GENERALISATION GRADIENTS AS A
MEASURE OF STIMULUS CONTROL
IN TWO-COMPONENT CHAINED SCHEDULES.

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ABSTRACT

The present thesis reports a number of experiments which measured the control each discriminative stimulus has on responding in a two-component chained schedule of reinforcement. In all experiments, generalisation gradients were utilised as the measure of stimulus-control in chained schedules. It was argued that generalisation gradients are a more sensitive measure than response rates in discrimination training, as each component stimulus may exert a different type of control on responding. Three indices of generalisation were derived: peak shift, generalisation index and asymmetry score. The asymmetry score was found to give more information on the generalisation gradient than the other two indices.

Variables which have been shown to be important in two-component chained schedules and in stimulus-control research, were evaluated. These were whether the stimulus used in preliminary training was made the initial or terminal component stimulus in discrimination training (Experiment 1), the component duration ratio (CDR) and interreinforcement interval (IRI) (Experiment 2), the training stimulus spacing along the test dimension (Experiment 3), the stimulus and response location (Experiment 4), interdimensional discrimination training (Experiments 5 and 6), and extended training (Experiment 7).

The results showed that the type of control the initial component stimulus has on responding is different from that of the terminal component stimulus. Generalisation gradients were a more informative measure of this difference than simple response rates within the chain. The gradients obtained following intradimensional discrimination training showed that the type of control was affected by the CDR, IRI and stimulus and response location. Interdimensional discrimination training also revealed gradients which indicated the difference in type of control the initial, compared to the terminal component stimulus, has on responding. The results were discussed in terms of the gradient interaction theory, conditioned reinforcement and the "aversiveness" of the initial component. Some implications for token economies were also presented.

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INTRODUCTION

Chained sequences of human and animal behaviour are of fundamental importance, as behaviour in the natural environment is often comprised of linked sequences of behaviour which are maintained by a discreet "reinforcing" event. In particular, the study of chained human behaviour has directed considerable research into evaluation of the properties of the "reinforcing" effect of stimuli which are able to maintain long behavioural sequences without the primary "reinforcing" event occurring until the end of the sequence. For example, the development of token economies has directly benefited from the study of chained behaviour as they employ the concept of conditioned reinforcement to explain the maintenance of chains of behaviour with the use of tokens, prior to the behaviour which produces primary reinforcement (Kazdin, 1982).

The development of token economies has originated as the result of the study of animal behaviour and has provided a useful, albeit not infallible, tool for the clinician in the design of behaviour management programmes. While token economies are an established strategy in behaviour management programmes, some programmes do not achieve the desired results, and some individuals just do not perform on a token economy programme. To find the cause of these undesirable results often requires investigation which is impossible to carry out with human subjects or within the environmental setting (for example, because of ethical or clinical restraints, or simply because of a lack of staff to run the programme), hence, further research is needed into the variables influencing chained behaviour. Specifically, greater attention must be paid to utilising a measure which is sensitive to subtle interactive effects of these variables and which provides more information about chained behaviour, than the simple response rate measures commonly used.

Traditionally, animal research has attempted to evaluate variables which are important in the acquisition and maintenance of response rate in chained schedules of reinforcement, by utilising response rate in the terminal component relative to the initial component as a measure of the strength or value of the reinforcing properties of the stimulus associated with the terminal component (Gollub, 1977). More recently, a number of different techniques have been employed to investigate the role of component stimuli in chained schedules, for example, tandem schedules as a comparison schedule, (Malagodi, DeWeese and Johnston, 1973); varying the order of component stimuli, (Gollub, 1977). These techniques indicate that the component stimuli exert some sort of control over responding, but they are often not sensitive enough to indicate the type of control exerted by the component stimuli (i.e. "excitatory" or "inhibitory"). Thomas (1966) used the avoidance paradigm in order to investigate the type of control exerted by the component stimuli and revealed that the initial component was avoided, and therefore by implication, was "aversive".

One technique which has been used in an attempt to overcome some of the ambiguities of the more indirect measures, is the use of generalisation or stimulus-control gradients (see Purtle, 1974; Rilling, 1977). This technique has been widely used in multiple and concurrent schedules, and has isolated the nature of the control (i.e. "excitatory" or "inhibitory") under certain stimulus conditions. Within this thesis this technique will be used to evaluate the nature of stimulus control in chained schedules as it will be argued that generalisation gradients are a more sensitive measure of stimulus control. An attempt will be made to evaluate a number of important variables which affect stimulus control in chained schedules. It will also be argued that because stimuli may exert different types of control over responding and that generalisation tests allow the measure of the different types of control exerted by individual stimuli, then the particular type of control a component stimulus has over responding can be isolated. A major aim of this thesis was to evaluate variables affecting generalisation gradients in chained schedules. It is expected that the component stimuli may produce different effects on generalisation gradients, given different training conditions, and that these effects may parallel those found under similar training conditions in multiple and concurrent schedules. In addition, because there are a number of different important features of generalisation gradients (area under the gradient, height of the gradient), it is suggested that the use of different measures or indices obtained from generalisation test data will give a direct measure of the effect of the variables and are more likely to give a reliable account of the mechanisms mediating chained behaviour.

The variables that will be specifically evaluated include the prior experimental history of the animal (see Experiments 1 and 7), the interreinforcement interval (IRI) (see Experiments 2 and 3), the component duration ratio (CDR) (see Experiments 2 and 3), the spacing between the training stimuli along the test dimension (see Experiment 3), the location of the training stimuli (see Experiment 4), and different training procedures (see Experiments 5 and 6). The present experimental work explored each of these variables in chained schedules of reinforcement.

1.1 CHAINED SCHEDULES.

In the analysis of behaviour, the relationship between an organism's environment and its behaviour are studied by manipulating environmental stimuli and observing the subsequent changes in the animal's response. While stimuli can be presented independently of responding, however, a much more important type of manipulation for the study of a wide range of behavioural processes is the consequential operation ($R:S^{c}$), which arranges some contingency between a response (R) and a consequential stimulus (S^{c}) (Catania, 1979).

In a behavioural sequence where S^{c} follows the response and there is an increase in responding, then the S^{c} is called a reinforcing stimulus (S^{c}) or simply a reinforcer, and the operation is called reinforcement. While reinforcers may follow every response they are typically arranged to follow only some responses according to a predetermined "schedule of reinforcement". Two major types of schedules of reinforcement are the ratio schedule, where the reinforcer follows a particular number of responses, and the interval schedule, where the reinforcer follows the first response occurring after a particular time period has lapsed. A major subdivision within each of these schedules is whether the particular number or particular time is constant from one reinforcer to the next (fixed ratio, FR; and the fixed interval, FI; respectively), or whether it varies from one reinforcer to the next (variable ratio, VR; and variable interval, VI; respectively). For example, in a VI schedule, a reinforcer follows the first response made after varying periods of time but with these periods having a specified average. This produces a relatively constant rate of reinforcement (i.e. reinforcer delivery) over a substantial range of possible response rates. As VI reinforcement produces a relatively constant response rate, and because it is able to demonstrate the relative independence of reinforcement rate from response rate, it has been used frequently as a baseline schedule from which to compare the effect on responding of subsequent independent variable manipulations.

Reinforcement, however, does not occur independently of other events in the environment, as often a particular consequence will follow a response only in some situations and not in others. Hence, an important extension to the consequential operation is the stimulus-control operation expressed as a three-term relationship, S^D ($R:S^C$). This specifies that in the presence of a particular environmental event, the discriminative stimulus (S^D) is associated with the consequential operation ($R:S^C$) in effect. In the presence of other S^Ds the specified consequential operation may not be operational, although some other may be. In this stimulus control operation, a contingency (i.e. the likelihood of one event may be affected or caused by other events) is said to exist between the three terms S^D, R and S^C (Skinner, 1938).

Although individual schedules of reinforcement are of fundamental interest, more complex behavioural processes can be studied by combining them in various ways to produce compound schedules of reinforcement. Compound schedules are formed from various combinations of the basic schedules and they are often more typical of how behaviour is maintained. Compound schedules can vary in the individual schedules that operate in each component and whether these component schedules operate simultaneously or successively. They can also vary in how changes between components are arranged, and whether there is a different S^D associated with each component (Catania, 1984).

The results presented in this thesis are restricted to the evaluation of a two-component chained schedule of reinforcement, because of its importance in the study of the token economy paradigm and sequential behaviour. In this schedule, the initial component is presented correlated with a distinctive S^D, the S_2. The only consequence of responding in this component is the production of the second S^D, the S_1. The consequence of responding in the terminal component (S_1) is the presentation of a reinforcer followed by the start of the chain again and the presentation of the initial component (S_2). Responding in individual components of chained schedules is determined by two variables: the component schedule and the temporal location of the component with respect to the primary reinforcement (Gollub, 1977). A schematic diagram of a two-component chain is presented in Figure 1.

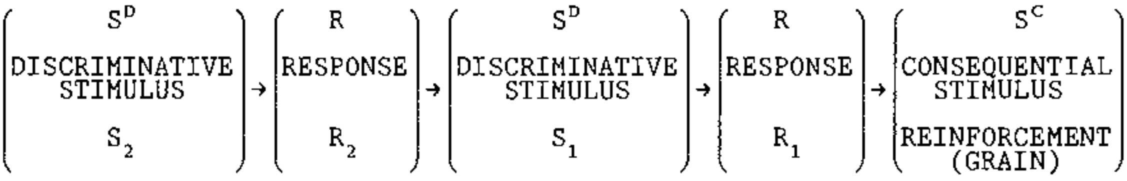


FIGURE 1 SCHEMATIC DIAGRAM OF A TWO-COMPONENT CHAINED SCHEDULE OF REINFORCEMENT.

Various techniques for investigating chained schedules include the study of changes in performance under chained schedules; the study of response patterns determined by the component schedules in chained schedules; the study of the choice between chained schedules (i.e. segmented schedules) and simple or less-segmented (i.e. less components) using the concurrent chains paradigm; and the analysis of the behavioural functions of the component stimuli of chained schedules. These techniques and their subsequent findings are discussed in the following sections.

1.1.1 Changes in performance under chained schedules

Changes in performance under chained schedules seem to depend on both the reinforcement history of the organism and the number of components in the chained schedule. In brief, when the stimulus presented in the initial component of the chained schedule had previously accompanied extinction (on multiple schedule), response rates increased under the chained schedule, however, when responses in the initial component had previously produced food, responding decreased under the chained schedule (Ferster and Skinner, 1957). Experiment 1 investigated this prior history effect by making the stimulus used in preliminary, single-stimulus training, the stimulus associated with the initial (S_2) component of the chained schedule in discrimination training. Responding in the presence of S_2 had previously been reinforced with food, whereas in discrimination training, responding in S_2 was never reinforced with food but with a stimulus change. This could be likened to extinction, although primary reinforcement does occur later, for responding to a different stimulus.

The effect of the number of components has typically been studied by examining responding under chained and comparable tandem schedules, although results do vary across studies. In a tandem schedule, successive completion of two or more component schedules is required before primary reinforcement, but a single stimulus accompanies all components (i.e. no stimulus change). Gollub (1958) found an initial decrease followed by an increase in initial component responding on a two-component chain compared to a tandem, however, Kelleher and Fry (1962) found decreases in response rate in the initial component of a three-component chain compared to a tandem. This suggests that the discriminative effects of the chain stimuli, in that responding is never reinforced with food in the presence of the stimuli (except the terminal component stimulus), are greater than the reinforcing effects of the contingency between responding and the onset of the next stimulus. Token economy programmes where several components are passed through before entering the terminal component, would suffer from very low response rates in the early components and hence, a decrease in the frequency of reinforcement.

Another comparison has been between chained and multiple schedules (i.e. where one component schedule and its associated stimulus alternates with the other component, but the alternation is independant of responding). For instance, a chain FI FI FI and multiple EXT EXT FI, with component durations matched, both involve a sequence of stimuli ending with a reinforcer and differ only in whether stimulus changes are produced by responses. Catania, Yohalem, and Silverman (1980) found that the rates in the next-to-last component are somewhat higher in chained than in equivalent multiple schedules. Hence, the stimulus changes in chained schedules have some reinforcing effects, but they are substantial only in the components close to the primary (food) reinforcer. Again this emphasises that token economy programs can be maximally effective when the chained schedule involves only two components (i.e. two chain stimuli). Furthermore, when the organism must respond to produce the token then the response rate prior to producing the token (and the terminal component) increases, compared to when responding is not required. Hence, the token (S_1) is maximally effective in maintaining behaviour in the component of which the token is the reinforcing stimulus (i.e. S_2) and where responding is required in order to produce the token (i.e. chained schedules). The reinforcer (i.e. food) will, therefore, have its greatest effect on the behaviour that precedes the terminal response and only minimal effect on the behaviour leading up to the production of the discriminative stimulus (S_2) in whose presence behaviour is reinforced with a token.

1.1.2 Component schedule effect

Experiments using chained FI (e.g. Gollub, 1958; Thomas, 1967; Boren and Gollub, 1972) or chained FR (e.g. Findley, 1962) components generally reveal a monotonic increase in reponse rate from beginning to end of the chained sequence. These rate patterns are due to the specific component schedules, as demonstrated by Ferster and Skinner (1957) where a chain FR 95 DRL 6-sec produced a very low response rate in the terminal component, compared to the initial component. The differential reinforcement of low rate (DRL) schedule reinforces a low response rate. Hence, the schedule effects on response rates in the components of a chained schedule are similar to those patterns of responding typically found when presented as a single (simple) schedule of reinforcement (i.e. not as part of a compound schedule). Findley (1962) trained three rats under a chain VI VI schedule, with the initial component constant on a VI 4-min schedule and the terminal component schedule varying from VI 0.5-min to VI 8-min. The response rate in the initial component was an inverse decelerating function of the VI values in the terminal component. In another experiment by Findley (1962), a chain VI FI schedule was used to investigate the effect of the initial component schedule parameter (i.e. the component duration) on responding during the terminal component. The findings were that the schedule in the initial component had a large effect on responding in both the initial and terminal components. The response rate in the initial component was an inverse function of initial component VI values, and response rate in the terminal component was an increasing function of the initial component values. Experiments 2 and 3 of the present thesis also show these effects (see chapters 3 and 4). Another variable which has been investigated is the effect of reinforcer duration on responding in two-component chains (Lendenmann, Myers and Fantino, 1982). It was found that both the initial and terminal component response rates were a linear function of reinforcement duration in chain VI 2-min VI 2-min and chain VI 4-min VI 4-min. Furthermore, the initial component response rate was more sensitive to reinforcer duration than the response rate in the terminal component. Generally, however, published literature on chain VI VI schedules is scarce compared to that on chain FI FI schedules. Hence, our understanding of the chain VI VI schedule is still in its infancy. Furthermore, such experiments as mentioned here only provide information as to the effect on response rates within each component by the component schedule, and not about the nature of the control by the component stimuli associated with those schedules.

The present series of experiments employed a variable interval schedule of reinforcement, because this schedule produces steady sustained responding, as found by Gollub (1958), who compared chained schedules of fixed interval to that of variable interval. Furthermore, most operant research on stimulus generalisation has preferred VI schedules in training as other schedules (e.g. DRL - Hearst, Koresko and Poppen, 1964) are known to produce special effects (i.e. near zero slope) on generalisation gradients (Honig and Urcioli, 1981). Moreover, even though little is known about the effects of different schedules on token economies, reinforcement is seldom dispensed on a FR 1 schedule, as much behaviour goes undetected. Hence, it is worthwhile to consider the effects on behaviour of the intermittent schedules, such as the variable interval, because that probably is a schedule which token economies are actually run on.

1.1.3 Concurrent chains

This procedure was developed by Autor (1969) and can be divided into two parts. In the first (concurrent) part (initial component), two response keys are lit. Equal VI schedules are associated with each key so that a response occasionally produces the second part (terminal component) associated with that key. In the terminal component, the colour of that key changes and the other key is not lit. Responses in the terminal component produce food according to a schedule associated with that key. After food, the concurrently lit keys are again available.

Much research has been carried out into the effects of reinforcement variables on relative measures of responding using this procedure, and, in particular, the study of preference for various chained schedules (e.g. Duncan and Fantino, 1972; Schneider, 1972; Leung, 1985). Responding in the initial components has been interpreted as indicating the preference for or the value of the terminal components (Killeen, 1972). To date, the preference is for a less-segmented (e.g. simple) schedule over a more segmented (e.g. two-component chain) (Duncan and Fantino, 1972; Leung, 1985). In addition, Leung (1985) found that the effect of components of a chained schedule on choice was jointly determined by the component duration ratio (CDR) and the inter-reinforcement interval (IRI). The present study examined these two defining variables of a chained schedule and evaluated their effect on generalisation gradients (see Experiments 2 and 3).

1.1.4 Stimulus functions in chained schedules

There have been several different methods used to study the function or role of the stimuli in chained schedules. Experimenters have used the tandem schedule either as a control or comparison schedule and varied the order of presentation of the initial and terminal component stimuli in chained schedules, and and "clock" schedules. Other methods have been used such as briefly presenting the component stimuli for response-dependent exposures and another has utilised the avoidance paradigm. A more direct measure of the control of stimuli is the use of generalisation gradients. Each of these various methods and the major findings of each, will be discussed below.

a). Tandem schedules: Experimenters have used the tandem schedule as a comparison or control schedule in order to examine the stimulus functions in chained schedules (e.g. Gollub, 1958; Malagodi, De Weese and Johnston, 1973). The comparison, however, has revealed complex and no clear-cut results. The tandem schedule omits stimulus changes but keeps the same schedule contingencies as a chained schedule. Gollub (1977), however, suggests that the tandem schedule may have so-called "time markers" serving the role of a stimulus change, and hence, not be a true comparison schedule for chained schedules.

b). Varying the order of component stimuli: Several experimenters have studied the stimulus functions in chained schedules by varying the order of presentation of the initial and terminal component stimuli in chained schedules. Kelleher and Fry (1962) showed that with continued exposure to a variable order of stimuli the pigeons responded at a more or less constant rate throughout each schedule sequence. Gollub (1977) showed that the chain component stimuli presented out of order (e.g. the terminal component stimulus presented in an earlier component), can increase responding that produces these stimuli, but that these effects may be transient.

c). "Clock" schedules: Another method has been to schedule the sequence of stimuli independent of responding by the use of "clock" schedules. In a clock schedule, a stimulus independent of responding is presented as an indication of where in the schedule the subject is at a particular point of time. Responding under the clock schedule is typically confined to the final (terminal component) stimulus (Tallen and Dinsmoor, 1969), which is not surprising as responding occurs at a very low rate in the presence of stimuli that are never associated with primary reinforcement. In a chain, however, responding in the presence of such stimuli is required for progression through the chain, then response rates increase substantially.

d). Brief stimulus: Briefly presenting the component stimuli for response-dependent exposures has been another technique used, although as Kendall (1972) showed, responses must produce the terminal clock stimulus at least part of the time to be maintained. In summary, there appears a rate-enhancing effect of briefly presenting component stimuli (terminal stimulus better than initial stimulus).

e). Avoidance paradigm: Another indirect demonstration of the control by stimuli in a two-component chained schedule has been shown using the avoidance paradigm. Findley (1962) trained pigeons to respond under a chain FI FR schedule where, once they entered the terminal component, the subjects could avoid returning to the initial component by emitting responses with short interresponse times (e.g. no longer than 6-secs). All subjects responded at a sufficient rate during the terminal component to remain in that component. In a follow-up study, Thomas (1966) programmed an avoidance contingency on one key which postponed the return to the initial component of a chain FI FR programmed on another key. All subjects subsequently learned the avoidance response that prevented the return to the initial component after the terminal component. These experiments support the idea that S_2 has a different effect on behaviour than S_1.

These various techniques have shown that by manipulation of the stimuli in chained schedules various effects in response rates can be produced. Whether responding is enhanced, suppressed, or unchanged in a chained schedule compared to some procedurally related condition, depends on the specific situations compared. What is apparent from the research reviewed thus far, is the need for a direct measure of the control which both the component stimuli have over the pattern of responding found in chained schedules. As Gollub (1977) notes, the strongest stimulus effects that are found in chained schedules are discriminative, and one measure which has often been used to investigate such discriminative effects in multiple and concurrent schedules, is generalisation gradients. Generalisation gradients allow the investigation of what type of control (i.e. excitatory or inhibitory) a component stimulus has over responding in that component. The previous methods so far discussed have revealed that there is a difference in the control by S_2 compared to S_1, but not what this difference is.

The aim of the present thesis was to clarify what type of control the component stimuli exerted over behaviour in a two-component chained schedule. The major defining variables of a chain, the component duration ratio and the interreinforcement interval, were to be examined by observing their effect on generalisation gradients. It is predicted that these variables could influence the shape of the gradient and reveal the type of control obtained under particular values of these variables. The following sections discuss stimulus control and generalisation (stimulus-control) gradients, and review studies which have used generalisation gradients to investigate stimulus control in various schedules, including chained schedules.

1.2 STIMULUS-CONTROL GRADIENTS.

Stimulus control is defined in terms of specific results obtained under controlled test conditions and refers to a correlation between a set of stimulus values and a set of response values. It is a descriptive term and does not have any explanatory or theoretical properties. Generalisation gradients have often been used as indices of stimulus control (Honig and Urcioli, 1981).

If an organism is taught to respond in the presence of a stimulus, then if other stimuli are presented that lie along the same physical dimension as this training stimulus, responding typically occurs to these stimuli also, though they have never been presented previously (i.e.generalisation occurs). Such a presentation of stimuli is called a generalisation test. The probability of responding will vary as the physical difference between the test stimulus and the training stimulus varies. These variations in responding can be plotted over the range of test stimuli within a dimension, giving a generalisation or stimulus-control gradient (Hanson, 1959). Generalisation gradients vary in their area, height, slope, and form, and if obtained under similar test conditions and assessed with the same measure, can be compared on the basis of these four characteristics. The area is defined by the total gradient, whereas height refers simply to the maximum level of responding along the gradient (usually occurring at the training value, S_1). Slope measures the rate of change in response rate or response probability between the points along the gradient, but they are not normally calculated, as the main concern in most studies is the qualitative difference in slope (Honig and Urcioli, 1981). The gradient slope is considered to be the most sensitive index of stimulus control. A gradient with zero slope (i.e.flat or horizontal), indicates the absence of stimulus control by the test dimension, whereas a decremental (inverted "V" shape) or incremental ("V" shape) gradient shows that the stimulus dimension varied during testing controls the rate or probability of response. Gradients often differ in area and slope, therefore, to compare gradients across subjects or groups of subjects, response output is often expressed as a percentage (or proportion) of total test responses, thus producing a relative gradient. The form or shape of the gradient can be either decremental or incremental, and is dependent on various factors, some of which will be outlined in the following sections.

Most experiments investigating stimulus generalisation effects use a generalisation test in which the test stimuli are presented successively, one at a time, and under extinction conditions (Honig and Urcioli, 1981). Other tests have been used to investigate generalisation effects, such as the choice or preference tests, where two or more stimuli are presented simultaneously (Honig, 1962); the resistance-to-reinforcement test, where a standard reinforcement schedule is in effect during presentation of all test stimuli (Hearst, Besley and Farthing, 1970) and the maintained generalisation tests, where testing is carried out during training sessions in which reinforcement is present (Friedman and Guttman, 1965; Blough, 1975). Generalisation tests in the present experiments were presented in extinction, because this method has been extensively utilised in various schedules of reinforcement (Rilling, 1977), including chained schedules (Frieman and Thomas, 1970). A comparison is allowed, therefore, between data obtained in the present thesis with that obtained in other relevant research.

In many studies where stimulus-control gradients have been generated, schedules of positive reinforcement have been used. Different schedules of reinforcement produce characteristically different patterns of responding (Ferster and Skinner, 1957; Schoenfeld, 1970). One stimulus associated with one schedule of reinforcement will control one pattern of responding and other stimuli associated with other schedules of reinforcement control other patterns of responding. Where this occurs, the organism is said to have made a "discrimination", and the procedure under which it occurs is discrimination training. Although a number of studies have investigated the effect of discrimination training using more than two stimuli, the simplest discrimination training procedures, and those most widely studied, have used two stimuli (Rilling, 1977). The stimuli used in discrimination training are called discriminative stimuli (S^D). Usually one discriminative stimulus is presented associated with some schedule of reinforcement that controls a high probability of responding, and another discriminative stimulus is presented either without any associated reinforcement (i.e. it is presented in extinction) or with a schedule of reinforcement that controls a very low probability of responding. In the present study the major focus was on the presentation of two training stimuli (S^Ds), although relevant research with more than two training stimuli will be considered.

Discrimination training procedures can be distinguished in terms of the schedules of reinforcement correlated with the training stimuli. The schedule of reinforcement used most widely in discrimination training is the multiple schedule. In a multiple schedule, one schedule of reinforcement correlated with one stimulus is operative at any one time, and it is alternated with a second independent schedule of reinforcement correlated with the other stimulus. Alternations between the two component schedules are arranged by the experimenter, so that the organism is able to respond to only one stimulus. In a two-component chained schedule, two independent schedules of reinforcement are each correlated with one training stimulus, and are presented in sequence. The initial component is presented with its associated discriminative stimulus (S_2) and upon completion of the schedule, the terminal component (S_1) is presented. Hence, the "reinforcer" delivered in association with responding in the presence of S_2, is access into the terminal component, signalled by the presentation of S_1. The first response after the completion of the terminal component requirement is reinforced with access to grain. Concomittant with delivery of the primary reinforcer is the turning off of the keylight and then S_2 is re-presented and another sequence is commenced. Hence, in contrast to the multiple schedule, there is a contingency between responding and component change.

The two defining characteristics of the chained schedule, therefore, are the component schedule (in the present experiments this is a variable interval schedule), which specifies the length of time or duration of the component, and the interreinforcement interval, which specifies the length of time or duration between reinforcements. The subject experiences these schedule variables in discrimination training and the effect of these variables can be later measured in generalisation tests. Stimulus variables, such as the physical dimension of the training stimulus and the distance between the training stimuli along the test dimension are also variables influencing generalisation gradients. In the next three sections, the effects of several variables on generalisation gradients will be discussed.

1.2.1 Generalisation gradients after single-stimulus training

If an organism is reinforced for responding to a stimulus and then given a generalisation test with stimuli that vary along the same physical dimension, but which are not correlated with any reinforcement, then a decremental generalisation gradient about that stimulus is frequently obtained (Terrace, 1966). A decremental gradient is a gradient in which responding is maximal to the training stimulus, and decreases to other test stimuli in proportion to their distance in the test dimension away from the training stimulus value. However, after single-stimulus training a gradient of zero slope may be obtained, in which no systematic variation in responding occurs with test stimuli variation along the dimension away from the training stimulus (Terrace, 1966). The level of responding to all test stimuli in such gradients is typically high. Other studies have shown that if the training and test stimuli lie along an intensity dimension, then responding may increase as the intensity of the test stimuli increases (Hull, 1949; Blue, 1967), however, Blough (1959) has shown this is not the case. Nevertheless, in the present thesis this possibly confounding variable of "intensity dynamism" was counteracted for by the choice of the training stimuli for each component of the chained schedule (i.e. S_2 was always the "brighter" stimulus).

The various factors which determine the shape of the gradient are not fully understood. The species of organism used is certainly a factor since, in order that a systematic decremental gradient be obtained, an organism must possess the physical capability to detect the different values of the stimuli lying in the generalisation test dimension. Also, some species exhibit marked preferences for certain stimuli, which are determined by hereditory and developmental rather than reinforcement variables. Newman and Benefield (1968) found that pigeons trained to respond to a white vertical line on a green background, produced a flat gradient with variations in the slope of the line if the green background was present, and decremental gradients if the green was absent. The green background may have confounded any control by the line (Mackintosh, 1977). It is possible that when gradients of zero slope are obtained, a generalisation test in which a different aspect of the stimulus is varied might produce a decremental gradient. Decremental gradients are more often obtained following single-stimulus training with certain dimensions (e.g. visual wavelength) than with others (e.g. auditory intensity).

The schedule of reinforcement used during single-stimulus training may also affect the slope of the generalisation gradient. Research on stimulus generalisation has typically involved VI schedules in training and periods of 30 secs or more in testing. Training schedules other than VI, however, are known to produce particular effects on generalisation gradients, suggesting that free-operant responding can be controlled by stimuli other than those presented on the response key (Blough, 1975; Honig and Urcioli, 1981). Relative gradients obtained after differential reinforcement of low rate (DRL) training were less peaked than gradients obtained after VI training (Hearst, Koresko and Poppen, 1964). These authors also showed that long VI schedules (i.e. VI 4-min) produced less peaked relative gradients than the short VI 1-min schedule usually employed in generalisation experiments. Thomas and Switalski (1966) yoked a bird receiving VI training to one receiving VR training, and demonstrated that the generalisation gradients were less peaked for the VR group than the VI group. These data indicate that the slope of a generalisation gradient can be altered by the particular schedule of reinforcement used during training. Honig and Urcioli, (1981) note that the vast majority of generalisation studies use standard VI schedules, and for this reason the present research employed VI schedules found in experiments with generalisation gradients and with chained schedules. The next two sections deal with generalisation gradients found after discrimination training involving two discriminative stimuli.

1.2.2 Generalisation gradients after intradimensional discrimination training

Intradimensional discrimination involves two stimuli, S_2 and S_1, both of which lie on the dimension in which the generalisation test stimuli lie, and therefore, as the test stimuli vary, for example, along the visual intensity dimension, each stimulus will move either closer to or away from S_2 and S_1. It has often been found that generalisation gradients following intradimensional discrimination training have their maximum, not at S_1, but at some stimulus value in the test dimension away from S_1, in a direction away from S_2 (Terrace, 1972). This phenomenon has been called "peak shift" (Hanson, 1959), in that the maximum responding has shifted to a new stimulus, compared to decremental gradients obtained after single-stimulus training where the maximum is to S_1. The term "peak shift" has also been applied to gradients showing maximum responding to a stimulus away from S_1, in a direction away from S_2, but without first showing that the peak occurred to S_1 during a generalisation test given prior to the discrimination training (Terrace, 1966; 1968). Peak shift is a phenomenon indicating an effect on responding to one stimulus by another stimulus along the same dimension. In the following discussion, variables affecting the likelihood of obtaining peak shift are presented, followed by a discussion of what peak shift can reveal about stimulus control in chained schedules.

Peak shift occurs under a wide range of experimental conditions. Although the pigeon is the most commonly used subject, peak shift is not species-specific. Peak shift has been observed with rats (Pierrel and Sherman, 1960), monkeys (McCoy and Lange, 1969), chickens (Rudolph and Honig, 1972), guinea pigs (Thomas and Setzer, 1972), goldfish (Ames and Yarczower, 1965) and humans (Thomas and DeCapito, 1966).

Peak shift has been observed along several dimensions, including wavelength (Hanson, 1959; Thomas, 1962), line tilt (Bloomfield, 1967; Thomas and Lyons, 1968; Wilkie, 1972), visual intensity (Ellis, 1970; Ernst, Engberg and Thomas, 1971; Winton, 1973), auditory frequency (Jenkins and Harrison, 1962; Gerry, 1971), auditory intensity (Pierrel and Sherman, 1960; Thomas and Setzer, 1972), temporal duration (Elsmore, 1971), gravity (McCoy and Lange, 1969), floor tilt (Riccio, Urda and Thomas, 1966), visual flicker rate (Sloane, 1964), auditory-click frequency (Farthing and Hearst, 1972), circle size (Wildemann and Holland, 1973), and weight lift (Mackinnon, 1972). The amount of preliminary training (Taus and Hearst, 1972) and whether preliminary training is single-stimulus or non-differential (i.e. no difference between the conditions associated with the two training stimuli) do not seem to have any effect on peak shift occurrence: nor does whether a houselight illuminates the chamber during training and testing, although it may mask stimulus control (Thomas, Svinicki and Svinicki, 1970; Thomas, Ernst and Andry, 1971).

Intradimensional discrimination training between successively occurring stimuli appears the most important factor in peak shift, although it is not a sufficient condition to produce it. It is following intradimensional discrimination training using multiple schedules that peak shift is most frequently reported (Thomas, 1962; Terrace, 1972; Dukkhayil and Lyons, 1973; Dysart, Marx and McLean, 1974). It has been found after training with concurrent schedules using a change-over key procedure (Winton and Beale, 1971) and with chained schedules (Frieman and Thomas, 1970).

Peak shift has been obtained following training with multiple schedules when S_2 was associated with (1) a zero rate of reinforcement (Dysart, Marx and McLean, 1971), (2) a rate of reinforcement that was lower than that associated with S_1 but greater than zero (Guttman, 1959), provided this produced a reduction in responding to S_2 (i.e. DRL) (Terrace, 1968), (3) a rate of reinforcement that was approximately equal to that associated with S_1, but which was presented according to a schedule that reduced the rate of responding to S_2 (i.e. DRO) (Yarczower, Gollub and Dickson, 1968), or was presented together with a schedule that occasionally delivered shock following responding to S_2 (Terrace, 1968), (4) a duration of reinforcement that was lower than that associated with S_1 (Mariner and Thomas, 1969), (5) a delay of reinforcement that was greater than that associated with S_1 (Wilkie, 1972).

While peak shift is often reported following intradimensional discrimination training on a multiple schedule, a number of studies have shown that it does not invariably follow such training. Peak shift did not occur following intradimensional discrimination training (1) when subjects were trained to discriminate S_1 from an S_2 correlated with extinction, using procedures that produced little or no responding to S_2 (i.e. after "errorless" discrimination training) (Terrace, 1964), unless shock was given in the presence of S_2 (Grusec, 1968), (2) when following training to S_1 alone, an S_2 correlated with extinction was presented without further presentations of S_1 prior to the post-discrimination generalisation test (Honig, Thomas and Guttman, 1959), unless prior to presenting S_2 correlated with extinction, interdimensional discrimination training was given which resulted in increased responding to S_1 (Friedman and Guttman, 1965, (3) when the rate of reinforcement to S_2 exceeded that to S_1 even though a schedule was used that resulted in reduced responding to S_2 (Yarczower, Gollub and Dickson, 1968), (4) on some occasions when similar procedures have produced the effect (e.g. Hearst, 1968; Honig, 1962).

Other variables affecting the production of peak shift are: (1) peak shift may decline after prolonged discrimination training (Terrace, 1966), although Dukkhayil and Lyons (1973) found it in some subjects after seven previous tests and after 108 days of discrimination training; (2) peak shift tends to be greater the closer S_2 and S_1 are to each other along the generalisation test dimension (Thomas, 1962) ; (3) an S-S+ or S_2S_1 stimulus sequence is necessary in discrimination training for peak shift to occur (Ellis, 1970) ; (4) the interval between the completion of discrimination training and the generalisation test that follows it can be important (Thomas and Burr, 1969) showed that if the test was given 24 hours after training greater peak shift was obtained than if the test was given immediately, although if a short period of further training immediately preceded the test, this difference did not occur; (4) Stevenson (1966) found that peak shift could be obtained, even when S_2 and any stimulus in the generalisation test dimension further away from S_1, were not presented during the test.

Hanson (1959) obtained a number of other effects of intradimensional discrimination training. He reported that if the gradient obtained after discrimination training was compared to that obtained prior to discrimination training, the proportion of "area" under the gradient on the side of S_1 away from S_2, had increased. It has been suggested that such an "area shift" (Terrace, 1966), or "distribution shift" (Hearst, 1968; 1969) may be a more sensitive measure of the effect of intradimensional discrimination training than peak shift. Rilling (1977) has suggested that an area shift may simply reflect chance variability or even stimulus preferences. However, where systematic variation occurs and where preferences have been accounted for, then these asymmetrical gradients may still reflect the control of a particular training procedure. Hanson (1959) also found that the amount of shift is inversely related to the difference between S_2 and S_1. A quantitative measure of the percentage of area or distribution has been reported under conditions where the responses made to S_1 are ignored, and the percentages of the rest are calculated for responses occurring to either side of S_1 (Terrace, 1969; Yarczower et.al, 1968; Thomas, 1969; Ellis, 1970; Bushnell and Weiss, 1980). This has been termed the "asymmetry" score (ASYM).

Another effect Hanson (1959) obtained in some subjects was negative peak shift. This occurs when minimum responding is made, not to S_2, but to a stimulus away from S_2 in the generalisation test dimension, in a direction opposite S_1. Guttman (1965) also reported both positive and negative peak shift, while further evidence for the negative peak shift came from Blough (1973, 1975). Nevertheless, negative peak shift has been obtained in some studies in the absence of peak shift (Winton and Beale, 1971). Hence, although it is a phenomenon which may occur it is not a reliable event after conditions which do produce peak shift.

In conclusion, all these various effects have been explored but the question which arises is: whether or not peak shift is an effective indicator of the type of the control by the component stimuli of a chained schedule of reinforcement. The reliability of orderly decremental gradients obtained around an S_1 correlated with a high rate of reinforcement during single-stimulus training or interdimensional discrimination training, and incremental gradients obtained around an S_2 correlated with a low, or zero, rate of reinforcement during interdimensional discrimination training, is of interest. However, in the case of peak shift, maximum responding does not occur to the stimulus which was correlated with a high rate of reinforcement during previous training, but to a stimulus which was never presented previously. Lashley and Wade (1946) interpreted responding during generalisation tests as simply a failure to discriminate, however, the orderly variation in responding typically obtained during the post-discrimination test as the test stimuli are presented, shows that the test stimuli are discriminated by the subject.

The phenomenon of peak shift, therefore, raises questions as to what aspects of the stimuli presented during discrimination training have come to control responding. For instance, is peak shift due to the interaction of individual control by each training stimulus or due to control by some relationship between the training stimuli? What differences in control by the training stimuli are produced when an intradimensional discrimination training procedure produces peak shift compared with one which does not produce peak shift? Does peak shift following intradimensional discrimination training in which responding is maintained by a chained schedule of reinforcement, mean that there exists an essential similarity in the control over responding shown by a two-component chained schedule compared to an equivalent multiple schedule (i.e. chain VI 1-min VI 1-min compared to multiple Ext VI 1-min), or can the presence of peak shift be explained in terms of the features of the experimental procedures used, other than the schedule of reinforcement? A discussion of explanations of peak shift and other phenomenon found in generalisation gradients is presented in section 1.3. Nevertheless, because peak shift is a general effect of intradimensional discrimination training and not simply an effect of training with stimuli from a particular physical dimension, it can provide a fairly clearly defined measure of the effects of various discrimination training procedures.

In the present thesis, peak shift was utilised to measure: (1) the effect of prior experimental history and the interpolation of blackout between the initial and terminal components (Experiment 1); (2) the effect of variations in the component duration ratio and interreinforcement interval (Experiments 2 and 3); (3) the spacing of training stimuli along the test dimension (Experiment 3); (4) the location of the training stimuli on different keys (Experiment 4); and (5) the effect of extended and subsequent training (Experiment 7).

1.2.3 Generalisation gradients after interdimensional discrimination training

Interdimensional discrimination training involves training with two training stimuli that lie on different or independent dimensions (Switalski, Lyons and Thomas, 1966). The criterion for the psychological independence of two stimuli has been that the stimuli are proven functionally independent, for example, if wavelength and line orientation are independent dimensions, then variations of the line orientation during a stimulus generalisation test would result in a gradient of zero slope had the training prior to the test been to a stimulus along the wavelength dimension. Rilling (1977) suggests that functional independence is an ideal state unlikely to be obtainable, and so encourages the experimenter to determine the organism's preference for certain stimuli and take this response bias into consideration when selecting the most appropriate stimuli for interdimensional training. The research to be reported in the present study used stimuli that had already been shown in previous research to produce clear generalisation gradients (Winton, 1973). Interdimensional discrimination procedures have some clear advantages over other procedures used to investigate stimulus control. The method does not require the experimenter to rely on a single episode of continuous extinction in order to obtain a generalisation gradient, as did Honig (1961), nor does the experimenter face the problem of getting increasingly narrower gradients when testing with the sort of procedure used by Blough (1975).

If a generalisation test is given with stimuli that lie on a dimension independent of that along which the S_2 lies, then a decremental gradient is usually obtained (Terrace, 1966). Interdimensional discrimination training tends to produce steeper decremental generalisation gradients around S_1 than does single-stimulus training (Terrace, 1966). It may also produce gradients of zero slope (Jenkins and Harrison, 1960; Newman and Benefield, 1968). If a generalisation test is given with stimuli that lie on a dimension independent of that of S_1, then an incremental gradient is frequently obtained (Terrace, 1972). An incremental gradient is one in which responding is minimal to the S_2 training stimulus, and increases to other test stimuli as their distance in the test dimension increases from the training stimulus. Incremental gradients have been obtained when S_2 is correlated with extinction (Honig, Boneau, Burnstein and Pennypacker, 1963; Farthing and Hearst, 1968), or with a lower, but non-zero rate of reinforcement (Weisman, 1969), and when the delay of reinforcement was greater than that associated with S_1 (Richards, 1973). Terrace, (1966, 1972) has shown that gradients of zero slope may be obtained around an S_2 correlated with extinction, if the interdimensional discrimination training involves procedures where few, or no responses are ever made to S_2. The level of responding to all test stimuli in such gradients is near zero. A comparison between the slopes of incremental and decremental gradients following symmetrical training procedures indicates that incremental gradients are flatter than decremental gradients (Honig and Urcioli, 1981). Jenkins (1965) suggests that the increase in "other behaviours" during S_2 reduces the number of responses which constitute the gradient along the S_2 dimension. Consequently, the gradient will be flatter than the decremental, in spite of the symmetrical test procedures. Incremental gradients have been seen as reflecting <u>inhibitory stimulus control</u>, as they are the outcome of inhibition generated by responding without reinforcement (Hearst, 1968) or with a low reinforcement rate compared to responding to the other training stimulus (Weisman, 1969). They are sometimes referred to as <u>inhibitory gradients</u>. In a chained schedule of reinforcement, the initial (S_2) component could be classified in a similar way as those conditions likely to generate inhibition, and hence, inhibitory gradients may be obtained around the S_2 following interdimensional discrimination training. The aim of Experiment 5 was to examine this possibility. The concept of inhibition, however, has theoretical connotations which are not fully understood. Section 1.3 presents a discussion of the theoretical implications or explanations of incremental gradients and peak shift, relating them to chained schedules of reinforcement.

1.3 EXPLANATIONS OF GENERALISATION GRADIENTS.

There are two principal explanations which have been offered for the findings in discrimination training: (1) absolute theory, which explains responding in terms of control by aspects of each training stimulus separately; (2) relational theory, which explains responding in terms of control by some relationship between aspects of the training stimulus.

The absolute view is fundamental to the theories of Spence (1936, 1937) and Terrace (1966, 1968, 1972). Absolute theories suggest that training produces control by a stimulus which will generalise to other similar stimuli, hence, if training is given to two stimuli, then a generalisation gradient around each of the stimuli would be predicted. If intradimensional discrimination training is given, then the resultant generalisation gradient would be predicted from an interaction of the separate gradients around each stimulus. Spence's theory provided predictions largely on the basis of hypothetical generalisation gradients of excitation around S_1 and inhibition around S_2. He suggested that in the course of discrimination training, S_1 (S+) acquires excitatory properties and S_2 (S-) acquires inhibitory properties, and that these properties generalise decrementally to other stimuli along the same dimension, producing a decremental gradient around S_1 and an incremental gradient around S_2. Guttman (1959) hypothesised that S_2 becomes "functionally negative" because of "extinction-like" effects that result from responding to S_2 (i.e. response-rate reduction in S_2).

The absolute viewpoint can be contrasted with that of relational theories which have usually been concerned with which of the two stimuli presented in a choice test, given after intradimensional discrimination training, will be chosen. Learning a successive discrimination has been explained in terms of responding to the relationship between the stimulus presented and the "memory trace" of the other stimulus (e.g. Koffka, 1935; Wertheimer, 1959). Unfortunately, relational theory does not provide an alternative account of peak shift to that of the absolute theory.

Neither absolute nor relational theories adequately handle all the existing data on the effects of intradimensional discrimination training on subsequent tests for generalisation (Riley, 1968). However, in general, absolute theory has probably been more successful. Furthermore, evidence exists to suggest that absolute theory is able to account for the results obtained from generalisation tests given following interdimensional discrimination training (Terrace, 1968, 1972). It should be noted, however, that generalisation tests present only one stimulus at a time, compared to the typical choice test yielding "transposition" (i.e.transfer of a relation learnt to a novel stimulus),hence, whether absolute or relational learning takes place could be a result of the experimental and test procedure used.

A more quantitatively developed viewpoint has been provided in terms of Helson's (1964) adaptation-level theory (James, 1953; Helson and Avant, 1967; Mackinnon, 1972). The theory postulates that during discrimination training, a neutral point or adaptation-level is established, and the subject will approach stimuli lying on one side of this level and avoid stimuli lying on the other side. During generalisation tests, the adaptation - level shifts to the centre of the series of test stimuli (usually located at S_1), and the peak of responding shifts an equal amount in order to maintain the previously established relation between the adaptation level and S_1. However, conflicting results have led Newlin, Rodgers, and Thomas, (1979) to suggest that there may be two different sources of peak shift, one unique to the discrimination learning paradigm, such as those postulated by

Spence, and one which results from adaptation level shifts between training and testing whether they occur in single-stimulus or discrimination training paradigms.

A theoretical issue which arose after the finding that some stimulus dimensions, such as auditory frequency, yielded flatter gradients than others, was that of attentional factors.Attentional factors are concerned with the general effects of discrimination training and have been examined using interdimensional and extradimensional (where training is conducted along a dimension independent to that on which stimulus control is acquired and tested) discrimination training procedures. Two principal theories have been proposed to explain how attentional processes operate. The first maintains that attentional effects reflect a selection among concurrently-available stimuli, which compete for control (Mackintosh, 1977). Such competition could explain the results of interdimensional discrimination training, and in particular, effects such as overshadowing (when the competing stimuli are presented simultaneously with the criterion stimuli [i.e.those that establish control in the course of training] during training), blocking (when the competing stimuli are introduced prior to training), and masking (when the competing stimuli are introduced only during the generalisation test), (see Appendix 2). The second theory maintains that peak shift occurs when there is forgetting of the significant events the stimuli signify, and that the extent of peak shift can be useful as an index of forgetting

Terrace (1968) developed an explanation of peak shift based on absolute theory in which he explained the generalisation gradient obtained following intradimensional discrimination training in terms of the interaction of excitatory dimensional control by S_1 with inhibitory control by S_2. The emphasis was on suppression of responding to S_2 as the important determinant of peak shift (and behavioural contrast [i.e. increase in response rate during S_1 which accompanies a decrease in rate during S_2, in discrimination training] and inhibitory stimulus control), in that the S_2 functions as an "aversive stimulus" which actively inhibits responding to S_2. Terrace considered that this active inhibition developed due to "frustration". This idea is an extension of

Ansel's (1958, 1962) elaboration of Hullian theory (Hull, 1952). Amsel suggested that non-reinforcement is a frustrative event and the inhibitory effects produced by the conditioned aversiveness of S_2, in turn produce such phenomena as peak shift.

Terrace argued that a major cause of frustration was non-reinforced responding, or "errors", which produced different amounts of frustration (and hence, different amounts of active inhibition) in different subjects due to variations in the amount of "frustration tolerance" that individuals possessed. Hence, active inhibition would seem to measure frustration tolerance, rather than frustration itself. Little explanatory value is gained by considering the concept of frustration or aversiveness. Aversiveness is a "hypothetical concept" and has no meaning independent of the defining experimental operations and observed behavioural effects. Although Terrace's notion of active inhibition does account for many results (e.g. no peak shift following errorless discrimination, a decline in peak shift with prolonged discrimination training, the effects of distance between S_2 and S_1 with respect to the generalisation test dimension and delay between training and testing), there are data which create difficulties for Terrace's explanation; for instance, the finding that peak shift is not obtained following a reduction of responding to S_2 if the rate of reinforcement for responding to S_2 is greater than that for responding to S_1.

Bloomfield (1969) has argued that the type of responding that occurred to S_2 would determine the finding of peak shift. The subject would inhibit responding to S_2 where responding in S_1 was reinforced (i.e. S_2 signalled a "change for the worse"). He suggested that if there is no "tendency through generalisation" for the organism to make initial responses to S_2 during discrimination training because it classifies S_2 as being different from S_1, it will not have to inhibit responding to S_2. Clearly, in a chained schedule even though S_2 may be very different from S_1, responding is required in the presence of S_2 for the chain to proceed. The initial component stimulus signals a longer delay to primary reinforcement than S_1, and hence, the S_2 can be considered to signal a change for the worse, therefore, inhibiting responding to a low level relative to S_1. Bloomfield has proposed that reduction in frequency of reinforcement, introduction of shock, and the development of inhibition were all changes for the worse.

If peak shift is somehow determined by the inhibition of responding to S_2, it should occur on those situations in which there is inhibitory control by S_2. The observation of peak shift in analogous situations to where inhibitory control by S_2 is found, supports a correlation between these two phenomena. It should be noted, however, that they are observed in independent experimental procedures, hence, such evidence as there is must be circumstantial. There are instances when inhibitory control occurs without peak shift and vice-versa. Nevin (1969) reported an absence of inhibitory control following training with mult.VI DRO, whereas peak shift does occur after training with the same schedule (Yarczower, Dickson and Gollub, 1966. Terrace's (1966) conclusion that inhibitory control is absent after errorless training was based on his observation of a completely flat gradient along the S_2 dimension. Deutsch (1967) has pointed out, however, that a flat gradient need not necessarily indicate absence of inhibitory control. To the contrary, inhibitory control may be so strong as to inhibit responding at all points along the S_2 dimension.

Amount of training is one of the few variables that has been explored explicitly in relation to its effects on both inhibitory control and peak shift. Although the nature of its influence is not completely clear, it seems that inhibitory control persists with extended training (Farthing and Hearst, 1968; Hearst, 1971), whereas peak shift drops out (Terrace, 1966; Hearst, 1971). However, contrary evidence has been cited by one study which obtained peak shift in some subjects after 108 days of discrimination training (Dukkhayil and Lyons, 1973).

Evidence regarding the relation between peak shift and inhibitory control is, therefore, equivocal. Furthermore, there are problems with the definition of inhibition as suggested by Hearst, Besley and Farthing (1970), in that the incremental gradient may not itself be sufficient evidence to label the control as inhibitory. These authors suggest that an incremental gradient may result from the differential excitatory effects of various dimensional values in relation to a neutral S_2, and therefore, other tests are also needed to show that a specific training stimulus itself was inhibitory. The measure of stimulus duration (Beale and Winton, 1970) and the resistance-to-reinforcement test Hearst et.al, 1970; Zentall, Collins and Hearst, 1971; Karpicke and Hearst, 1975; Rilling, Howard, Caplan and Brown, 1975), are two alternative ways to measure inhibitory control.

In conclusion, explanations of decremental and incremental generalisation gradients are far from being explicit or comprehensive. Much of the theorising has given explanatory power to terms which were initially used simply as descriptive (e.g. "aversive"). This is not to decry the usefulness of looking for explanations, but danger arises when those explanations are used to encompass situations which have not been experimentally examined. The chained schedule of reinforcement has been neglected in generalisation research and yet it has such wide relevance in the applied setting. It was the aim of this thesis, therefore, to provide generalisation test data resulting from a two-component chained schedule of reinforcement in order to add to the knowledge of behaviour patterns resulting from the use of this schedule.

1.4 EXPERIMENTAL STRATEGY

The present thesis employed the small-N experimental design. The design utilises a small number of subjects (usually range from 1 to 6), in each experimental condition, and is the design typically found in experiments using generalisation gradients (e.g. Bushnell and Weiss, 1980; Dysart, Marx and McLean, 1971; Frieman and Thomas, 1970; Hanson, 1959; Terrace, 1968; Winton and Beale, 1971). In fact, most studies in the field of operant research utilise the small-N design.

The experiments reported in this thesis all use this design to explore the potent variables of chained schedules. The design allows individual generalisation gradients, which are sensitive to those variables chosen to manipulate, to be studied. It will be argued that internal consistency of data within groups and consistency between experiments within this thesis and with research using other schedules of reinforcement, would provide the necessary evaluation of this design. Summarised data, in some cases, is presented as well as individual data. Summarised data are only presented where they reflect the individual data and can provide an accurate desciption of any trends in those data. Group means are given. However, they do not often show the sensitivity and selectivity of stimulus control that individual data can show (See Experiment 2).

Chapter 2

EXPERIMENT 1

2.1 INTRODUCTION.

The first purpose of the present experiment was to demonstrate peak shift after intradimensional discrimination training on ch VI 1-min VI 1-min along the visual intensity dimension. Frieman and Thomas (1970) found peak shift after ch VI 1-min VI 1-min discrimination training along the wavelength dimension, however, the visual intensity dimension was chosen in the present experiment because it provided stimuli for an intradimensional discrimination task, while allowing other dimensions, such as wavelength and line-tilt, to be used in an interdimensional discrimination task (see section 1.2.3). Peak shift is considered a robust phenomenon and has been shown to occur following multiple schedule training along the visual intensity dimension (Ellis, 1970; Ernst, Engberg and Thomas, 1971; Winton, 1973), hence, it was predicted that the present experiment would provide an adequate paradigm in which to study peak shift in chained schedules.

A second purpose of the present experiment was to investigate two features of the Frieman and Thomas (1970) study: whether the stimulus used in single-stimulus training was made the subsequent S_2 or S_1 of the chained schedule, and the introduction of a 4-sec blackout between component changes within the chain. These authors had two groups of subjects; one trained with S_1 in preliminary single-stimulus training (group 1) and another trained with S_2 (group 2). Frieman and Thomas found that group 2 produced peak and area shift more often than group 1. Training with S_2 allows the subject experience of responses in the presence of S_2 being reinforced with food, whereas training with S_1 ensures that responding in the presence of S_2 is never reinforced with food. For group 2 subjects, the introduction of the chained schedule in discrimination training, signals a "worsening of conditions" (see section 1.3) which is possibly "worse" than that experienced by group 1 subjects. Perhaps the S_2 is more "aversive" if it has been directly associated with primary reinforcement in the prior history of the subject, as the prior history has been shown in other experiments to affect the probability of obtaining peak shift (Rilling, 1977). The present experiment divided subjects into these two groups to test whether more peak shift is obtained following the S_2 preliminary-trained subjects than the S_1 trained.

Another major feature of the Frieman and Thomas (1970) study was the introduction of a 4-sec blackout of both the keylight and the houselight between S_2 offset and S_1 onset (i.e. between components), similar to that occurring during primary reinforcement. Previous research has shown that the presentation of the brief stimulus which is also present during reinforcement delivery, leads to an increase in response rate (Kelleher, 1966). If the S_2 response rate is raised, then it becomes more like that occurring in the presence of S_1. Wheatley and Thomas (1974) have shown that the probability of obtaining peak shift is lower when there is little difference in response rates in S_2 and S_1 components of a multiple schedule, as indicated by a low discrimination index (i.e. response rate in S_1 divided by the total of response rates in S_2 and S_1). The present experiment, therefore, further divided groups 1 and 2 into a blank key (B) group and a no-blank key (N-B) group. Group B had the 4-sec blackout of the key between both S_2 and S_1 component changes, whereas group N-B only had it when primary reinforcement was delivered and not between S_2 offset and S_1 onset. This was done to test whether there was any effect on the probability of peak shift, by the interpolation of the 4-sec blackout of the key between S_2 offset and S_1 onset.

In summary, the major aim of this experiment was to find peak shift following intradimensional discrimination training along the visual intensity dimension after ch VI 1-min VI 1-min discrimination training. Two variables of the Frieman and Thomas (1970) study were investigated: the stimulus used in single-stimulus training and the 4-sec of blank key between S_2 offset and S_1 onset. The present experiment also served to confirm the occurrence of peak shift and as a basis on which the effects of other variables could be evaluated.

2.2 METHOD.

2.2.1 Subjects

Twelve experimentally naive homing pigeons were maintained at 80% ±15 grams of their free-feeding body weights.

2.2.2 Apparatus

A Grason-Stadler three-key pigeon chamber was used in this experiment. A force of 0.9N (newton) on either of the two outer keys operated a micro-switch behind the key. The centre key was inoperative during all experiments. Side keys could be illuminated by white light produced by a 24 volt, 2.8 watt bulb mounted in a white translucent holder 2.5 cms behind the right key. The electric potential across the bulb could be varied from 12 to 24 volts, in 1.5 volt steps. This provided nine light intensities which ranged in luminance from 0.45 cd/m^2 at 12 volts to 12.98 cd/m^2 at 24 volts (measured with a Tektronix J6523-2, 1 degree narrow angle luminance probe). The nine intensities were readily distinguishable by human observers. Appendix 1 lists the luminance readings for each stimulus, averaged across experiments. Stimuli C and E were S_2 and S_1 respectively. A 1.2 watt houselight was on throughout each experiment.The experiments were controlled by relay circuitry located away from the chamber. The reinforcer was wheat and during reinforcement all response keys were dark and pecks to them had no effect. The houselight remained on.

2.2.3 Procedure

Subject grouping:

The twelve subjects were divided into two groups of six subjects each. For group 1 subjects, the single-stimulus training stimulus was made the stimulus associated with the terminal component (S_1) and for group two subjects, the single-stimulus training stimulus was made the stimulus associated with the initial component (S_2). Each group was further subdivided so that for three subjects in each group the change from the initial component (and S_2) to the terminal component (S_1) was immediate (N-B), while for the other three subjects a four-second blackout of the key intervened (B). During blackout the keys were dark and ineffective but the houselight remained on.

Experimental procedure:

The procedure used by Frieman and Thomas (1970) was followed in the experiment. All subjects were given single-stimulus (i.e. preliminary) training on a variable interval (VI) 2-min schedule of reinforcement for ten sessions. The various interreinforcement intervals which averaged the schedule interval, were derived from progressions which provided approximately constant probabilities of reinforcement (Flesher and Hoffman, 1962), except that, if necessary, the longest interval was increased so that the shortest interval was never less than four seconds in order to allow the mechanical tape timers and programmers to operate. Each subject was given one session of training, of one hour's duration each day. Discrimination training followed, in which each subject was placed on a two-component chained schedule with equal but independent component VI 1-min schedules (chain VI 1-min VI 1-min). The first peck after completing the required time in the initial component (in the presence of S_2) produced the S_1 for group N-B or blackout followed by S_1 for group B and the terminal component (arranged by the other VI 1-min schedule), at the end of which the first peck produced food reinforcement followed by the immediate re-presention of S_2. A session always commenced in the initial component and terminated after one hour's training. Discrimination training was given for five daily 1-hour sessions. In all training sessions the number of responses in each component were recorded and response rates were calculated. In the next session subjects were given a further 30 minutes discrimination training and then a generalisation test. During the test, seven (stimuli B to H in Appendix 1) white light generalisation stimuli were presented in six random sequences. Each of the 42 presentations lasted 60 seconds, and a four-second blackout occurred between presentation for those subjects who had a blackout during discrimination training, so as not to introduce a different and possibly confounding variable. No reinforcement was given during testing, and all changes between test stimuli occurred independently of the subject's responding. The number of responses made to each test stimulus was recorded.

2.3 RESULTS.

During single-stimulus training response rates typically increased during the first few sessions and then remained fairly constant for the remaining sessions. Within the first two sessions of discrimination training, all subjects were discriminating markedly between S_2 and S_1, with response rates in the presence of S_1 always higher than those in the presence of S_2. Table 2.1 presents the average response rates for the last three sessions of discrimination training, (see Wheatley and Thomas, 1974) and average DIs. All subjects show are higher response rate to S_1 than to S_2.

Discrimination indices were calculated over the last three discrimination sessions prior to testing and reveal that all subjects given a blank key within the chained schedule (B) except one, had a lower DI than all subjects given a blank key only at the end of the chain (during reinforcement), (N-B). Those subjects (except one), which had S_1 as the single stimulus in single-stimulus training (group 1), gave similar DIs to those subjects which had S_2 as the single stimulus (group 2) when there was the blank key within the chain. Five of the six B subjects had a DI in the range of 0.66 to 0.69. Comparing between groups for the N-B subjects, however, shows that the group 1 all had a lower DI than group 2 subjects. Analysis of the average response rates show that all group 2 subjects made more responses to S_1 than group 1 subjects. There was not as clear a difference in the responding to S_2.

TABLE 2.1

MEAN RESPONSE RATES IN THE INITIAL (S_2) AND TERMINAL (S_1) COMPONENTS, AND DISCRIMINATION INDICES.

GROUP			AVERAGE RESPONSE RATE		AVERAGE
			S_2	S_1	DI
1	N-B		1.03	2.66	0.76
			0.71	1.86	0.72
			0.33	1.03	0.72
		$\bar{X}$	0.69	1.83	0.73
1	B		1.28	2.47	0.66
			0.62	1.21	0.67
			0.95	2.04	0.68
		$\bar{X}$	0.95	1.91	0.67
2	N-B		0.69	2.61	0.89
			0.48	3.85	0.80
			1.03	4.02	0.78
		$\bar{X}$	0.73	3.49	0.82
2	B		0.29	1.59	0.66
			0.76	1.48	0.69
			1.16	2.52	0.85
		$\bar{X}$	0.74	1.86	0.73

NOTE. 1. MEAN = AVERAGE OF DATA OVER LAST THREE DISCRIMINATION TRAINING SESSIONS PRIOR TO TESTING.

2. MEAN FOR EACH GROUP IS ALSO REPRESENTED ($\bar{X}$)

Stimulus - control gradients were obtained from all subjects during the generalisation test with peak responding occurring to either the S_1 or the stimulus adjacent to the S_1 in the direction opposite S_2 (i.e. peak shift occurred), and responding decreased systematically on either side of the peak. Figure 2.1 presents the mean relative gradients for each group and for N-B and B subjects. Figures 2.4 and 2.5 present the absolute gradients (i.e. actual responses made to each test stimulus). These absolute gradients vary greatly in the mean total number of responses to the test stimuli, and so Figures 2.2 and 2.3 present relative gradients for each subject (as in Hearst, 1968; Tomie, Davitt and Thomas, 1973).

This transformation to relative gradients weights equally the contribution of each subject to the group mean, and it also eliminates variance due to (sometimes extreme) individual differences in absolute level of responding. The total number of responses made during the test did not show any trend across subjects, neither did the percentage of total reponses that were made to S_1.

Peak shift was obtained from one of group 1 subjects and four of group 2 subjects. Of those two group 2 subjects showing peak shift, both had a blank key (B) during discrimination training and generalisation testing. The generalisation index (GI) (i.e responses to the stimulus on the immediate side of S_1 away from S_2 as a proportion of responses to that stimulus and to S_1), for each subject is show in Table 2.2. A GI of 0.5 or higher indicates peak shift.

TABLE 2.2

GENERALISATION INDICES (GI) AND ASYMMETRY SCORES FOR EACH SUBJECT. MEANS OF EACH GROUP ARE PRESENTED.

GROUP		GI	ASYM	% TO SI
1	N-B	0.48	0.34	20.30
		0.49	0.73	32.04
		0.51	0.55	32.58
	$\bar{X}$	0.49	0.54	28.31
1	B	0.46	0.48	38.14
		0.49	0.49	27.36
		0.47	0.44	27.15
	$\bar{X}$	0.47	0.47	30.88
2	N-B	0.51	0.73	29.61
		0.57	0.95	31.39
		0.48	0.85	29.20
	$\bar{X}$	0.52	0.84	30.07
2	B	0.47	0.47	23.89
		0.50	0.87	34.08
		0.57	0.85	27.73
	$\bar{X}$	0.51	0.73	28.57

NOTE. 1. % TO S_1 IS THE PERCENTAGE OF TEST RESPONSES MADE TO S_1.
2. MEAN SCORES FOR EACH GROUP ARE GIVEN ($\bar{X}$)

The generalisation index and peak shift are dichotomous variables which reveal little information on the generalisation test data other that to S_1 and to the stimulus one removed from S_1 in a direction opposite S_2. Table 2.2 presents the generalisation indices of all subjects and reveals that subjects either showed peak shift or did not show it. Obviously a subject with a GI of 0.57 showed greater peak shift than a subject with a GI of 0.50, and similarly a subject with a GI of 0.46 showved no peak shift 'stronger' than a subject with a GI of 0.49. These data, however are limited and the asymmetry score was utilised to give more information on the shape of the generalisation gradient.

Table 2.2 presents the asymmetry scores for each subject. The asymmetry score is calculated by presenting the responses made to stimuli away from S_1 in a direction away from S_2, as a proportion of the total responses made to all stimuli other than S_1, in the generalisation test (Frieman and Thomas, 1970). This score reveals information on the distribution of responses to stimuli on either side of S_1 along the test dimension. An ASYM score of more than 0.50 indicates that the subject made more responses to stimuli on the side of S_1 opposite S_2 and an ASYM score of less than 0.50 indicates more responding to the stimuli on the side of S_1 towards S_2. Typically after non-differential training to S_1, an ASYM score of 0.50 would be expected (equal responding on either side of S_1). It can be seen that high ASYM scores do not always coincide with a GI of 0.50 or higher (see Group 1 N-B subjects). This finding shows that although peak shift was obtained, the gradient then dropped away quickly compared to the gradient on the side of S_1 towards S_2. Where there is a high ASYM score (see Group 2 subjects), the gradient stayed high on the side of S_1 opposite S_2 for both test stimuli.

Group 2 subjects produced the highest ASYM scores (except for one B subject), with only one group 1 subject (N-B) giving an ASYM score near that of group 2 subjects. All B subjects in group 1 gave ASYM scores of less than 0.50 (range 0.44-0.49) and one B subject of group 2 scored 0.47. Although not all B subjects scored lower than N-B subjects, there was a tendency for this to occur, particularly in group 1. This phenomenon can also be seen with the GIs and DIs.

Table 2.2 also presents the number of responses made to S_1 as a percentage of the total responses made in the generalisation test. These data are very similar across all subjects (range 20.30-38.14) and reveal little information other than that the height of the gradient at S_1 is similar across all subjects. It was considered of so little informative value that future experiments would not record these data.

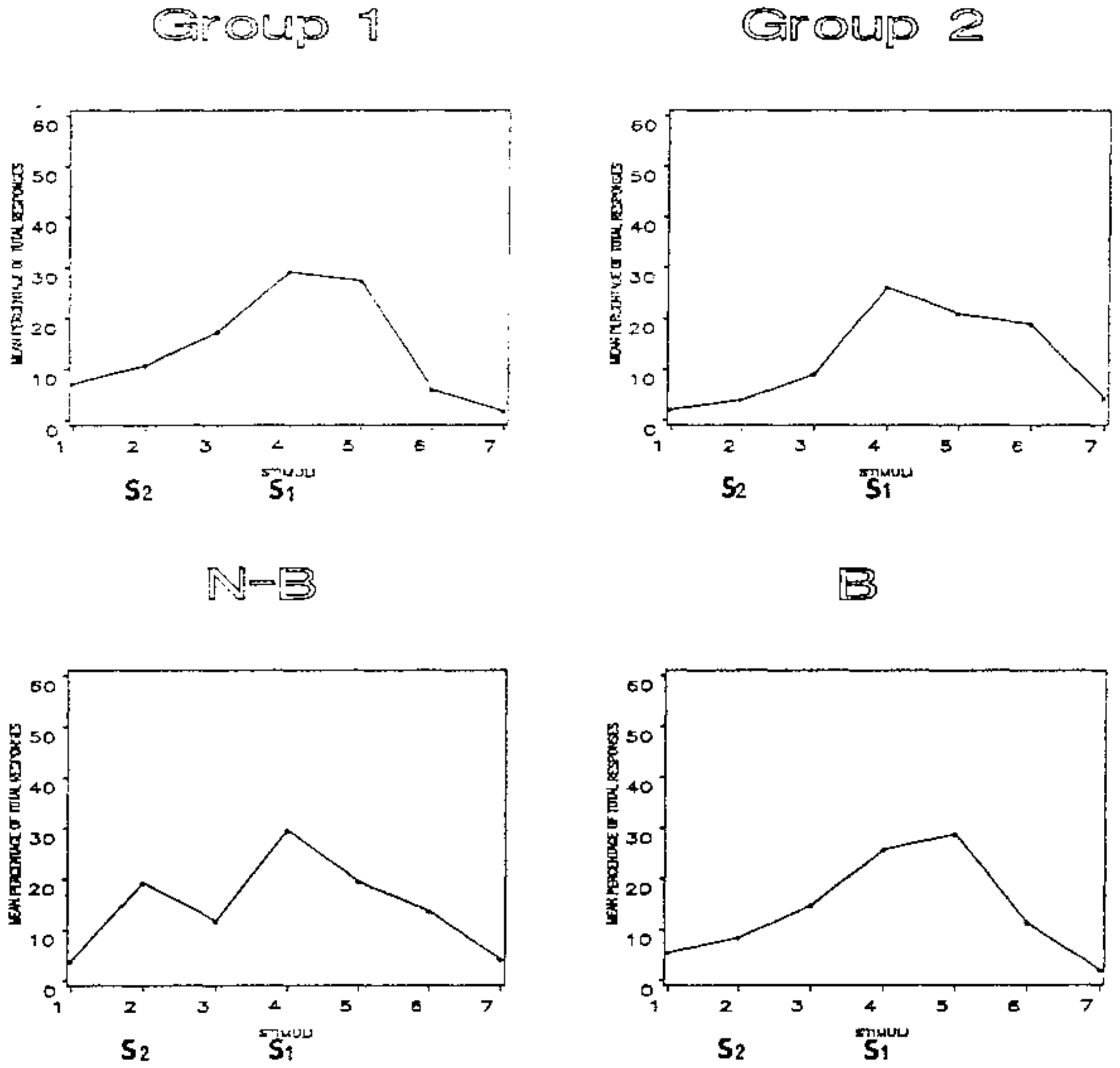


Figure 2.1 Mean relative (% of total responses) gradients for groups 1 and 2, and the no-blackout and blackout subjects (across groups).

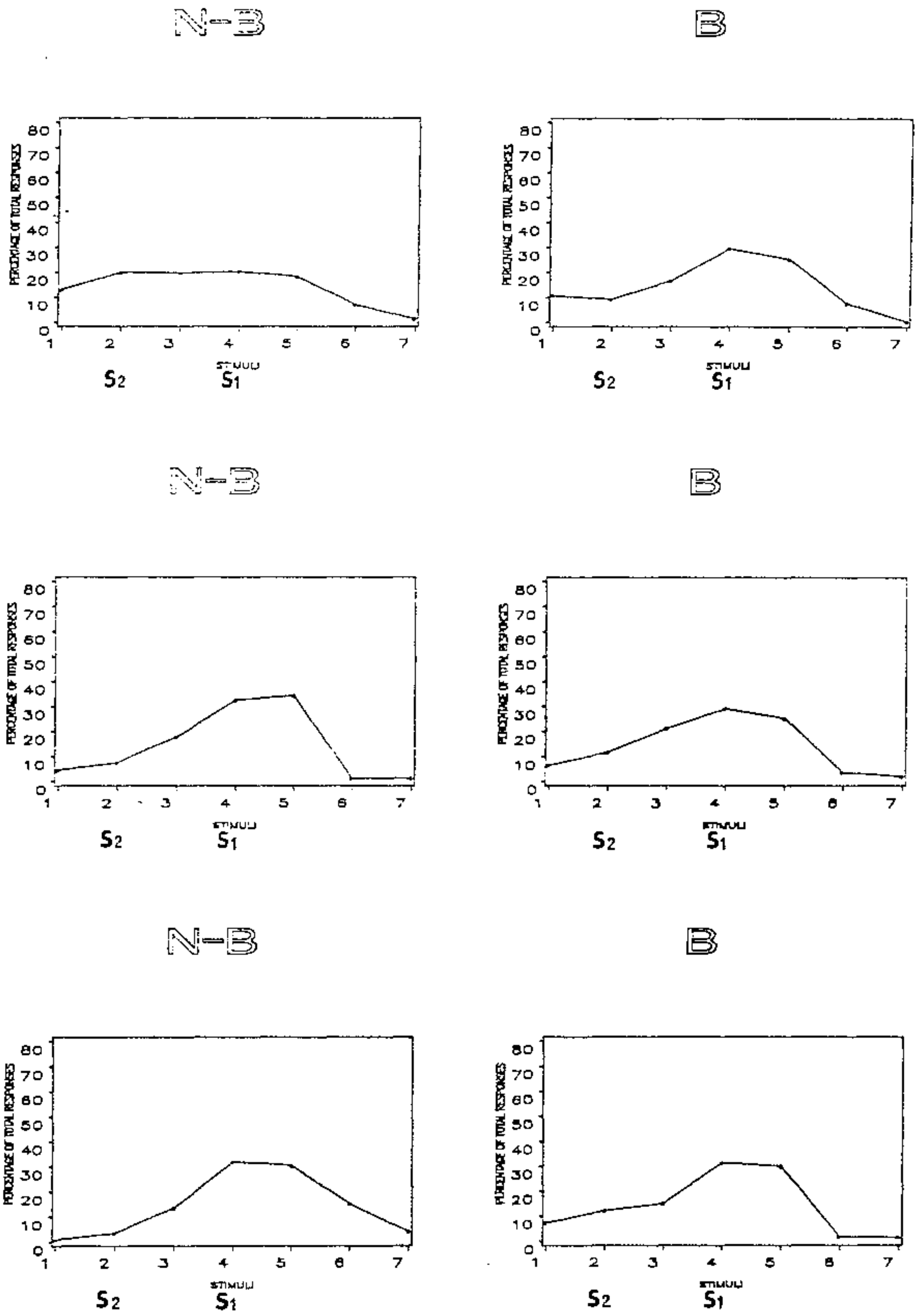


Figure 2.2 Relative gradients for group 1 subjects.

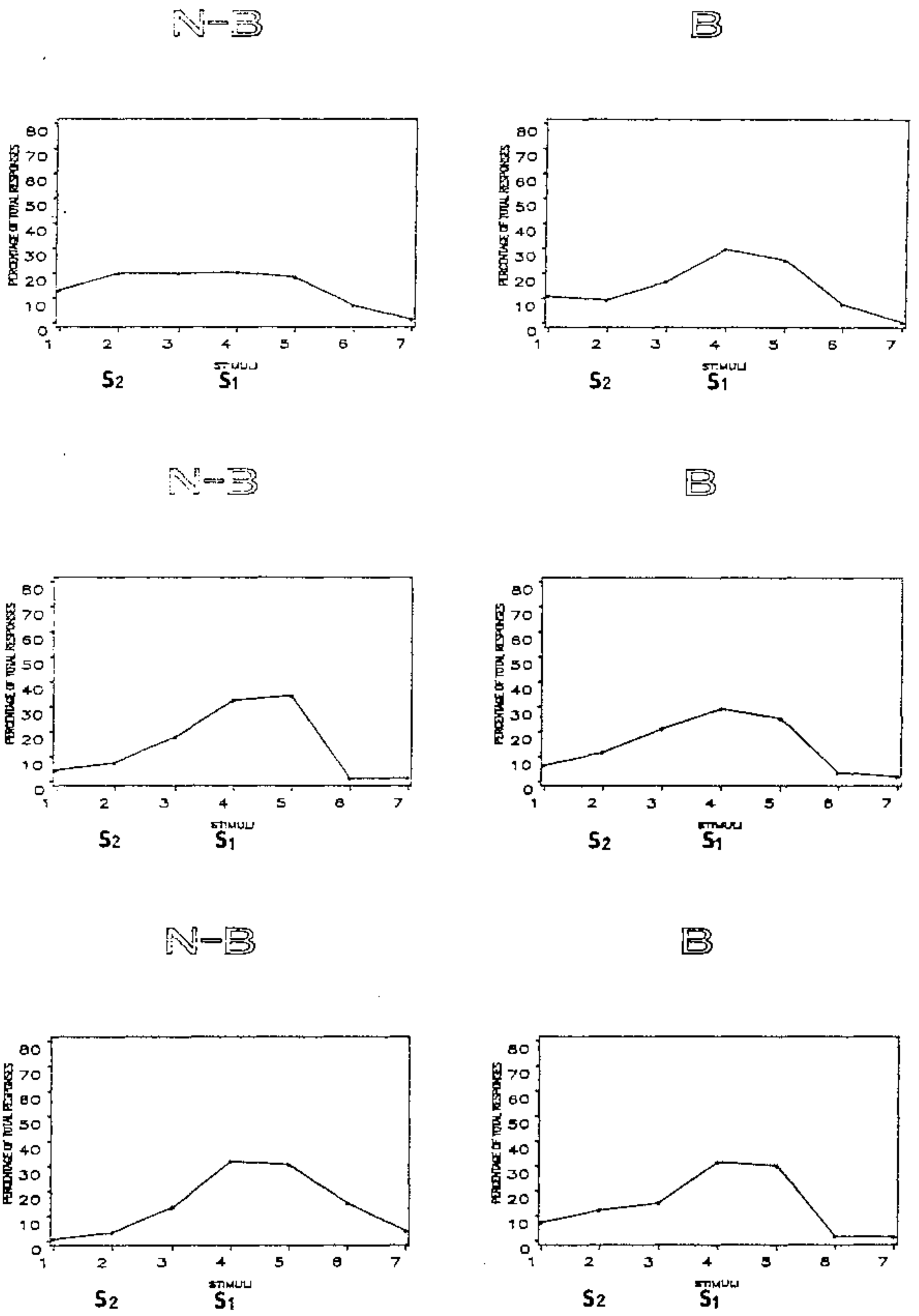


Figure 2.2 Relative gradients for group 1 subjects.

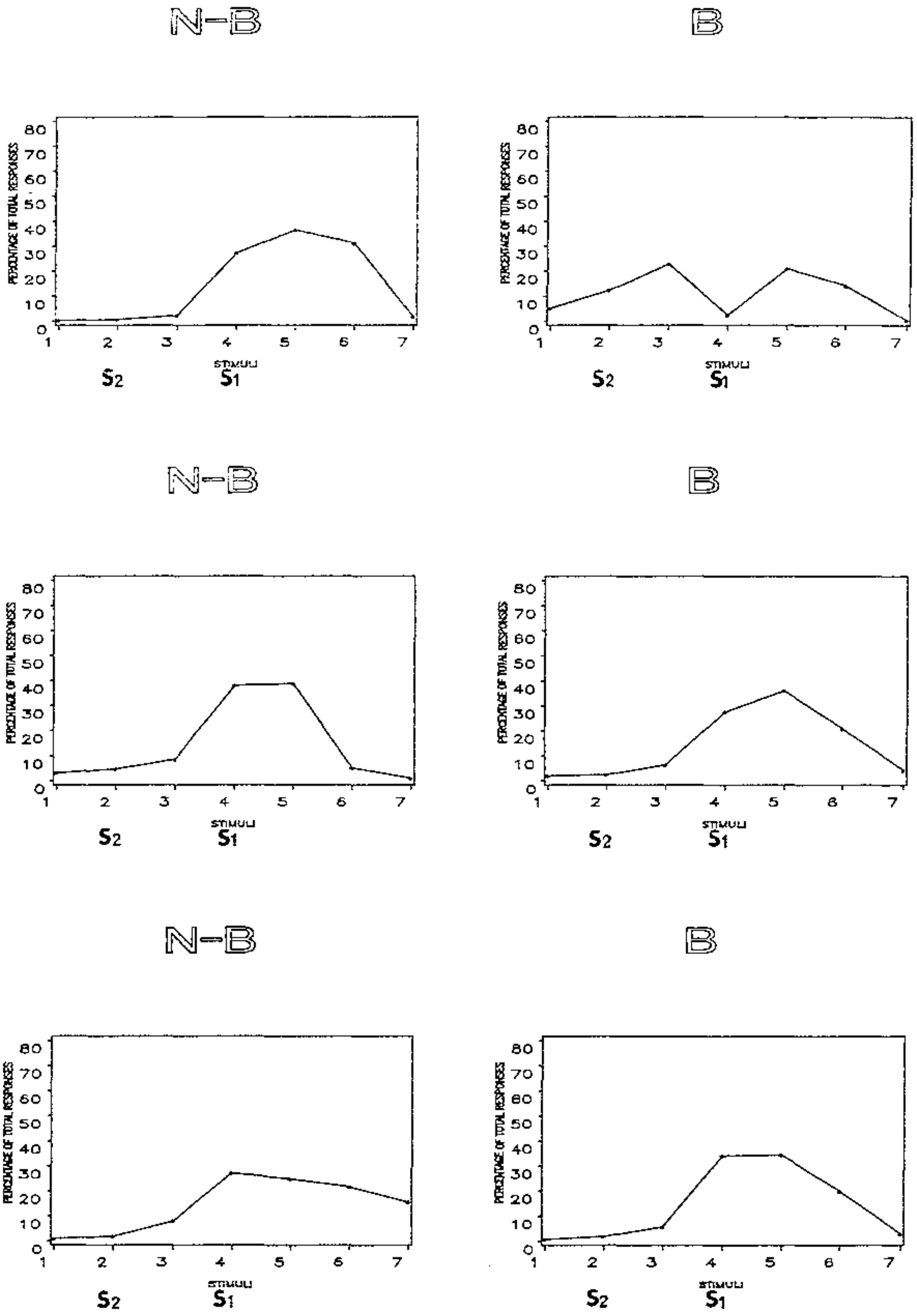


Figure 2.3 Relative gradients for group 2 subjects.

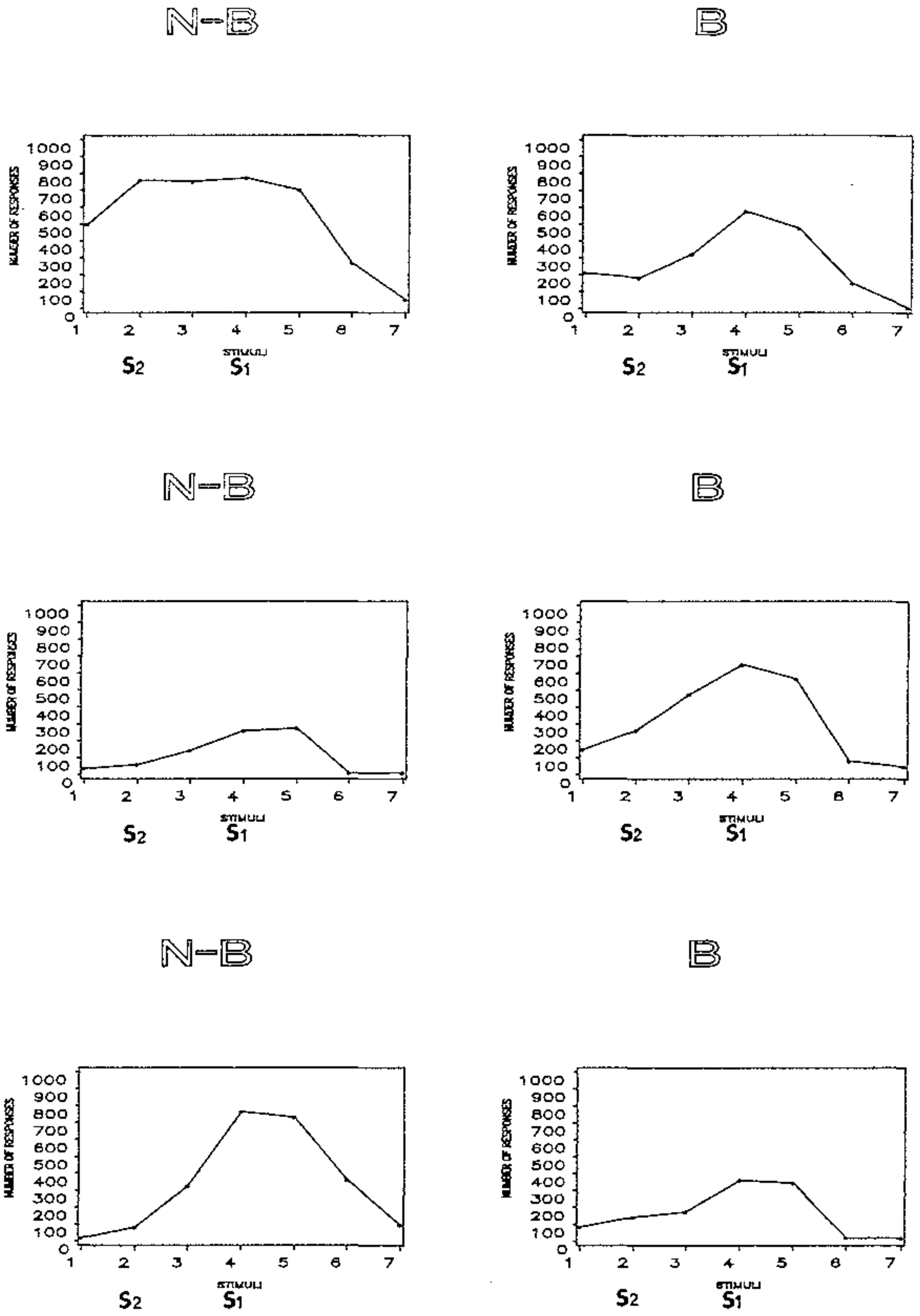


Figure 2.4 Absolute (number of responses made) gradients for group 1 subjects.

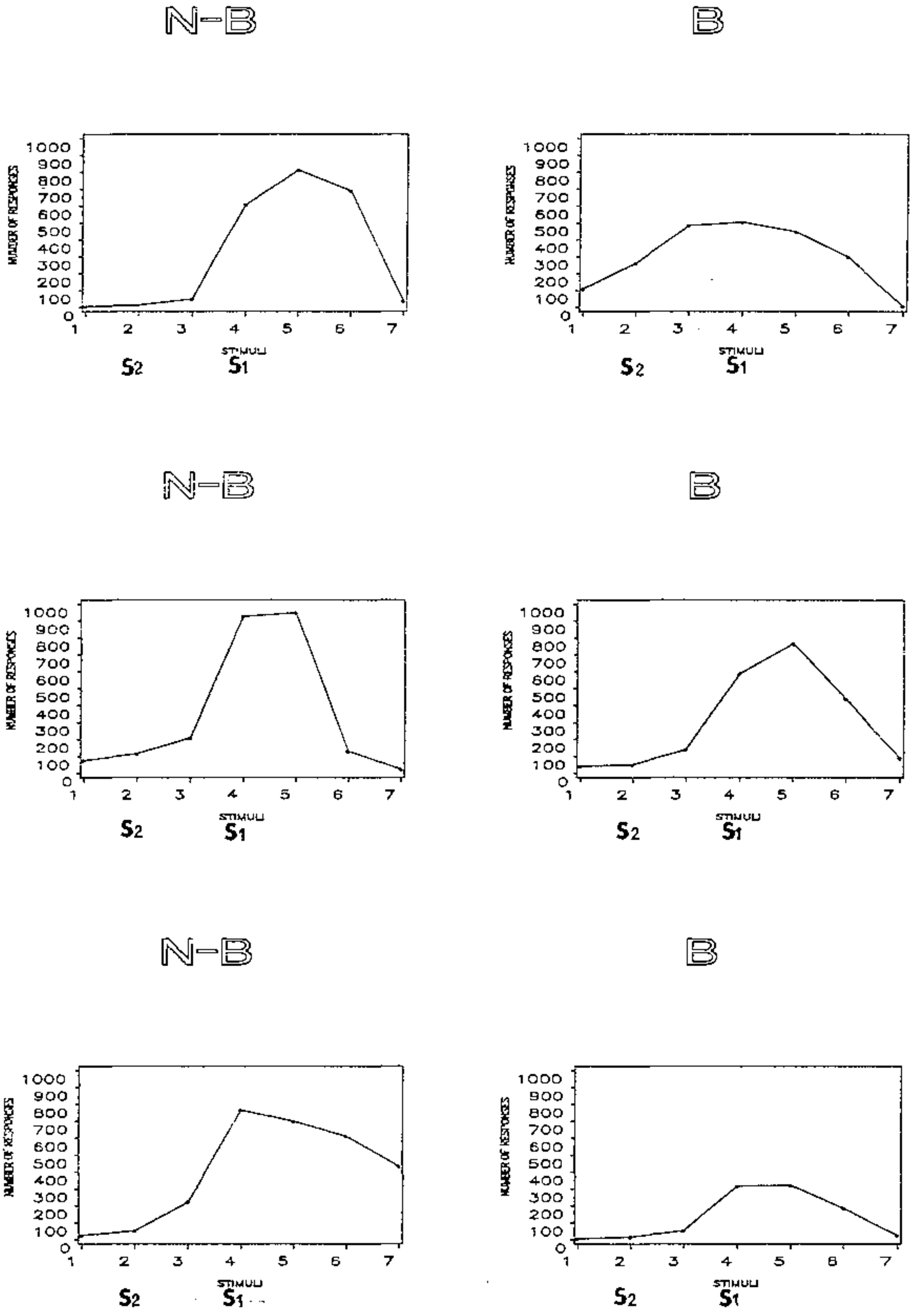


Figure 2.5 Absolute gradients for group 2 subjects.

2.4 DISCUSSION.

The results of Experiment 1 suggest that the training stimulus presented during single-stimulus training affected the pattern of behaviour in both discrimination training and generalisation testing, when it was one of the component stimuli during discrimination training. Where it was made S_2 a higher DI, GI and ASYM occurred, compared to when it was made S_1. This suggests that a stimulus which is subsequently the S_2 in a two-component chained schedule has a greater effect on maintaining a low response rate relative to that occurring to S_1, than a stimulus which is subsequently the S_1, where the stimuli have been associated with reinforcement for responding in their presence during single-stimulus training. Furthermore, under these conditions greater responding occurs to the right of S_1 during a generalisation test, when S_2 was the stimulus employed in single-stimulus training. The results also indicate that the introduction of a blank key between the cessation of S_2 and the onset of S_1 during discrimination training, and similarly between stimulus presentations in a generalisation test, produces less difference in responding to S_2 and S_1 (in discrimination training) and fewer responses occurring to the right of S_1 in a generalisation test, than when there is no blank key. Both groups showed a similar difference in ASYM scores between N-B and B results, with B subjects tending to show a slightly lower ASYM score than N-B subjects. This experiment showed that peak shift can be obtained after discrimination training with a ch VI 1-min VI 1-min schedule of reinforcement along the visual intensity dimension. These results cannot be explained in terms of Hull's (1949) suggestion that animals may respond faster during more intense stimuli, since the stimuli in the region of peak responding were of lowest intensity. Data are now available, therefore, from two dimensions (wavelength and visual intensity), showing that peak shift can be found after training with a chained schedule of reinforcement. Although the exact proportion of subjects showing peak shift varied from those found by the Frieman and Thomas study (which is not surprising considering such differences in the stimulus dimension used), the findings of peak shift and a higher probability of peak shift in group 2 were similar.

The results of Experiment 1 showed that making the preliminary or single-stimulus training stimulus the S_2 during discrimination training, raised the likelihood of obtaining peak shift and maintained a lower response rate in the S_2 component relative to that occurring in the S_1 component, compared to when the stimulus was made S_1. S_2 had been associated with primary reinforcement being delivered as a consequence of responding in its presence when used in single-stimulus training, hence, this prior history of reinforcement affected the occurrence of peak shift. Why?

Discrimination training involves the cessation of the previous association with reinforcement for responding in the presence of S_2. Reinforcement is only delivered as a consequence of responding in the presence of S_1. In contrast to a multiple schedule, however, within the chained schedule, S_2 and S_1 are linked and responding in S_2 affects the probability of reinforcement obtained in the S_1 component. Therefore, responding in the presence of S_2 can be seen as being maintained by, as many authors claim, conditioned reinforcement, (see Fantino, 1977) or by a decrease in the delay of reinforcement or by access to the primary reinforcer - all of which are defined by the same operation and entail the same process. To claim that it is one and the other is to promote unproductive semantic debate.

Experiment 1 also showed that the presentation of the blank key between the two components both at the end of and within the chained schedule resulted in a slightly lower ASYM score than when the blank key only occurred during delivery of reinforcement (i.e. between the end of one and the beginning of the next chain sequence). The blank key at the end of the initial component as well as the terminal component allowed greater similarity in the consequences of responding within the two components than when there was only a blank key occurring with the delivery of reinforcement (i.e. as a consequence of responding in the presence of S_1). This may have lessened the "aversiveness" of S_2 by the consistent relation of the stimulus to subsequent food presentation.

Insofar as an increased likelihood of peak shift is indicative of the "aversiveness" of a stimulus, the initial component of a two-component chained schedule can be considered to be aversive relative to the terminal component stimulus. As experiments in this laboratory have shown, the preference, as indicated by the choice to respond or not to respond in the presence of a stimulus, is clearly to the stimulus associated with the terminal component. This preference is strong enough to determine more responses being made to novel stimuli along the test dimension away from S_1 in a direction opposite S_2; hence, to stimuli as similar to S_1 but as dissimilar to S_2 as possible.

Experiment 1 considered only one chained schedule (ch VI 1-min VI 1-min), which had equal component duration ratios (CDR), (i.e. S_2 component schedule length relative to the S_1 component length [S_2:S_1]), 1:1. Chained schedules, however, can vary in the CDR, as well as the interreinforcement interval (IRI), (i.e. the time programmed between reinforcements [2 mins in the case of a ch VI 1-min VI 1-min schedule]). Generalisation gradients have shown that these two variables affect behaviour patterns obtained under multiple schedules, hence, the following experiment was designed to investigate these two major variables in chained schedules of reinforcement.

Chapter 3

EXPERIMENT 2

3.1 INTRODUCTION

Experiment 1 showed that peak shift can be found after intradimensional discrimination training along the visual intensity dimension with a ch VI 1-min VI 1-min schedule of reinforcement.

The position of S_2 relative to S_1 means that S_2 always signals a longer delay to reinforcement than does S_1, and data from multiple schedule research would suggest that peak shift would be the usual finding under such conditions (Richards, 1972). Hence, the aim of the present experiment was to investigate the generalisation gradients following intradimensional discrimination training on a variety of chained schedules of reinforcement.

The choice of which chained schedules to use was determined by the two characteristics of a chained schedule: component duration ratio (CDR) and interreinforcement interval (IRI) (see section 1.1). Experiment 1 used a CDR of 1:1 (i.e. equal component schedules of VI 1-min) and an IRI of two minutes (i.e. reinforcement was delivered on the average of once every two minutes).

The present experiment sought to investigate this same 1:1 CDR, but at a much lower IRI, and to take extreme CDRs at extreme IRIs. The minimum time period the apparatus would allow was seven seconds, hence, a VI 7-sec was the richest schedule (i.e. highest reinforcement rate) that could be used. An IRI of 11 minutes was compared to 77 seconds, with CDRs of 10:1 and 1:10 at each of these IRIs. Such extremes were chosen so as to highlight any effect that these variables may have on the probability of peak shift.

A CDR of 10:1 means that the S_2 signals a very long component duration relative to S_1, and the S_1 signals a very short component duration relative to S_2. This large difference between the CDRs may, however, have different effects at different IRIs. For instance, a 10:1 CDR at a short IRI may not have a very different effect on the probability of obtaining peak shift, compared to a 1:10 CDR. This may be because at a short IRI there are many component changes and the high reinforcement rate may negate any effect of a 10:1 or a 1:10 CDR. The subject does not have long to wait for reinforcement, hence, the CDR may not greatly influence stimulus control in chained schedules of reinforcement. At long IRIs, however, the CDR may have greater effect because there are very few component changes, a long wait between reinforcements and perhaps the relative length of waiting time (i.e. delay) in each component has greater influence, compared to short IRIs.

The present experiment sought to investigate the effect of varying the CDRs and IRIs on the probability of obtaining peak shift. It was predicted that the 10:1 CDR would produce the higher likelihood of obtaining peak shift. Futhermore, a long IRI might allow this CDR effect to show, but a short IRI might not do so.

3.2 METHOD.

3.2.1 Subjects

Twenty experimentally naive homing pigeons were maintained at 80% ±15 grams of their free-feeding body weight.

3.2.2 Apparatus

As in Experiment 1.

3.2.3 Procedure

Five groups each were given single-stimulus training to the stimulus which was S_1 in later discriminatiom training. Each group of subjects received different chain VI VI schedules with food reinforcement occurring, on the average, either every 11 minutes (VI 11-min) or every 77 seconds (VI 77-sec), and mean component durations either in the ratio of 10:1, 1:1, or 1:10 (i.e. S_2:S_1 respectively). S_2 and S_1 were the same stimulus values as in Experiment 1. Table 3.1 presents the conditions for each group. There was no blackout of the key prior to the onset of S_1. A generalisation test was given after responding stabilised in discrimination training.

TABLE 3.1

COMPONENT DURATION RATIO (CDR) AND INTERREINFORCEMENT INTERVAL (IRI) FOR EACH GROUP OF (N) SUBJECTS, IN EXPERIMENT 2.

GROUP	N	CHAINED SCHEDULE	CDR	IRI
1	4	CH VI 10-MIN VI 1-MIN	10:1	11-MIN
2	4	CH VI 5½-MIN VI 5½-MIN	1:1	11-MIN
3	4	CH VI 70-SEC VI 7-SEC	10:1	77-SEC
4	4	CH VI 7-SEC VI 70-SEC	1:10	77-SEC
5	4	CH VI 1-MIN VI 10-MIN	1:10	11-MIN

3.3 RESULTS.

During the single-stimulus training response rates typically increased over the first few sessions and then maintained reasonably constant levels across the remaining sessions. Table 3.2 presents the mean response rates for each subject and the mean for each group across the last three sessions of discrimination training prior to testing. The reinforcement schedules of low rate (IRI 11-min) maintain lower response rates than those of higher rate (IRI 77-sec). During discrimination training all subjects responded at a higher rate to S_1 than to S_2, however, three of the four group 5 subjects gave the lowest average response rate to S_1 and the lowest average discrimination indices. Those subjects given a schedule with component durations in the ratio of 1:10 (groups 4 and 5) all showed lower response rates in the presence of S_1 compared to those subjects with 10:1 CDR (groups 1 and 3). This same difference was not evident in responding to S_2. All subjects which had a 10:1 CDR and a short IRI (group 3) gave higher response rates both to S_2 and to S_1, than those subjects which had a 1:10 CDR and a short IRI (group 4). Both groups, however, gave very similar discimination indices. In comparison, those subjects which had a 10:1 CDR and a long IRI (group 1) all showed higher response rates to S_1 than those subjects which had a 1:10 CDR and a long IRI (group 5). This resulted in in all subjects but one in group 5 giving lower discrimination indices than group 1 subjects. Group 2 (1:1 CDR) subjects all showed low response rates to both S_2 and S_1, and discimination indices closer to group 5 subjects' than that of any other group.

TABLE 3.2

MEAN RESPONSE RATES IN THE INITIAL (S_2) AND TERMINAL (S_1) COMPONENTS AND DISCRIMINATION INDICES

GROUP		SCHEDULE COMPONENT		DI
		S_2	S_1	
1		0.84	2.12	0.71
		0.32	1.91	0.84
		0.53	2.15	0.80
		0.25	1.90	0.89
	$\bar{X}$	0.49	2.02	0.81
2		0.36	0.80	0.69
		0.17	0.37	0.70
		0.40	0.65	0.63
		0.22	0.85	0.81
	$\bar{X}$	0.29	0.67	0.71
3		0.46	2.19	0.83
		0.40	2.37	0.85
		0.68	3.28	0.83
		0.40	2.13	0.84
	$\bar{X}$	0.49	2.49	0.84
4		0.21	1.12	0.84
		0.13	0.73	0.85
		0.24	1.39	0.86
		0.25	1.12	0.82
	$\bar{X}$	0.21	1.11	0.84
5		0.14	0.56	0.80
		0.33	0.49	0.61
		0.55	0.75	0.59
		0.28	0.48	0.63
	$\bar{X}$	0.33	0.57	0.66

NOTE. 1. MEAN = AVERAGE OF DATA OVER LAST THREE DISCRIMINATION TRAINING SESSIONS PRIOR TO TESTING.

2. MEAN FOR EACH GROUP IS ALSO REPRESENTED ($\bar{X}$)

Generalisation gradients are presented in Figures 1.1 and 1.2. Peak shift or decremental gradients around S_1 were found in all but two subjects (two of group 4 subjects peaked at stimulus between S_2 and S_1 along the test dimension). Peak shift was obtained for two of the four group 1 subjects and for one of the groups 2,3 and 4.

No subjects in group 5 showed peak shift. Generalisation indices and asymmetry scores are presented in Table 3.3. All subjects in group 5 gave lower generalisation indices and asymmetry scores than all subjects in group 1. All subjects in groups 4 and 5 showed lower asymmetry scores than all subjects in group 1. Asymmetry scores tended to be low if there was a 1:10 CDR and higher if a 10:1 CDR. The largest difference in asymmetry scores between all subjects of a group occurred on a long IRI (groups 1 and 5). Ths smallest difference in asymmetry scores occurred between those subjects on a 1:10 CDR (groups 4 and 5). The asymmetry score took more generalisation test data into account than the generalisation index although both measures indicate the general trend of lower scores when there is a 1:10 CDR. A CDR of 1:1 produced one subject showing peak shift but all subjects with asymmetry scores higher than all of group 5 subjects and four of group 4 subjects.

TABLE 3.3

GENERALISATION INDICES (GI) AND ASYMMETRY SCORES (ASYM) FOR EACH SUBJECT.

GROUP	INDICES OF TEST DATA	
	GI	ASYM
1	0.51	0.68
	0.49	0.67
	0.49	0.63
	0.53	0.85
	$\bar{X}$ 0.51	0.71
2	0.49	0.64
	0.61	0.63
	0.45	0.50
	0.46	0.76
	$\bar{X}$ 0.50	0.63
3	0.51	0.50
	0.47	0.64
	0.47	0.59
	0.44	0.55
	$\bar{X}$ 0.47	0.57
4	0.19	0.06
	0.46	0.52
	0.47	0.48
	0.51	0.25
	$\bar{X}$ 0.41	0.33
5	0.29	0.21
	0.47	0.38
	0.42	0.37
	0.45	0.41
	$\bar{X}$ 0.41	0.34

NOTE. MEAN SCORES FOR EACH GROUP ARE GIVEN ($\bar{X}$)

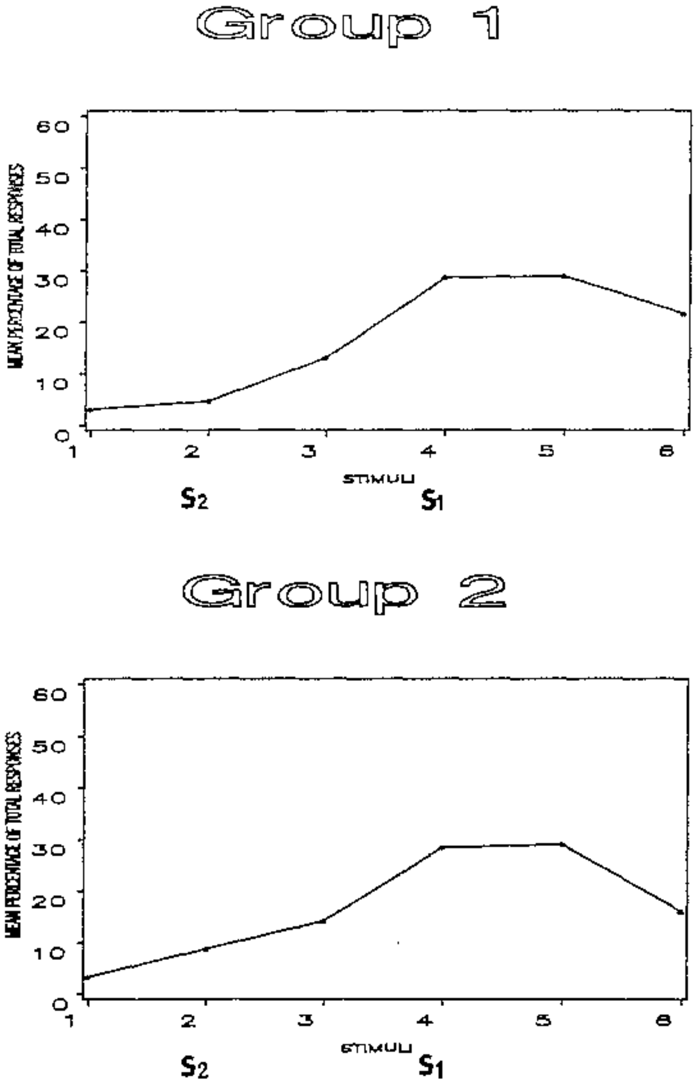
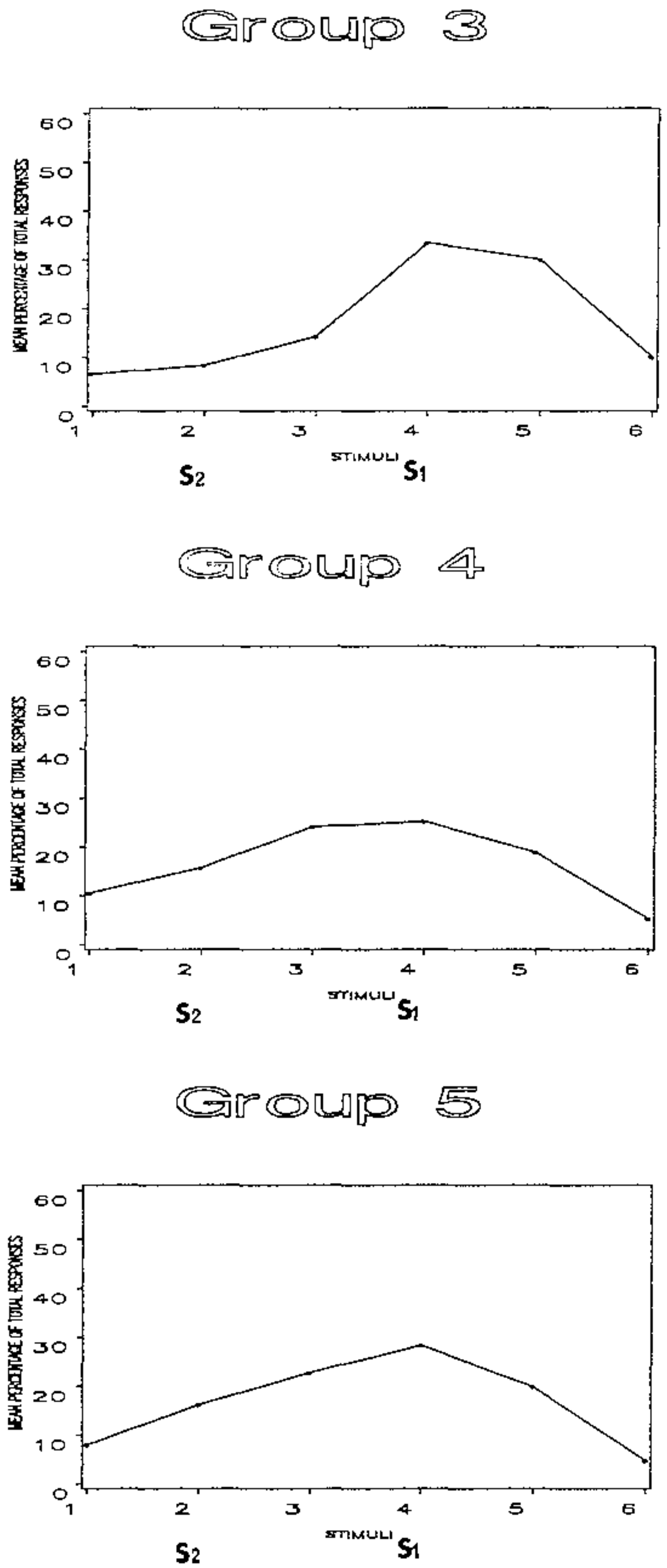


Figure 3.1 Mean relative gradients for groups 1 and 2.



<u>Figure 3.2</u> Mean relative gradients for groups 3, 4 and 5.

3.4 DISCUSSION.

This experiment investigated different two-component chained schedules and found that stimulus control in chained schedules is affected by both the reinforcement schedule and the component durations. There were greater concentrations of responding to the side of S_1 opposite S_2 during a generalisation test, where there was a low reinforcement rate and a long S_2 component relative to the S_1 duration. A concentration of responding occurred to the side of S_1 towards S_2 where there was a short S_2 relative to S_1 component duration irrespective of whether there was a low or high reinforcement rate. The finding of decremental stimulus-control gradients where there had been high responding to S_2 relative to S_1, implies that the suggestion by Bushnell and Weiss (1980) that S_2 responding may be due to a poorly developed discrimination, may not be correct for chained schedules.

The results also show that the "aversiveness" of S_2 (as indicated by peak shift), could be modified by a change in component durations of S_2 relative to S_1. If the ratio of initial component duration to terminal component duration was 10:1, then a greater likelihood of peak shift was obtained, compared to a 1:10 ratio. The greater difference in the likelihood of peak shift was obtained when these ratios were combined with a low rate of reinforcement (i.e. once in every eleven minutes). Hence, stimulus control in chained schedules of reinforcement appears to be more affected by the component duration ratios (S_2:S_1) at a low rate of reinforcement. One possible explanation is that the conditioned reinforcing value of S_1 is greatly reduced in a 1:10 CDR at a low IRI, hence S_2 and S_1 become "more alike". In other words, S_1 also signals a long delay to reinforcement (as does S_2 in the 1:10 CDR), and hence, there is not as great a difference between the two stimuli in terms of access to primary reinforcement. In the 10:1 CDR, however, the two stimuli vary greatly in their delay to reinforcement and hence, differences in the type of control each stimulus exerts is more likely. When there is a high rate of reinforcement, however, the differences between what the two stimuli signal are counteracted by the fact that the time between reinforcements is not that great. Typically, with the emission of behaviours other than key-pecking (in particular, after reinforcement delivery), the time spent in the two components often does not differ greatly when there is a high rate of reinforcement.

Stimulus control in chained schedules, therefore, is affected by the rate of reinforcement and the relative component durations, and it cannot be said the chained schedules of themselves, entail an "aversive" initial component stimulus relative to the terminal component stimulus.

Chapter 4

EXPERIMENT 3

4.1 INTRODUCTION.

In Experiment 2, stimulus-control gradients were shown to be affected by varying the interreinforcement interval (i.e. the rate of reinforcement and the component duration ratio). A long IRI and a 10:1 CDR produced the highest probability of finding peak shift. These variables entail manipulation of the chained schedule.

Another way of increasing the probability of peak shift is to decrease the distance between the two training stimuli along their physical dimension (Hanson, 1959; Thomas, 1962). In Experiments 1 and 2 the two discrimination training stimuli, S_2 and S_1, were always the same distance apart in the generalisation test dimension (i.e. there were the same number of stimuli between the two training stimuli). From results using multiple schedules, if the two training stimuli were more closely spaced, the probability of obtaining peak shift would be increased (Hanson, 1959; Thomas, 1962).

The present experiment was designed to test whether this stimulus-spacing effect could also be found in generalisation gradients following chained schedules of reinforcement. The S_2 and S_1 training stimuli were brought closer together along the visual intensity dimension (i.e. became more similar in intensity).It is suggested that because this manipulation is a stimulus rather than a schedule variable, the results should be similar to those obtained after similar multiple schedule training It was predicted that a greater probability of obtaining peak shift would be found in the present experiment compared to that found in Experiment 2. This would indicate that generalisation gradients in chained schedules are affected by and are measuring the effects of stimulus control the same as is done in other schedules.

4.2 METHOD.

4.2.1 Subjects

Twenty-five experimentally naive homing pigeons were maintained at 80% ±15 grams of their free-feeding body weight.

4.2.2 Apparatus

As in Experiments 1 and 2.

4.2.3 Procedure

The procedure was that used in Experiment 2 except that S_2 was stimulus D (see Appendix 1), i.e. it was the stimulus in the test dimension immediately adjacent to S_1. There was an additional group, given ch VI 1-min VI 1-min training, to allow a comparison with the results from Experiment 1. A summary of the chained schedule given to each group is presented in Table 4.1.

TABLE 4.1
COMPONENT DURATION RATIO (CDR) AND INTERREINFORCEMENT INTERVAL (IRI) FOR EACH GROUP OF (N) SUBJECTS, IN EXPERIMENT 3.

GROUP	N	CHAINED SCHEDULE	CDR	IRI
1	4	CH VI 10-MIN VI 1-MIN	10:1	11-MIN
2	3	CH VI 5½-MIN VI 5½-MIN	1:1	11-MIN
3	4	CH VI 70-SEC VI 7-SEC	10:1	77-SEC
4	6	CH VI 7-SEC VI 70-SEC	1:10	77-SEC
5	4	CH VI 1-MIN VI 10-MIN	1:10	11-MIN
6	4	CH VI 1-MIN VI 1-MIN	1:1	2-MIN

4.3 RESULTS.

During the single-stimulus training response rates again typically increased over the first few sessions and then leveled off across the later sessions with the low overall rate of reinforcement schedules (i.e. VI 11-min) maintaining lower response rates. During discrimination training all subjects all subjects responded at a higher rate to S_1 than to S_2, except three of the four group 5 birds (ch VI 1-min VI 10-min), who maintained a higher mean response rate to S_2 than to S_1. All subjects in group 3 (ch VI 70-sec VI 7-sec) gave higher mean response rates to S_1 than all other subjects, which is indicated in this group having the highest group average discrimination index (0.86). High group average discrimination indices were obtained by group 4 (0.81), group 6 (0.76) and group 1 subjects (0.74). Comparing how these discrimination indices were obtained, group 1 subjects all showed high response rates to S_1 (range 1.41-2.34), whereas both groups 4 and 6 had a wider range and lower rates to S_1 (group 4, range 0.70-1.46; group 6, range 0.76-1.26). Response rates to S_2 tended to be higher in group 1 (0.49-0.93) compared to group 4 (0.07-0.77) and group 6 (0.14-0.47). Hence, response rates to S_2 varied across subjects, however, response rates to S_1 showed clear differences between groups. The lowest discrimination indices were found in groups 2 (range 0.44-0.68) and 5 (range 0.33-0.54) with group 5 showing the lowest group average (0.45).

The data reveal that the subjects with a long IRI tended to produce the lowest discrimination indices (i.e. groups 1,2 and 5) and also the greatest difference in discrimination indices between varying CDRs (groups 1 and 5). Where there was a short IRI (groups 3,4 and 6), there was not as great a difference in discrimination indices (0.86, 0.81 and 0.71 respectively). At both levels of IRI, the 10:1 CDR subjects gave the highest DI and a higher rate of responding to S_1 (as in Experiment 2).

TABLE 4.2

MEAN RESPONSE RATES IN THE INITIAL (S_2) AND TERMINAL (S_1) COMPONENTS AND DISCRIMINATION INDICES

GROUP	SCHEDULE COMPONENT		DI
	S_2	S_1	
1	0.93	2.34	0.71
	0.49	2.12	0.81
	0.67	1.68	0.74
	0.56	1.41	0.71
$\bar{X}$	0.66	1.89	0.74
2	0.65	0.74	0.55
	0.13	0.10	0.44
	0.15	0.19	0.68
$\bar{X}$	0.31	0.34	0.56
3	0.46	3.9	0.90
	0.32	2.22	0.87
	0.60	2.23	0.78
	0.27	1.86	0.87
$\bar{X}$	0.41	2.55	0.86
4	0.37	1.46	0.80
	0.07	0.70	0.91
	0.37	1.29	0.78
	0.77	1.46	0.66
	0.24	1.05	0.82
	0.12	0.75	0.87
$\bar{X}$	0.32	1.12	0.86
5	0.20	0.19	0.49
	0.50	0.36	0.43
	0.59	0.69	0.54
	0.31	0.15	0.33
$\bar{X}$	0.40	0.35	0.45
6	0.43	0.92	0.68
	0.14	0.79	0.85
	0.22	0.76	0.79
	0.47	1.26	0.73
$\bar{X}$	0.32	0.93	0.76

NOTE. 1. MEAN = AVERAGE OF DATA OVER LAST THREE DISCRIMINATION TRAINING SESSIONS PRIOR TO TESTING.

2. MEAN FOR EACH GROUP IS ALSO REPRESENTED ($\bar{X}$)

Mean relative generalisation gradients for each groups are presented in Figures 4.1, 4.2 and 4.3. These figures indicate that the greater shift in the peak of responding occurred for group 1 subjects. This can be seen from the generalisation test data presented for individual subjects in Table 4.3. All group 1 subjects showed a peak shift, as evidenced by a GI of greater than 0.50. Two subjects in each group 3,4 and 5 showed peak shift, and one subject each in groups 2 and 6. Although all of group 1 subjects had a GI of greater than 0.50, higher GIs were found in groups 3 (0.55), 4 (0.57) and 5 (0.60). Group 5 also had the lowest GI (0.13), indicating a large range within that group compared to that in group 1 (0.52-0.54).

The asymmetry score data reveal similar trends in that group 1 subjects produced the higher group average score (0.78). Group 3 also produced a high average of 0.75. Therefore, at both levels of IRI, the 10:1 CDR subjects produced the higher group average ASYM scores. Although some individual subjects in the 1:1 and 1:10 CDR groups did produce high ASYM scores (one subject each of groups 2, 4 and 6), there was not the consistancy across all subjects as shown by groups 1 and 3.

All subjects in groups 1 and 3 (10:1 CDR) gave higher ASYM scores than all subjects in group 5 (1:10 CDR and long IRI). All group 5 subjects gave ASYM scores of equal to or less than 0.42, which indicates higher responding on the side of S_1 towards S_2. This finding was also obtained in groups 2 and 4, but not by all subjects. The largest difference between ASYM scores was found between groups 1 and 5. Experiment 2 found the largest difference between groups 1 and both 4 and 5.

TABLE 4.3

GENERALISATION INDICES AND ASYMMETRY SCORES FOR EACH SUBJECT AND GROUP MEANS.

GROUP	GI	ASYM
1	0.54	0.71
	0.54	0.94
	0.52	0.81
	0.53	0.64
	$\bar{X}$ 0.53	0.78
2	0.51	0.40
	0.28	0.82
	0.46	0.55
	$\bar{X}$ 0.42	0.59
3	0.30	0.62
	0.50	0.75
	0.46	0.77
	0.55	0.84
	$\bar{X}$ 0.45	0.75
4	0.47	0.31
	0.57	0.77
	0.47	0.50
	0.41	0.31
	0.42	0.33
	0.51	0.72
	$\bar{X}$ 0.48	0.49
5	0.44	0.31
	0.53	0.32
	0.60	0.42
	0.13	0.26
	$\bar{X}$ 0.43	0.33
6	0.48	0.59
	0.51	0.86
	0.43	0.54
	0.496	0.57
	$\bar{X}$ 0.48	0.64

NOTE. MEAN SCORES FOR EACH GROUP ARE GIVEN ($\bar{X}$)

Where there was a long IRI, subjects which had a 10:1 CDR produced higher asymmetry scores than those which had a 1:10 CDR. There was also the same tendency where there was a short IRI, but two of the group 4 subjects did show high ASYM scores (0.77, 0.72). Where there was a 1:1 CDR, there was not as great a difference, however, the group average gave a higher score for those subjects which had a short IRI.

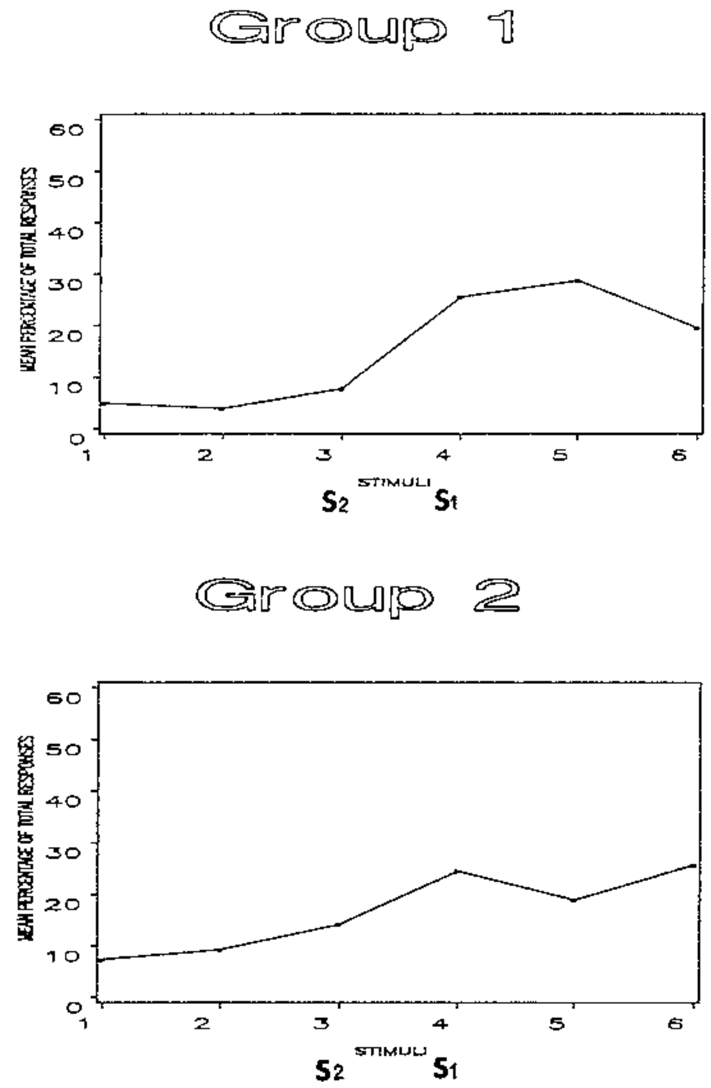


Figure 4.1 Mean relative gradients for groups 1 and 2.

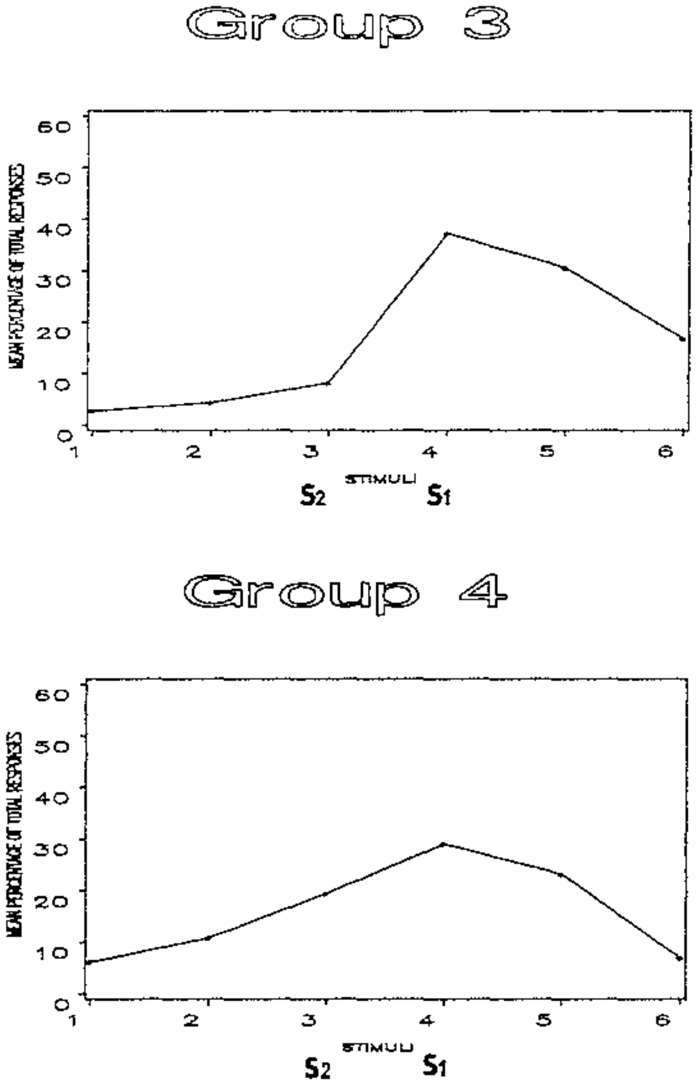


Figure 4.2 Mean relative gradients for groups 3 and 4.

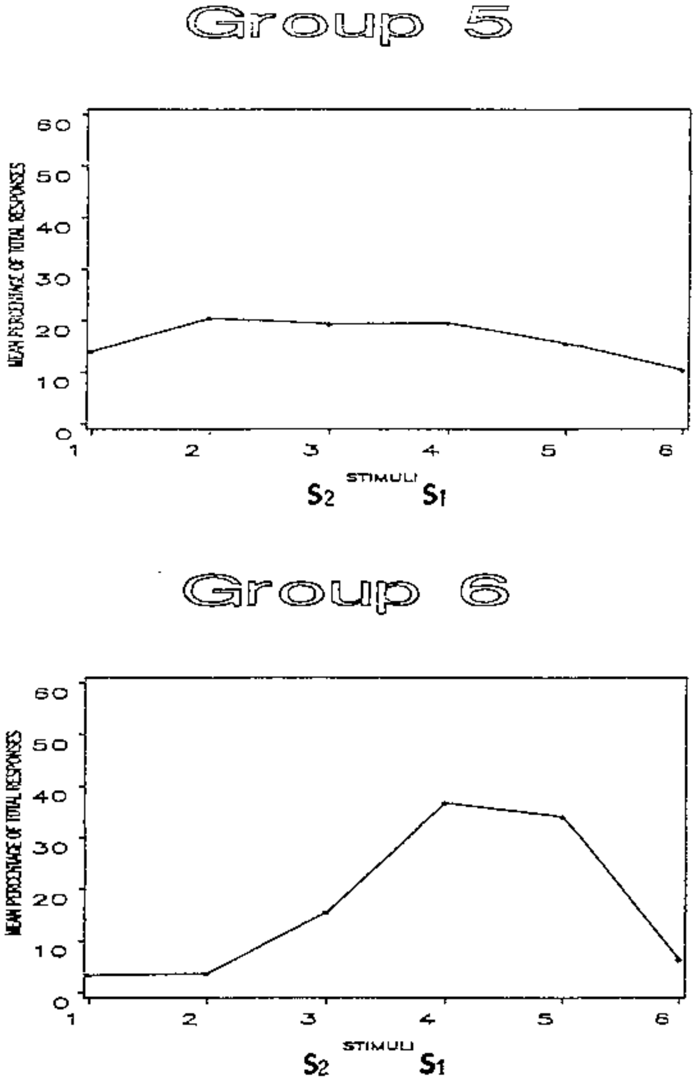


Figure 4.3 Mean relative gradients for groups 5 and 6.

4.4 DISCUSSION.

This experiment has shown that the stimulus-spacing effect found in multiple schedules, can also be found in generalisation tests following discrimination training on chained schedules of reinforcement. In comparison with the results obtained with equivalent schedules in Experiment 2, the closer spacing of S_2 and S_1 along the test dimension resulted in more subjects showing peak shift. This phenomenon of greater peak shift when S+ (S_1) and S- (S_2) are more closely has been reported in previous research with multiple schedules (Hanson, 1959; Thomas, 1962).

The closer spacing of training stimuli produced an increase in group-averaged GI and/or ASYM scores in all groups. Data from both experiments comfirm that subjects given a 10:1 CDR produced more peak shift and had higher GI and ASYM scores than subjects on a 1:10 CDR, and that this difference was more extreme at a long IRI (low overall rate of reinforcement), than at a short IRI (high overall rate of reinforcement). The finding in both experiments of differential effects on responding by different component duration ratios, suggests that these effects may be of some permanence across two-component chained schedules. The closer stimulus spacing allowed the difference between the two operations associated with the two component stimuli to be heightened (or more obvious) by requiring the subject to take more notice of the two stimuli because they were more alike in physical appearance. Perhaps the greater physical proximity along the dimension forced the subject to attend more to the operation differences between the two component stimuli. Hence, the results of Experiment 2 were attenuated in Experiment 3. The first three experiments have shown that the initial component of a two-component chained schedule has "aversive" properties, as indicated by the phenomenon of peak shift and these "aversive" properties can be manipulated by varing some parameters of the chained schedule. The present experiment has implied that the more similar S_2 is to S_1, the more "aversive" S_2 is, and hence S_2 is less aversive if it less similar to S_1. In the experiments reported thus far, both S_2 and S_1 are presented at the same location (on the same key). Perhaps the "aversiveness" of S_2

can be altered by changing this variable of similarity - i.e. stimulus location. This stimulus variable of location has been shown to affect peak shift probability in concurrent schedules (Honig, 1962), and the following experiment was designed to consider the variable in chained schedules of reinforcement.

Chapter 5

EXPERIMENT 4

5.1 INTRODUCTION.

All chained schedules utilised have had both components presented on one response key. Research using concurrent schedules has shown that presenting the two stimuli on two separate response keys resulted in no peak shift being obtained (Honig, 1962), but when they were presented on a single key (with a changeover procedure on a seperate key), peak shift was obtained (Winton and Beale, 1971). Although concurrent schedules involve a simultaneous discrimination task, whereas the present experiments are concerned with the successive discrimination task in chained schedules, there does appear to be an effect of the location of the two training stimuli, on the probability of finding peak shift. Honig(1962) suggests that the simultaneous presentation on two keys provided an alternative response when S- (S_2) was presented, of switching to the S+ (S_1) key. This resulted in no peak shift occurring because the S- simply was a cue to switch to S+ and inhibitory control around S- was not sufficent to produce peak shift. In contrast, the successive presentation does not allow the subject any alternative response during the S- periods, hence, extinction occurred and inhibitory control around S- developed, resulting in peak shift.

The present experiment sought to investigate the effect of the two component stimuli of a chained schedule being presented on two separate keys (i.e. S_2 on the left key and S_1 on the right key). The stimuli occurred successively, hence, the chained schedule was maintained. The S_2 (left key) was now even more clearly disassociated from primary reinforcement, compared to the single-key procedure in which a response on the key was associated with reinforcement, albeit after a delay in which another stimulus occurred, because reinforcement occurred on the same key. It was predicted that the separation of the component stimuli onto different response keys would affect the likelihood of obtaining peak shift, possibly to the extent of not finding it when expected (i.e. ch VI 10-min VI 1-min). However, as Honig(1962) would suggest, the response requirement in S_2 being present on a different key to S_1, may be sufficent to not produce peak shift under conditions otherwise likely to produce peak shift.

5.2 METHOD.

Each of the four major chained schedules used in previous experiments was used. One subject was assigned to each schedule (i.e. 10:1 and 1:10 C.D.R. at low and high rates of reinforcement). The 10:1 C.D.R. subjects had a generalisation test on the left key first followed by one on the right key, and for the 1:10 subjects this was reversed. Table 5.1 presents a summary of the schedule conditions for each subject and whether one key or two-key training was given. The component had the same values (cd/m^2) as in Experiments 1 and 2.

TABLE 5.1

TRAINING SCHEDULE AND ONE OR TWO-KEY CONDITION FOR EACH SUBJECT IN EXPERIMENT 4.

SUBJECT	CHAINED SCHEDULE	ONE/TWO-KEY
1	CH VI 10-MIN VI 1-MIN	ONE-KEY
1 (DB)	CH VI 10-MIN VI 1-MIN	TWO-KEY
2	CH VI 70-SEC VI 7-SEC	ONE-KEY
2 (DB)	CH VI 70-SEC VI 7-SEC	TWO-KEY
3	CH VI 7-SEC VI 70-SEC	ONE-KEY
3 (DB)	CH VI 7-SEC VI 70-SEC	TWO-KEY
4	CH VI 1-MIN VI 10-MIN	ONE-KEY
4 (DB)	CH VI 1-MIN VI 10-MIN	TWO-KEY

NOTE. DB = DOUBLE OR TWO-KEY PROCEDURE.

5.3 RESULTS AND DISCUSSION.

All four, two-key subjects showed high responding around the S_2. Table 5.2 presents the average response rates for each subject.

TABLE 5.2

MEAN RESPONSE RATES IN THE INITIAL (S_2) AND TERMINAL (S_1) COMPONENTS FOR EACH GROUP.

SUBJECT	SCHEDULE COMPONENT	
	S_2	S_1
1	0.84	2.12
1 (DB)	0.31	2.21
2	0.46	2.19
2 (DB)	0.85	1.86
3	0.21	1.12
3 (DB)	0.15	0.72
4	0.14	0.56
4 (DB)	0.09	1.24

NOTE. MEAN = AVERAGE OF DATA OVER LAST THREE DISCRIMINATION TRAINING SESSIONS PRIOR TO TESTING.

Figures 5.1 and 5.2 provide the relative gradients on both keys for each subject given two-key training. Figure 5.3 presents the relative gradients for the one key birds. At the low rate of reinforcement, the 10:1 C.D.R. two-key subject peaked at the stimulus between S_2 and S_1 on the test dimension for the left key test and peaked to both this stimulus again and to S_1 for the right key test. The 1:10 C.D.R. subject peaked at S_1 for the right key test, but then on the left key test, peaked at S_2 and made similarly high responses to two stimuli on the side of S_2 away from S_1. When the rate of reinforcement was high, the 10:1 C.D.R. subject peaked at the stimulus to the side of S_2 away from S_1 and showed high responding to all stimuli away from S_1 in a direction towards S_2 on the left key test, but peaked at S_1 in the right key test. The 1:10 C.D.R. subject peaked at S_2 on the right and left key tests.

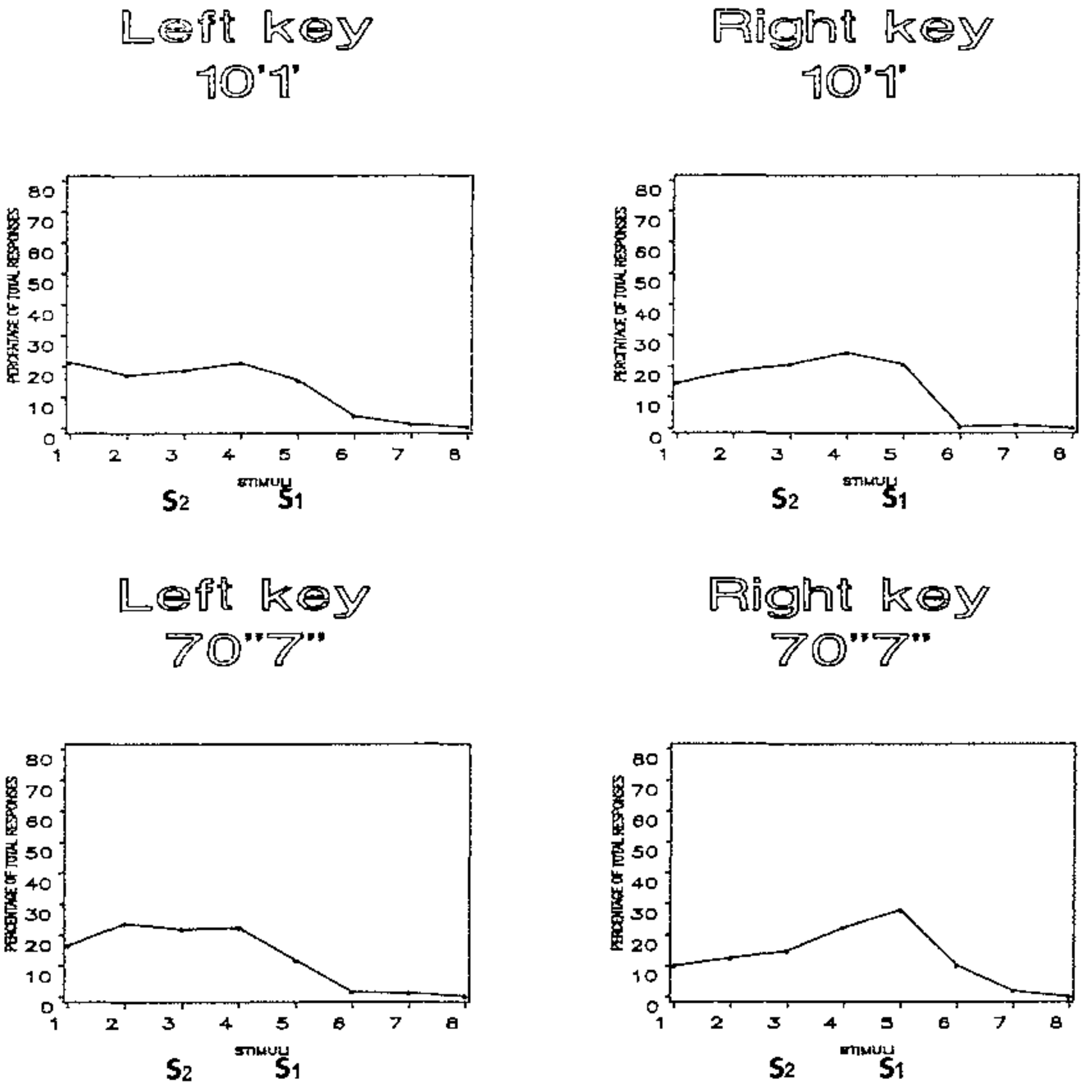


Figure 5.1 Relative S_2 gradients for 10:1 C.D.R. two-key subjects.

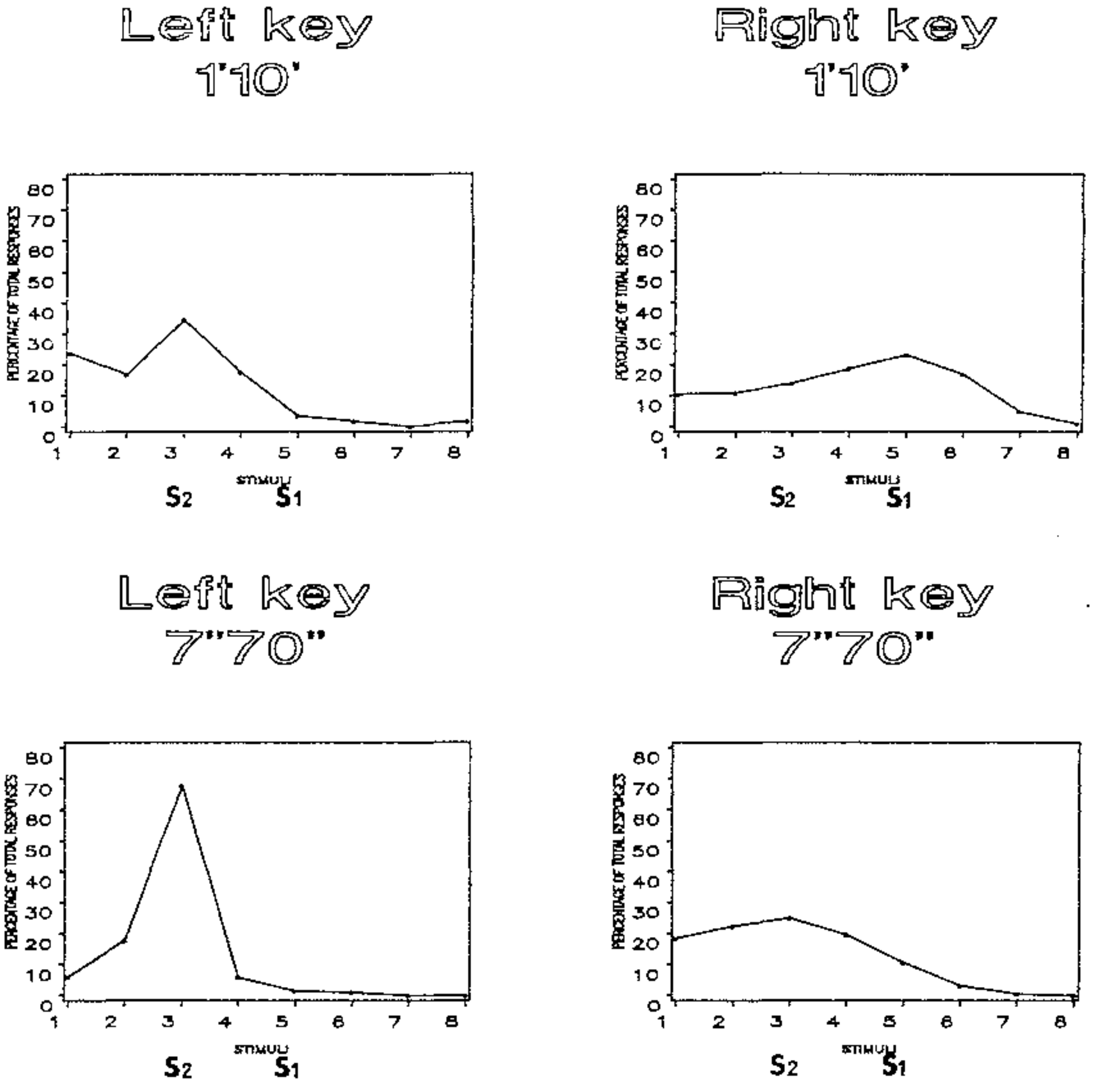


Figure 5.2 Relative S_2 gradients for 1:10 C.D.R. two-key subjects.

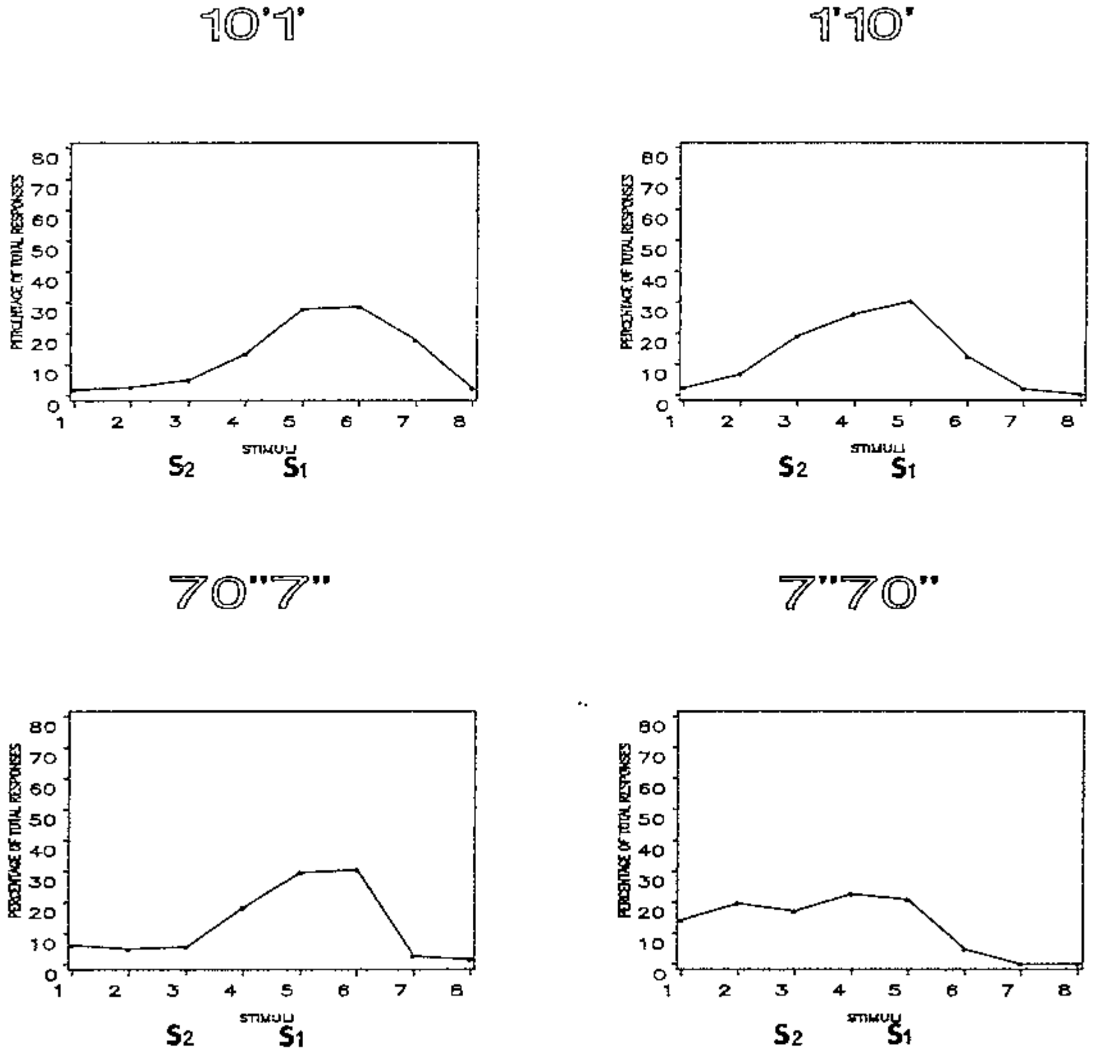


Figure 5.3 Relative S_2 gradients for one-key subjects.

Table 5.3 presents the generalisation indices, asymmetry scores and % of responses to S_1 for each subject.

TABLE 5.3

GENERALISATION INDICES, ASYMMETRY SCORES AND PERCENTAGE OF TOTAL RESPONSES TO S_1 IN THE TEST, FOR EACH SUBJECT ON EACH KEY.

SUBJECT	INDICES OF TEST DATA					
	GI		ASYM		% TO S_1	
	LEFT-KEY	RIGHT-KEY	LEFT-KEY	RIGHT-KEY	LEFT-KEY	RIGHT-KEY
1		0.51		0.68		31.60
1 (DB)	0.20*	0.02	0.07	0.02	20.00	24.10
2		0.51		0.50		32.30
2 (DB)	0.12*	0.26	0.04	0.17	14.30	31.30
3		0.19		0.06		24.40
3 (DB)	0.40	0.23*	0.01	0.04	1.60	13.00
4		0.29		0.21		31.30
4 (DB)	0.33	0.42*	0.04	0.30	4.80	26.20

NOTE * = TEST PRESENTED FIRST.

These results indicate that stimulus-control gradients obtained following intradimensional discrimination training on chained schedules can be dramatically altered in shape by the separating of the stimulus topography. The "aversiveness" of S_2 is completely reversed in all cases, with only the 10:1 and low rate of reinforcement subject not peaking at S_2 or beyond (in a direction opposite S_1). Even though there was a response requirement in the presence of S_2, this was not sufficent to produce peak shift under optimal conditions, when the stimuli were presented on different keys. To explore possible reasons why these results were obtained, experimentation would need to investigate various differences between the keys and use time schedules (e.g. ch VT 10-min VI 1-min, where T indicates response-independent reinforcement) to test out whether introducing no response requirement in the presence of S_2, would produce peak shift.

However, utilising a time schedule is precluded from the present research as it is no longer a chained schedule, according to the definition (see section 1.1). The two-key chained schedule, therefore, was not the subject of further research in the present thesis.

Chapter 6

EXPERIMENT 5

6.1 INTRODUCTION.

The first four experiments demonstrated that peak shift can be obtained following intradimensional discrimination training with chain VI VI schedules of reinforcement, and that parameters found to affect peak shift in multiple and concurrent schedules, are also found to affect peak shift in chained schedules.

Peak shift has been used to identify an "aversive" stimulus and hence, indicate the interaction of the "aversive control" of S_2 and the excitatory control of S_1 (see section 1.3.2). The "aversiveness" of S_2 can be shown by the finding of an incremental gradient around the S_2 following interdimensional discrimination training. An incremental gradient occurs where the minimum of the gradient is located at S_2, and responding to stimuli either side of S_2 gradually increases. The incremental gradient indicates that S_2 is an aversive or inhibitory stimulus because of its training history, relative to the other stimuli along the test dimension.

Research has indicated that conditions which produce peak shift following intradimensional discrimination training are similar to those that produce inhibitory gradients around S_2 following interdimensional discrimination training with multiple schedules of reinforcement (Terrace, 1968; Weisman, 1969) and also with concurrent schedules (Beale and Winton, 1970; Winton and Beale, 1971).

The aim of the present experiment was to investigate generalisation gradients following interdimensional discrimination training on ch VI 10-min VI 1-min. This schedule was shown to produce the highest probability of finding peak shift and, therefore, it should also have the highest probability of showing an inhibitory gradient around S_2 (see Experiments 2 and 3). Furthermore, the gradient around the S_1 should be a clear excitatory gradient, indicating the different types of control the component stimuli exert on responding in chained schedules.

The particular dimensions used in the present experiment were the result of extensive research using various combinations of training stimuli from the commonly used wavelength and line-tilt dimensions. This preliminary research using interdimensional discrimination training revealed that wavelength for the S_2 (i.e. green) and line-tilt for the S_1 (i.e. white line on a black background) were the stimuli which allowed no obvious masking or overshadowing effects (Mackintosh, 1977), and allowed stimulus-control gradients to be obtained around each training stimulus. The brightness of the green and line were varied across sessions of discrimination training so as to train the subject to ignore irrelevant cues in the discrimination task and generalisation test. Although clear inhibitory gradients in the past have been difficult to obtain, it was predicted that the present experiment would show inhibitory gradients around the S_2, as the earlier experiments had clearly shown the aversiveness of S_2 using the peak shift measure.

6.2 METHOD.

The subjects were seven experimentally naive homing pigeons. The procedure was basically similar to the ch VI 10-min VI 1-min intradimensional discrimination training in Experiments 2 and 3, but with the following variations. During single-stimulus preliminary training and subsequent interdimensional discrimination training, only the left key was lit and operative. Various types of stimuli could be projected onto the left key. These consisted of either five homogeneous coloured fields of 490nm, 538nm, 555nm, 578nm and 601nm, or five 2mm white lines of 15°, 30°, 45°, 60° and 75° (from the vertical) projected on a blank key or projected on the 555nm (green) field. For each subject the 555nm field alone was S_2 and either the 45° line alone or the 45° line on the 555nm background, was the S_1. During a generalisation test session, two separate tests were given in the following order: one with each of the five coloured fields randomly presented six times for 30 seconds, and one with each of the five lines either alone or with the 555nm background randomly presented six times for 30 seconds. Each test was preceded by a five minute warm-up of discrimination training.

Groups varied as to the number of subjects and what type of training they were given (i.e. I^{ER} only, I^{A}/I^{ER}, or $I^{A} \rightarrow I^{ER}$). All subjects had the brightness of training stimuli varied. A summary of the procedure for each group is presented in Table 6.1.

TABLE 6.1

INTRADIMENSIONAL (I^{A}) AND/OR INTERDIMENSIONAL (I^{ER}) TRAINING CONDITIONS FOR EACH GROUP OF (N) SUBJECTS.

GROUP	N	TRAINING CONDITION
1	2	I^{ER} ONLY
2	2	I^{ER} / I^{A} (HALF SESSION ON EACH)
3	3	$I^{A} \rightarrow I^{ER}$ (INTRADIMENSIONAL TRAINING AND TESTING PRIOR TO INTERDIMENSIONAL)

6.3 RESULTS.

During single-stimulus training response rates typically increased over the first few sessions and then remained fairly constant for the remaining sessions. Within the first few sessions of discrimination training, all subjects were discriminating markedly between S_2 and S_1, with response rates in the presence of S_1 always higher than in the presence of S_2. Table 6.2 presents the average response rate for the last three sessions of discrimination training, for each group.

TABLE 6.2

MEAN RESPONSE RATES IN THE INITIAL (S_2) AND TERMINAL (S_1) COMPONENTS FOR EACH GROUP.

GROUP	SCHEDULE COMPONENT	
	S_2	S_1
1	0.31	1.36
	0.62	2.72
2	0.27	1.50
	0.21	0.85
3	0.14	2.33
	0.49	1.43
	0.33	0.83

NOTE. MEAN = AVERAGE OF DATA OVER LAST THREE DISCRIMINATION TRAINING SESSIONS PRIOR TO TESTING.

The first four subjects show very similar discrimination indices, and yet vary in both S_2 and S_1 response rates, although larger variation occurred in the S_1 response rates than in S_2. Subject 5 had a high discrimination index, while subjects 6 and 7 produced the lowest. Stimulus-control gradients were obtained for all subjects. These are plotted in Figures 6.1 to 6.4. Figure 6.1

presents the mean relative gradients along the S_2 and along the S_1 dimensions, and individual subject's relative gradients are presented in the remaining figures.

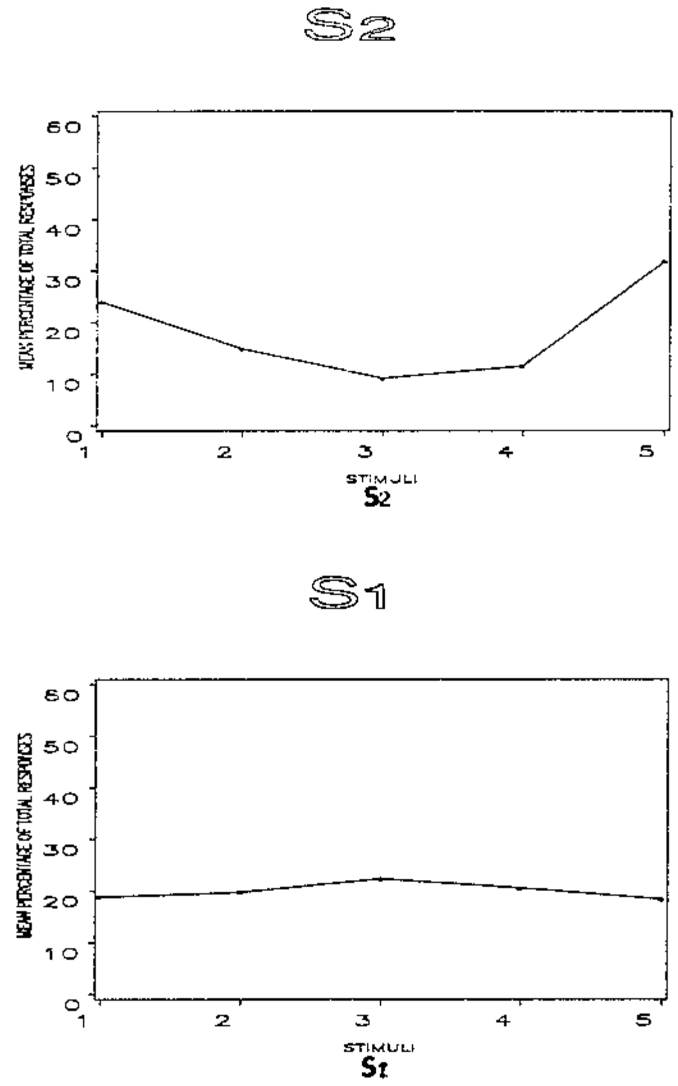


Figure 6.1 Mean relative gradient along the S_2 and S_1 dimensions for all subjects.

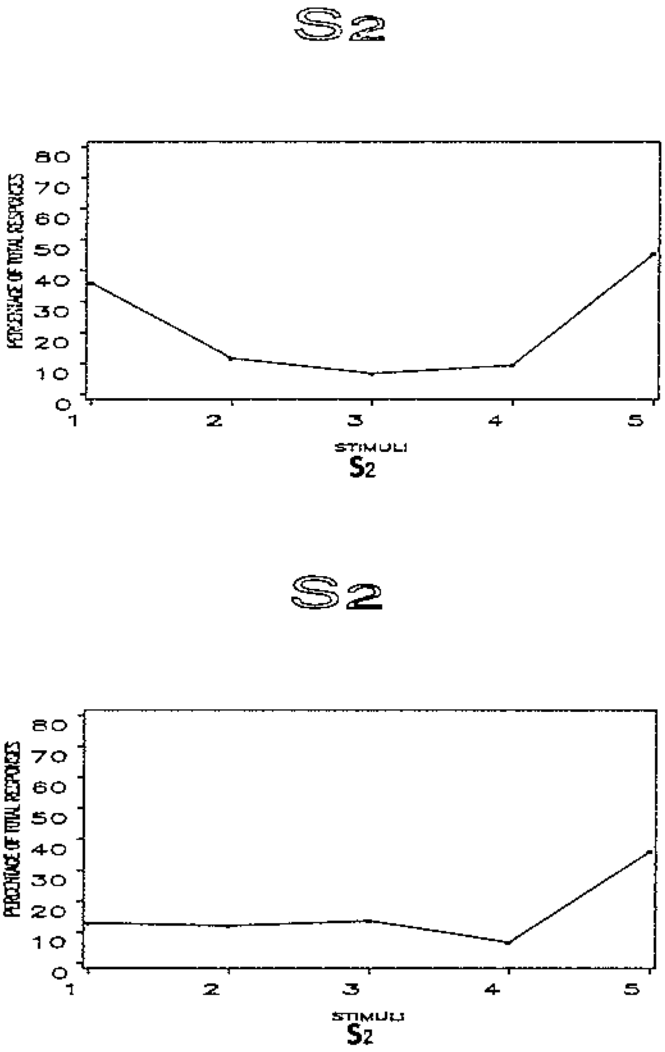
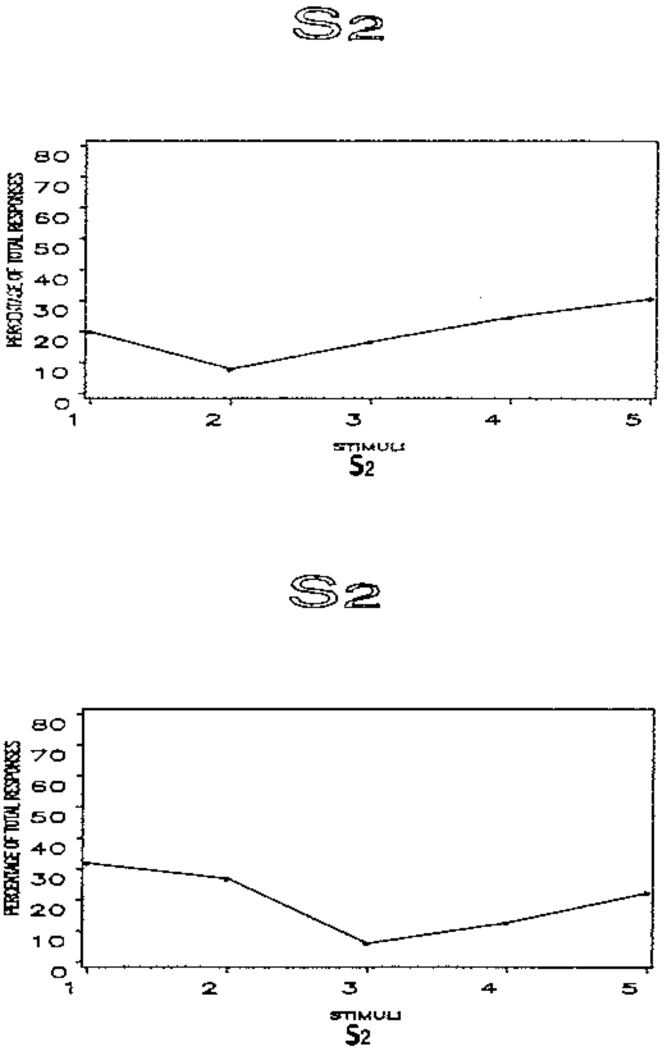


Figure 6.2 Relative S_2 gradients for I^{ER} subjects.



<u>Figure 6.3</u> Relative S_2 gradients for I^A/I^{ER} subjects.

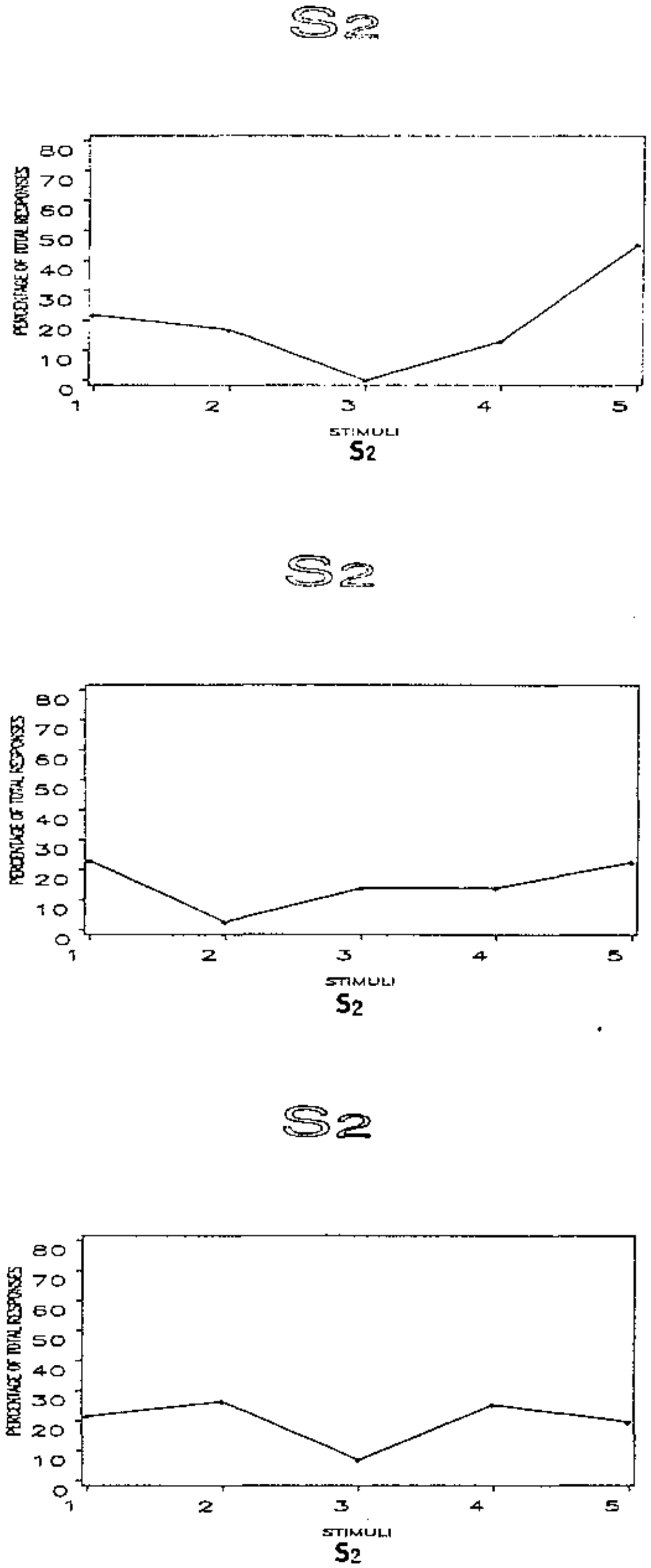


Figure 6.4 Relative S_2 gradients for $I^A \rightarrow I^{ER}$ subjects.

The mean relative gradient for all subjects shows an inhibitory gradient with the minimum (nadir) at S_2. Groups 2 and 3 also produced mean relative gradients with the minimum at S_2, while for group 1 the minimum was at one stimulus removed from S_2. Analysis of individual subject's relative gradients reveal that all but two produced the minimum at S_2, with one subject from group 1 giving the minimum at 575nm and the other subject, from group 2, at 535nm (both stimuli being one removed from the training stimulus S_2). The total number of responses made during the generalisation test was similar across birds.

Stimulus-control gradients along the S_1 dimension (i.e. line orientation) reveal a mean relative gradient with the maximum at the training stimulus S_1 (45° line). There was greater variation in individual results along the S_1 test dimension than along the S_2. Both group 1 subjects produced a maximum at S_1, both group 2 subjects produced a maximum at one stimulus removed from S_1 (i.e. 30°), while two of group 3 subjects had a maximum at one removed (i.e. 60°) and the other subject at two removed (i.e. 15°).

6.4 DISCUSSION.

Inhibitory gradients were obtained following interdimensional discrimination training on ch VI 10-min VI 1-min. This result confirmed the similarity between the conditions of S- in multiple and concurrent schedules, with those of S_2 in chained schedules. Although this experiment presents the results for the particular stimuli reported, many other experiments were conducted using various combinations of line orientation and wavelength stimuli in the three different types of training conditions (i.e. I^{ER} only, I^{ER}/I^{A}, and $I^{A} \rightarrow I^{ER}$) - see Appendix 2. Months of research finally revealed optimal stimulus conditions for detecting inhibitory control by S_2.

The finding of inhibitory gradients around the S_2, together with the findings of Experiments 2 and 3 of peak shift, indicate that the control by S_2 differs from that of S_1. The data support the notion of the "aversiveness" of S_2 in relation to S_1, under certain training conditions. It also provides support for the "spencerian" notion of inhibitory and excitatory control, and an absolute theory of peak shift, in that the type of control each component stimulus exhibits appears to differ, within a ch VI 10-min VI 1-min schedule of reinforcement.

Chapter 7

EXPERIMENT 6

7.1 INTRODUCTION.

Experiment 5 obtained inhibitory gradients following interdimensional discrimination training on a ch VI 10-min VI 1-min schedule. Peak shift has also been obtained following intradimensional discrimination training on this schedule (Experiments 2, 3 and 4), but with different groups of subjects from those used in Experiment 5. Many experimenters have shown such results with other schedules (e.g. multiple), but typically using different groups of subjects. Hickis, Robles and Thomas (1977), however, gave two different interdimensional discrimination problems (same dimensions) to subjects on alternate days (i.e. odd days was problem 1 and even days , problem 2). Generalisation tests revealed peak shift along both dimensions (wavelength and line-tilt) when the context of training was held constant or randomly presented during testing. This procedure did not allow for inhibitory gradients to be investigated, but did show that subjects could learn two discrimination tasks, each given on alternate days.

The present experiment sought to investigate whether peak shift and inhibitory gradients could be obtained within the same subject and after equivalent amounts of intradimensional and interdimensional discrimination training on ch VI 10-min VI 1-min, within the same session. If this was found, it would perhaps lend weight to the idea that both phenomena were in fact measuring the same thing i.e. "inhibition" of S_2 responding generated in a chained schedule of reinforcement.

7.2 METHOD.

7.2.1 Subjects

Sixteen experimentally naive homing pigeons were maintained at 80% ±15 grams of their free-feeding body weight.

7.2.2 Apparatus

As in Experiments 2 and 5.

7.2.3 Procedure

The two outer keys were in operation, with the brightness intensity (intradimensional) stimuli presented on the left key and the wavelength and line stimuli presented on the right key. Subjects received twenty minutes of either intradimensional or interdimensional discrimination training (the order of which was randomised), followed by the other type of training on the other outer key. Only one key was operative during training. Stimulus values (cd/m^2) were the same as in Experiments 1, 2, and 4.

Generalisation tests were given following discrimination training, the order of which was varied across subjects, so that either intradimensional test stimuli were presented followed by a 5-min warm-up and then the interdimensional test stimuli, or the other way round. All generalisation tests given following interdimensional discrimination training were in the same order, that is, first the test along the S_2 test dimension, followed by a 5-min warm-up (i.e. discrimination training again), then the test along the S_1 test dimension - as in Experiment 5. Table 7.1 presents the training conditions for each subject.

TABLE 7.1

TRAINING SCHEDULE, THE INTERDIMENSIONAL (I^{ER}) TRAINING STIMULI AND THE GENERALISATION TEST GIVEN FIRST (I^{ER} OR I^{A}), FOR EACH SUBJECT IN EACH GROUP.

GROUP	SUBJECT	CHAINED SCHEDULE	INTERDIMENSIONAL STIMULI S_2	INTERDIMENSIONAL STIMULI S_1	WHICH TEST
1	1	CH VI 10-MIN VI 1-MIN	45°+555NM	555NM	I^{ER}
	2		555NM	45°+555NM	I^{ER}
	3		45°+555NM	555NM	I^{A}
	4		45°+555NM	555NM	I^{A}
	5		45°+555NM	555NM	I^{A}
	6		45°+555NM	555NM	I^{A}
2	7	CH VI 1-MIN VI 1-MIN	45°+555NM	555NM	I^{ER}
	8		555NM	45°+555NM	I^{A}
3	9	CH VI 7-SEC VI 70-SEC	555NM	45°+555NM	I^{ER}
	10		45°+555NM	555NM	I^{A}
	11		45°+555NM	555NM	I^{A}
	12		45°+555NM	555NM	I^{A}
	13		45°+555NM	555NM	I^{A}
	14		45°+555NM	555NM	I^{A}
4	15	CH VI 70-SEC VI 7-SEC	45°+555NM	555NM	I^{A}
	16		45°+555NM	555NM	I^{A}

7.3 RESULTS.

Single-stimulus training revealed response rates similar to previous experiments, as did discrimination training, with response rates in the presence of S_1 always higher than in the presence of S_2. Table 7.2 presents the average response rates for the last three sessions of discrimination training, for each group.

TABLE 7.2

MEAN RESPONSE RATES IN THE INITIAL (S_2) AND TERMINAL (S_1) COMPONENTS FOR EACH GROUP.

GROUP	SCHEDULE COMPONENT			
	S_2		S_1	
	I^A	I^{ER}	I^A	I^{ER}
1	0.55	0.42	1.65	1.67
2	0.61	0.79	1.65	1.44
3	0.24	0.21	1.03	1.02
4	0.58	0.44	2.61	2.66

NOTE. MEAN = AVERAGE OF DATA OVER LAST THREE DISCRIMINATION TRAINING SESSIONS PRIOR TO TESTING.

Table 7.3 presents the data obtained from the tests following intradimensional discrimination training. Peak shift was found in three of the six ch VI 10-min VI 1-min subjects (with a fourth giving equal responses to S_1 and the stimulus one removed from S_1 away from S_2), two ch VI 1-min VI 1-min subjects and in one of the six ch VI 7-sec VI 70-sec subjects (by one response). The ASYM scores again show that the gradients obtained following ch VI 10-min VI 1-min discrimination training had higher response levels (0.51) to the right of S_1 (i.e. away from S_2) than after the other schedules, with ch VI 7-sec VI 70-sec showing the lowest score (0.31).

TABLE 7.3

WHETHER PEAK SHIFT WAS OBTAINED, THE GENERALISATION INDICES AND ASYMMETRY SCORES FOR EACH SUBJECT. THE NUMBER OF RESPONSES MADE IN THE TEST AND THE PERCENTAGE OF THAT TOTAL MADE TO S_1 ARE ALSO PRESENTED.

SUBJECT	PS	GI	ASYM	% TO S_1	TOTAL RESPONSES
1	YES	0.53	0.85	33.00	820
2	NO	0.43	0.81	39.20	222
3	YES	0.51	0.70	26.50	1517
4	NO(EQ)	0.50	0.73	30.40	723
5	NO	0.47	0.79	33.70	712
6	YES	0.51	0.67	30.50	1293
		$\bar{X}$ 0.49	0.51	32.20	881
7	NO	0.496	0.63	28.90	1214
8	YES	0.52	0.75	31.80	1325
		$\bar{X}$ 0.51	0.48	30.40	1270
9	NO	0.47	0.40	29.90	1205
10	NO	0.39	0.46	38.60	591
11	NO	0.41	0.41	35.00	320
12	YES	0.50	0.94	37.90	327
13	NO	0.42	0.27	20.70	1614
14	NO	0.43	0.29	23.40	1161
		$\bar{X}$ 0.44	0.46	30.90	870
15	NO	0.48	0.63	30.50	1063
16	NO	0.46	0.52	31.50	867
		$\bar{X}$ 0.47	0.58	31.00	965

NOTE. MEAN SCORES FOR EACH GROUP ARE GIVEN ($\bar{X}$)

Generalisation gradients were obtained and mean relative gradients for each group are presented in Figures 7.1 to 7.4. Five of the six subjects which had had ch VI 10-min VI 1-min interdimensional discrimination training showed a nadir (minimum) at or next to S_2. Only one other subject showed a similar result (subject 12, ch VI 7-sec VI 70-sec -the subject which had only just showed peak shift).

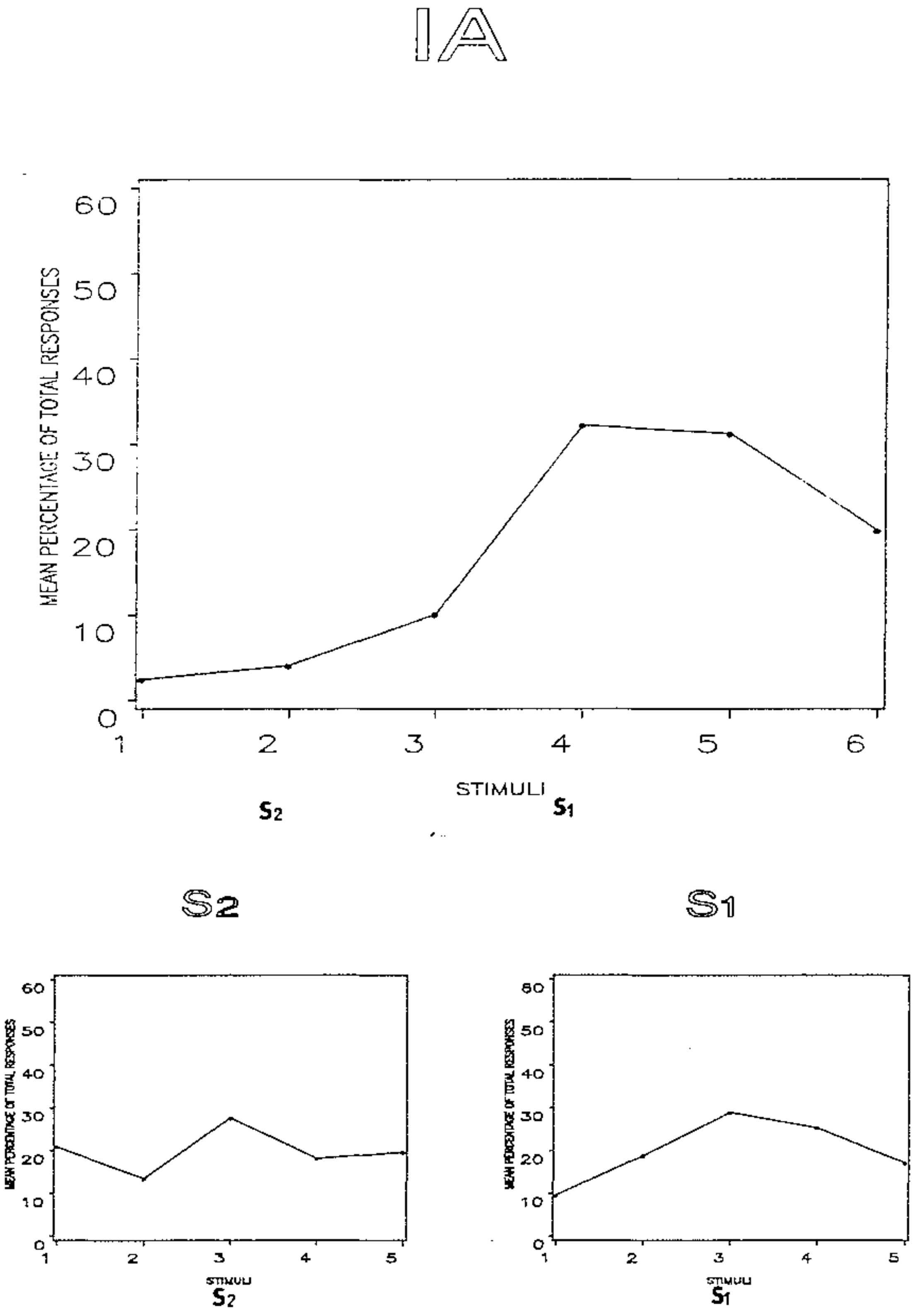


Figure 7.1 I^{ER} and I^{A} mean relative gradients for Ch VI 10-min VI 1-min subjects.

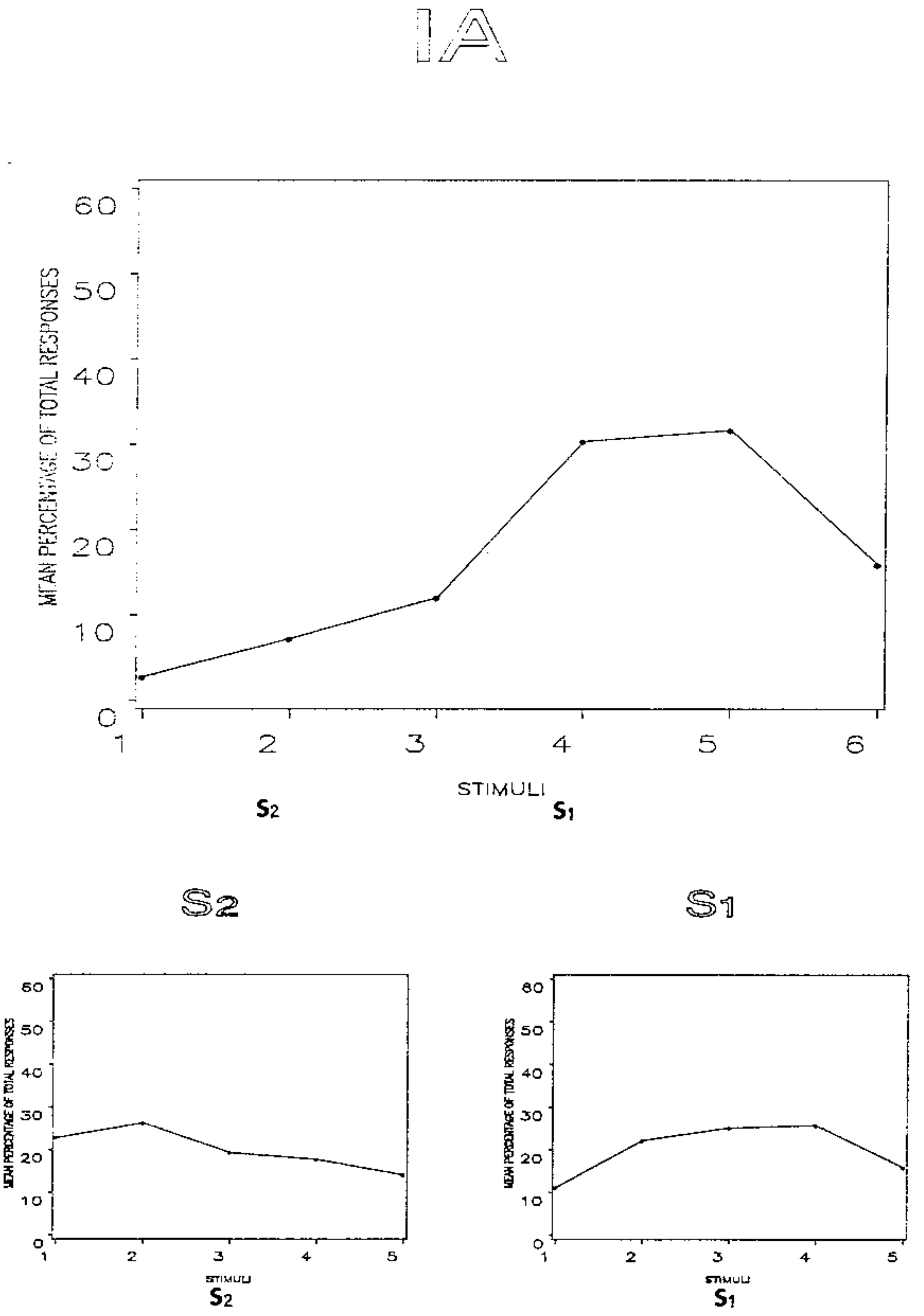


Figure 7.2 I^{ER} and I^{A} mean relative gradients for Ch VI 1-min VI 1-min subjects.

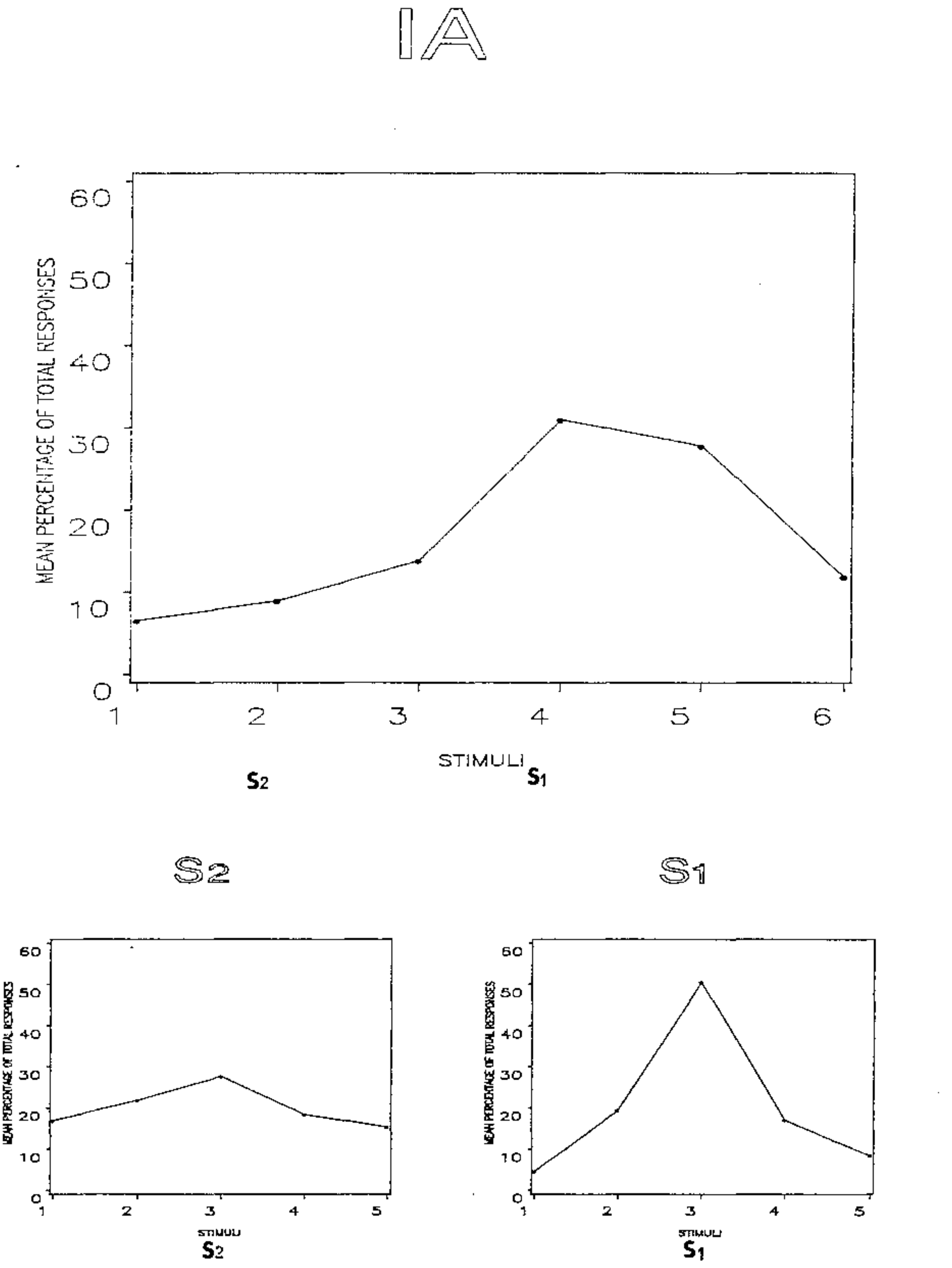


Figure 7.3 I^{ER} and I^{A} mean relative gradients for Ch VI 70-sec VI 7-sec subjects.

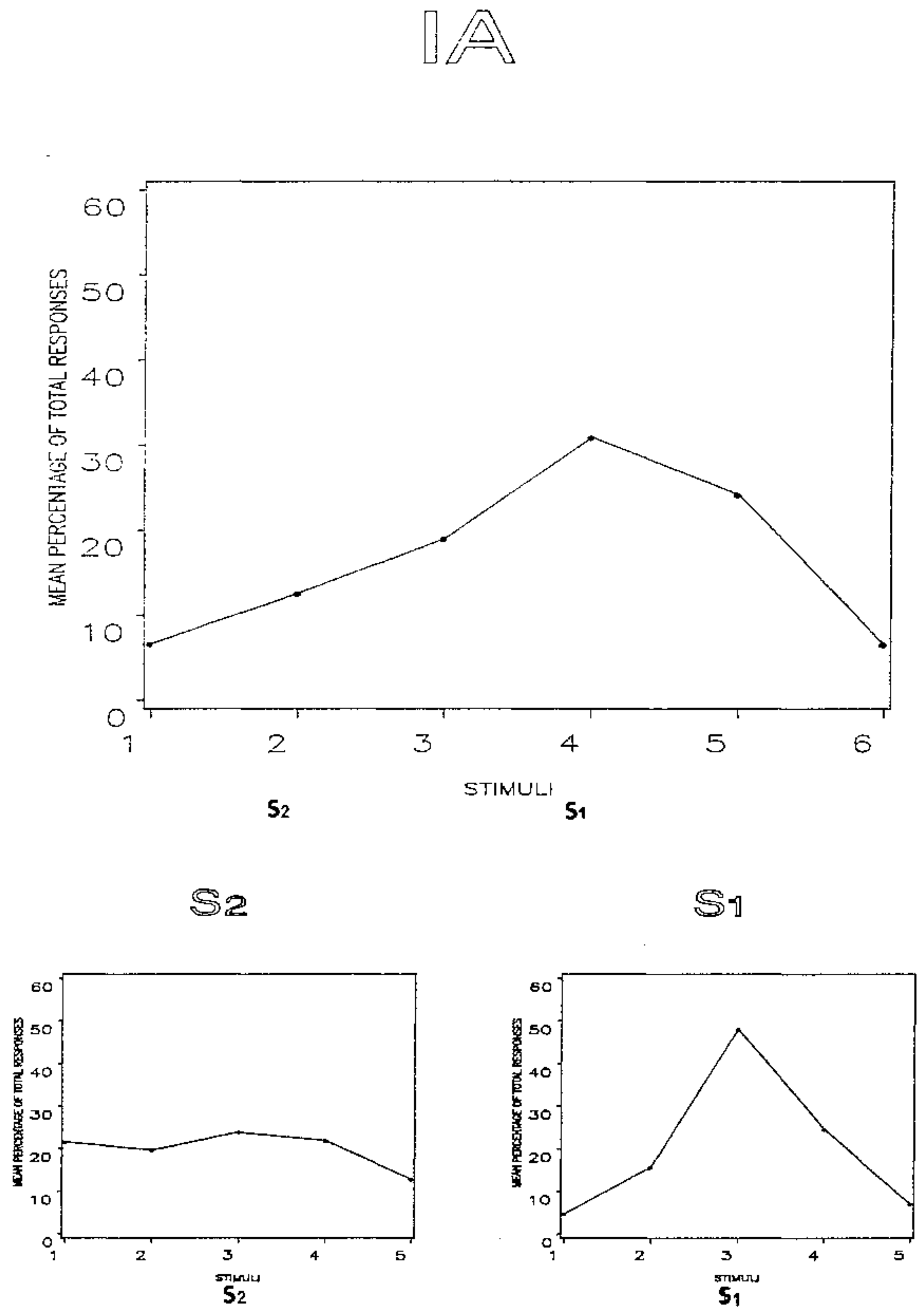


Figure 7.4 I^{ER} and I^{A} mean relative gradients for Ch VI 7-sec VI 70-sec subjects.

7.4 DISCUSSION.

The present experiment showed that both peak shift and inhibitory gradients can occur following discrimination training using this "double" procedure.Three of the five subjects showing peak shift also gave inhibitory-type gradients, with the nadir at S_2 or to the stimulus next to S_2. Subject 3 gave equal responding to S_1 and the stimulus to the right of S_1 away from S_2 after intradimensional discrimination training, and also showed a nadir at S_2 in an inhibitory gradient following interdimensional discrimination training.The one subject in Experiment 4 which had interdimensional following intradimensional discrimination training both on the same schedule (ch VI 10-min VI 1-min), showed peak shift after intradimensional followed by an inhibitory gradient after interdimensional discrimination training. These results, therefore, suggest that both peak shift and inhibitory gradients may be found within the same subject. The present experiment gave each subject approximately half the exposure time to each set of stimuli during discrimination training than subjects that had the single procedure of either intradimensional or interdimensional discrimination training prior to testing (Experiments 1 to 5). This shortened exposure time may have affected the results in comparison to Experiments 2 and 5, in that not all subjects with ch VI 10-min VI 1-min training showed peak shift (two, and one with equal responses) nor inhibitory gradients (one subject). Further refinement and exploration of this technique appears warranted so as to gather a more accurate assessment of stimulus control. If these two phenomena of stimulus control (peak shift and inhibitory gradients), are indeed indicative of the same type" of control (i.e. the "aversiveness" of S_1), then it appears logical that these two phenomena should be obtained within the same subject using such a procedure as was used in the present experiment.

Chapter 8

EXPERIMENT 7

8.1 INTRODUCTION.

In Experiments 1, 2, 3, and 6, peak shift was found after several sessions of discrimination training on chained schedules of reinforcement. Subjects in those experiments were given one generalisation test, from which the gradient was obtained.

Subjects can, however, be given more than one generalisation test. After the first test either the same or different conditions of discrimination training can be given, followed by a second generalisation test. Where training conditions remain the same prior to the second test as those given prior to the first test (i.e. extended training is given), peak shift has been found after as many as seven previous tests and after as much as 108 days of discrimination training (Dukkhayil and Lyons, 1973), although Terrace (1966) found that it declined after prolonged discrimination training. Several variables can, however, be changed prior to subsequent testing, and the aim of the present experiment was to investigate some of these variables and the effect the change had on peak shift. The experiment also investigated extended training on chained schedules of reinforcement.

The two major variables to be investigated in the present experiment were those defining variables of a chained schedule. The IRI or rate of reinforcement either increased, decreased or remained the same in the discrimination training sessions prior to the second generalisation test. The aim of exploring this variable was that, as a major variable affecting peak shift in generalisation tests after chained discrimination training (Experiment 2), it may be sufficient in itself to influence the likelihood of peak shift after exposure to a chained schedule prior to the first test.

The other major variable found to affect peak shift in chained schedules was the component duration ratio (Experiment 2). The CDRs were changed by making them longer or shorter than those used prior to the first test. Terrace (1968) found that when subjects were initially trained on multiple schedules with equal VI 1-min component schedules, followed by a "downshift" from VI 1-min to VI 5-min (i.e. made leaner) on S_2 (S_1 remained on VI 1-min), they produced peak shift after the second lot of training only (i.e. after the "downshift"). Whereas, when they experienced an "upshift" of multiple. VI 5-min VI 5-min to mult. VI 1-min VI 5-min (i.e. made richer), they did not show peak shift in either test (i.e. before or after the "upshift"). Weisman (1969) reported similar effects on inhibitory gradients. Perhaps in chained schedules of reinforcement, going from a ch VI 15-sec VI 1-sec to a ch VI 1-min VI 15-sec is a "downshift" (i.e. S_2 component lengthened, therefore, made more aversive). The present experiment sought to investigate this possibility.

Another variable which may be likely to affect peak shift is the reversal of S_2 and S_1 prior to the second generalisation test. The stimulus which was S_2 prior to the first test would be made the S_1 in the discrimination training prior to the second test.

This experiment, therefore, provided exploratory investigation of extended training and the effects of prior training on various other chained schedules, on performance in chained schedules of reinforcement, as measured by generalisation gradients.

8.2 METHOD.

8.2.1 Subjects

Sixty-four experimentally naive homing pigeons were maintained at 80% ±15 grams of their free-feeding body weight.

8.2.2 Apparatus

As in previous Experiments 2 to 6.

8.2.3 Procedure

Subjects were given chain discrimination training followed by a generalisation test and then were given further training and testing. Subjects had either intradimensional and/or interdiscrimination discrimination training prior to testing, and were given either the same or a different chained schedule, and either the same or reversed component stimuli. A reversal of the component stimuli occurred where the initial-link stimulus became the terminal-link stimulus, and vice-versa, in the second training condition. The cd/m^2 values of the stimuli were as in Experiments 1, 2, 4, and 6.

8.3 RESULTS.

The results are presented and discussed under the headings of peak shift and inhibitory gradients.

8.3.1 Peak Shift

Rate of reinforcement change:

Where the rate of reinforcement remained the same in the second training condition, only one of the four subjects showed peak shift. Those subjects which experienced an increase in the reinforcement rate in the second training condition, all showed peak shift except where S_1 component duration was shortened relative to S_2 component duration (which remained the same in both conditions). All subjects showed peak shift when they experienced a decrease in reinforcement rate, except where S_1 component duration was lengthened (S_2 remained the same).

Component duration change:

Consideration of the component duration ratios reveals that changes in the S_2 component duration affected the probability of obtaining peak shift greater than changes in the S_1 component duration. When the S_2 component duration was shortened, no peak shift was obtained. This occurred whether S_1 component duration remained the same, was lengthened, or was shortened. When the S_2 component duration was lengthened, peak shift was obtained by all subjects except one (where the S_1 component duration was shortened and hence, there was no change in the rate of reinforcement).

Stimulus reversal:

Those subjects which had ch VI 10-min VI 1-min discrimination training in both training conditions, but had reversal of the component stimuli in the second compared to the all showed consistency. The findings of Experiment 1 were consistant with the finding of Frieman and Thomas (1970). More subjects given S_2 as the stimulus in single-stimulus training showed peak shift than subjects trained with S_1. Experiments 2 and 3 were consistent with the prediction that the 10:1 CDR and long IRI would give the greatest likelihood of finding peak shift and highest asymmetry scores (Richards, 1973). Experiment 3 found the same result in chained schedules as has been found in multiple schedules, in that the closer spacing of the training stimuli along the test dimension resulted in more peak shift. The results of Experiment 4 also concurred with those of Honig (1962), where the seperation of the training stimuli onto two different response locations gave no peak shift. The finding of inhibitory gradients following training on the chained schedule which had given peak shift, also is consistent with research using multiple and concurrent schedules (Terrace, 1968; Winton and Beale, 1971). Experiments 6 and 7 provided further evidence of the trend across CDRs and IRIs found in experiments 2 and 3.

The small-N approach has allowed manipulation of the independent variable as has succeeded in providing much information on stimulus control in chained schedules.

9.2 POTENT VARIABLES AFFECTING GENERALISATION GRADIENTS IN CHAINED SCHEDULES.

9.2.1 Effect of rate of reinforcement / IRI

This thesis has shown that the interreinforcement interval or rate of reinforcement is a potent variable in studying stimulus control in chained schedules. A lean (i.e. low reinforcement rate) chained variable interval schedule was clearly shown to produce the best evidence of finding peak shift and of not finding peak shift (i.e. ch VI 10-min VI 1-min and ch VI 1-min VI 10-min, respectively). A rich (i.e. high reinforcement rate) chained variable interval schedule did show these differences, but to a lesser extent. By keeping extremes of IRI, this thesis was able to show the effects of the component schedules (i.e. CDRs).

9.2.2 Effect of component duration ratio (CDR)

This variable was found to be most important in determining peak shift. A 10:1 CDR led to a much higher incidence of peak shift than the 1:10 CDR. The finding of peaked gradients away from S_1 in a direction towards S_2 in some ch VI 1-min VI 10-min subjects, implied that the type of control around the S_2 of a two-component chained schedule was not inhibitory in all cases. It could be excitatory, depending on the particular variables employed (i.e. long IRI and 1:10 CDR). Hence, there are circumstances in which the aversiveness of a stimulus can be reduced to the extent that it disappears entirely, as indicated by a particular measure.

Perhaps these results imply, therefore, that such concepts as "aversiveness" and "inhibitory" can only be considered descriptive under the particular conditions operating at the time.

9.2.3 Effect of preliminary training

Experiment 1 investigated the effect of preliminary single-stimulus training on the subsequent performance in discrimination training and the generalisation test. Single-stimulus training with the stimulus that was subsequently made the S_2 was found to slightly raise the DI, with a higher average response rate to S_1 and lower to S_2, than those subjects whose single-stimulus training was with the stimulus that was made S_1. The difference between component response rates, therefore, was greater where S_2 was the stimulus used in preliminary training.

During single-stimulus training, reinforcement is delivered as a consequence for responding to one particular stimulus and not given for responding to any other stimulus. The subject comes to respond only in the presence of that particular stimulus. In chain discrimination training, where that stimulus is made the initial-link stimulus (S_2), responding in its presence suddenly is never followed by reinforcement. In fact, a "delay" is introduced as a consequence of responding to S_2, and S_1 is presented throughout that delay. S_1 is now the stimulus associated with reinforcement.

In comparison to this, where S_1 is the single-stimulus used in preliminary training, the introduction of the chain discrimination training provides no change to the consequence of responding in the presence of this stimulus. There has been prior experience of the same conditions, whereas in the S_2 training-stimulus case, there was no prior experience of the opposite conditions (i.e. reinforcement - no reinforcement). It is presumed, therefore, that the prior history would affect responding in the presence of S_2 more in the S_2 training group than in the S_1 training group, which is what the data show.

Generalisation gradients also showed this difference between subjects who had S_2 or S_1 as the single stimulus in preliminary training, with more peak shift, higher GI and ASYM scores being found with subjects who had had S_2. Prior history of reinforcement being delivered as a consequence of responding in the presence of a stimulus was found to indicate more aversive control by that stimulus when it became the initial component stimulus of a two-component chained schedule. If there had been no such prior history, the aversiveness was reduced.

9.2.4 Effect of S_2/S_1 separation along the test dimension

Reducing the S_2/S_1 separation along the test dimension produced a higher probability of obtaining peak shift (see Experiment 3). This confirmed other researcher's findings using multiple schedules (Hanson, 1959; Thomas, 1962). This result indicates that stimulus control in chained schedules changes in the same direction as it does in multiple schedules, given equivalent training conditions Hence, conditions which affect stimulus control in multiple schedules may affect stimulus control in chained schedules in a similar way.

When the stimulus separation along the test dimension is reduced, the discrimination between S_2 and S_1 is made more difficult (i.e. the stimuli are made more similar, in that there is less difference in visual intensity between them). The subject, therefore, must learn to discriminate between the two training stimuli. Purtle (1973) suggests that pigeons learn the relation between S_2 and S_1, and attempt to maintain this relation (or separation) in the generalisation test. He suggests that this "relational responding" accounts for the finding of the inverse relationship between the extent of peak shift and the S_2, S_1 separation.

Spence's absolute theory would also predict that the magnitude of the peak shift increases as the difference between S_2 and S_1 is reduced. Where there is a large difference between S_2 and S_1, peak shift is not obtained, since there is no overlap or interaction between the excitatory gradient around S_1 and the inhibitory around S_2.

9.3 THEORETICAL CONSIDERATIONS.

9.3.1 The aversiveness of S_2 in a chain

The experiments reported in this thesis provide evidence that the initial-link stimulus (S_2) maintains a lower response rate than S_1 and is associated with peak shift and inhibitory gradients under certain training conditions. These findings may be described by assuming that S_2 has acquired aversive properties which will manifest themselves under certain training conditions. In a chain, behaviour in the presence of S_2 is never followed by the primary reinforcer, whereas that in the presence of S_1 is always followed by the primary reinforcer. Stimuli associated with non-reinforcement have been described as being aversive (Rilling, Askew, Ahlskog and Krammer, 1969; Terrace, 1966;1971), hence, S_2 may be aversive.

Evidence from avoidance studies also indicates the aversiveness of S_2, in that subjects will actually avoid returning to the initial component of a chain FI FR by emitting the required response pattern, that is, responses with short interresponse times of 6-sec or less (Findley, 1962). Thomas (1966) showed that subjects would make an avoidance response on one key in order to postpone the return to the initial component of a chain FI FR programmed on another key.

Research using a punishment paradigm (i.e. where a stimulus suppresses behaviour on which it is made contingent) has shown that following chain training rats will produce fewer responses, the consequence of which was to produce S_2, than when the consequence was to produce a neutral stimulus, that is, neither S_2, S_1, nor the reinforcer (Kaufman and Baron, 1969). Together with the research using the avoidance paradigm, data indicate the aversive property of S_2.

Data gathered from choice experiments using the concurrent chains procedure also confirms the notion of the aversiveness of S_2, in that the research has found that segmented schedules (as in chained schedules), are preferred less than less segmented schedules (as in simple schedules) (Leung, 1984). One explanation could be that the S_2 signalled non-reinforcement always and hence, introduced an aversive element into the schedule, compared to a simple schedule where S_1 was the only stimulus and which always signalled reinforcement. In a chained VI schedule with a short IRI both components can be brief and S_2 may sometimes be in a close temporal relationship to a reinforcer, possibly causing a reduction in the aversiveness. Whereas, in those chained VI schedules with a long IRI there is never a close temporal relationship to a reinforcer, only an occasional close temporal relationship between the two component stimuli (S_2 and S_1). Concurrent chains research shows that segmenting an FI schedule had a less dramatic effect on choice than segmenting an FI schedule, hence, the VI schedule may have to be a long IRI in order for the effects of differing CDRs to be evident. The results of Experiment 2 illustrate this in that the long IRI of eleven minutes produced the greatest difference in data from the varying CDRs.

9.3.2 The Conditioned Reinforcement Hypothesis

Previous research has reliably shown that the S_1 in a chain is a conditioned reinforcer (Fantino, 1977), hence, in a chain any reinforcing effect of S_1 (i.e. maintain responding to S_2) may act as a buffer against the aversive properties of S_2 (i.e. tendency to inhibit responding in its presence). If this is the case, then the greater the reinforcing value of S_1, the less aversive the S_2. The delay-reduction hypothesis (Fantino, 1977),maintains that S_1 becomes more reinforcing as the terminal component becomes relatively shorter than the initial component (e.g. 10:1). In other words, for a given IRI the reinforcing strength of S_1 is a positive function of the CDR or segmentation ratio. In Experiments 2 and 3, peak shift and ASYM scores were positively related to the CDR. The aversiveness of S_2, therefore, increased with the larger CDR and with the larger reinforcing value of S_1. Moreover, higher response rates during S_2 were maintained in a 1:10 CDR than a 10:1 CDR, hence, the reinforcing effect of S_1 was correlated with, rather than acting as a buffer against, the aversiveness of S_2. Hence, the usefulness of the conditioned reinforcement hypothesis in studying stimulus control in chained schedules is limited.

Davison (1974) suggests that the control exerted by S_2 on behaviour, is relatively constant when compared to that exerted by S_1, and this is confirmed by the present thesis. When the CDR increased, the response rate in the presence of S_1 increased, while that in the presence of S_2 showed relatively little change. Hence, in terms of the discrimination index, as the CDR increased, the DI also increased (see Experiments 2 and 3, comparing 10:1 and 1:10 CDRs). A high DI has been shown to be associated with peak shift and inhibitory stimulus control (Wheatley and Thomas, 1974), and hence, with increased aversiveness of S_2 within the chained schedule. In Experiment 1 the greater increase in S_1 response rate, and decrease in S_2 response rate, and subsequent stimulus-control measures, when S_2 was the preliminary training stimulus (compared to when it was S_1), also agrees with the notion of a higher DI and reinforcing value of S_1 being associated with increased aversiveness of S_2. The reinforcing value of S_1, while positively related to the CDR is also positively related to the aversiveness of S_2. Therefore, the conditioned reinforcer does not negate or compensate for the aversiveness of S_2, but is positively associated with it. As the reinforcing value of S_1 increases, so does the aversiveness of S_2 relative to S_1.

It was not that the increased reinforcing value of S_1 determines the aversiveness of S_2, as Experiments 2 and 3 showed that a high reinforcing value of S_1 is associated with peak shift and inhibitory stimulus control when there is a long IRI and there was not as great an association when there was a relatively short IRI. In fact, the long IRI showed up the effects of the reinforcing value of S_1 more than a short IRI.

Perhaps when there is a short IRI the reinforcing value of S_1 is not as much a concern, even though the reinforcing values can vary as much as 10:1 CDR to a 1:10 CDR. When there is a long IRI, however, the reinforcing value of S_1 may play a part in determining the aversiveness of S_2, with a high reinforcing value associated with a high ASYM score and peak shift, whereas a low reinforcing value never being associated with peak shift and always with a low ASYM score. Perhaps a low reinforcing value of S_1 makes S_2 and S_1 more similar. Certainly response rates were more similar (see Experiments 2 and 3).

What does this indicate about the conditioned reinforcement hypothesis? It indicates that the notion of conditioned reinforcement is insufficient to explain the findings of peak shift and inhibitory stimulus control and hence, the type of control exerted by the component stimuli in a chained schedule. The reinforcing value of S_1 affects the control by S_2 but the type of control varies with the interreinforcement interval.

9.3.3 Gradient interaction theory

The results of this series of experiments provide support for Spence's remarkably robust gradient interaction theory. Peak shift was obtained following discrimination training with certain chained schedules (Experiments 1, 2 and 3), and inhibitory gradients were obtained with the schedule found to produce the highest probability of peak shift (Experiment 5). The data suggest, therefore, that there is a different type of control in the S_2 component than that in the S_1 component: excitatory control around S_1 and inhibitory control around S_2.

The phenomenon of negative peak shift (i.e. where the minimum was not at S_2 but at a stimulus in the test dimension beyond S_2), however, was not always obtained when positive peak shift was, contrary to Spence's theory. However, 82% of all subjects employed in all the experiments conducted, showed agreement between finding either both or neither of positive and negative peak shifts. A comparison across schedules revealed that 68% of ch VI 10-min VI 1-min subjects showed both positive and negative peak shifts, 40% for ch VI 70-sec VI 7-sec, 29% for ch VI 7-sec VI 70-sec, 25% for ch VI 1-min VI 1-min, and none for ch VI 1-min VI 10-min. The largest number of subjects who showed negative, but not positive peak shift was also found with those subjects trained on ch VI 10-min VI 1-min. These results are consistent with the results of Experiments 2 and 3. The results also concur with those of Guttman (1965), Blough (1973, 1975), indicating that stimuli lying away from S- (S_2), opposite S+ (S_1) are more aversive than S- (S_2).

9.4 IMPLICATIONS FOR TOKEN ECONOMIES.

The present research provides some implications for token economies in that it has shown that the behaviour in a two-component chained schedule can be altered by manipulating the CDR and IRI. Essentially from an economic viewpoint, token-earning behaviours (i.e. behaviour occurring in the S_2 component) represent work output; the tokens (i.e. S_1) represent income or wages; and back-up events (i.e. reinforcers) represent expenditure (Kazdin, 1982). What the present study has shown is that when there are few back-up events or the supply of back-up events is slow, the requirement to emit the token-earning behaviours is aversive if there is a long delay in receiving the back-up event (i.e. ch VI 10-min VI 1-min). On the other hand, when there are few back-up events and there is a long delay for these events (i.e. reinforcer) relative to the delay to receiving the token, then the token-earning behaviour is found to not be aversive (i.e. ch VI 1-min VI 10-min). Furthermore, the study has shown that these differential effects occur to a lesser degree when there are plenty of back-up events and there is only a relatively short space of time between receiving each back-up event. An example of the rich schedule could contain the back-up event of watching a video, which is an event that an individual could earn possibly each day. A lean schedule, however, might result in the back-up event of a rise in pay, which is something that might only occur once within a 12 month period. Realisation of these implications from basic research of chained schedules could aid the responsiveness of clients to token economy programmes, and enhance the programmes' effectiveness.

9.5 CONCLUSIONS.

The present thesis attempted to provide more understanding of chained schedules of reinforcement by employing generalisation gradients as the dependent variable. It first considered the effects of the major defining variables of a chained schedule, namely the interreinforcement interval and the component duration ratio. In general, the results consistently showed that a long IRI and a 10:1 CDR produced the highest probability of finding peak shift.

The study then went on to show some of the factors already found in research by other investigators to affect generalisation gradients in multiple and concurrent schedules, also similarly affected generalisation gradients in chained schedules (i.e. stimulus separation, two-key procedure). Moreover, inhibitory gradients were obtained under training conditions where peak shift was obtained, as has been the case with multiple and concurrent schedules. This research, therefore, suggests that stimulus control in chained schedules is similar to those found in other schedules, in that it changes in ways similar to that in other schedules, given equivalent training conditions.

Although peak shift and inhibitory gradients were found in the present series of experiments, the finding that the aversiveness of S_2 could be reversed under certain training conditions suggests that the "absolute" properties of a stimulus may be determined by the "relation" between the training stimuli (i.e. schedule associated with each stimulus, stimulus spacing, etc.). Hence, stimulus control should be seen as only a descriptive term for the conditions and resultant behaviour occurring at a particular time. Further research using other techniques for measuring stimulus control may elucidate further conditions under which excitatory or inhibitory control may occur.

Furthermore, although it was beyond the scope of the present research to investigate the two-key procedure more, future research could do this in order to explain why this procedure allowed the S_2 to become less aversive and even gain excitatory control not seen on the one-key procedure.

The present study has raised some implications for the use of token economies within the applied setting, and hence, may aid in increasing the effectiveness of this widely-quoted procedure.

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APPENDIX 1

LUMINANCE READINGS FOR ALL TRAINING STIMULI.

STIMULI	CD/M^2
A	12.98
B	8.24
C	5.83
D	3.9
E	2.67
F	1.88
G	1.29
H	0.45
490NM	0.10
538NM	0.23
555NM	0.33
576NM	0.30
601NM	0.30
15°	0.65
30°	0.75
45°	0.60
60°	0.55
75°	0.70

APPENDIX 2

The following experiments were exploratory research along the dimensions of line orientation and wavelength. The aim of this research was to identify functionally orthogonal dimensions along which stimulus control gradients could be obtained.

EXPERIMENT A.

Summary of procedure

Stimuli used were a 45° white line on a black background for S_2 and 555nm keylight for S_1. The brightness of both S_2 and S_1 was varied across sessions for half the subjects (i.e. two subjects) and not varied for the other half. Four subjects were used. All training proceeded as given in Experiment 5. The schedule used was ch VI 10-min VI 1-min.

Summary of results

The two subjects given brightness variation showed inhibitory gradients with a nadir at S_2. Of the two subjects for whom the brightness of the training stimuli was not varied, one showed an inhibitory-type gradient with the nadir at 60°, while the other gradient was irregular, with the nadir at 30°. All subjects showed excitatory gradients around the S_1 except for one subject (one of the brightness-varied subjects) whose nadir was at 538nm.

EXPERIMENT B.

Summary of procedure

Stimuli used were 555nm for S_2 and a 45° line on a black background for S_1. The brightness of the training stimuli were not varied across sessions. Four subjects were used and all training proceeded as in Experiment 5. Schedule used was ch VI 10-min VI 1-min.

Summary of results

All subjects showed inhibitory-type gradients but with the nadir at 576nm. No subject showed a clear excitatory gradient around the S_1.

EXPERIMENT C.

Summary of procedure

Stimuli used were a 45° line on a green background for S_2 and 555nm for S_1. The brightness of the training stimuli was varied across sessions. Four subjects were trained on a ch VI 10-min VI 1-min schedule. Training proceeded as in Experiment 5 for two subjects and as in Experiment 6 (i.e. double procedure) for two subjects.

Summary of results

I^{ER} only: One subject showed an inhibitory-type gradient with the nadir at 60°. The other gave an excitatory gradient, peaking at 60°. Both subjects gave clear excitatory gradients around the S_1 (555nm).

I^A/I^{ER} : Both subjects gave excitatory-type gradients around the S_2 and around the S_1.

EXPERIMENT D.

Summary of procedure

Stimuli used were 555nm as S_2 and a 45° line on a green background as S_1 for four subjects and the stimuli were reversed for one subject. The brightness of the training stimuli was varied across sessions only for the S_2=line+green subject. All subjects were trained on a ch VI 1-min VI 1-min schedule. Training proceeded as in Experiment 5.

Summary of results

All subjects showed excitatory gradients, with all but two peaking at S_2. One subject gave an excitatory gradient which peaked at S_1. The other subjects gave only slight peaks but to varying stimuli (538nm, 576nm and 601nm).

EXPERIMENT E.

Summary of procedure

Stimuli used were 555nm as S_2 and a 45° line on a green background as S_1. The brightness of the training stimuli was not varied. Four subjects were trained on ch VI 1-min VI 10-min.

Summary of results

All subjects responded very little during the generalisation tests, however, all four subjects showed excitatory gradients which peaked at S_2. Similarly, excitatory gradients were obtained along the line orientation dimension, with all peaking at S_1.

EXPERIMENT F.

Summary of procedure

Stimuli used were 555nm as S_2 and a 45° line on a green background as S_1. The brightness of the training stimuli was varied across sessions. Two subjects had the green background behind all line test stimuli and the other two had it removed during testing (as in all other experiments). All subjects were trained on a ch VI 10-min VI 1-min schedule and training proceeded as in Experiment 5, except for the background of line test stimuli as mentioned.

Summary of results

All subjects showed inhibitory gradients with the nadir at either S_2 or 576nm, but only the subjects without the green background during testing showed excitatory gradients around S_1. Those subjects that had the green background with all line test stimuli, showed an inhibitory gradient around S_1 as well as S_2. These results confirm those of Newman and Benefield (1968), which found that pigeons trained to respond to a white vertical line on a green background, produced flat (i.e. zero slope) generalisation gradients with variations in the slope of the line if the green background was present, and decremental (excitatory) if the background was black. Wavelength could be said, therefore, to "mask" the control by line orientation, rather than referring to any "brightness contrast" between the line and the green background as proposed by Santiago and Wright (1980).