apparatus used was identical to that used in Experiment 1.

Stimuli. The stimuli were presented on the TV screen, which was otherwise black. During Stage 1, the stimuli consisted of one circle, 2.4 cm in diameter located at the centre of the TV screen. During Stage 2, the stimuli consisted of 2 horizontally adjacent circles, each 2.4 cm in diameter. The point at which the circles joined was located at the centre of the TV screen. For all subjects in both groups the stimuli consisted of one of four colours; red, yellow, cyan and blue.

The stimuli were counterbalanced in the following way. For half of the subjects in both groups A, B, C, D represented red, yellow, cyan and blue respectively. For the remaining half A, B, C, D represented cyan, blue, red and yellow respectively. In both cases A and B consistently signalled food, and C, D consistently signalled the absence of food.

During Stage 2, for Group Separate, each trial type consisted of one previously reinforced and one previously non-reinforced stimulus in adjacent circles thus replicating the type of stimuli displayed to Group Pre-exposed during Experiment 3. On half of presentations, the relevant stimulus appeared in the left-hand circle, and on the other half it appeared in the right-hand circle. For Group Combined however, each trial type consisted of one previously reinforced stimulus and one non-reinforced stimulus displayed as stripes. For example AC+ would represent two adjacent red and cyan striped circles. Stimuli used during both stages can be seen in Table 3.3.

Procedure. The subjects were initially trained in the same manner as in Experiment 1. Subjects were then randomly assigned to Group Separate or Group Combined with 16 birds in each.

Session 1 of Stage 1 began on the day after the final session of autoshaping. During each of the 16 sessions of training, the 2 groups received discrimination training with the four trial types A+, B+, C-, D-. There were 40 trials in each session: each trial type was presented ten times. The following details applied to all stages of the experiment. Each stimulus was presented for 10 s, and the mean inter-trial interval was 60 s (range = 40-80 s). The trial types were presented in a random order with the constraint that no more than two reinforced or two non-reinforced trials could occur in succession.

67

Table 3.3. Stimuli used in Stage 1 and 2 of Experiment 4. Half of each group received the top discriminations and half the bottom discriminations.

On the day following Session 16 of training, all groups received the first session of the test discrimination. There were 6 sessions in this stage of the experiment, during which all animals received the discrimination AC+ BC- AD-. There were 40 trials in each session, consisting of 20 reinforced presentations of AC, 10 non-reinforced presentations of BC and 10 non-reinforced presentations of AD. The procedural details that have been omitted were the same as for the previous experiment.

Results

Figure 3.4 shows the mean rate of responding during reinforced trials, and that during non-reinforced trials, for both groups on each session of Stage 1. From this figure it appears that both groups acquired the discriminations at a similar rate.
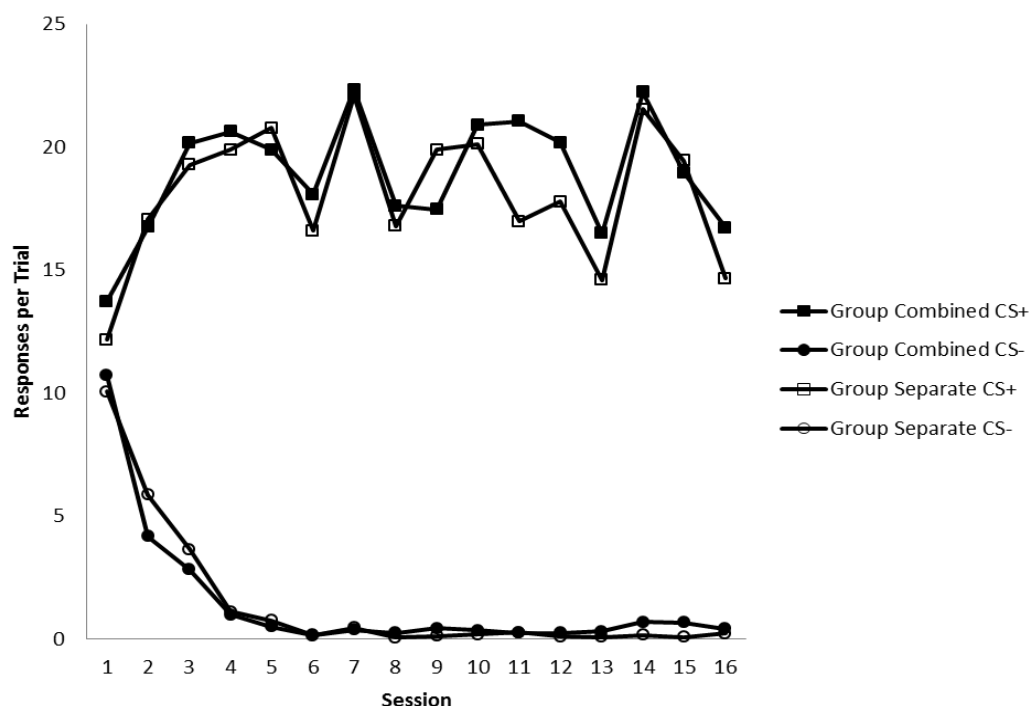
Figure 3.4. The mean rates of responding during the reinforced (CS+) and non-reinforced (CS-) trials for both groups throughout Stage 1 of Experiment 4.

69

A three-way ANOVA of individual mean rates of responding during each of the 16 sessions was carried out and revealed a significant effect session, $F(15, 450) = 5.48$, MSE = 17.32, and stimulus, $F(1, 30) = 110.27$, MSE = 676.23. No effect of group was found, $F < 1$. A significant Stimulus x Session interaction, $F(15, 450) = 22.43$, MSE = 15.11, was found. The interaction of Group x Stimulus, $F < 1$ and Group x Session, $F < 1$, was not significant, nor was the Group x Stimulus x Session interaction, $F < 1$.

Tests of simple main effects were conducted in order to explore the two-way interaction of Stimulus x Session. These revealed a significant effect of session for the reinforced stimuli, $F(15, 900) = 12.02$, MSE = 16.22, and for the non-reinforced stimuli, $F(15, 900) = 14.74$, MSE = 16.22. Further tests revealed that the rate of responding during the reinforced stimuli was significantly faster than during the non-reinforced stimuli for both groups combined from Session 2 onwards, $Fs(1, 480) > 39.98$, MSE > 56.43 .
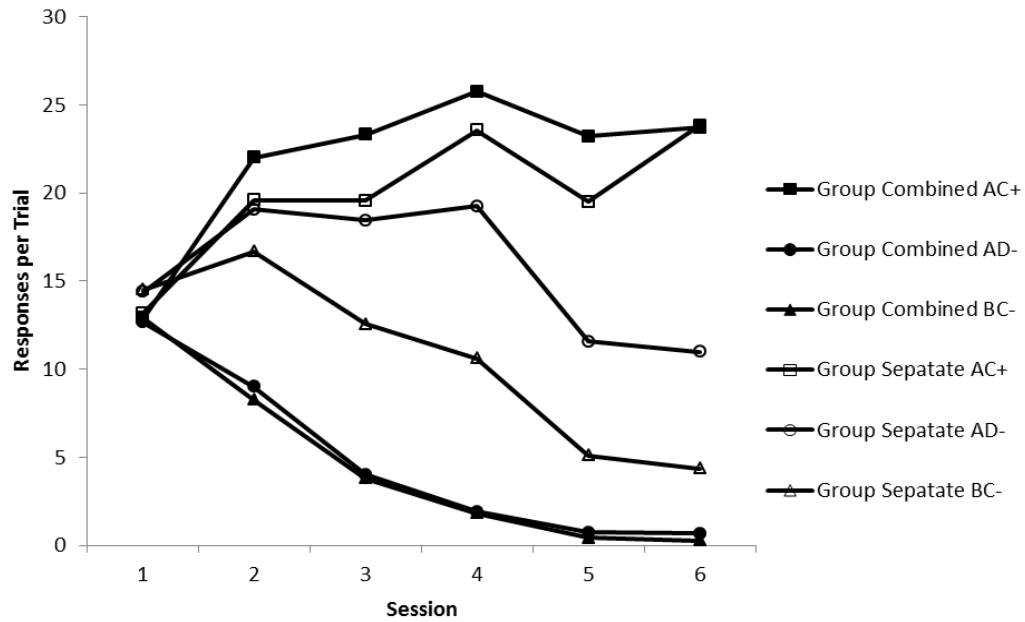
Figure 3.5. The mean rates of responding to each compound stimulus during Stage 2 for both groups of Experiment 4.

During the six sessions of the test stage, responding to AC+ appears to be at a similar rate for both groups, as can be seen in Figure 3.5. A two-way ANOVA of the individual mean response rates during AC, for each of the ten sessions, revealed that the effect of group was not significant, $F < 1$, but the effect of session was significant, $F(5, 150) = 21.96$, MSE = 24.69. The interaction of Group x Session was not significant, $F(5, 150) = 1.04$, MSE = 24.69.

In order to compare the performance of the groups during the non-reinforced compounds, discrimination ratios were calculated for individual subjects in the same manner as in Experiment 1. Figure 3.6 shows the mean discrimination ratios for the two groups for each of the ten test sessions during the discrimination for which the distinctive cues were reinforced during Stage 1 (AC+ BC-), and for the discrimination for which the distinctive cues were non-reinforced during the original training (AC+

AD-). Group Combined solved the two discriminations at a similar rate, Group

Separate solved the discrimination based upon previously reinforced stimuli (AC+

BC-) more rapidly than the discrimination based upon previously non-reinforced

stimuli (AC+ AD-).
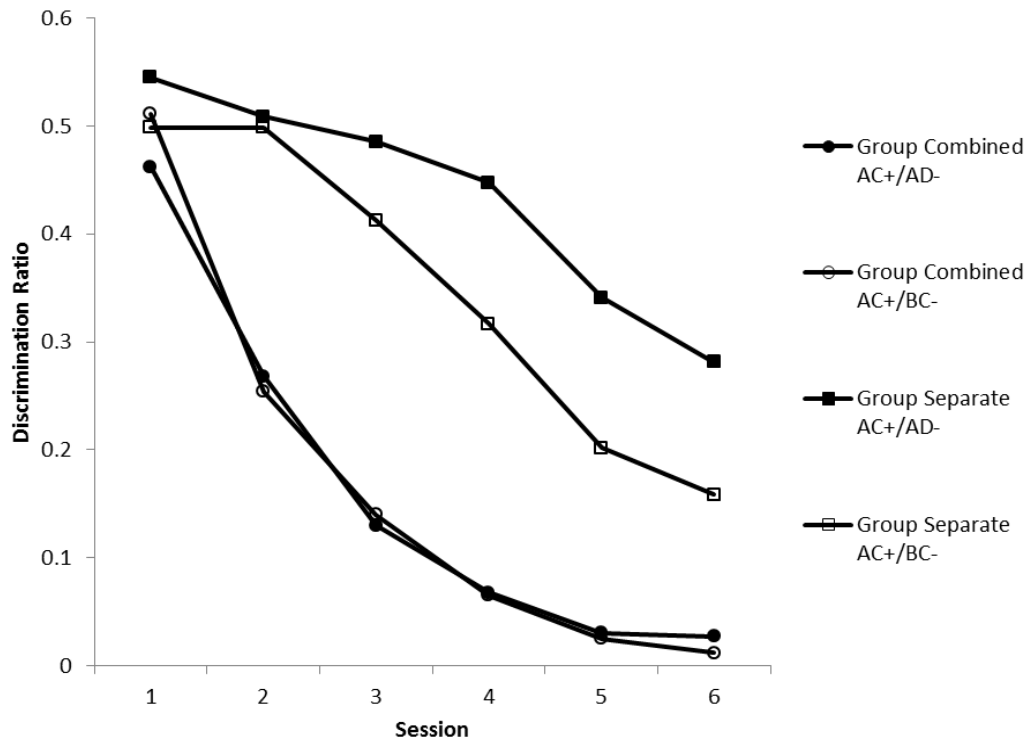
Figure 3.6. Discrimination ratios for the AC+/BC- and AC+/AD- discriminations for

Groups Separate and Combined during Stage 2 of Experiment 4.

A three-way ANOVA of individual ratios from the two components of the test

discrimination, for each of the six sessions, revealed significant effects of, group,

$F(1,30) = 78.93$, MSE = 0.06, discrimination, $F(1,30) = 5.63$, MSE = 0.03, and

session, $F(9, 150) = 136.62$, MSE = 0.01. A significant Group x Discrimination, $F(1,$

$30) = 6.57$, MSE = 0.03, and Group x Session, $F(5, 150) = 17.32$, MSE = 0.01

interaction was found. But the Discrimination x Session, $F(5, 150) = 1.69$, MSE = 0.01, interaction was not significant, nor was the Group x Discrimination x Session interaction, $F(5, 150) = 1.00$, MSE = 0.01. Further analysis to explore the two-way interaction between group and session revealed that the effect of session was significant for Group Combined $F(5, 150) = 104.74$, MSE = 0.01, and for Group Separate $F(5, 150) = 49.20$, MSE = 0.01. Subsequent tests of simple main effects tests revealed that there was a significant effect of group from Session 2 onwards $Fs(1, 180) > 50.92$, MSE = 0.02.

Further analysis to explore the two-way interaction between group and discrimination revealed no significant difference in the rate in which the two discrimination were learnt in Group Combined, $F < 1$. However, Group Separate solved the AC+/BC- discrimination significantly more quickly than the AC+/AD- discrimination, $F(1,30) = 12.18$, MSE = 0.03. Analysis of the two-way interaction between group and discrimination revealed that Group Combined solved both the AC+/BC- discrimination $F(1, 60) = 34.41$, MSE = 0.05, and the AC+/AD- discrimination $F(1, 60) = 76.94$, MSE = 0.05, significantly more quickly than Group Separate.

Discussion

Results from Experiment 4 show that there was no difference in the rate at which Group Combined solved the AC+/BC- and the AC+/AD- discrimination. Group Separate however, solved the discrimination based upon previously relevant stimuli (AC+/BC-) significantly faster than the discrimination based upon pre-exposed stimuli (AC+/AD-). These findings are consistent with the proposed claim that pigeons look and thus attend principally to the stimulus at which they are

pecking. When faced with the compound stimuli in Stage 2, Group Separate would be expected to peck considerably more rapidly at the previously reinforced than the previously non-reinforced component. The greater attention that would consequently be paid to A and B, than to C and D, would then result in the AC+ BC- discrimination being acquired more readily than the AC+ AD- discrimination. In Group Combined, however, when, during Stage 2, the pigeons pecked at a circle, it is likely that they perceived both the previously reinforced and non-reinforced colours at the same time. The amount of attention paid to A and B would then be similar to that paid to C and D, and the two discriminations should be acquired at the same rate.

3.4   General Discussion

The initial aim of this chapter was to attempt to observe the effects of latent inhibition; however the results of Experiment 3 provided no evidence of any such effect. Group Pre-exposed, in which the effect was sought, did indeed solve the subsequent discrimination based upon previously relevant stimuli significantly faster than a discrimination based upon pre-exposed stimuli, which follows the pattern expected had latent inhibition occurred. However, Group Novel solved the discrimination based upon previously relevant stimuli significantly more quickly than the discrimination based upon novel stimuli. This was unexpected given the assumption that novel stimuli will be attended to as much as previously reinforced stimuli. It might be argued that the attention paid to a stimulus that signals food is greater than to one that is novel, which would then account for the results of Group Novel, and leave open the possibility that the results of Group Pre-exposed were, indeed, a consequence of latent inhibition. With this possibility in mind, it is instructive to look at the discrimination ratios in Figure 3.3 which indicates there was

74

no hint that the discrimination based on the pre-exposed stimuli in Group Pre-exposed was acquired more slowly than the same discrimination based on novel stimuli in Group Novel. If pre-exposure to C and D resulted in a loss in attention to them then the AC+ AD- discrimination should have been acquired more readily by Group Novel than by Group Pre-exposed. It therefore seems likely that something other than latent inhibition was responsible for the findings of both groups.

It was reasoned that the lack of attention paid to either pre-exposed stimuli or novel stimuli during Stage 2 may be due to the associative strength of a stimulus controlling the amount of attention it receives. Or put more simply, it seems likely that a pigeons will only attend to, and learn about, a stimulus while they are looking at it and will only look at a stimulus while they are pecking at it. It would follow that during Stage 2, subjects continued to peck at the previously reinforced stimuli of the compound stimulus thus they failed to look at and learn about the pre-exposed or the novel stimulus. Thus the discrimination based upon previously reinforced stimuli was learnt about more rapidly than the discrimination based upon pre-exposed or novel stimuli. As noted in the discussion to Experiment 3, this explanation for the results of the experiment can also be applied to the results from Experiments 1 and 2, as well as from related studies by Pearce at al. (2008) and Dopson et al. (2010a).

To establish whether support could be obtained for the proposal that the rate of pecking to a stimulus determines the attention it is paid, the compounds for the test stage of Experiment 4 for Group Compound were composed of the colours from individual training stimuli superimposed upon each other in bands. The purpose of this manipulation was to present the stimuli in such a way that any tendency to orient towards previously relevant stimuli would not automatically result in previously irrelevant stimuli being ignored. In keeping with this aim, it was found that Group

75

Combined solved the component of the test discrimination based on previously irrelevant stimuli, AC+/AD-, as readily as the discrimination based on previously relevant stimuli, AC+/BC-. On the basis of these results, therefore, it appears that an important determinant of the amount of attention that a stimulus is paid, and thus how readily it is learned about, is the rate at which pecking is directed towards it. A similar conclusion was drawn by Pearce et al. (2008) who conducted a comparable study, except that the training and test stimuli were patterns and colours presented at the same location.

There could however be another reason for the lack of latent inhibition in Group Compound of Experiment 4, which is based on the explanation of latent inhibition developed by (Wagner 1978). Wagner proposed that the conditionability of an unexpected stimulus will be greater than of an expected stimulus. If a stimulus is consistently presented in the same context, for example a test chamber, then the chamber itself becomes predictive of the stimulus. It then follows that the stimulus is no longer unexpected when the animal is in the chamber and learning about it will progress more slowly, if it should now signal an event of significance, than when it was novel.   In other words, latent inhibition is predicted to be context specific, so that subsequent conditioning to a pre-exposed stimulus will be slower if the context used for conditioning is the same rather than different to that used for pre-exposure. Channell and Hall (1983) demonstrated such an effect in rats. The experimental group was first pre-exposed to a light while the control group was placed in the same conditioning chamber in the absence of the light. Half the animals from each group were then trained using the light as a signal for food, in the same context as during pre-exposure. The remaining half were given the same training to the light but the context was changed by way of differing background noise and smell to that which

they had been exposed to during pre-exposure. While those animals in the experimental group for whom the context remained constant learnt slowly about the significance of the light during training, it was found that the animals who had undergone pre-exposure to the light and were subsequently placed in a novel context for conditioning learnt the significance of the light during training as readily as animals in the control group.

With the foregoing discussion in mind, it could be said that during Experiment 4, the initial training of the form A+ B+ C- D- resulted in the formation of associations between C and D and the context. Presenting these stimuli integrated with A and B for the test stage in Group Combined might then weaken these contextual associations and restore the conditionability of C and D. As a consequence, the AC+ AD- component of the test discrimination is then predicted to progress more rapidly for Group Combined than Group Separate, which was the result observed. The experiment also revealed that the AC+ BC- component of the test discrimination was acquired more readily by Group Combined than Group Separate. To explain this outcome within the framework of Wagner's (1978) proposals, it could be argued that during the training stage of the experiment the A+ B+ trials resulted in associations developing between these stimuli and the context. In the manner that has just been described, these associations would be weaker during the test stage for Group Combined than Group Separate so that the discrimination would then progress more rapidly in the former than the latter group.

Although the theory of Wagner (1978) is able to explain some of the results reported in this chapter, the results from Experiment 3 pose it a challenge. In that experiment, Group Pre-exposed received training of the sort A+ B+ C- D-, and Group Novel received A+ B+ E- F- trials. Both groups then received an AC+ BC- AD-

77

discrimination in which they performed similarly during the AC+ AD- component. The theory of Wagner predicts that the training in Stage 1 will permit the development of associations between C and D and the context in Group Pre-exposed which will then disrupt the acquisition of the discrimination based on these stimuli in the test stage, relative to Group Novel. In view of the failure of the theory to predict the correct outcome of this experiment, it must be concluded that the theory of Wagner provides, at best, only a partial explanation for my results.

One further finding from Experiment 4 remains somewhat intriguing; the rate at which the AC+/ BC- discrimination was solved by Group Combined was significantly more rapidly than the rate at which it was solved by Group Separate. Given that subjects in Group Separate really only had to learn that B signalled the absence of food and that both A and B were previously relevant, it would be expected that the two groups solve the discrimination at a similar rate. One possible explanation for this finding to the contrary is that in Group Separate, while attention will be higher to previously relevant stimuli, the presence of C will serve to distract attention away from B to a certain extent so that during some trials attention will not be fully on the relevant stimuli thus retarding learning. Conversely it could be argued that the combining of stimuli in Group Combined in essence produced novel stimuli. if this is the case not only will attention be higher by merit of their novelty (e.g. Sokolov 1963) but it could further be argued that if each combination is regarded as a single entity then in fact only three individual stimuli were used thus making the discrimination easier than it may be for Group Separate.

The results from Experiment 4 show forcefully that if pre-exposure is given to a stimulus by itself, then learning about the significance of this stimulus can be rapid if it is subsequently employed for a discrimination in which previously relevant and

irrelevant stimuli are superimposed on each other. One explanation for this outcome is that the pre-exposure treatment did not result in latent inhibition, but I have just shown that other explanations are possible for this outcome. It is important to note, therefore, that the results from Experiment 3 also failed to reveal evidence of latent inhibition and it is not possible to account for this outcome by appealing to the explanations that were offered for the failure to detect latent inhibition in Experiment 4. The results from Experiment 3 thus join findings mentioned at the start of this chapter which indicate that non-reinforced exposure to a neutral stimulus is unlikely to result in latent inhibition in pigeons. Having said that, the results from both experiments also lend support to the suggestion that an important determinant of the rate at which pigeons learn about the significance of a stimulus is the rate at which it is pecked. Once this suggestion is acknowledged, then the possibility remains that the A+ B- treatment during Stage 1 resulted in latent inhibition with B in Group Pre-exposed, but the design of the experiment was inappropriate for detecting this effect. During the test phase, pigeons may have devoted so much of their attention to the previously relevant stimuli that it would not be possible to observe any differences between the two groups in latent inhibition to the other stimuli belonging to the test compounds.

4. Partial Reinforcement and Changes in Associability

4.1 Introduction

During Experiment 3, it may be possible that a reduction in attention occurred to non-reinforced stimuli (C and D) in Group Pre-exposed, however any evidence of this was not apparent as during the test stage pigeons only looked and pecked at previously reinforced stimuli (A and B). Experiment 5 was therefore conducted to investigate whether changes in attention take place to stimuli, using a rather different test to that of Experiment 3. It seeks to ascertain whether, as claimed by Pearce and Hall (1980), more attention is paid to unreliable predictors of outcome (partially reinforced stimuli), than to reliable predictors of outcome (continuously reinforced stimuli). Evidence for such a claim can be found from experiments using rats. Kaye and Pearce (1984) found that the orienting response to a light was higher when trials in which a light-tone-food sequence was presented were interspersed with trials of the light in isolation when compared to a second group for which only the light-tone-food sequence was presented. Further evidence came from a subsequent test in which the light was directly paired with the food where it was found that the partially reinforced group conditioned to the light more rapidly than the consistently reinforced group. Swan and Pearce (1988) obtained equally supportive findings. They trained rats using a light-tone-food sequence interspersed with a light-tone-nothing sequence. A second group received light-tone-food sequences interspersed with light-nothing sequences. They found the second group paid greater attention to the light as a result of this training than the first group. The greater attention was revealed by a stronger orienting response to the light, and by the higher conditionability of the light as revealed in a subsequent test, in the second than the first group. These results support

the claim that more attention is paid to stimuli that are inaccurate than accurate predictors of the events that follow them. For the first group, the light was always followed by the tone whereas for the second group on some trials the light was followed by the tone and by nothing on others so rendering the light an unreliable predictor of outcome; accordingly more attention was paid to it.

A similar effect has been demonstrated in pigeons. Collins and Pearce (1985) used serial autoshaping in which for one group stimulus A was never followed by food, but the sequence AB was followed by food, A- AB+. Responding during A was substantially faster than for a second group in which the serial compound AB was paired with food on 50% of the trials, AB+/-. Thus even though the relationship between A and food was the same in both conditions, it elicited faster responding with the A- AB+ schedule. To explain this finding, Collins and Pearce (1985) argued that A was an inaccurate predictor of B in the A- AB+ schedule, and an accurate predictor in the AB+/- schedule, and that this resulted in more attention being paid to A during A- AB+ trials than AB+/- trials. They further argued that this enhanced attention revealed itself as an orienting response of pecking at the key which augmented pecking maintained by authoshaping (see also Pearce, Kaye and Collins, 1985).

Although the results by Collins and Pearce (1985) suggest that pigeons pay more attention to stimuli that are inaccurate rather than accurate predictors of their immediate consequences, they do not show that this difference in attention is reflected by a difference in the conditionability of the stimuli. One purpose of the next experiment was to determine whether stimuli that differ in their predictive accuracy also differ in their conditionability, as predicted by Pearce and Hall (1980). The experiment thus compared the conditionability of two stimuli that had been paired with food on either a continuous or a partial reinforcement schedule, by using the

81

novel methodology that was employed for the previous experiments. It was hoped that the use of this methodology will permit a difference in conditionability to be observed. Previous studies have shown that partial reinforcement, using autoshaping with pigeons, can result in at least as high a rate of responding as continuous reinforcement (e.g. Gibbon, Farrell, Locurto, Duncan, & Terrace, 1980). Given the earlier conclusion that pigeons will only learn about those stimuli which they are pecking, it was hoped that by using stimuli during Stage 1 that elicited a high rate of responding would make it easier to detect changes in attention in the subsequent test discrimination than for the previous experiments.

4.2   Experiment 5

An initial discrimination was presented to a group of pigeons where A and B signalled the presence of food and X and Y signalled the presence of food 50% of the time and the absence of food 50% of the time. All stimuli constituted patterns with each letter representing a different orientation of striped black lines on a white background. A subsequent discrimination of the form AX+/AY-/BX- was then presented to the subjects. If, as Pearce and Hall (1980) propose, attention is greater to partially reinforced stimuli then it would be expected that the test discrimination based upon previously partially reinforced stimuli (AX+/AY-) would be learnt more rapidly than the discrimination based upon previously reinforced stimuli (AX+/BX-). If, however, as proposed by Mackintosh (1975a), more attention were paid to reliable predictors of an outcome than to unreliable predictors then it would be expected that the discrimination based upon previously reinforced stimuli (AX+/BX-) would be learnt about more readily than the discrimination based upon previously partially reinforced stimuli (AX+/AY-).

Method

Subjects. The subjects were 16 naïve adult homing pigeons (*Columba livia*), maintained in the same manner as in Experiment 1.

Apparatus. All apparatus used was identical to that used in Experiment 1.

Stimuli. The stimuli were presented on the TV screen, which was otherwise black. During Stage 1, the stimuli consisted of one circle, 2.4 cm in diameter located at the centre of the TV screen. During Stage 2, the stimuli consisted of 2 horizontally adjacent circles, each 2.4 cm in diameter. The point at which the circles joined was located at the centre of the TV screen. For all subjects the stimuli consisted of straight black lines on a white background, oriented in one of four ways.

The stimuli were counterbalanced in the following way. For half of the subjects A, B, X and Y represented vertical lines, horizontal lines, lines tilted at 45° and lines tilted at -45° respectively. For the remaining half, A, B, X and Y represented lines tilted at 45°, lines tilted at -45°, vertical lines and horizontal lines respectively. In both cases A and B consistently signalled food, and X and Y consistently signalled the presence of food 50% of the time and the absence of food 50% of the time.

During stage two, each trial type consisted of one previously reinforced and one previously partially reinforced stimulus in adjacent circles. On half of presentations, the relevant stimulus appeared in the left-hand circle, and on the other half it appeared in the right-hand circle. Stimuli used can be seen in Table 4.1.

Procedure. The subjects first received 8 sessions in which they were trained to eat food whenever it was presented by the hopper. They were then given 5 sessions of

Table 4.1. Stimuli used in Stage 1 and 2 of Experiment 5. Half of subjects received the top discriminations and half the bottom discriminations.

autoshaping in which a white circle with a diameter of 2.4 cm was presented in the middle of the TV screen for 10 s. There were 45 trials in a session, the mean interval between the start of each trial was 60 s (range = 40-80 s), and food was made available in the hopper for 4 s whenever the white circle was removed from the TV screen.

Session 1 of Stage 1 began on the day after the final session of autoshaping. During each of the 18 sessions of training, the pigeons received discrimination training with the four trial types A+, B+, X+/- and Y+/-. There were 48 trials in each session: each trial type was presented twelve times, six presentation of X and six of Y were followed by food, six by the absence of food. The following details applied to all stages of the experiment. Each stimulus was presented for 10 s, and the mean inter-trial interval was 60 s (range = 40-80 s). The trial types were presented in a random order with the constraint that no more than two reinforced or two non-reinforced trials could occur in succession.

On the day following Session 18 of training, pigeons received the first session of the test discrimination. There were 10 sessions in this stage of the experiment, during which all animals received the discrimination AX+/AY-/BX-. There were 40trials in each session, consisting of 20 reinforced presentations of AX, 10 non-reinforced presentations of AY and 10 non-reinforced presentations of BX. The procedural details that have been omitted were the same as for the previous experiment.

Results

Figure 4.1 shows the mean rate of responding during continuously reinforced trials, and that during partially-reinforced trials, on each session of Stage 1. From this

figure it appears that pigeons responded consistently highly to both continuously reinforced and partially reinforced stimuli however responding to continuously reinforced stimuli remained higher than to partially-reinforced stimuli throughout.
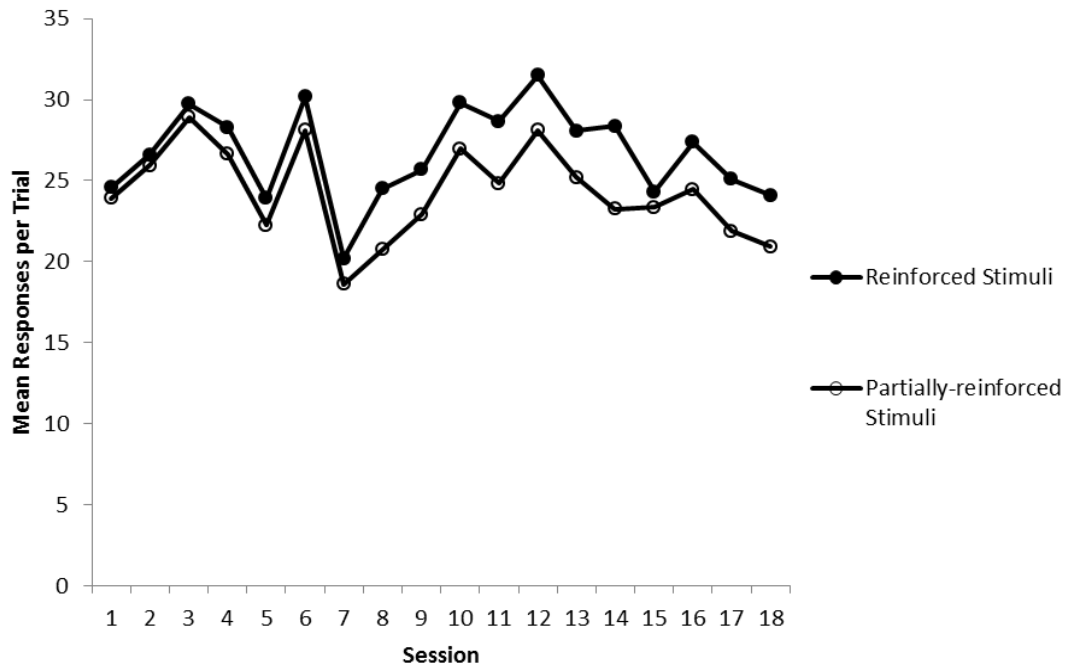
Figure 4.1. The mean rates of responding during the continuously reinforced (CS+) and partially reinforced (CS+/-) trials throughout Stage 1 of Experiment 5.

A two-way ANOVA of individual mean rates of responding during each of the 18 sessions was carried out and revealed a significant effect of session, $F(17, 255) = 3.96$, MSE $= 62.92$, stimulus, $F(1, 15) = 22.22$, MSE $= 38.41$. A significant Stimulus x Session interaction, $F(17, 255) = 4.10$, MSE $= 3.09$, was found.

Tests of simple main effects were conducted in order to explore the two-way interaction of Stimulus x Session. These revealed a significant effect of session for the

continuously reinforced stimuli, $F(17, 510) = 4.01$, MSE $= 33.01$, and for the partially-reinforced stimuli, $F(17, 510) = 3.93$, MSE $= 33.01$.

Further tests revealed a significant effect of stimuli during sessions 4-18, excluding Session 15, $Fs(1, 270) > 4.24$, MSE $= 5.05$.

During Stage 2, subjects responded more rapidly to the reinforced stimulus, AX than to the two non-reinforced stimuli, AY and BX, to which responding was at a similar rate, as can be seen in Figure 4.2
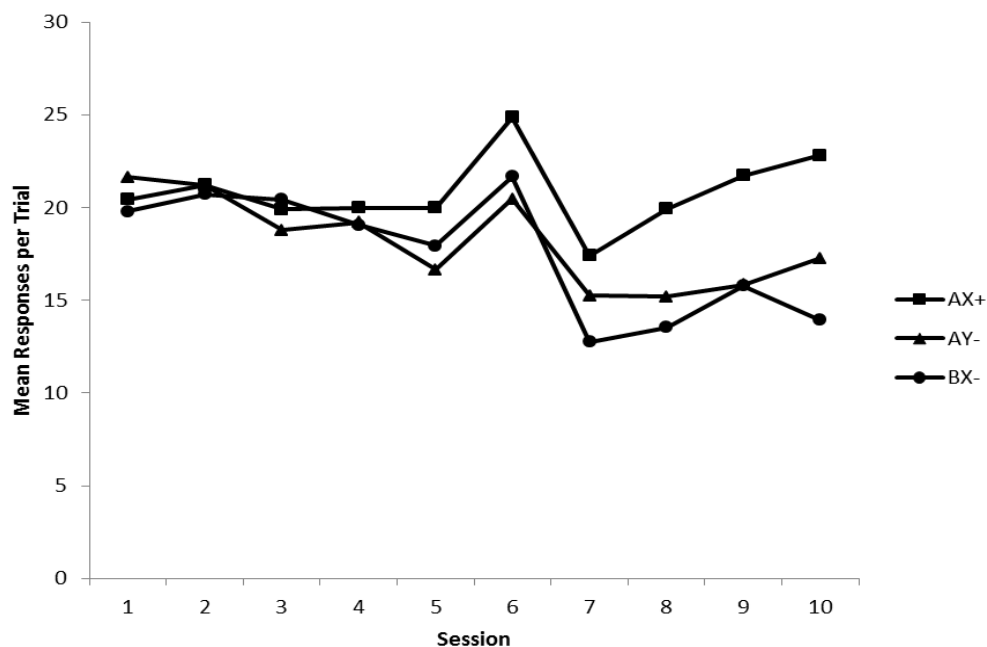
Figure 4.2. The mean rates of responding to each compound stimuli during Stage 2 of Experiment 5.

In order to compare the performance of the pigeons during the two non-reinforced compounds, discrimination ratios were calculated for individual subjects in the same manner as in Experiment 1. Figure 4.3 shows the mean discrimination ratios for each of the ten test sessions during the discrimination for which the distinctive cues were continuously reinforced during Stage 1 (AX+ BX-), and for the

discrimination for which the distinctive cues were partially reinforced during the

original training (AX+ AY-).

Neither discrimination was solved completely by the end of testing and there

was little difference in the responding to the two non-reinforced stimuli.
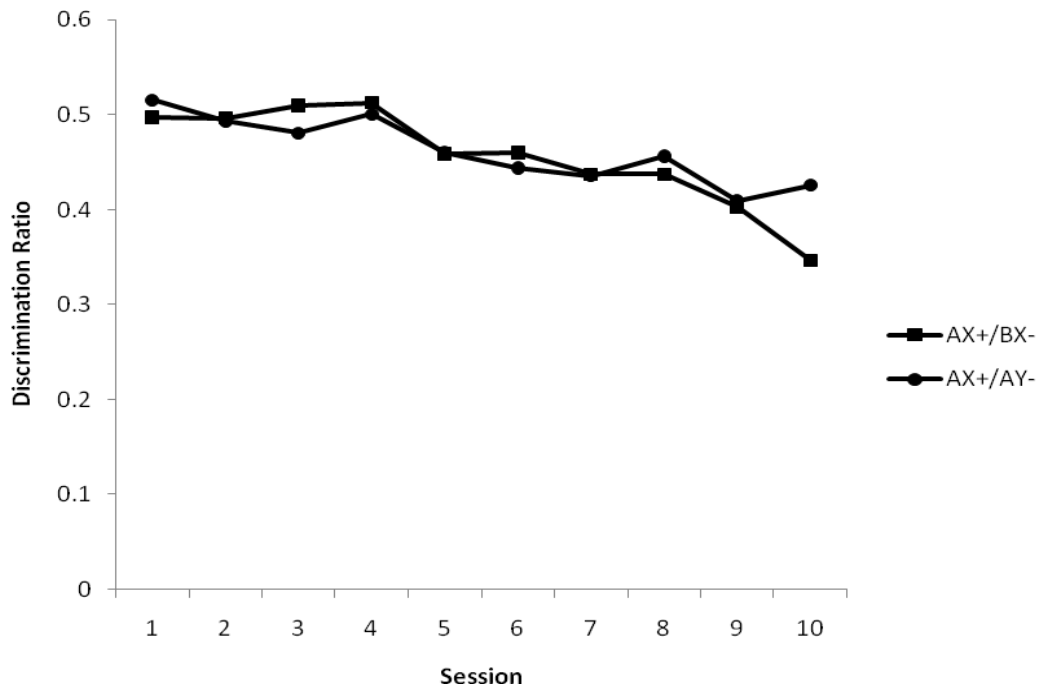
Figure 4.3. Discrimination ratios for the AX+/BX- and AX+/AY- discriminations for

Stage 2 of Experiment 5.

A two-way ANOVA of individual ratios from the two components of the test

discrimination, for each of the ten sessions revealed significant effects of session, $F(9,

135) = 6.95$, MSE $= 0.01$, but not of discrimination, $F < 1$. No significant

Discrimination x Session interaction was found, $F(9,135) = 1.16$, MSE $= 0.01$.

Discussion

For support to be shown for the theoretical claims of Pearce and Hall (1980), during Stage 2, the discrimination based upon previously partially reinforced stimuli (AX+/BX-) would have been solved more rapidly than the discrimination based upon previously relevant stimuli (AX+/AY-). No evidence of this was found. There was no difference in the rate of acquisition of the two discriminations. The solution of the two discriminations improved as training progressed but this improvement did not differ between the two discriminations. Experiment 5 gives no support to the theory proposed by Pearce and Hall (1980) and moreover, with neither group solving either discrimination more rapidly than the other, provides no evidence of conventional attentional changes in pigeons (e.g. Mackintosh, 1975).

While it is unwise to compare directly the results of separate experiments, one curious result is the apparent difference in the findings of the second stage of Experiments 3 and 5. The discrimination based upon previously relevant stimuli, AC+/BC- in the case of Experiment 3 and AX+/BX- in the case of Experiment 5, was acquired much more slowly in Experiment 5 than in Experiment 3. The associative strength of C was low relative to X and it is perhaps this which was responsible for the differing results and which will be explored further in Experiment 6.

4.3 Experiment 6

Experiments 3 and 5 show a noticeable difference in the acquisition rate of the discrimination based upon previously relevant stimuli, which also contains previously pre-exposed stimuli (Experiment 3), and the discrimination based upon previously relevant stimuli, which also contains previously partially reinforced stimuli (Experiment 5). Thus far I have assumed that the rate of acquisition of the AX+ BX-

and the AX+ AY- components of an AX+ BX- AY- test discrimination, after standard Stage 1 training, is determined by the rate of pecking at the distinctive cues of the two subsequent discriminations at the start of the test stage. But it is possible that the ease with which a subsequent discrimination is acquired, say AX+ BX-, is also influenced by the rate at which the common cue, X, is pecked at the outset of the test stage. If it elicits a high rate of pecking, such as would occur had it been previously partially-reinforced, then it is likely to distract attention away from the relevant cues, and disrupt the acquisition of the discrimination, to a greater extent than if it elicits a low rate of pecking, such as would occur had it been pre-exposed. Indeed, I have already alluded to this possibility in the discussion of Experiments 4 and 5. The differences outlined above between Experiments 3 and 5 can be explained by suggesting that as a result of previous partial reinforcement the irrelevant stimuli in the discrimination in Experiment 5 distracted attention away from the relevant stimuli and thus disrupted learning about them. Conversely, in Experiment 3, pigeons would not be expected to look at the irrelevant stimuli as a result of the pre exposure training and would thus be able to devote more attention than in Experiment 5 to learning about the significance of the relevant stimuli. Experiment 6 was designed to directly test this proposal.

Two groups of pigeons were presented with five patterned stimuli, four reinforced and two non-reinforced. For Group Low, A, B, C and D signalled the presence of food and E and F the absence of food. For Group High, A, B, E and F signalled the presence of food and C and D the absence. Both groups were then presented with a subsequent discrimination of the form AE+/BE-/AF-. If the previous explanation for the differing results of Experiment 3 and 5 is to be substantiated then the AE+/BE- discrimination will be acquired more readily by Group Low than by Group High. This arises from the assumption that the associative strength of E will be

low in Group Low as a result of previous non-reinforcement and will thus not be attended to, allowing the gaze of the pigeons to be solely on the relevant stimuli within the discrimination. Conversely, for Group High, E will have gained high associative strength as a result of its previous reinforcement and the act of looking at E will distract from looking at and learning about A and B thus causing the discrimination to be learnt about slowly.

Method

Subjects. The subjects were 32 naïve adult homing pigeons (*Columba livia*), maintained in the same manner as in Experiment 1.

Apparatus. All apparatus used was identical to that used in Experiment 1.

Stimuli. The stimuli were presented on the TV screen, which was otherwise black. During Stage 1, the stimuli consisted of one circle, 2.4 cm in diameter located at the centre of the TV screen. During Stage 2, the stimuli consisted of 2 horizontally adjacent circles, each 2.4 cm in diameter. The point at which the circles joined was located at the centre of the TV screen. For all subjects, the stimuli consisted of one of five patterns.

The stimuli were counterbalanced in the following way. For half of the subjects in the Group High and half in Group Low A, B, C and D represented vertical lines, horizontal lines, lines tilted at 45º and lines tilted at -45º respectively, E consisted of three white circular bands, each with a width of 2 mm. The outermost band formed a circle with diameter 2.4 cm. Each band was separated by black circular bands of the same width. In the centre of the stimulus was a black circle

(diameter 4 mm). F consisted of a 'spotted' pattern consisted of a white circle containing 7 black circles, each with diameter 0.64 cm. For the remaining half in each group, A, B, C and D represented lines tilted at 45º, lines tilted at -45º, vertical lines and horizontal lines respectively. E consisted of circular bands and F spots. For Group High, A, B, C and D consistently signalled food, and E and F consistently signalled the absence of food. For Group Low, A, B, E and F consistently signalled food and C and D consistently signalled the absence of food.

During stage two, for Group High, each trial type consisted of two previously reinforced stimuli in adjacent circles. On half of presentations, one stimulus appeared in the left-hand circle, and on the other half it appeared in the right-hand circle. For Group Low each trial type consisted of one previously reinforced and one previously non-reinforced stimulus presented in the same manner. Stimuli used can be seen in Table 4.2.

Procedure. The subjects were autoshaped in a manner consistent with all previous experiments and were then randomly assigned to the High or Low Group, with 16 birds in each. Session 1 of Stage 1 began on the day after the final session of autoshaping. During each of the 18 sessions of training, the two groups received discrimination training with the four trial types A+, B+, E+, F+, C- and D- in the case of Group High and A+, B+, C+, D+, E- and F- in the case of Group Low. There were 48 trials in each session, each trial type was presented eight times. The following details applied to all stages of the experiment. Each stimulus was presented for 10 s, and the mean inter-trial interval was 60 s (range = 40-80 s). The trial types were presented in a random order with the constraint that no more than two reinforced or two non-reinforced trials could occur in succession.

Table 4.2. Stimuli used in Stage 1 and 2 of Experiment 6. Half of each group received the top discriminations and half the bottom discriminations.

On the day following Session 18 of training, both groups received the first session of the test discrimination. There were 10 sessions in this stage of the experiment, during which all animals received the discrimination AE+/BE-/AF-. There were 40 trials in each session, consisting of 20 reinforced presentations of AE, 10 non-reinforced presentations of BE and 10 non-reinforced presentations of AF. The procedural details that have been omitted were the same as for the previous experiment.

Results

Figure 4.4 shows the mean rate of responding during reinforced trials, and that during non-reinforced trials, for both groups on each session of Stage 1. From this figure it appears that Group Low learnt to stop responding to non-reinforced stimuli more rapidly than Group High, however both groups responded at a similar rate to reinforced stimuli and both learnt the discrimination. Presumably this difference between the groups arose from using non-reinforced stimuli that were more similar to at least some of the reinforced stimuli in Group High than Group Low.
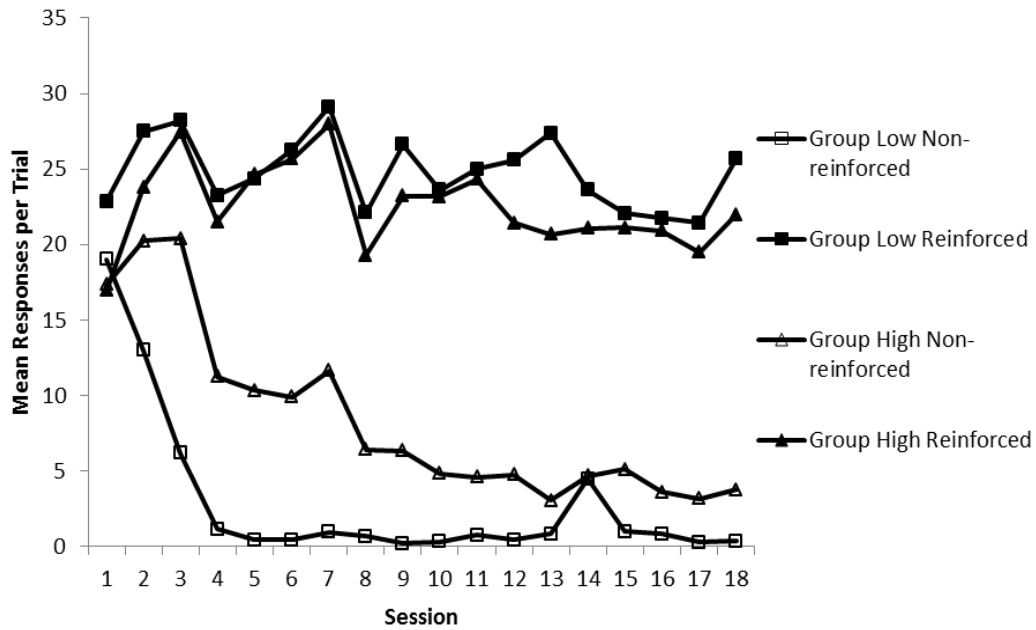
Figure 4.4. The mean rates of responding during the reinforced (CS+) and non-reinforced (CS+/-) trials for both groups throughout Stage 1 of Experiment 6.

A three-way ANOVA of individual mean rates of responding during each of the 18 sessions was carried out and revealed a significant effect session, $F(17, 510) = 14.02$, MSE $= 40.61$, and stimulus, $F(1, 30) = 109.37$, MSE $= 853.95$. No effect of group was found, $F < 1$. A significant Group x Stimulus interaction, $F(1, 30) = 5.23$, MSE $= 853.95$, Group x Session interaction, $F(17, 510) = 2.82$, MSE $= 40.61$, and Stimulus x Session interaction, $F(17, 510) = 16.46$, MSE $= 26.74$, was found. The Group x Stimulus x Session interaction was significant, $F(17, 510) = 1.75$, MSE $= 26.74$.

Tests of simple main effects were conducted in order to explore the three-way interaction of Group x Stimulus x Session. These revealed a significant Stimulus x Session interaction for Group Low, $F(17, 510) = 9.18$, MSE $= 26.73$, and for Group High, $F(17, 510) = 9.04$, MSE $= 26.73$. The interaction of Group x Session was

95

significant for the non-reinforced, $F(17, 1020) = 3.89$, MSE = 33.67, but not for the reinforced stimuli, $F < 1$. A significant Group x Stimulus interaction was found for Sessions 2-9, 12 and 13, $Fs(1, 540) > 3.90$, MSE = 72.69.

Further tests revealed a significant effect of session in Group Low during reinforced stimuli, $F(17, 1020) = 2.67$, MSE = 33.67, and non-reinforced stimuli $F(17, 1020) = 12.54$, MSE = 33.67, and in Group High during reinforced stimuli, $F(17, 1020) = 3.84$, MSE = 33.67, and non-reinforced stimuli, $F(17, 1020) = 15.73$, MSE = 33.67. The effect of stimulus was found to be significant in Group Low from Session 2 onwards, $Fs(1, 540) > 23.11$, MSE = 72.69, and in Group High from Session 3 onwards, $Fs(1, 540) > 5.47$, MSE = 72.69. An effect of group was found for reinforced stimuli during Session 13 only, $F(1, 1080) = 3.81$, MSE = 94.23, and for non-reinforced stimuli during Sessions 2-7, $Fs(1, 540) > 4.47$, MSE = 94.23.
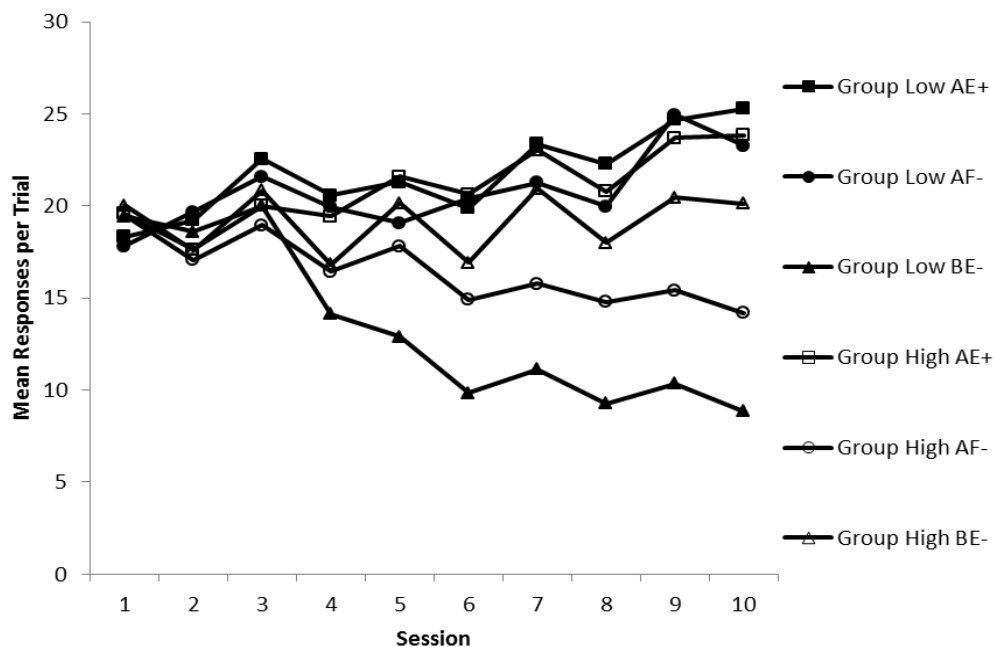
Figure 4.5. The mean rates of responding to each compound stimuli by both groups during Stage 2 of Experiment 6.

Figure 4.5 shows that both groups responded at a similarly high rate to the reinforced stimuli during Stage 2. Group Low solved the AE+/BE- discrimination more rapidly than Group High who in turn solved the AE+/AF- discrimination more rapidly than Group Low.

A two-way ANOVA of the individual mean response rates during AE, for each of the ten sessions, revealed that the effect of group was not significant, $F < 1$, but the effect of session was significant, $F(9, 270) = 6.40$, MSE = 21.61. The interaction of Group x Session was not significant, $F < 1$.

In order to compare the performance of the groups during the non-reinforced compounds, discrimination ratios were calculated for individual subjects in the same manner as in Experiment 1. Figure 4.6 shows the mean discrimination ratios for the two groups for each of the ten test sessions during the discrimination for which the distinctive cues were reinforced for both groups during Stage 1 (AE+/BE-), and for the discrimination for which the distinctive cues were reinforced for Group High and non-reinforced for Group low during Stage 1 (AE+/ AF-). It can be seen that Group High solved the AE+/AF- discrimination slightly more slowly than the AE+/ BE- discrimination. Group Low solved the AE+/ BE- discrimination, which for this group was based upon previously relevant stimuli, more rapidly than the AE+/ AF- discrimination, which for this group was based upon previously non-reinforced stimuli.
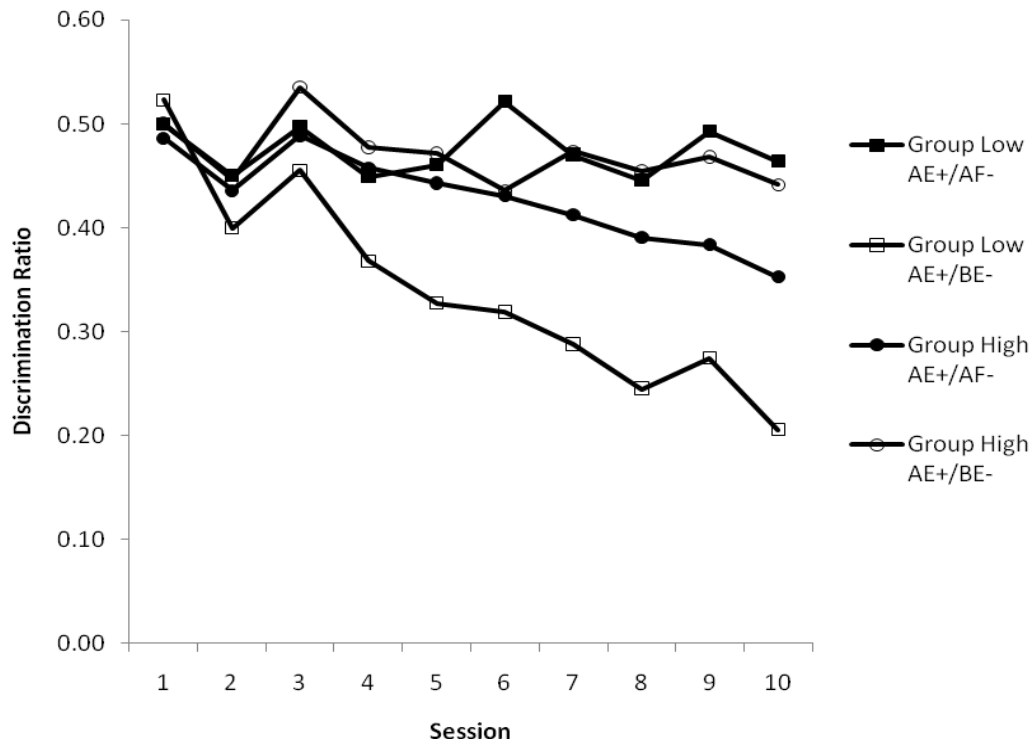
Figure 4.6. Discrimination ratios for the AE+/BE- and AE+/AF- discriminations for Groups High and Low during Stage 2 of Experiment 6.

A three-way ANOVA of individual ratios from the two components of the test discrimination, for each of the ten sessions, revealed significant effects of, group, $F(1,30) = 4.12$, MSE = 0.07, discrimination, $F(1,30) = 7.63$, MSE = 0.04, and session, $F(9, 270) = 7.82$, MSE = 0.02. A significant Group x Discrimination, $F(1, 30) = 28.53$, MSE = 0.04, and Discrimination x Session, $F(9, 270) = 3.19$, MSE = 0.01, interaction was found. The Group x Session, $F < 1$, interaction was not significant. The Group x Discrimination x Session interaction, $F(9, 270) = 7.57$, MSE = 0.01, was significant. Further analysis to explore the three-way interaction between group, discrimination and session revealed that the Discrimination x Session interaction was significant for Group Low, $F(9, 270) = 9.65$, MSE = 0.07, but not for Group High $F(9, 270) = 1.12$, MSE = 0.01. The Group x Session interaction was significant for the

AE+/BE- discrimination, $F(9, 540) = 4.69$, MSE = 0.05, but not for the AE+/ AF-discrimination, $F(9, 540) = 1.41$, MSE = 0.02.

The Group x Discrimination interaction was significant from Session 4 onwards $Fs(1, 300) > 3.87$, MSE = 0.01. The effect of session in Group Low was significant for the AE+/BE- discrimination, $F(9, 540) = 13.73$, MSE = 0.01, but not for the AE+/ AF- discrimination, $F < 1$. The effect of session in Group High was significant for the AE+/AF- discrimination, $F(9, 540) = 2.82$, MSE = 0.01, but not for the AE+/ BE- discrimination, $F(9, 540) = 1.26$, MSE = 0.01.

The effect of discrimination in Group Low was significant from Session 4 onwards, $Fs(1, 300) > 4.93$, MSE = 0.01. In Group High, the effect was significant during session 9 and 10 only, $Fs(1, 300) = 5.39$, MSE = 0.01

The effect of group on the AE+/BE- discrimination was significant from Session 4 onwards, $Fs(1, 600) = 6.13$, MSE = 0.02, and on the AE+/ AF-discrimination during sessions 9 and 10 only, $Fs(1, 600) = 6.20$, MSE = 0.02.

Discussion

Results from Experiment 6 show no significant difference, between Group Low and Group High, in the rate of responding to the reinforced compound during Stage 2. The rate at which responding decreased to the two non-reinforced compounds did however differ between the two groups. Responding to the AE+/ BE-discrimination was significantly lower in Group Low compared to Group High from Session 4 onwards. This supports the proposal that stimuli which have gained a high associative strength will interfere with attending to and thus learning about a discrimination in which the same stimuli are irrelevant. For Group High, E was reinforced during Stage 1, thus at the start of Stage 2 has high associative strength.

Pigeons will spend time looking at E to the detriment of looking at A and B and will therefore learn the discrimination slowly. On the other hand for Group Low E was previously non-reinforced and will therefore have low associative strength at the start of Stage 2. Pigeons will not be looking at E allowing them instead to direct their gaze towards A and B and thus learn the discrimination rapidly.

4.4   General Discussion

Experiment 5 sought to find support for the claims of Pearce and Hall (1980) that stimuli, which are unreliable predictors of outcome, will be attended to more than stimuli, which are reliable predictors. No evidence of such a claim was found with no difference in the rate of solution of a discrimination based upon previously partially reinforced stimuli being solved at a similar rate to one based upon previously reinforced stimuli. The findings no more provide support for other theories such as that of Mackintosh (1975a) who would predict that the discrimination based upon previously reinforced stimuli should be learnt about more rapidly than that based upon previously partially reinforced stimuli. Instead the findings can be explained by suggesting that pigeons can only learn about the significance of stimuli which they are pecking and thus looking at. By the end of Stage 1 of Experiment 5, pigeons had been pecking rapidly at both reinforced and partially reinforced stimuli and so during Stage 2 they would again peck at, and hence look at, these stimuli and learn about them at a similar rate.

Experiment 6 sought to test whether the associative strength of accompanying irrelevant stimuli affect learning about the relevant stimuli when the two are paired in compound. The acquisition of a discrimination based upon previously reinforced stimuli (AE+/ BE-) was compared between two groups. For one of the groups, Group

Low, the irrelevant feature of the discrimination, E, was previously non-reinforced, and for the other, Group High, E was previously reinforced. In support of the conclusions drawn from the differences in the results of Experiments 3 and 5, the discrimination was learnt more rapidly by Group Low than by Group High. For Group Low A and B had high associative strength relative to E as a result of A and B being previously reinforced and E non-reinforced. During Stage 2 therefore, pigeons were expected to direct their gaze solely at A and B and were able to learn the discrimination rapidly. Conversely for Group High, A, B and E, all had high associative strength at the start of Stage 2 of Experiment 6 and therefore pigeons' gazes would be expected to be directed at all three, the act of spending time looking at E detracted from looking at A and B and thus the discrimination was learnt slowly.

A second discrimination (AE+/ AF-) based upon, for Group Low, previously non-reinforced stimuli and for Group High previously reinforced stimuli, was learnt more rapidly by Group High than Group Low. Again this supports earlier claims; birds in Group Low would be expected to direct their gaze solely at A which had high associative strength as a result of previous reinforcement. This would then mean that the pigeons paid little attention to, and hence did not learn the significance of E and F and therefore learnt the discrimination slowly. In Group High pigeons would be expected to direct their gaze at A, E and F due to the previous reinforcement of all three stimuli. Learning therefore took place about all three including E and F albeit at a slow rate due to the birds also directing their gaze towards A.

In summary, it seems a growing body of evidence is pointing away from conventional attentional changes occurring in pigeons and that rather than altering the associability of a stimulus as a result of its relevance, pigeons only learn about the stimulus to which they are pecking at. However at present this conclusion may be

somewhat premature, in order to access whether any attentional changes occur, which

cannot be attributed to orienting towards a stimulus as a result of its high associative

strength, it is necessary to examine whether animals can pay considerable attention to

stimuli that signal the non-occurrence of a US. Experiment 7 seeks to ascertain this.

5. Conditioned Inhibition and Changes in Association

5.1 Introduction

The purpose of the experiments in this chapter is to use the methodology of Dopson et al (2010a) to assess the changes in attention that occur to the non-reinforced cue, B, that take place during an AX+/ BX- discrimination.

According to Mackintosh (1975a) in such a discrimination, more attention is paid to stimuli that are relevant to the solution, than to irrelevant stimuli. Thus A and B would increase in the amount of attention they receive, relative to X, given that A is the best predictor of reinforcement relative to all other stimuli and B is the best predictor of non-reinforcement. Little attention will be paid to X as it is worse than the stimuli that accompany it as a predictor for the outcome of the trials on which it is presented. However, Mackintosh does not directly account for how attention to B will increase. As previously stated the only real reference for likely increase in the associative strength of a non-reinforced stimulus, such as B comes from the statement 'The simple assumption that the value of λ for non-reinforcement is either zero or some negative number will permit appropriate changes in α on non-reinforced trials' (Mackintosh 1975a, p. 288).

It is not only Mackintosh (1975a) who claims that non-reinforced stimuli will gain in the attention they are paid. More recent hybrid theories such as that proposed by LePelley (2004) also make the same assumptions. There is rather little evidence however, to demonstrate that stimuli, which reliably signal non-reinforcement, are paid considerable attention. An appreciation of the problem that arises with attempting to test this claim can be gained by studying an experiment by Lawrence

(1949). Rats were trained in a discrimination in which stimuli from one dimension signalled the presence of food and stimuli from another dimension signalled no change (i.e. were irrelevant to the solution of the discrimination). Subjects were given a choice of two maze arms, differing in width, texture and colour. For each of the three groups one of these dimensions was relevant and the other two irrelevant. A subsequent discrimination was then presented in which subjects were required to turn left when presented with one cue and right when presented with another from the same dimension. When the relevant stimuli presented in the subsequent discrimination were from the same dimension as the relevant stimuli from the initial discrimination, subjects learnt the discrimination more quickly than when the relevant stimuli were from a previously irrelevant dimension. These findings are consistent with the suggestion that attention will be greater to stimuli that are relevant rather than irrelevant to the solution of a discrimination. In terms of the theory of Mackintosh (1975a), for example, during the training stage, stimuli from the relevant dimension were either always paired with reinforcement or always paired with no reinforcement. Thus ensuring stimuli from the relevant dimension were always the best predictors of the outcome relative to all other stimuli and therefore attention was paid to them. Conversely stimuli from the irrelevant dimension were coupled equally with reinforcement and non-reinforcement making them no better a predictor of the outcome than the surroundings and therefore demanding little attention. However, one of the flaws of this experiment is that is not possible to determine if attention to non-reinforced stimuli of the relevant dimension increased. A similar outcome to the experiment could have occurred if the initial training resulted solely in an increase in attention to the stimuli that reliably signalled reward.

Further studies have extended the work carried out by Lawrence (1949) using the previously detailed IDS/EDS shift design. One such experiment was carried out by Mackintosh and Little (1969). Pigeons were presented with the discriminations AX+/BX-and AY+/BY-. Using a single line in one of two colours, and in one of two orientations, for half the subjects A and B represented colour and X and Y orientation of the line and for half the subjects A and B represented orientation and X and Y colour. A subsequent discrimination, with novel colours and orientations, of the form CW+/DW- and CZ+/DZ- was then presented, with C and D belonging to the same dimension as A and B and W and Z belonging to the same dimension as X and Y. For those subjects previously trained to respond to colours, this represented an intradimensional shift, while for those trained to respond to orientation, an extradimensional shift. Results showed the discrimination was more quickly learnt in those subjects, for which the subsequent discrimination featured an intradimensional shift, thus supporting Mackintosh's (1975a) views that attention to relevant stimuli will be higher than attention to irrelevant stimuli.

Once again, however, attention to non-reinforced stimuli may remain constant and yet the total attention paid to relevant stimuli on the subsequent discrimination would still be higher than attention paid to irrelevant stimuli, as a result of increased attention paid to reinforced stimuli.

One experiment where changes in attention to non-reinforced stimuli may have occurred was carried out by Hearst and Franklin (1977). During their experiment food was presented to the subjects at various intervals. A response key, illuminated for 20 s signalled the absence of food. Floor sensors were used to assess the pigeon's location within the test chamber and it was shown that despite the illuminated response key accurately predicting that food would not be delivered,

subjects withdrew to the other side of the test chamber when the key was illuminated. One interpretation of these findings is that birds were keen to pay as little attention as possible to the keylight. The experiment thus, contrary to Mackintosh's (1975a) views that attention to stimuli that reliably signal the absence of food will be high. Further evidence that this might be the case was documented by Pearce and Kaye (1985). They successfully trained rats to form an inhibitory relationship between presentation of a 10-sec light and food. Random presentations of food were presented at varying time lengths but never during presentation of the light or for a period of one minute after it was turned off. Using orienting responses, defined as rearing in front of the light or touching the light in any way with either nose or paws, a measure of attention to the light was taken. They found that rather than attention being directed towards the non-reinforced light, orienting responses declined during the course of conditioning, more rapidly than in a group for whom the light and presentation of food occurred rapidly with no correlation between the two.

Whilst there is evidence of attention to relevant stimuli being higher than attention to irrelevant stimuli (Lawrence 1949, Mackintosh & Little 1969), thus far very little evidence has been found to provide adequate support for the claim that attention to non-reinforced or conditioned inhibitors is higher than to irrelevant stimuli.

5.2   Experiment 7

Experiment 7 was conducted in an attempt to ascertain whether there is merit to such a claim. Experiments detailed here so far, have pointed to pigeons only attending to stimuli with high associative strength so perhaps rather than the predictions of Mackintosh (1975a), it could be expected that during a test

discrimination, as a result of pigeons looking solely at previously reinforced stimuli they will fail to learn about the significance of previously non-reinforced stimuli. Two groups of pigeons received discrimination training using compound stimuli featuring a relevant and an irrelevant stimulus. The eight compound stimuli used during Stage 1 can be seen in Table 5.1.

Stage 1		Stage 2	
AX+ BX-		Group Irrelevant	AY+ AZ- CY-
AX+ BX-		Group Relevant	AB+ AD- CB-
CY+ DY-			
CZ+ DZ-			

Table 5.1. Stimuli used during both stages of Experiment 7.

Pigeons then went on to receive either a discrimination of three compound stimuli made up of one previously reinforced and one previously irrelevant stimulus (Group Irrelevant) or a discrimination of three compound stimuli made up of one previously reinforced and one previously non-reinforced stimulus (Group Relevant). The stimuli used during Stage 2 can be seen in Table 5.1.

If Group Relevant acquires the AB+/AD- discrimination at the same rate as the AB+/ CB- discrimination then it would imply that the associability of stimuli that signal the absence of food is similar to the associability of stimuli that signal the presence of food. Given the findings thus far this expectation may be dubious and so to attempt to demonstrate attentional changes to previously non-reinforced stimuli, a second group, Group Irrelevant, was included. This group should acquire the AY+/

CY- discrimination as rapidly as the AB+/ CB- discrimination in Group Relevant. However it is the comparison of the AB+/AD- discrimination in Group Relevant and the AY+/AZ- discrimination in Group Irrelevant that is of interest. If Group Relevant learns the AB+/AD- discrimination more rapidly than Group Irrelevant learn the AY+/AZ- discrimination then this would suggest that during Stage 1 more attention was paid to non-reinforced stimuli than to irrelevant stimuli.

Method

Subjects. The subjects were 30 naïve adult homing pigeons (*Columba livia*), maintained in the same manner as in Experiment 1.

Apparatus. All apparatus used was identical to that used in Experiment 1.

Stimuli. The stimuli were presented on the TV screen, which was otherwise black. During both stages, the stimuli consisted of two horizontally adjacent circles, each 2.4 cm in diameter. The point at which the circles joined was located at the centre of the TV screen. For all subjects, each circle consisted of one of seven patterns. For each trial type, each of the two patterns presented appeared in the left-hand circle on half of the trials, and in the right-hand circle on the other half of the trials. Four of the patterns were created from three black bars, each 3 mm wide, separated by white bars of the same width. For each pattern the orientation of the bars with respect to the top of the TV was different; horizontal, +45º, vertical or -45º. Another pattern consisted of three white circular bands, each with a width of 2 mm. The outermost band formed a circle with diameter 2.4 cm. Each band was separated by black circular bands of the same width. In the centre of the stimulus was a black

circle (diameter 4 mm). A 'spotted' pattern was also used, which consisted of a white circle containing 7 black circles, each with diameter 0.64 cm. The final pattern was a black 5-point star within a white circle with diameter 2.4 cm. The points of the star touched the edges of the circle, with the top point being at the midpoint of the upper edge of the circle.

For all subjects, X represented the 45° pattern. The other stimuli, which were used during the test phase, were counterbalanced so that each pattern served as a consistently reinforced, consistently non-reinforced and an irrelevant stimulus. The six counterbalanced subgroups are shown in Table 5.2; pictorial examples of the stimuli used can be seen in previous experiments.

Subgroup/ Stimulus	A	B	C	D	X	Y	Z
1	90°	Spotted	Horizontal	Circle	+45°	Star	-45°
2	90°	Star	Horizontal	45°	+45°	Spotted	Circle
3	Star	90°	-45°	Horizontal	+45°	Spotted	Circle
4	Star	-45°	Spotted	Circle	+45°	90°	Horizontal
5	Spotted	90°	Circle	Horizontal	+45°	Star	-45°
6	Spotted	Star	Circle	-45°	+45°	90°	Horizontal

Table 5.2. Stimuli used during Stage 1 and 2 of Experiment 7

Procedure. The subjects were autoshaped in a manner consistent with all previous experiments and were then randomly assigned to one of the six sub-groups, with five birds in each.

Session 1 of Stage 1 began on the day after the final session of autoshaping. During each of the 24 sessions of training, the six groups received discrimination training with the six trial types AX+, BX-, CY+, DY-, CZ+ and DZ-. There were 48 trials in each session: each trial type was presented six times with the exception of AX+ and BX- which were presented 12 times each. The following details applied to all stages of the experiment. Each stimulus was presented for 10 s, and the mean inter-trial interval was 60 s (range = 40-80 s). The trial types were presented in a random order with the constraint that no more than two reinforced or two non-reinforced trials could occur in succession.

On the day following Session 24 of training, both groups received the first session of the test discrimination. Group Relevant was made up of two subjects from sub-groups 1, 3 and 6 and three subjects from sub-groups 2, 4, and 5. Group Irrelevant was made up of three subjects from sub-group 1, 3 and 6 and two subjects from sub-group 2, 4 and 5. There were 14 sessions in this stage of the experiment, during which animals in Group Relevant received the discrimination AB+/AD-/CB- and animals in Group Irrelevant received the discrimination AY+/AZ-/CY-. There were 40 trials in each session, consisting of 20 reinforced presentations of AB or AY, 10 non-reinforced presentations of AD or AZ and 10 non-reinforced presentations of CB or CY. The procedural details that have been omitted were the same as for the previous experiment.

Results

Figure 5.1 shows the mean rate of responding during reinforced trials, and that during non-reinforced trials, for both groups on each session of Stage 1. From this figure it appears that Group Relevant responded to reinforced stimuli at a slightly

higher rate the Group Irrelevant, however both groups decreased responding at a similar rate to non-reinforced stimuli and both learnt the discrimination.
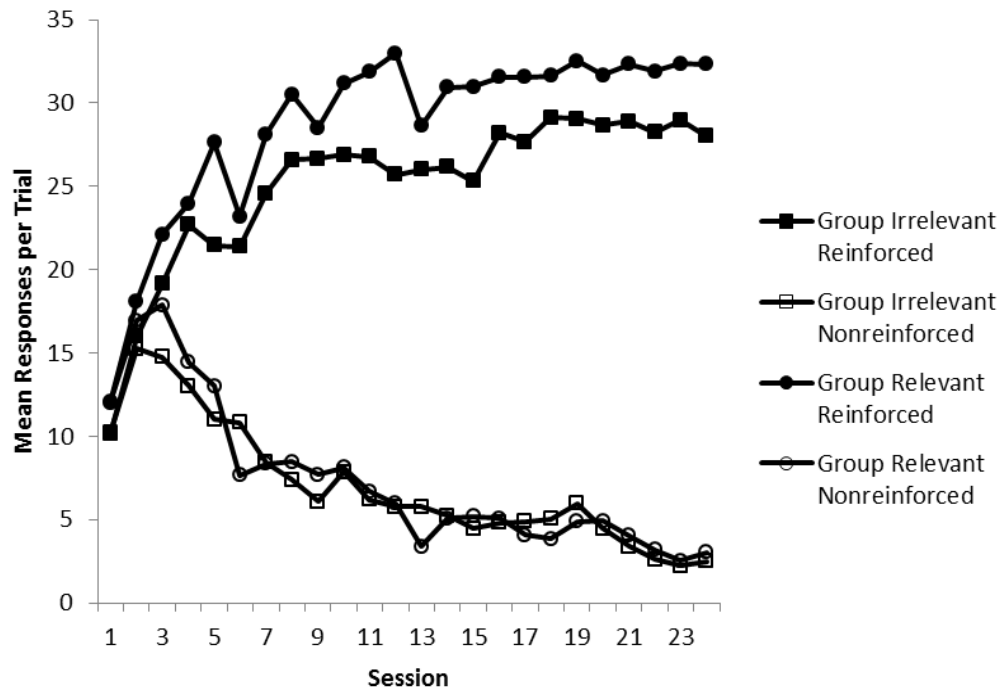
Figure 5.1. The mean rates of responding during the reinforced (CS+) and non-reinforced (CS-) trials for both groups throughout Stage 1 of Experiment 7.

A three-way ANOVA of individual mean rates of responding during the reinforced and non-reinforced trials during each of the 24 sessions was carried out and revealed a significant effect of session, $F(23, 644) = 3.93$, MSE $= 34.31$, and stimulus, $F(1, 28) = 158.64$, MSE $= 882.31$. No effect of group was found, $F < 1$. A significant Stimulus x Session interaction, $F(23, 644) = 43.25$, MSE $= 24.82$, was found however, the Group x Stimulus interaction was not significant, $F(1, 28) = 1.07$, MSE $= 882.31$, nor was the Group x Session interaction, $F < 1$, or the Group x Stimulus x Session interaction, $F < 1$.

The Stimulus x Session interaction was analyzed using simple main effects tests, which revealed that responding was significantly faster during the reinforced than the non-reinforced trials from Session 3 onwards, Fs(1, 672) > 4.59, MSE = 278.04.

During the 14 sessions of the test stage both groups responded at a similarly high rate to the reinforced stimulus (AY in Group Irrelevant, and AB in Group Relevant), which can be seen in Figure 5.2.
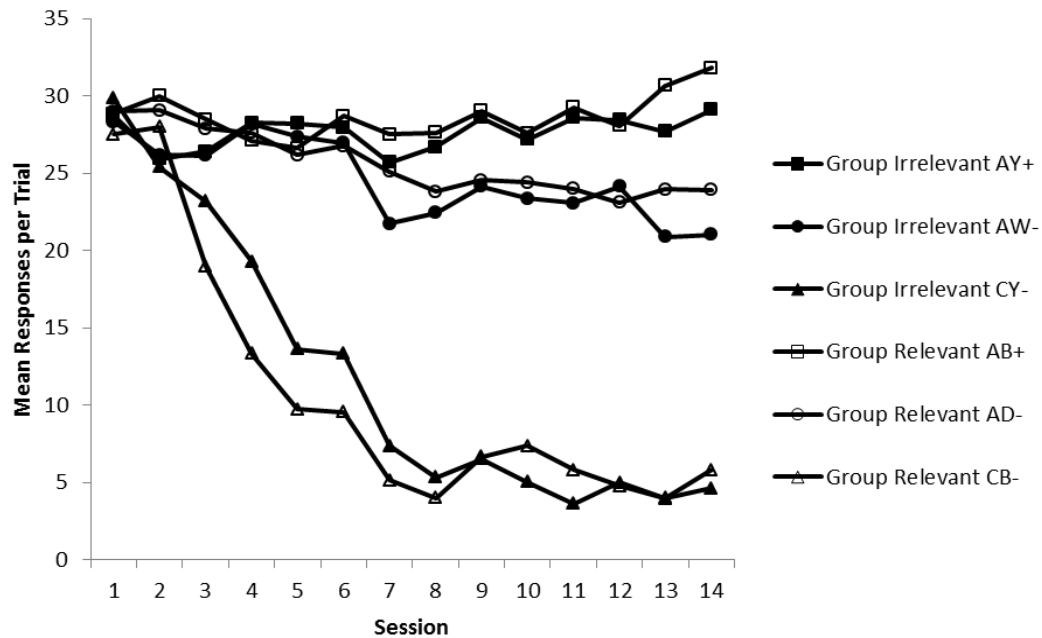
Figure 5.2. The mean rates of responding to each compound stimuli by both groups during Stage 2 of Experiment 7.

It is also apparent that while both groups solved the discrimination based upon previously reinforced stimuli, AB+/CB- in the case of Group Relevant and AY+/CY- in the case of Group Irrelevant, the former failed to solve the discrimination based

upon previously non-reinforced stimuli and the later the discrimination based upon previously irrelevant stimuli.

A two-way ANOVA of the individual mean response rates during the reinforced compound, for each of the 14 sessions, revealed that the effects of group, F <1, and session, F <1, and the Group x Session interaction, F <1 were not significant.

In order to compare the performance of the groups during the non-reinforced compounds, discrimination ratios were calculated for individual subjects in the same manner as in Experiment 1. The distinctive cues for the discrimination between the compounds AY+ CY- in Group Irrelevant, and between AB+ CB- in Group Relevant, were A and C, which had been relevant as signals for food for both groups during Stage 1 training. The distinctive cues for the other discrimination received by Group Irrelevant, AY+ AZ-, had previously been irrelevant, whereas the distinctive cues for the other discrimination received by Group Relevant, AB+ AD-, had been relevant as signals for the absence of food during Stage 1. Figure 5.3 shows the mean discrimination ratios for the two groups for each of the 14 test sessions during these discriminations.
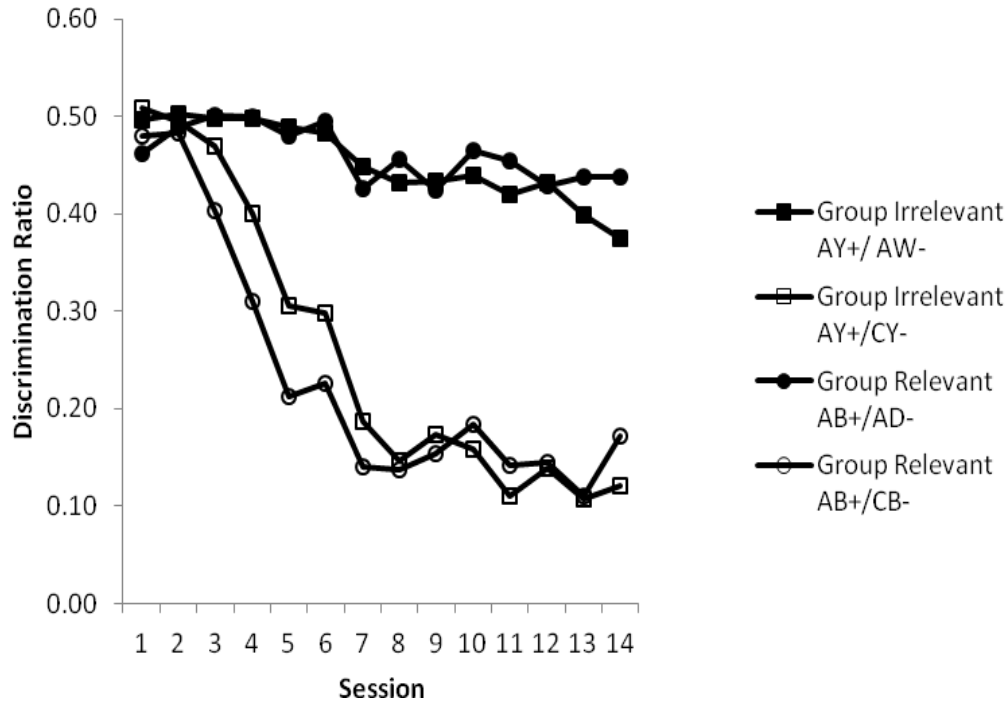
Figure 5.3. The mean discrimination ratios throughout the test stage of Experiment 7 for both groups for the component of the test discrimination for which the distinctive cues had been relevant signals for food, AY+ /CZ- in Group Irrelevant, and AB+ /CB- in Group Relevant, and for the other component of the test discrimination, AY+ /AY- in Group Irrelevant and AB+ /AD- in Group Relevant, where the distinctive cues had been irrelevant, or relevant signals of the absence of food, respectively.

From Figure 5.3 it is evident that both groups acquired the discrimination for which the distinctive cues had been relevant during Stage 1 more readily than the other discrimination. Thus, a discrimination based on two stimuli that had been relevant signals for the absence of food (AB+ /AD- in Group Relevant) was found to be as difficult as a discrimination based on previously irrelevant stimuli (AY+ /AZ- in Group Irrelevant). A three-way ANOVA of individual ratios from the two

components of the test discrimination (that based on two previously relevant signals for food, and that based on irrelevant stimuli or relevant signals for the absence of food), for each of the 14 sessions revealed that there was no significant effect of group, $F<1$, and no significant Group x Session interaction, $F(13, 364) = 1.72$, MSE = 0.01, Group x Discrimination interaction, $F <1$, or Group x Discrimination x Session interaction, $F <1$. There was a significant effect of discrimination, $F(1, 28) = 112.69$, MSE = 0.08, and session, $F(13, 364) = 46.67$, MSE = 0.01, and a significant Discrimination x Session interaction, $F(13, 364) = 24.72$, MSE = 0.01. The significant interaction was analysed using simple main effects tests, which revealed that the discrimination based on previously relevant signals for food was more adequately solved, than that based upon previously irrelevant/ non-reinforced signals, on Session 3 onwards, Fs$(1, 392) > 4.39$, MSE = 0.01.

Discussion

The findings of the current experiment indicate that no more attention is attributed to stimuli which signal non-reinforcement than to irrelevant stimuli and therefore can do little in the way of substantiating theoretical claims made by Mackintosh (1975a) that non-reinforced stimuli will be attended to, to the same degree as reinforced stimuli. Instead it seem that these results strengthen previous findings that only those stimuli which have attained high associative strength during the first stage of an experiment will be attended to and thus learnt about during the second stage. During Stage 1 of this experiment all pigeons learnt to respond rapidly to reinforced stimuli. When, during Stage 2, they were presented with compound stimuli made up of a previously reinforced stimulus and either a previously non-reinforced stimulus or a previously irrelevant stimulus, their gaze will be expected to

be directed solely at the previously reinforced feature of the compound and thus they will fail to learn about either the non-reinforced or the irrelevant features. This could explain why no difference was seen between the acquisition of a discrimination based upon previously irrelevant stimuli and one based upon previously non-reinforced stimuli; in both cases pigeons were looking solely at previously reinforced stimuli and thus failed to learn the new discrimination.

5.3   Experiment 8

Experiment 8 was carried out to further attempt to detect associative changes in previously non-reinforced stimuli. The design was altered to allow a direct test of the associabilities of previously non-reinforced and previously irrelevant stimuli. Evidence has previously been stated in support of the claim that pigeons will only learn about the stimuli, which they are looking at. It therefore follows that during the second stage of an experiment, if previously reinforced stimuli are used pigeons will look at these stimuli to the detriment of learning about other stimuli. However it may be possible to detect associative changes to previously non-reinforced stimuli if only previously non-reinforced and previously irrelevant stimuli are used during the second stage of an experiment.

Two groups of pigeons, Group Irrelevant and Group Relevant were presented with the discriminations shown in Table 5.3. During Stage 1, for Group Irrelevant, colours were relevant and patterns irrelevant, for Group Relevant, patterns were relevant and colours irrelevant to the solution of the discrimination. Once both groups had acquired the discriminations in Stage 1 they progressed to Stage 2 where the discrimination DZ+ DY- was presented. For Group Relevant the relevant elements of this discrimination (patterns) were previously relevant although crucially were

previously non-reinforced. For Group Irrelevant, the relevant elements of this discrimination were previously irrelevant. Patterns were selected as the relevant dimension in Stage 2 because of the findings of Pearce et al(2008) that it was easier to modify the attention paid to patterns than to colours.

Group	Discrimination (Stage 1)				Discrimination (Stage 2)
Irrelevant	Aw+	Cw-	Bw+	Dw-	DZ+ DY-
	Ax+	Cx-	Bx+	Dx-	
	Ay+	Cy-	By+	Dy-	
	Az+	Cz-	Bz+	Dz-	
Relevant	aW+	aY-	aX+	aZ-	DZ+ DY-
	bW+	bY-	bX+	bZ-	
	cW+	cY-	cX+	cZ-	
	dW+	dY-	dX+	dZ-	

Table 5.3. Discriminations used in Stage 1 and 2. Letters A-D represents colours and W-Z patterns. Uppercase letters represent relevant stimuli, lowercase letters represent irrelevant stimuli.

If Mackintosh's (1975a) claim that attention is paid to non-reinforced stimuli is correct, then Group Relevant will solve the test discrimination more quickly than Group Irrelevant as the relevant stimuli used in the test discrimination are from the same dimension as the relevant stimuli in the training discrimination for Group Relevant. According to Mackintosh (1975a) attention will have been paid to the non-reinforced stimuli and so it is reasonable to predict similar results to those found by

Dopson et al(2010a) when previously reinforced stimuli are used during the test discrimination.
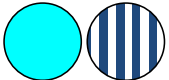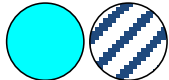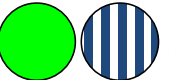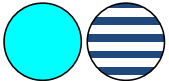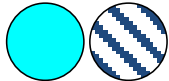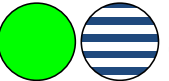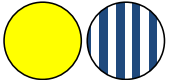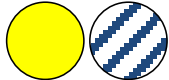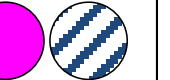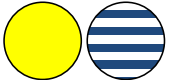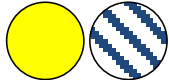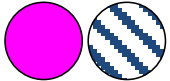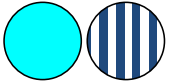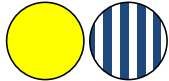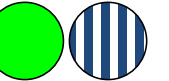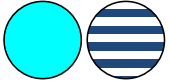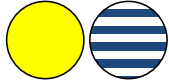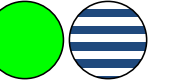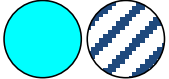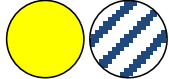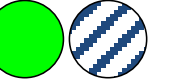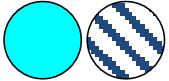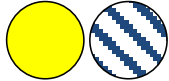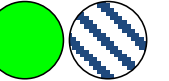
Method

Subjects. The subjects were 16 naïve adult homing pigeons (*Columba livia*), maintained in the same manner as in Experiment 1.

Apparatus. All apparatus used was identical to that used in Experiment 1.

Stimuli. The stimuli were presented on the TV screen, which was otherwise black. The stimuli consisted of 2 horizontally adjacent circles, each 2.4 cm in diameter. The point at which the circles joined was located at the centre of the TV screen. For all subjects, one circle always contained a colour and one circle a pattern, with the colour appearing on the left in half of the trials and on the right during the other half. Four different colours were used, cyan, yellow, green and magenta, and four patterns each consisting of three black bars, 3 mm wide, separated by white bars of the same width oriented in one of four ways 0º, 90º, 45º, or -45º. For all subjects A, B, C and D represented cyan, yellow, green and magenta respectively, and W, X, Y and Z represented lines of orientation 0º, 90º, 45º and -45º respectively. In Group Irrelevant, colours were relevant, signalling either the presence or absence of food, and patterns were irrelevant. In Group Relevant, patterns were relevant and colours irrelevant. Stimuli used can be seen in Table 5.4.

Procedure. The subjects were autoshaped in a manner consistent with all previous experiments and were then randomly assigned to Group Relevant or

Table 5.4. Stimuli used in Stage 1 and 2 of Experiment 8. Uppercase letters represent relevant stimuli and lowercase letters represent irrelevant stimuli

Group Irrelevant, with 8 birds in each.

Session 1 of Stage 1 began on the day after the final session of autoshaping. During each of the 22 sessions of training, the two groups received discrimination training with the trial types shown in Table 5.3. There were 64 trials in each session, each trial type was presented eight times. The following details applied to all stages of the experiment. Each stimulus was presented for 10 s, and the mean inter-trial interval was 60 s (range = 40-80 s). The trial types were presented in a random order with the constraint that no more than two reinforced or two non-reinforced trials could occur in succession.

On the day following Session 22 of training, both groups received the first session of the test discrimination. There were eight sessions in this stage of the experiment, during which all animals received the discrimination DZ+/DY-. There were 40 trials in each session, consisting of 20 reinforced presentations of DZ and 20 non-reinforced presentations of DY. The procedural details that have been omitted were the same as for the previous experiment.

Results

During Stage 1 the mean rate of responding for all subjects was calculated for both reinforced and non-reinforced trial types for each session. Figure 5.4 represents these mean response rates and shows initially Group Irrelevant (the group for which colours were the relevant feature) acquired the discrimination between reinforced and non-reinforced stimuli more rapidly than Group Relevant (the group for which patterns were the relevant feature). However by the end of Stage 1, both groups had acquired the discrimination and were responding rapidly to reinforced stimuli and barely responding to non-reinforced stimuli.

120
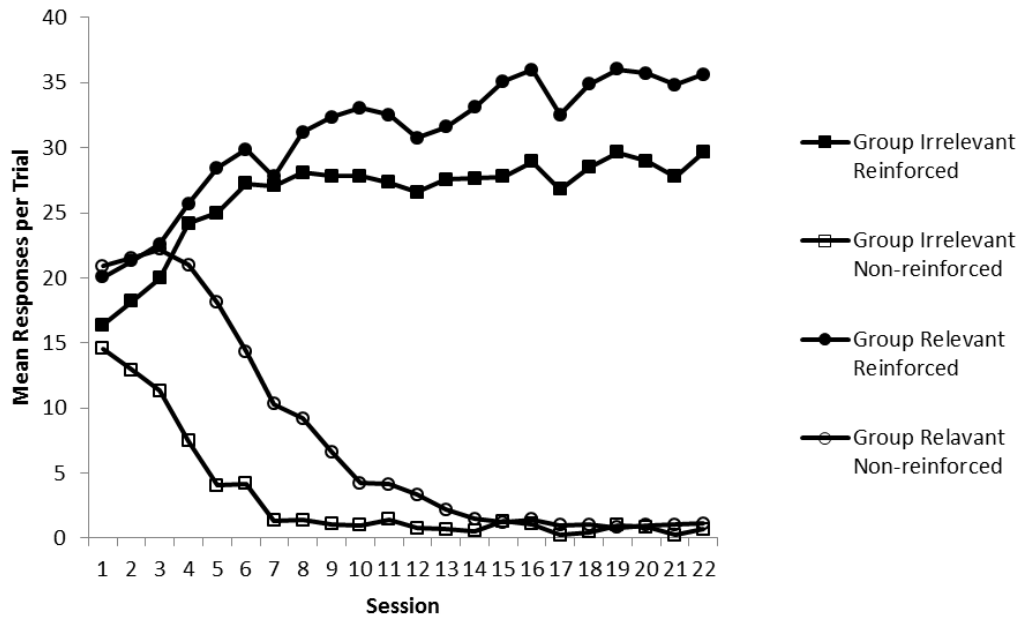
Figure 5.4. The mean rates of responding during the reinforced (CS+) and non-reinforced (CS-) trials throughout Stage 1 of Experiment 8 for both groups.

A three-way ANOVA calculated on the individual mean rates of responding during presentations of each trial type was conducted, with the factors of group (Relevant or Irrelevant), stimulus (reinforced and non-reinforced) and session, for the 22 sessions of training. The results revealed a significant effect of session, $F(21, 294)$ = 16.17, MSE = 941.12, and stimulus $F(1, 14)$ = 157.22, MSE = 25452.30, but no significant effect of group, $F(1, 14)$ = 1.79, MSE = 42022.31. There was no significant Group x Session interaction, $F(21, 294)$ = 1.50, MSE = 941.12, or Group x Stimulus interaction, $F< 1$, but the Stimulus x Session interaction was significant, $F(21, 294)$ = 49.49, MSE = 721.50, as was the Group x Stimulus x Session interaction, $F(21, 294)$ = 2.79, MSE = 721.50. The three-way interaction was explored through further analysis of the Group x Stimulus and Group x Session interactions.

121

The Group x Stimulus interaction was significant only on Session 4, Fs(1, 308) = 5.06, MSE = 1845.63. Subsequent simple effects tests revealed that on this session Group Irrelevant had solved the discrimination between reinforced and non-reinforced stimuli, $F(1, 308) = 22.54$, MSE = 1845.63, but Group Relevant had not, $F(1, 308) = 2.45$, MSE = 1845.63. The Group x Session interaction was significant only for non-reinforced trials, $F(21, 588) = 3.62$, MSE = 831.31, and simple effects tests revealed that responding during these trials was significantly different in the two groups on Sessions 3, 4 and 5, Fs(1, 616) > 8.23, MSE = 2327.04.

Figure 5.5 shows the mean rate of responding to both stimuli during Stage 2. Responding to DZ+ increased throughout the test sessions in Group Relevant however responses by Group Irrelevant increased for the first three sessions but from them on was at a noticeably lower rate than in Group Relevant. Responding to DY- initially increased for the first three session in both groups after which responding decreased at a comparable rate in both groups. The test phase of the present experiment involved fewer compounds than for the previous studies. Accordingly, there was no need to simplify the analysis by calculating discrimination ratios. Instead I analysed the response rates directly.
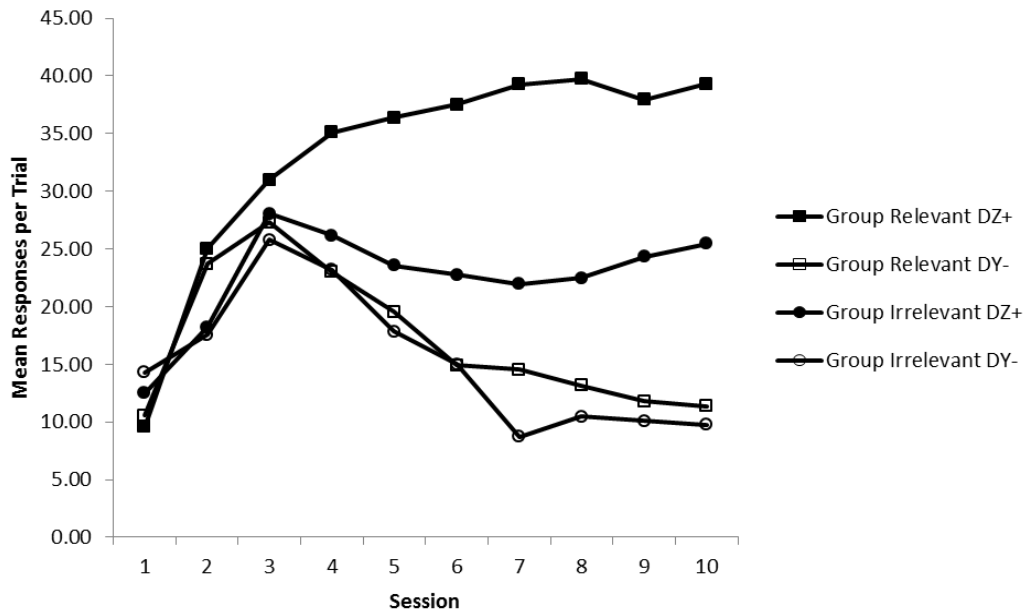
Figure 5.5. The mean rates of responding during both trial types throughout Stage 2 for both groups.

A three-way ANOVA of individual mean rates of responding during both compounds was carried out and revealed no significant effect of group, $F(1, 14) = 1.99$, MSE = 38122.02, but significant effects stimuli, $F(1, 14) = 15.73$, MSE = 12813.96, and session, $F(7, 98) = 7.29$, MSE = 3904.77. There was no significant Group x Stimulus interaction, $F(1, 14) = 2.88$, MSE = 12813.96, or Group x Session interaction, $F(7, 98) = 1.63$, MSE = 3904.77, but the Stimulus x Session interaction was significant, $F(7, 98) = 15.44$, MSE = 1221.59, as was the Group x Stimulus x Session interaction, $F(7, 98) = 2.21$, MSE = 1221.59. Further analysis revealed that the Group x Stimulus interaction was significant on Sessions 6 and 8, $Fs(1, 112) > 5.73$, MSE = 2670.63. Tests of simple effects then revealed that Group Relevant responded at a significantly higher rate than Group Irrelevant during presentations of DZ on these sessions, $Fs(1, 224) > 5.77$, MSE = 5426.28. Furthermore, the

123

discrimination between DZ and DY was significant for Group Relevant on both of these sessions, Fs(1, 112) > 27.51, MSE = 2670.63, but was only significant for Group Irrelevant on Session 8. F(1, 112) = 7.78, MSE = 2670.63.

Discussion

The results of Experiment 8 provide evidence that attention paid to reliably non-reinforced relevant stimuli is greater than that paid to irrelevant stimuli. Group Relevant, for which patterns were initially relevant, acquired the subsequent discrimination based on previously non-reinforced patterns more readily than Group Irrelevant for which patterns were originally irrelevant. Both groups, during the test phase, rapidly stopped responding to DY- but a clear difference in the rate at which they learnt to respond to DZ+ was observed. These findings are in line with Mackintosh's (1975a) theory, however to date there has been little evidence to support the claim that non-reinforced stimuli are attended to more than irrelevant stimuli. This experiment therefore, provides novel support for a hitherto untested prediction of the theory. Whilst the findings of this experiment no doubt have important implications with regard to substantiating the theories of, for example, Mackintosh (1975a) and LePelley (2004), it is not supportive of the claims of Pearce and Hall (1980) who predict that attention to a non-reinforced stimulus will be equal to the attention paid to an irrelevant stimulus. This model states that once the events on reinforced and non-reinforced trials are predicted accurately, then attention to all stimuli, including relevant and irrelevant, will decline to the same low level.

Previous experiments have been suggestive that attention is only high to stimuli which have acquired high associative strength as it will only be those with high associative strength which a pigeon's gaze will be expected to be oriented

towards allowing for learning to occur. However this experiment brings this conclusion into some doubt. It seems likely that non-reinforced stimuli are indeed paid more attention relative to irrelevant stimuli as evidenced by the difference in acquisition of the Stage 2 discrimination between the two groups.

5.4   General Discussion

The findings of Experiment 7 found no evidence that more attention is paid to stimuli which signal non-reinforcement than to irrelevant stimuli. Rather than revealing a lack of evidence for Mackintosh (1975a) it was concluded that the design did not allow for subtle changes in attention to non-reinforced stimuli to be measured. Experiment 8 featured an altered design with no previously reinforced stimuli during Stage 2. The findings of Experiment 8 showed differences in the attention paid to non-reinforced and irrelevant stimuli with greater attention being paid to non-reinforced. When the findings of both experiments are examined it seems plausible that during the first stage of an experiment most attention is paid to reinforced stimuli, explaining the results of Experiment 7. It is possible that some attention is paid to non-reinforced stimuli, less than is paid to reinforced yet more than to irrelevant stimuli, explaining the findings of Experiment 8.

The findings of the two experiments presented in this chapter clearly provide support for the claim that greater attention is paid to stimuli, which most accurately predict an outcome, relative to all other stimuli present. How then can these conclusions be reconciled with the findings of Pearce and Kaye (1985) described in the introduction of this chapter? At first sight they seem to support polar arguments. Experiment 7 and 8 clearly demonstrate positive transfer i.e. faster learning about stimuli, which have previously been accurate predictors, while Pearce and Kaye

(1985) demonstrated a loss of attention to stimuli, which previously were poor predictors of outcome. The answer may be found in the hybrid model proposed by LePelley (2004). This model seeks to account for both the occurrence of negative and positive transfer by incorporating elements of both the Pearce and Hall theory (1980) and Mackintosh's theory (1975). Within the hybrid theory, LePelley claims that it is the design of the experiment itself that determines whether negative or positive transfer occurs. If the design places emphasis on the relative predictiveness of multiple stimuli such as will occur when compound stimuli are used then positive transfer will result. Conversely when the predictiveness of a stimulus is absolute and not relative to other stimuli then negative transfer will follow such as would occur when a single stimulus is used during a training phase. Thus this hybrid model could account for both the findings for the experiments documented in this chapter using complex stimuli and resulting in positive transfer and the findings of the experiment by Pearce and Kaye (1985) using a single CS and resulting in negative transfer.

6. General Discussion

The purpose of the experiments reported here was to use a novel methodology to attempt to gain answers to outstanding questions related to the role of selective attention in learning. Experiment 1 was designed to ascertain whether attention is paid to entire dimensions such as colours or patterns (e.g. Sutherland & Mackintosh 1971) or whether attention is paid to individual stimuli (e.g. Mackintosh 1975a). Pigeons were trained with a set of discriminations of the form AX+ CX-, with all stimuli being from the same dimension. It was possible to demonstrate that in a subsequent test, pigeons learnt a discrimination based upon previously relevant stimuli more rapidly than they did a discrimination based on previously irrelevant stimuli. Thus in keeping with the proposal that attention is paid to individual stimuli. However doubt was still cast over what constitutes a dimension. If colours close to each other on the colour spectrum could be said to form a single dimension then perhaps there was still scope for Sutherland and Mackintosh's (1971) view in the findings from Experiment 1.

With this in mind, Experiment 2 replicated the design of the first experiment with the manipulation that each compound was made up of closely related colours. This meant that pigeons would now have to treat colours close to each other on the colour spectrum, for example red and orange, as being either relevant or irrelevant. If, as suggested, dimensions within the broader category of 'colours' can be found, pigeons would struggle considerably during the test phase of Experiment 2. In opposition to this suggestion, findings replicated those of Experiment 1 thus it was concluded that attention occurred to individual stimuli rather than to dimensions.

Experiment 3 was carried out to attempt to detect latent inhibition in pigeons. It was hoped that by using a novel methodology, the effect, which had proved somewhat elusive in pigeons, may be more readily observed. Two reinforced stimuli,

127

A and B were interspersed by two non-reinforced stimuli, C and D for half the subjects and E and F for the other half. When a test discrimination, AC+/ AD-/ BC-, was then presented it was hoped that a difference would occur between those subjects for whom C and D were novel and those for whom they had been previously exposed but non-reinforced. No difference was found between the groups in the acquisition of the test discriminations, with both groups solving the AC+/ BC- discrimination more rapidly than the AC+/ AD- discrimination. While this pattern of results in Group Pre-exposed, for whom C and D were previously non-reinforced, is in keeping with the effect of latent inhibition, similar findings in Group Novel for whom C and D were novel in the test phase, suggested a different account was needed to explain the findings. It was thus concluded that the amount of attention paid to a stimulus is determined by the degree of responding to it that occurs. If it is assumed that a pigeon will only look at a stimulus while pecking it, then it follows that attention and thus learning will only occur to stimuli which are pecked at. In a compound stimulus, in which the elements are placed beside each other, it would then follow that little would be learned about any component that elicited a low rate of responding. While it was expected subjects for whom C and D were novel would solve both discriminations rapidly, that they did not could be explained by reasoning that their gaze may have been solely on the previously reinforced stimuli, retarding learning about the novel stimuli.

These findings threw new light on the conclusions drawn from Experiments 1 and 2; rather than assuming attentional changes to individual relevant and irrelevant stimuli had taken place it now seemed possible, even plausible, that attention was paid principally to the stimulus which a pigeon was pecking, and thus looking at. In Experiment 4, this conclusion was tested by creating compounds in which one

component was superimposed on the other. For example, striped blue lines were placed on a red background. It was hoped that by displaying the stimuli in this manner, pigeons would be forced to look at both the red and the blue stimulus, regardless of which was relevant. The design of Group Pre-exposed in Experiment 3 was replicated in Experiment 4 using colours, during the test phase half the subjects received the discriminations with combined stimuli and half with separated stimuli. Those for whom the stimuli were combined solved both test discriminations at an equal rate while those for whom the stimuli were separated mirrored the findings of Group Pre-exposed in Experiment 3. Again, it seemed likely that the explanation for these findings was that pigeons only learn about those stimuli which they peck at.

While this argument seems to have some merit, it was also suggested that a reduction in attention to non-reinforced stimuli during Experiment 3 had occurred but that any effect was lost through pigeons solely directing their gaze at reinforced stimuli during the test phase. Thus Experiment 5 was conducted to attempt to observe such changes in attention, or more specifically to determine whether more attention is paid to reliable predictors of outcome (e.g. Mackintosh 1975a) or to unreliable predictors of outcome (Pearce & Hall 1980). A test discrimination, AX+/ AY-/ BX- was presented to pigeons previously trained with A+ B+ X+/- Y+/-. The expectation, if support for Pearce and Hall was to be found, was that the discrimination based upon previously partially reinforced stimuli, AX+/AY-, be learnt more rapidly than the discrimination based upon previously continuously reinforced stimuli, AX+/BX-. The opposite would be expected during the test phase if the claims of Mackintosh were to be substantiated. It was found however, that no difference in the acquisition of the test stage discriminations occurred. Again, orientation of the pigeons gaze during the first stage can be used as a possible explanation; a pigeon's gaze is likely to focus on A

and B but additionally their gaze will also be focused upon X and Y thus during the second stage learning about both discriminations will be facilitated.

Experiment 6 was carried out to explore a curious difference in the acquisition of the discrimination based upon previously reinforced stimuli in Experiments 3 and 5. In both experiments pigeons received an AX+ BX- AY- test discrimination in which the stimuli were presented beside each other and for which A and B had previously been paired with food. For Experiment 3, X and Y had no associative strength, whereas for Experiment 5 they had been paired with food according to a partial reinforcement schedule. It was found that the AX+ BX- discrimination was acquired more readily in Experiment 3, than 5. To explain this outcome I suggested that when X elicited a high rate of responding it distracted attention away from the relevant stimuli, A and B. To test this proposal in a single experiment, Experiment 6 presented pigeons with an AE+ BE- AF- discrimination. For half the subjects E and F had been previously non-reinforced and so had low associative strength at the start of the test phase and for half E and F had been previously reinforced so had high associative strength at the start of the test phase. It was indeed found that those pigeons for which E and F had a high associative strength solved the AE+/ BE- discrimination at a significantly slower rate than did those pigeons for which E and F had a low associative strength. This provided further support of the claim that it is the amount of pecking and thus looking at a stimulus receives which controls the amount of attention paid to it and thus learning about it. When an accompanying irrelevant stimulus has high associative strength it receives a proportion of a pigeon's gaze thus reducing the time spent looking at the relevant stimuli and retarding learning.

By the completion of Experiment 6 it seemed evident that attention paid to a stimulus is not only related to the amount of time spent pecking and therefore looking

at it and but also to the associative strength of the stimuli which accompany it. With this in mind it seemed prudent to attempt to determine whether attentional changes can occur to non-reinforced relevant stimuli, for example B in an AX+/ BX- discrimination. Experiment 7 sought to answer this question. Pigeons trained in discriminations of the type AX+/ BX- then received test discriminations made up of three compound stimuli containing either one previously reinforced and one previously irrelevant stimulus or one previously reinforced and one previously non-reinforced stimulus. From this it was hoped that a difference in the acquisition of the discrimination based upon previously non-reinforced stimuli in one group would be learnt more rapidly than the discrimination based upon previously irrelevant stimuli by the other group. Findings however, showed no such success with no evidence found for any difference in attention attributed to non-reinforced and irrelevant stimuli. It seemed little support from these conclusions could be given to claims of Mackintosh (1975a) that attention will increase to non-reinforced stimuli.. Rather it seemed, in keeping with findings thus far, that only stimuli which have gained high associative strength will be attended to. Alternatively it was proposed that perhaps attentional changes to non-reinforced stimuli had taken place but that they were to a lesser extent than changes to reinforced stimuli. It has been stated throughout that it seems likely the amount of time a pigeon spends looking at a stimulus reflects the amount of learning that takes place about that stimulus. It would then follow that in a discrimination made up of reinforced and non-reinforced stimuli, a pigeon's gaze is likely to remain on the reinforced stimulus to the detriment of looking at and therefore learning about the non-reinforced stimulus.

Experiment 8 implemented a different design. Pigeons were first trained with a set of discriminations of the type AX+/ CX- where for one group patterns formed the

relevant dimension and colours the irrelevant dimension and for the other colours the relevant and patterns the irrelevant dimension. A test discrimination then followed which crucially, was made up of previously non-reinforced and irrelevant stimuli. For Group Irrelevant, the relevant component had previously been irrelevant and for Group Relevant the relevant component had been previously non-reinforced. The aim being that without the presence of reinforced stimuli during the test phase, any difference in the associability of non-reinforced and irrelevant stimuli would be shown if Group Relevant solve the discrimination more rapidly than Group irrelevant. This difference was indeed observed providing novel support for the claims of theorists such as Mackintosh (1975a) and LePelley (2004) that attention to non-reinforced stimuli is greater than to irrelevant stimuli.

In summary, several conclusions can be drawn from the above experiments. First, the amount of attention paid by a pigeon to a stimulus is determined, to a large extent, by the rate at which it is pecked. Second, the attention paid to one stimulus will be reduced if it is accompanied by a stimulus that itself elicits a high rate of pecking. Perhaps surprisingly, this conclusion lends support to the Inverse Hypothesis, albeit in not quite the way Sutherland and Mackintosh (1971) envisioned. Third, when stimuli elicit low rates of responding then it appears that more attention is paid to one that is relevant, through signalling the absence of food, than one that is irrelevant. The purpose of the remaining discussion is to pursue in more detail the theoretical implications of my findings.

Mackintosh (1975a)

The backbone of the theory laid down by Mackintosh (1975a) is the claim that when two or more stimuli are present, attention will be paid to the stimulus which is

the most accurate predictor of the outcome. The experiments reported here provide some support for this claim. For example, Experiment 1 showed that following discriminations of the type AX+ CX- a test discrimination based upon previously relevant stimuli was learnt more rapidly than one based upon previously irrelevant stimuli, despite all stimuli belonging to a single dimension. Similarly, Experiment 2, which had a similar design, also provided evidence to support the claims that attention increases to relevant stimuli. However the findings of Experiment 4 pose a problem for Mackintosh's theory. Initial discrimination training was given with the stimuli A+, B+, C- and D-, which was followed by a test discrimination of the form AC+/BC-/AD-. When the different stimuli for the test discriminations were not presented in separate circles but inter-mixed so that both circles contained stripes of the two colours, both components were acquired at the same rate. Conversely, when the test stimuli were presented in the conventional manner with each circle containing a single colour, the AC+/BC- component was learnt about significantly more quickly than the AC+/AD- component. If changes in attention, as envisaged by Mackintosh were responsible for the similar rate of acquisition seen in the superimposed group, then a similar pattern of results should have been seen in the non-superimposed group.

A further problem is posed by Experiment 6; pigeons were initially presented with either A+, B+, C+, D+, E-, F- or A+, B+, E+, F+, C-, D- with all subjects then being presented with a test discrimination of the form AE+/BE-/AF-. The group for which E and F had been previously non-reinforced solved the AE+/BE- more rapidly than the group for which E and F were reinforced. This contradicts the predictions that would be made by Mackintosh (1975a). According to this theory, at the outset of the test phase both groups will pay equal attention to A and B and should thus solve the AE+/BE- discrimination at the same rate. It could be argued that as a result of

training, attention to E and F was high in the group for which they had been previously reinforced. It could then follow that attention paid to E and F during the test phase distracted from learning about A and B. However, Mackintosh stated that attention to one stimulus was not at the cost of attention to other stimuli so it would perhaps be expected form Mackintosh's theory that as attention to A, B, E and F would be high in this group at the start of the test phase, they would easily be able to learn about the significance of A and B. It might now be argued that because of its high associability, the presence of E in the AE+ BE- discrimination will allow this stimulus to gain considerable associative strength on the reinforced trials and thus enhance responding on the non-reinforced trials and disrupt the development of the discrimination. Unfortunately, Mackintosh does not provide a formal account of how an AE+ BE- discrimination will be solved, and it is thus difficult to derive precise predictions from the theory concerning the way in which changes in attention to E will influence the solution of the AE+ BE- discrimination. One might argue, for example, that if E has high associative strength then this will facilitate the acquisition of inhibition by B during BE- trials and thereby facilitate the AE+ BE- discrimination.

So it would seem that while some experiments provide clear support for Mackintosh (1975a), other clearly present a problem. From Experiment 3 onwards it became apparent that perhaps a factor other than attention was playing a role in the amount of learning about a stimulus. It was instead suggested that the amount a pigeon pecks at a stimulus determines the amount it learns about that stimulus. If the assumption is made that a pigeon can only look at a stimulus it is pecking at, then it follows that learning can only occur about stimuli a pigeon is pecking at. The easiest demonstration of findings to support this claim comes from Experiment 4. The design which inter-mixed test stimuli, in such a way as to make it unlikely a pigeon is able to

look only at one part of the compound stimulus resulted in both components of the discrimination being acquired at the same rate. Perhaps therefore, any Mackintosh (1975a) changes in attention were masked by changes determined by the rate of pecking at a stimulus.

Experiment 8 lends weight to this proposal; initial training either of the type AW+ CW- for Group Irrelevant or AW+ AY- for Group Relevant was followed by the test discrimination DZ+/DY-, for both groups. This ensured at the outset of the test phase, responding to all stimuli was low by merit either of their previous non-reinforcement or irrelevance. Under these circumstances a Mackintosh (1975a) effect was observed whereby the test discrimination was acquired more readily by the group for which Y and Z had previously signalled the absence of food. This would suggest that Mackintosh like attentional changes may occur but can be masked by the amount of pecking a stimulus receives.

Pearce and Hall (1980)

Overall, the experiments presented here provide very little support for the Pearce and Hall (1980) theory. Perhaps some support could be offered from the findings of Experiment 4 as the pattern of acquisition found in the group exposed to superimposed stimuli is in line with predict predictions made by the theory; following training with stimuli A+, B+, C- and D-, according to Pearce and Hall, attention will be low to all stimuli at the start of Stage 2 as all have been proven to be good predictors of outcome. Accordingly, acquisition of the two components of the test discriminations will be learnt at a similar rate. The difference in the acquisition between this group and the group for which test compounds were presented separately can still be explained by way of the amount of pecking a stimulus receiving dictating

135

the learning which takes place. While superficially this experiments fits neatly with the predictions made by Pearce and Hall, there is a caveat; as stated, attention to all stimuli at the start of Stage 2 will be low thus it would be expected that learning about both components of the test discrimination will be slow. This was not shown to be the case, learning about both components proceeded rapidly through the test phase.

Furthermore, little support can be gleaned from the findings of the other experiments. For example in Experiment 1, if it is assumed that the responding at the end of Stage 1 was at asymptote, the theory wrongly predicts that both the AZ+/BZ- and the AZ+/AY- discriminations would be learnt at the same rate. During training, pigeons learnt the significance of all compounds resulting in, according to Pearce and Hall (1980), attention to all stimuli being low at the start of Stage 2. It follows that both components of the test discrimination would be learnt about equally which was not observed. Instead there was evidence to suggest greater attention paid to previously relevant stimuli than to previously irrelevant stimuli.

In Experiment 5, Pearce and Hall (1980) would predict acquisition of the test discrimination based upon previously partially reinforced stimuli to be acquired more rapidly than the discrimination based upon previously continuously reinforced stimuli. During Stage 1, subjects were given the discrimination A+, B+, C+/- and D+/-. It would be expected that attention would eventually decline to A and B given their reliability in predicting food. Conversely attention to C and D would remain high throughout given their inability to predict the outcome. It would then follow that during Stage 2, the AX+/AY- discrimination would be solved more rapidly than the AX+/BX- discrimination. This prediction was found to be unsubstantiated with both components being solved at an equal rate.

However, it may be possible that some of the Experiments reported can be explained by Pearce and Hall (1980) if it is assumed that responding had not reached asymptote at the end of Stage 1. During the early trials of an AX+ BX-discrimination, A will be a consistently poor predictor of the food that follows it, X will also be a poor predictor of food but it will also be a reasonably accurate predictor for the absence of food, while B will be reasonably accurate predictor of food. Given these relationships, the theory then predicts that attention to A will be greater than to X which will be greater than to B (LePelley, personal communication). This would enable the theory to be used to explain the findings of Experiments 1 and 2. In the test discrimination, AZ+/BZ-/AY-, A and B were previously reinforced thus, assuming asymptote had not been reached, would continue to receive the most attention at the start of Stage 2. Conversely, Z and Y were previously irrelevant and so will receive less attention if asymptote had not been reached previously. With these assumptions in place it follows that the AZ+/BZ-component, based upon previously relevant stimuli be solved more rapidly than the AZ+/AY- component which is based upon previously irrelevant stimuli.

Experiment 8, however, poses a substantial problem to this claim given that evidence was presented to suggest that greater attention is paid to non-reinforced stimuli than to irrelevant stimuli. Whether asymptote had been achieved by the end of Stage 1 or not, the Pearce and Hall (1980) theory would not predict that a discrimination based upon previously non-reinforced stimuli would be learnt about more rapidly than a discrimination based upon previously irrelevant stimuli. It would seem despite the proposal that asymptote had not been reached by the end of Stage 1 little support can be provided for the Pearce & Hall theory from the experiments reported here.

Esber and Haselgrove (2011)

A recent theory proposed by Esber and Haselgrove (2011) is in keeping with a Mackintosh (1975a) view that the overall associative strength of a CS determines the overall attention paid to it. Additionally it aims to reconcile the major difference between the Pearce and Hall (1980) theory and the Mackintosh (1975a) theory; whether reliable or unreliable predictors will be afforded more attention. To explain the finding that more attention is paid to stimuli that are partially rather than continuously reinforced (e.g. Pearce, Kaye, & Hall, 1982; Swan & Pearce, 1988; Haselgrove, Esber, Pearce, & Jones, 2010), they argued that the former enters into two associations - one with food and one with no food (see Pearce and Hall, 1980) - while the latter enters into only a single association. The overall associative strength of a stimulus was then said to be determined by the sum of the absolute values of all its associations. Given sufficient training, it then follows that a partially reinforced stimulus will have more associative strength than one that is continuously reinforced, and will thus be paid more attention. Finally, the theory uses a version of the Rescorla-Wagner (1972) rule to determine changes in associative strength.

This theory is able to explain a number of my findings. In the case of Experiment 1, for example, an AX+ CX- discrimination is predicted by the theory to leave A with considerably more associative strength than X. As a result of this difference in associative strength, the associability of A is then predicted to be greater than of X. During the test discrimination of this experiment, AZ+ AY- BZ-, it would then follow pigeons will find it easier to solve the AZ+ BZ- discrimination, for which A and B were previously relevant, than the AZ+ AY- discrimination, for which Y and Z were previously irrelevant. In a similar way, the theory is also able to explain

138

the results of Experiment 2, which was of similar design to Experiment 1. Turning

now to Experiment 3, in which Group Pre-exposed first received A+ B+ C- D- trials,

and Group Novel first received A+ B+ E- F- trials, the test stage revealed that both

groups performed similarly and acquired the AC+ BC- component of the AC+ BC-

AD- discrimination more rapidly than the AC+ AD- component. Despite the different

treatments with C and D during Stage 1 of the experiment, these stimuli can be

expected to be of similar low associative strength at the outset of the test stage for the

two groups. It then follows from Esber and Haselgrove (2011) that the associability

of A and B at the start of the test stage will be greater than of C and D and thus be

responsible for the pattern of results that was observed.

      The results from Experiment 4 are not so easy to explain with the theory of

Esber and Haselgrove (2011). The design of this experiment was the same as for

Experiment 3, except that the pairs of stimuli were combined to create a single cue for

the test trials in Group Combined. Although it follows from the theory that this

manipulation should not affect the outcome of the test stage, it resulted in both

components of the test discrimination being acquired rapidly, and at the same rate.

      A further result that poses a problem for the theory of Esber and Haselgrove

(2011) can be found in my final experiment. Here, as previously stated, evidence was

found for greater attention being paid to a previously non-reinforced stimulus than to

one that was previously irrelevant, after training with an AX+ BX- discrimination. .

According to Esber and Haselgrove, the net excitatory strength of X will be of

equivalent absolute magnitude to the inhibitory strength of B. However, because X

will have been intermittently paired with food it will enter into both excitatory and

inhibitory associations, the combined influence of which will be to result in the

overall associative strength of X being greater than of B. It then follows that the

conditionability of X will be greater than of B whereas the test phase of the final experiment revealed the opposite outcome. Once again, a single theory is unable to account for all the findings documented here.

Rescorla (2001)

Finally, we need to consider if the results in my thesis have anything at all to do with changes in attention. The proposals of Rescorla (2001) offer an alternative and can be appreciated once an experiment of his has been described. Subjects were exposed to two reinforced stimuli, A and C. They then received reinforced trials with the compound AB, with B being a novel stimulus and counterbalanced with another novel stimulus, D. This procedure meant that in a subsequent test phase, in which all animals received exposure to the compounds AD and BC, the relative changes in associative strength to A and B that resulted from the reinforced trials with AB could be assessed. Greater responding to AD than BC would indicate that A had acquired more associative strength than C, whereas the opposite outcome would indicate that C had acquire more associative strength than A. Rescorla found that a greater increase in associative strength was found to have taken place to the novel stimulus, C, than had taken place to the reinforced stimulus, A. A further manipulation led to the additional finding that non-reinforcement of the test compound led to a greater loss in associative strength of the previously reinforced stimulus, A, than to the novel stimulus, C. On the basis of these findings, Rescorla proposed that the distance a stimulus' associative strength is from asymptote will affect the amount of learning that takes place about that stimulus when in compound. More specifically, the further away from asymptote a stimulus is the more readily it will be learnt about when in compound.

140

This proposal is able to explain many of the results reported in my thesis. Suppose that animals are given an AX+/BX-/AY- discrimination for which A and B were previously relevant, and X and Y were irrelevant, by virtue of being used previously for an AX+/CX- and a BY+/CY- discrimination. This training is similar to that used for Experiments 1 and 2. During the non-reinforced trials with BX and AY it follows from the proposals of Rescorla that B will lose associative strength more rapidly than Y, which means that responding will fall of more rapidly to BX than AY, which was the result I found. A similar analysis can be applied to many of my experiments. To take one further example, consider Experiment 8. At the start of the test phase, for Group Relevant, Z would have a very low associative strength due to its continuous non-reinforcement during Stage 1. Conversely for Group Irrelevant, Z was partially reinforced throughout Stage 1, thus at the start of the test phase its associative strength would be greater than for Group Relevant. Accordingly, the associative strength of Z should increase more rapidly during the reinforced trials with DZ in Group Relevant than Group Irrelevant and result in excitatory conditioning with the compound also taking place more rapidly.

It would seem, therefore, that the proposals of Rescorla (2001) can explain many of my findings. One result that does not appear to fit with his proposals was revealed in Experiment 6. The AX+ BX- component of a test discrimination, for which A and B had previously signalled food, was acquired more rapidly when X was of low rather than high associative strength. Since the acquisition of this discrimination depends upon changes in the associative strength of A and B, which were of the same value in both groups, some factor other than that put forward by Rescorla must have been responsible for the outcome that was found.

Another problem posed by the present results for the views of Rescorla (2001) can be found in Experiment 4. Pigeons received during the test stage an AX+/BX-/AY- discrimination in which A and B had previously signalled food, and X and Y had signalled nothing. In keeping with the proposals of Rescorla, the AX+/BX- discrimination was acquired more readily than the AX+/AY- when the stimuli were presented as adjacent circles. However, when the stimuli during the test phase were superimposed on each other then the two discriminations were both acquired at the same, relatively rapid rate. According to the proposals of Rescorla, the same result should have been seen in both conditions.

The merits of the proposals of Rescorla (2001) are also called into question by an experiment reported by Dopson et al (2010b) which is similar in design to Experiment 8 above. Two groups received the same training as the groups in Stage 1 of Experiment 8. This was followed by the discrimination CY+/CZ-/DY- during the test stage; all three compounds had been non-reinforced during Stage 1. In essence, the experiment revealed that the CY+/CZ- discrimination was acquired more readily when Y and Z had previously been relevant by signalling the absence of food, than when they had been irrelevant. On this occasion the associative strength of Z for the CZ- trials was more distant from the asymptote for non-reinforcement when it had previously been irrelevant rather than relevant. It then follows from the proposals of Rescorla that the associative strength of Z should have declined more rapidly when it had previously been relevant rather than irrelevant. As a result, the CY+/CZ- discrimination should then have been acquired more readily when Z had previously been irrelevant, whereas the opposite was found.

Overall, therefore, it would seem that it is not possible to base a complete explanation for my results, and those from related studies (e.g. Dopson et al., 2010a, b) by appealing to the findings and theoretical proposals of Rescorla (2001).

Future Research

As discussed throughout, the major limitation of the design used in the experiments described here is that the rate of pecking at the screen may have influenced the amount of attention paid to a stimulus, and thus made it difficult to test the theoretical predictions. Firstly it would be sensible to attempt to ascertain whether, during testing, pigeons do orientate their peck towards one half of a compound stimulus. This could be achieved by filming subjects during an experiment and if this is found to occur then it would certainly add weight to the argument that the rate of pecking at a stimulus influences the attention paid to it. Secondly a reworking of the experimental design used is needed, in order to prevent such a problem from occurring. This could be achieved by changing the stimuli used. If pigeons are first trained to peck a white circle on the screen to get food, stimuli such as tones, clickers and diffuse coloured lighting in the ceiling of the test box could be used in a typical AX+/BX- discrimination. This would prevent the pigeon from pecking towards a relevant stimulus and would thus enable the same experiments to be used to determine whether attention is greater to relevant than irrelevant stimuli.

Final comment

The methodology devised by Dopson et al (2010a) seemed to offer a chance to revisit and gain answers to some fundamental yet unresolved questions concerning the role of selective attention in learning. From the findings presented here it appears,

frustratingly, that attentional changes were consistently masked by the amount of time a pigeon spent pecking at a stimulus. The only experiment in which this factor was excluded was the final experiment. From these findings it seems attentional changes as envisaged by Mackintosh (1975a) may occur, but will only become apparent when the overriding effect of the amount of pecking is reduced.

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