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AN ANALYSIS OF RESPONSE-CONTINGENT LIGHT CHANGE REINFORCEMENT

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SUMMARY

This thesis is concerned with experimental and theoretical issues arising from the rewarding effects of response-contingent light change in rats. The phenomenon, a special instance of sensory reinforcement, is characteristically known as light-contingent bar pressing (LCBP).

Section 1 consists of a review of the literature pertaining to LCBP. The evidence is reviewed firstly to evaluate the prominent and contesting theoretical explanations of LCBP. By an examination of the evidence bearing on the Facilitation hypothesis it is shown that response-contingent light change satisfies the criteria of a reinforcer. It is concluded that Stimulus-Change theory, which asserts that the light change functions as a change *per se*, provides the most satisfactory and parsimonious account of LCBP. The question was then examined: what is the nature of the presumed "motivational state" which underlies the reinforcing effect of a response-contingent change *per se*? Attention here focussed on a general Need or Drive for stimulus-change.

Section 2 consists of a brief outline of the general features of the research methodology and statistical procedures employed in the experiments reported here. The research technique is an important factor contributing to the strength of the conclusions drawn from the findings.

In order to obtain firm foundations for the experimental work in this thesis, two parametric studies, concerned with the effects of the magnitude, direction and duration of light change on LCBP, were conducted. They are reported in section 3. It was found that the duration of change is an important parameter determining responding. The results of these studies are discussed in the context of Stimulus-Change theory. The subsequent research on the presumed "motivational state" underlying LCBP were based on the results of the parametric studies. This research is presented in section 4.

The experimental attack on the presumed "motivational state" underlying LCBP behaviour involved a rigorous examination of the effects of several kinds of prior experience of light change on subsequent responding for light change. One experiment evaluated the notion of a Need or Drive for stimulus-change, and another, the notion of a "curiosity Drive" aroused by novel stimuli. The results did not support either form of Drive theory. It was argued that the reinforcement in LCBP arises from the control over a light change which occurs when it is made

response-contingent. Two additional experiments were designed to specifically investigate the latter formulation by examining the effects of nonresponse-contingent light changes during the apparatus habituation trials on subsequent LCBP. The results are compatible with the position that the reinforcement in LCBP arises from control of an environmental stimulus-change.

Section 5 is devoted largely to a theoretical appraisal of LCBP based on the findings presented in sections 3 and 4. A theory of response-contingent light change reinforcement in terms of the reward associated with control of an environmental stimulus-change is outlined.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any University and, to the best of my knowledge and belief, contains no material previously published or written by another person, except when due reference is made in the text.

Alan Russell

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1. A REVIEW OF THE LITERATURE ON LIGHT-CONTINGENT BAR PRESSING

1.10. Introduction

It is now well established that a response-contingent stimulus change which is unrelated to any of the common biological reinforcers such as food or water, can act as a reinforcer *per se* (e.g. Harlow, 1953b; Butler, 1960; Kish, 1966). This has been shown in a number of sensory modalities and for a variety of organisms. Following the first report of the phenomenon by Girdner (1953a,b) and Henderson (1953), considerable attention has been directed to the reinforcing effects to rats and mice of a response-contingent light change. Girdner and Henderson found that when a short period of increased light intensity in a dark or dimly lit Skinner box was made contingent on a bar press, responding increased. It has since been shown that as well as light Onset or Increment, a short period of light Offset or Decrement can also be reinforcing when made response-contingent (Kish, 1966; Berlyne, 1969a; Glow, 1970). Prior to the discovery by Girdner and Henderson, the effects of light on rats and mice had been considered essentially in an aversive context (e.g. Keller, 1941; Hanson, 1951).

Following the strategy of Girdner and Henderson, in much of the subsequent work on the reinforcing effects of short periods of light change rats or mice have been used as Ss and the Skinner box has been used as the test environment, with the bar press as the operant. As a result, the phenomenon has become known as light-contingent bar pressing (LCBP). For present purposes LCBP will be used to refer to situations where a short period of light change is made contingent on a bar press in a Skinner box or similar test environment with rats or mice as Ss. The typical procedure involves testing the animal for periods of from 10 to 60 minutes on one or more trials. A response-contingent light change usually lasts for 3 sec. or less. The inter-trial interval is usually 24 hrs, but longer and shorter intervals have been used. No attempt is made to shape the behaviour.

This thesis, as an analysis of response-contingent light change reinforcement, is concerned primarily with LCBP behaviour as it is in this area that most of the research has been conducted. LCBP has now been reliably established as a phenomenon and extensively investigated. The purpose of section 1 is to review the literature dealing with LCBP, largely in an attempt to:

(1) examine and discredit an account of LCBP in terms of secondary reinforcement,

(2) via an examination of the facilitation hypothesis, demonstrate that response-contingent light change satisfies the criteria of a reinforcer,

(3) evaluate the contribution to LCBP of visual scanning of the test environment,
(4) establish that the light change in LCBP operates primarily as a change _per se_, and
(5) given that LCBP mainly involves a response-contingent change _per se_, analyse the nature of the presumed motive state or need underlying the reinforcing effect of response-contingent light change.

It can be seen that the general approach here is to first establish that response-contingent light change can be legitimately classed as a reinforcer and having done so, to examine in detail some possible explanations of the reward value of response-contingent light change.

1.20. Secondary Reinforcement

One of the notions considered by some early researchers of LCBP (but largely rejected) was that light change reinforcement may be due somehow to reward properties acquired through association with food and water (Marx, Henderson & Roberts, 1955; Barnes, Kish & Wood, 1959; Premack & Collier, 1962). There are several lines of evidence which oppose a secondary reinforcement interpretation of LCBP.

Whereas a secondary reinforcer has transitory effects when tested under the extinction procedures (Kelleher, 1966; Zimmerman, 1957), the reinforcing effects of light change can be relatively durable, as indicated by the asymptotic response rates[1] established by Glow (1970), Goodrick (1970) and Stewart (1960). An increase in LCBP over trials reported in a number of experiments (Glow, 1970; Roberts, Marx & Collier, 1958; Levin & Forgays, 1959; Leaton, Symmes & Barry, 1963) is also inconsistent with a secondary reinforcement formulation.

Further, the association of light or darkness with food reward seems to have little or no effect on the reinforcing value of light changes. Roberts, Marx and Collier (1958) fed their animals in either light or darkness over a 30-day period and then tested the reinforcing effects of light Onset and Offset. No effect attributable to the feeding experience occurred. Hurwitz and Appel (1959) report some enhancement of light Onset as a reinforcer in the first LCBP trial for rats repeatedly fed during the latter portions of the light phase of a 12 hour light-dark cycle. However, this result is open to other interpretations. The group fed in the light responded more for light Onset than a group fed in the dark when both groups were tested two hours before feeding time. Therefore while the group fed in the dark was taken from a dark environment to a dark Skinner box, the light group was taken from a lighted environment and placed in a dark box.

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[1] The term "response rate" as used here is synonymous with "the number of responses per trial".

It is possible that this treatment difference contributed to the differential response rates on the first trial.

Finally, no secondary reinforcing properties were acquired by a light change when it was paired with the presentation of food (Marx & Knarr, 1963), or with the consumption of food (Schoenfeld, Antonitis & Bersh, 1950). It seems that a stimulus may have to provide information about the later arrival of food reward to become a secondary reinforcer (Hendry, 1969).

There is now ample documented evidence that a variety of behaviour usually considered under the heading of curosity or exploration is "autonomous in nature, in the sense that it is not derived from the primary appetitive drives such as thirst or hunger" (Lana, 1960, p.23). The data reviewed here permit the conclusion that the reinforcing effect of response-contingent light change can also be considered autonomous in this sense.

1.30. The Facilitation Hypothesis

Demonstration that a response-contingent event is capable of producing learning is probably the most basic prerequisite for classifying that event as a reinforcer. A number of factors other than learning can contribute to responding (Kimble, 1961; Berlyne, 1969a). The facilitation hypothesis argues that light change increases activity *per se*, and as a consequence, raises the incidence of bar pressing (Nash & Crowder, 1960; Kiernan, 1964; Lockard, 1963). A more specific variation of this hypothesis, "positive feedback facilitation", is described as "a transient condition......... in which the animal is likely to repeat whatever it has just been doing" (Berlyne, Salapatek, Gelman & Zener, 1964, p.148). According to the facilitation hypothesis then, response-contingent light change is not a reinforcer. To evaluate this suggestion possible learning and performance differences must be separated. If it can be shown that LCBP performance is due to learning, then light change can be designated a reinforcer.

After reviewing evidence relevant to the facilitation hypothesis both Berlyne (1960) and Lockard (1963) came to the conclusion that there is little to support the hypothesis. However, Kiernan (1964) was not so convinced that a rejection of the facilitation hypothesis is justified. The present treatment of the problem will consist of separate analyses of the results of experiments using different techniques for separating the facilitory and reinforcing effects of response-contingent light changes. It is argued that when these various kinds of evidence are taken in conjunction they provide substantial support for a reinforcement interpretation of LCBP. The relevant data arise from experiments in which (1) learning has been tested in extinction trials (2) yoked controls are included and (3) the ability of light change to support discrimination learning has been investigated.

1.310. LCBP and Extinction Responding

A classical procedure for separating learning and performance differences is by extinction testing. If responding during LCBP is due to facilitation, any differences between LCBP animals (experimental Ss) and control animals (which can be either yoked to the experimentals but receive no response-contingent change, or are simply tested under operant conditions) should disappear during extinction. Alternatively, in a double lever situation where the light change is made contingent on responding on one lever (F) and not the other (NF), no preference between the two levers should be exhibited in extinction. The relevant extinction research can be divided into three classes, studies in which; LCBP and extinction are included in the one trial; one LCBP trial is run with extinction tested after a 24 hour interval; several LCBP and extinction trials are run, usually with a constant intertrial interval of 24 hours. The likelihood of obtaining significant learning effects in extinction seems to differ according to which methodology is used.

1.311. Single Session Studies

The inclusion of both LCBP and extinction testing in the one trial seems to be the least sensitive method of testing for learning. This is due to the normal within trial decline in LCBP (e.g. McCall, 1965; Roberts, Marx & Collier, 1958). Extinction in this situation is rapid and responding falls "to a value at, or slightly below, operant level response frequency" (Barnes & Baron, 1961a, p.463). This might account for the failure of some researchers to obtain learning effects in extinction.

For example, Morris, Crowder & Crowder (1961) report no differences between their three experimental groups in a 20 min. extinction session which followed 10 response-light pairings. But, control animals were not included in the experiment and there is no way of determining if the three treatment conditions were differentially reinforcing during LCBP. Crowder (1961) obtained no learning effects in an extinction trial following immediately after 10 response-light Onset pairings in a double lever situation in a group of high responding rats as determined by earlier operant tests (Experiment 3), and in a group not given a period of adaptation to the apparatus before LCBP (Experiment 2). Learning effects did occur for low responders (Experiment 3) and a group given 30 min. adaptation to the apparatus before LCBP (Experiment 2). There seems no obvious way of accounting for Crowder's discrepant results.

However, in two experiments by Barnes and Baron (1961a,b) learning effects were obtained when extinction followed immediately after LCBP. Barnes and Baron (1961a, Experiment 2) first gave 20 min. of operant responding, then 0, 4, 9, 16, or 25 light reinforcements followed by 20 mins. of extinction. A covariance analysis of the extinction responses with the number of reinforcements yielded a probability of .054, with a probable maximum effect at 16 reinforcements. In their 1961(b) study they ran 18 mins. of operant testing, 18 mins. of LCBP and 18 mins. of extinction. Their data suggest that differences between the various experimental and control groups were maintained in extinction, but the LCBP and extinction data were not analysed separately.

To summarise: under certain conditions, which may well be a function of the reinforcing value of the light change used, and despite within trial declines in the reinforcing value of light change, learning has been shown in single session studies when the reinforcer is a light change.

1.312. One LCBP Trial and Separate Extinction Testing

In many cases, no learning effect in extinction was obtained when extinction occurred on the day or days following one LCBP trial (Nash & Crowder, 1960; Crowder, Morris, Dyer & Robinson, 1961, [30 and up to 90 reinforcement groups]; Crowder, Wilkes & Crowder, 1960, [Experiment 1]; Crowder, 1961, [Experiment 1, 5" lever group]; Berlyne, Salapatek, Gelman & Zener, 1964, [test day 1]; Kiernan, 1965b). Nevertheless, learning has been shown in an equal number of cases (Crowder, Morris, Dyer & Robinson, 1961, [10 reinforcement group]; Crowder, Wilkes & Crowder, 1960, [Experiment 2]; Crowder, 1961, [Experiment 1, 1" lever group]; Kish, 1955; Berlyne & Koenig, 1965, [test day 1]; Berlyne, Koenig & Hirota, 1966, [test day 1]). Although Berlyne and his associates did not analyse the data from the first extinction trial (test day 1) separate from later extinction trials (which followed additional LCBP trials) the findings of Berlyne & Koenig (1965) and Berlyne, Koenig & Hirota (1966) are consonant with a learning effect.

Several points can be made about studies failing to obtain evidence of learning. Firstly, Kiernan's results may have arisen because of the long delay between LCBP and extinction (3 days in Experiment 1 and 2 days in Experiment 2). Much of the data reported by Crowder and his associates may simply be due to a positive relationship between the reinforcing value of the light change and response rate in extinction. In two of their experiments (Crowder, Morris, Dyer & Robinson, 1961; Crowder, Wilkes & Crowder, 1960) they found that the more response-light change pairings allowed in the LCBP trial, the <u>less</u> likely it was for learning effects in extinction to occur. This suggests that the reinforcing value of the light change decreased with exposure to it. The research of Crowder and his co-workers would therefore have provided far more difficulty for a reinforcement interpretation of LCBP if they had shown, in all cases where a significant learning effect did not occur, that the light change was still reinforcing at the commencement of extinction. It is not so easy to explain away the findings of Berlyne, Salapatek, Gelman & Zener (1964), but it is noteworthy that in their study learning was detected on later extinction trials which followed additional LCBP trials. Their data suggest that after only one LCBP trial extinction may occur very rapidly, but that if several LCBP trials are allowed extinction is much slower.

In general, these data appear to support a reinforcement interpretation of LCBP. They also suggest, as would be expected, that there is a positive relationship between the reinforcing value of the light change and response rate in extinction.

1.313. Extinction Responding after more than one LCBP Trial

The particular advantage of designs which include two or more LCBP trials before the extinction test is that the behaviour becomes more firmly established and the ability of the light change to maintain responding can be adequately determined. In general, results from these experiments are more damaging to the facilitation hypothesis than data already considered. In almost all the relevant studies response rate differences between experimental groups (e.g. groups responding for different magnitudes of light change) and between experimental and control groups which are evident during LCBP have tended to remain in extinction, although in some cases the extinction data has not been subjected to statistical test (Singh, Johnston & Maki, 1969; Berlyne & Koenig, 1965, [Experiment 1]; Berlyne, Salapatek, Gelman & Zener, 1964; Berlyne, Koenig & Hirota, 1966; Williams & Lowe, 1967; Hurwitz, 1956; Lockard, 1966, [Experiments 2, 3, 4]; Forgays & Levin, 1958; Wilson, 1962, [Experiment 1]; Stewart & Hurwitz, 1958). However, the size of the difference between groups in extinction is invariably reduced, and therefore in some studies experimental-control differences are not significant, while in others the overall difference between experimental and control groups in extinction is reliable but experimental groups which were significantly different during LCBP do not always remain so during extinction (Wilson, 1962, [Experiment 2]; Berlyne & Koenig, 1965, [Experiment 2]; Stewart, 1960; Williams & Lowe, 1967; Berlyne, Salapatek, Gelman & Zener, 1964; Kling, Horowitz & Delhagen, 1956; Lockard, 1966, [Experiment 4]; McCall, 1965). In the study of Barnes, Kish & Wood (1959), (in which there were 5 daily 25 min. operant trials, 10 LCBP trials, and 5 extinction trials), extinction was immediate in all groups, with no evidence of learning.

These data provide convincing evidence that a response-contingent light change can produce learning. But, they also indicate that the same relationships between experimental groups during LCBP often do not hold in extinction. It is rare to find that significant differences between such groups during LCBP are reliably carried over into extinction. Does this mean that performance during LCBP is not a valid indicator of the reinforcing value of the response-contingent light change? Not necessarily. In the first place it seems that light change is a comparatively weak reinforcer (cf. work on schedules of reinforcement by Glow, 1970; Stewart & Hurwitz, 1958; and Stewart, 1960), and second, that the spatio-temporal relationship between response and reinforcement is conducive to immediate learning and rapid extinction. In contrast to the situation with food and water reward there is no complex and time consuming consummatory response to be made and the animal does not have to learn an association between a bar press and the availability of reward somewhere else in the environment. The LCBP situation in this respect seems to be directly comparable to the situation of bar pressing for electrical brain stimulation (EBS), where it has also been found that learning and extinction are rapid (Olds & Milner, 1954; Howarth & Deutsch, 1962; Morgan, 1965; Trowill, Panksepp & Gandelman, 1969). It is worthy of note that when the spatio-temporal relationship between response and EBS reward has been made equivalent to that with food and water reward much slower acquisition and extinction functions are generated (Gibson, Reid, Sokai & Porter, 1965; McIntyre & Wright, 1965; see also, Panksepp & Trowill, 1967). It would appear then that the apparent absence of a consistent relationship between responding for light change and extinction responding is probably more a function of the rapidity of extinction of a comparatively weak reinforcer than facilitatory effects during LCBP. For this reason extinction testing may not be the most sensitive means of estimating learning in LCBP. The status of the facilitation hypothesis is best evaluated by placing the extinction data in the context of evidence from the other procedures for assessing the reinforcement properties of response-contingent light change.

1.32. Yoked Controls and LCBP

An additional and elegant technique for separating learning and performance in LCBP (more particularly, the contributions of reinforcement and facilitation) is by including yoked controls. For the yoked control _S_s the light change occurs randomly and independent of its behaviour. If the light change simply increases the response rate because it raises activity _per se_ there should be no difference between the number of responses of yoked and experimental _S_s. The yoked control procedure has been criticised by Church (1964) on the grounds that possible individual differences in the extent to which the light change raises activity may produce more responding in experimental animals. As there is little evidence of increases in activity of either experimental or control animals the criticism is of little relevance to these data. A more serious problem is posed by Kiernan's (1964) suggestion concerning the nature of any facilitation effects. His argument applies to the yoked control experiment as well as the double lever studies discussed in the next section. The claim is that when stimulation occurs following the bar press the animal will be touching, or will just have touched the bar. "Hence stimulation will facilitate responses on, or in the region of, the onset lever" (p.353). However, this approach predicts no learning effects in extinction which, as has already been shown, do occur. The evidence will be reviewed in spite of these criticisms.

Two kinds of comparisons in these data are relevant to the facilitation hypothesis: comparisons between yoked controls and normal operant controls, and comparisons between experimental animals and yoked controls. If response facilitation is a factor in LCBP it would be predicted that yoked controls will respond more than normal operant controls and not significantly different from experimental _S_s. With respect to the comparison between experimental _S_s and yoked controls, significantly more responding during LCBP by the experimental Ss has been reported by Nash & Crowder (1960), Kling, Horowitz & Delhagen (1956) and Berlyne, Salapatek, Gelman & Zener (1964).

Comparisons of the response rate of yoked control and normal operant control Ss also largely fail to support the facilitation hypothesis. Berlyne, Salapatek, Gelman & Zener (1964) found a tendency for less responding by yoked animals over several LCBP trials, although apparently this difference was not significant. Kling, Horowitz & Delhagen (1956) found a rise in the response rate of yoked controls on the first LCBP trial following 6 operant trials. They did not test the rise for statistical significance and it disappeared on the second LCBP trial. Roberts (1962) also found a slight, and apparently nonsignificant, tendency for yoked Ss to respond more than operant controls. He suggested that the yoked Ss may have received accidental response-reinforcement pairings. The only experiment in which a clear facilitation effect was obtained is reported by Nash & Crowder (1960), where yoked control Ss responded significantly more than the operant controls during the single LCBP trial which was run.

In two studies, instead of yoking, the light changes were introduced by E. On day 13 of his experiment Kish (1955) introduced 150 ½ sec. presentations of light at 10 sec. intervals to the normal controls which had been participating in the experiment. Their response rate increased, but not significantly. Kish reported the rise due to three animals which were normally high responders and suggested it likely that accidental pairings of the light change and a response may account for this result. Kish & Baron (1962) investigated the effect of pre-exposure to the light reinforcer on later LCBP. During the first 30 min. of an hour trial animals received either darkness, continuous light, regular blinking light or irregular blinking light. The kind of exposure had no effect on response rate during the first 30 min. period. Similarly, Williams & Lowe (1970) obtained no difference in operant response rate between animals in either continuous light or flickering light.

In summary, the evidence suggests that in most cases response facilitation does not occur and if it does, that it is a transitory effect.

1.33. Discrimination Learning

The ability of response-contingent light change reinforcement to support discrimination learning has been tested in double lever Skinner boxes with a functional (F) lever, on which a light change is made response-contingent and a nonfunctional (NF) lever. This situation enables a test of the facilitation hypothesis. It has been argued that the facilitation hypothesis predicts no difference in response rate on the two levers (Barnes & Kish, 1958;

Tapp & Simpson, 1966).

Contrary to this prediction, a significant preference for the F lever during LCBP has been reported by a large number of researchers (Crowder, Wilkes & Crowder, 1960; Barnes & Kish, 1958; Forgays & Levin, 1959; Lockard, 1966, [Experiments 2, 3, 4]; Tapp, Mathewson & Simpson, 1968; Tapp, Mathewson & Jarrett, 1968; Tapp & Simpson, 1966; Barry & Symmes, 1963; Weldon, 1968, [Experiment 2]; Goodrick, 1970; Kiernan, 1965a,b). These include experiments with rats (hooded and albino) and mice, food and water deprived and food and water sated animals, drugged and nondrugged animals, and experiments in which light Onset, Offset, Increment and Decrement have been used as the reinforcer. A preference for the F lever did not occur under all conditions in some of these experiments, while in others the preference only developed after several trials. Nevertheless, taken in conjunction these data support the generalisation that a discrimination is made between a lever on which a light change is response-contingent and a lever on which no light change occurs as a result of a bar press. Therefore, these data do not support the facilitation hypothesis.

Kiernan's criticism noted in the previous section is also applicable here. But it has been argued that this notion cannot accommodate learning detected in extinction trials. Therefore, by arguing from both the extinction and discrimination data it seems reasonable to reject facilitation as a viable hypothesis, as indeed Berlyne, Salapatek, Gelman & Zener (1964) do on the basis of their data.

Kiernan (1964) also claims that the influence of two levers (Forgays & Levin, 1959) "demonstrates probable facilitation effects and suggests problems for any reinforcement theory of LCBP" (p.354). Forgays & Levin found that twice as much responding occurred if both levers were made functional than if only one lever was functional. However, this result is open to the interpretation that each lever mediated a relatively independent reinforcing event. Two lights, one immediately above each lever, were used and a bar press turned on only the light above that lever. The latter view is supported by the operant rate data of Antonitis & Baron (1961). They report "significantly more responses were made by mice in two-bar cages than by mice in one bar cages" (p.460).

Finally, it is difficult to understand Kiernan's reasoning that the finding of Thomas, Appel & Hurwitz (1958) of more responding for light change on a 1 sq. inch lever than on a lever ½" in diameter demonstrates probable facilitation effects.

1.34. Conclusions

The basic question underlying this examination of the facilitation hypothesis has been: if a light change is made contingent on responding on a single lever, can the frequency of responding on that lever be taken as a valid indicant of the reward value associated with such responding? There seems little reason at this stage to assume otherwise. Certainly the experiments reviewed here suggest that most of the responding in LCBP cannot be accounted for by the facilitation hypothesis. If facilitation plays any part its effects may be confined to the initial trial. It is not claimed that these conclusions are generalizable to species other than rats and mice, or to situations in which the operant is other than a bar press. (cf. Tapp, Mathewson, D-enacarcao & Long, 1970). There is some evidence, for example, that facilitation may be an important factor in the response-contingent light change behaviour of chicks (Meyer, 1968a,b,c, 1969; Meyer & Auguston, 1969).

A second question, related to the first, concerns techniques for determining whether or not a particular response-contingent light change is reinforcing, and if so, whether it is more or less reinforcing than another light change. Three such techniques have been used: (1) by comparing the LCBP rate with the previously established operant rate of the same animals, (2) by comparing the LCBP rate of one group with an independent operant group, and (3) by comparing the performance of the same animals on F and NF levers. There would seem to be little difference between the first two methods, provided that in the case of the first technique sufficient operant testing is made to obtain a reliable estimate of the operant rate. On the other hand, there is some evidence that the difference between F and NF responses may be a less sensitive measure than the first two. While discrimination between F and NF levers has been repeatedly shown, it seems there is a tendency for a positive correlation between response rate on the two levers (cf. Lockard, 1966, [Experiment 4]; Kiernan, 1965a; Tapp, Mathewson & Jarrett, 1968; Leaton, Symmes & Barry, 1963; Goodrick, 1970). This might be taken to indicate facilitation. But it seems more reasonable to interpret it in terms of a less than perfect discrimination, with some generalisation from the F to the NF lever. The implication is that the F-NF measure may not be a wholly satisfactory measure of the reinforcing effects of a particular response-contingent light change. This has been recognised by other workers since most researchers using F and NF levers base their major analyses of the data on F responses and not on the F-NF difference.

1.40. Scanning Theory

Hurwitz (1956) noted that animals in a LCBP situation appeared to visually scan the test environment "when the light is kept on for extended periods" (p.33). This observation was given theoretical status by Robinson (1959, 1961) when he hypothesised that the presence of light "provides S with an opportunity to obtain further reinforcement by scanning the visual inhomogeneities of the lighted test environment" (1961, p.470). The scanning theory was formulated in the context of several failures to obtain reinforcing effects for light Offset when comparable Onset changes were reinforcing (Barnes & Kish, 1957; Hurwitz, 1956; Robinson, 1959). Robinson claimed that the fact that light Offset prevented visual scanning while Onset enhanced it may account for these results. Scanning theory does not deny that other factors, such as stimulus change (see section 1.5) also contribute to the reinforcing value of light change. The point is that it argues that scanning will modify the effects of other factors.

Following from the proposition that light enhances visual scanning and darkness hinders it, scanning theory predicts (1) that light increases[2] will be more reinforcing than light decreases,[2] (2) that light Increment will be less reinforcing than light Onset, and (3) that light Offset will be less reinforcing than light Decrement. It will be remembered that an Increment occurs from a base intensity above total darkness and a Decrement results in a light intensity above total darkness. In addition, scanning theory predicts (4) that the more there is to see in the test environment (its visual complexity) the less reinforcing

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[2] Increase is used here to refer to light Onset and/or Increment, while decrease refers to light Offset and/or Decrement.

light decreases will be and the more reinforcing light increases will be. The first three predictions will now be discussed in conjunction, followed by the fourth prediction.

1.41. Scanning Theory and the Reinforcing Value of Light Increases and Decreases

There is some evidence supporting the prediction that light increases will be more reinforcing than light decreases (Barnes, Kish & Wood, 1959; Eacker, 1967, [Experiment 2, 3]; Leaton, Symmes & Barry, 1963; Hurwitz, 1956; Lockard, 1966, [Experiment 3]; Robinson, 1957, 1959; Roberts, Marx & Collier, 1958; Tapp, Mathewson & Simpson, 1968; Wilson, 1962, [Experiment 1,2]). However, there is also a considerable volume of evidence showing either no difference between light increase and decrease (Robinson, 1961; McCall, 1965; Weldon, 1968, [Experiment 1]) or greater effects for light decreases (Singh, Johnston & Maki, 1969; Lockard, 1966, [Experiment 4]; McCall, 1966; Barry & Symmes, 1963; Glow, 1970; Goodrick, 1970). These findings provide difficulties for scanning theory.

Of course, it is possible that scanning did affect responding in some, or even all, of these studies. The difficulty here is that there is no direct way of separating out the contribution to responding of scanning.

Notwithstanding this, it could be expected that any effects of scanning would be greatest on the initial trials and that as trials continued these effects would diminish. A consideration of these experiments justifies the conclusion that scanning does not make a consistent and powerful contribution to LCBP behaviour.

An extensive review of the literature did not reveal a report in which the second and third predictions from scanning theory were directly tested. However, Robinson (1961) inferred from a comparison of his data on light Increments and Decrements with research by other workers "that the reward effect of light increase is attenuated when Increment rather than Onset is used, while light Decrement as opposed to termination appears to enhance the reward value of light decrease". There are many reasons why making this kind of comparison is a hazardous procedure, but probably the most germane is the difficulty of equating the magnitude of change in all cases (see section 1.54 for the effects of the magnitude of change). Therefore, light Onset may be more reinforcing than light Increment because it is a larger magnitude of light change. Robinson's conclusions with respect to Offset and Decrement are based on findings that Offset is not reinforcing (Robinson, 1959; Hurwitz, 1956; Barnes & Kish, 1957). This conclusion is largely invalidated by more recent results showing that Offset can be reinforcing and is often more reinforcing than Onset (see above). [Arguments are presented below (section 1.5) that the apparently discrepant findings concerning light Offset might be due to certain methodological differences]. It may prove impossible to test the second and third predictions from scanning theory because of the problem of controlling for other variables, such as the magnitude of change, which also have been shown to affect the relative reinforcing value of light changes. There are no extant data which provide conclusive evidence one way or the other about predictions 2 and 3.

1.42. The Visual Complexity of the Test Environment and LCBP

It follows from scanning theory that the more there is to see in the test environment (its visual complexity) the more reinforcing light increase will be and less reinforcing light decreases will be. Several experimenters have tested this prediction and much of their data are accordant with scanning theory. For example, Sackett (1965) investigated the LCBP behaviour of hooded rats in either a flat black, flat white, or black and white checkered environment. Animals responded for either dim or bright light Onset or Offset and were tested 24 hrs. a day over 44 days from the time their eyes opened. His results are consistent with scanning theory to the extent that responding for Onset was higher in the patterned than black or white environments, while the response rate for Offset was higher in the black than white, and higher in the white than the patterned environment.

In an experiment with albino rats (Eacker, 1967, Experiment 1) animals were tested in either a uniform gray or a black and white patterned environment. Ss responded for light Onset. The light change was reinforcing only in the complex environment. In Experiment 2 Eacker studied responding for light Onset or Offset in the same visually simple or complex chambers. The light change occurred for the duration of the response in this experiment (in his first study the change occurred for a fixed duration of 2 secs.). No effect for the complexity of the environment was detected. Eacker then replicated Experiment 2 with the light change now occurring for a fixed duration of 2 secs. But, "as with Experiment 2 the results showed no significant difference between the visually simple or complex chambers when either light Onset or termination was the consequence of bar contact" (p.143). Nevertheless, from his fig. 1 and the obtained three way interaction between trials, contingency and visual complexity it is apparent that after the first two trials there was a tendency for more responding for Onset in the complex than the simple environment. In another study (Singh, Johnston

& Maki, 1969), albino rats were reared under conditions of visual pattern exposure or restricted visual pattern and then tested for the reinforcing effects of light Onset or Offset in a flat white or black and white striped chamber. As predicted by scanning theory light Onset was more reinforcing in the striped chamber and light Offset was more reinforcing in the white chamber.

Less direct evidence concerning the effects of the visual complexity of the test environment arises from Donahoe's work. Donahoe (1967) noted that responding for light Onset was about half that obtained in his earlier work (Donahoe, 1965). He claimed, "the reduction in responding can be ascribed to the decreased complexity of test chamber stimuli available to the animals with each visual stimulus presentation". Finally, additional support for the claim that some of the reinforcing effects of light Onset are provided by the opportunity to visually explore the environment arises from the finding that animals prevented from making such exploration by white translucent plastic lens placed over the eyes responded less for light Onset than animals wearing clear plastic lens (Eacker, 1968).

In general then, it appears that when other factors are held constant the visual complexity of the test environment may affect LCBP behaviour in the way predicted by scanning theory. It is fair to conclude, on the basis of the data presented here and in section 1.41, that when a homogeneous black, white or aluminium test environment is used, as in most LCBP studies, visual scanning has little effect on responding for light change (especially in relation to other determinants of responding). However, when the test environment is made more visually complex it seems that visual scanning can have a palpable effect on LCBP behaviour.

1.50. Preference and Stimulus-Change Theory of LCBP

When a short period of light intensity change is made contingent on a response, the response produces a change from an initial light intensity to a consequent light intensity. Both Stimulus-Change theory (e.g. Barry & Symmes, 1963; Forgays & Levin, 1959; Kish & Antonitis, 1956; Lowe & Williams, 1968) and Preference theory (Lockard, 1963, 1966) emphasise the difference between the two intensities. But whereas Stimulus-Change theory "attributes the reinforcing properties of response-contingent light stimuli to the mere change in the stimulus-level function without ascribing any importance to S2 [the consequent light intensity] other than its difference from S1 [the initial intensity]" (Lockard, 1966, p.415), Preference theory asserts that the light change will be reinforcing only if the consequent intensity is preferred to the initial intensity. According to Stimulus-Change theory the light change operates as a change *per se*. According to Preference theory the light change operates so as to place the organism in a level of illumination which may be more or less preferred to the ambient or initial level of illumination.

If Preference theory is to be used to account for the reinforcing value of short periods of response-contingent light change, light intensity preferences should first be shown to exist. The light intensity preferences of rats have been investigated by determining the duration of self exposure to various light intensities in a Skinner box where a unidirectional change is made contingent on bar pressing and the consequent intensity continues until another response is made (the "preference procedure"). If light intensity preferences are found with this procedure it could be predicted that preferences may be important in the LCBP situation (where, it will be remembered, a short period of change is used). Consequently, before discussing LCBP research as it relates to Preference and Stimulus-Change theory, some independent evidence concerning the existence of light intensity preferences in rats will be presented.

A critical point pertaining to all the research concerned with Stimulus-Change and Preference theory is that differences in techniques of reporting light values, as well as differences in the albedo of the test environment, make comparisons amongst studies difficult (cf. Lockard, 1965). Light values are sometimes reported in units of luminance (e.g. mL) and sometimes in units of illumination (e.g. ft.c.).

Mostly these values are recorded in the vicinity of the lever, but they have also been recorded at the light source and in the centre of the cage. Also, the fact that test environments have varied from mat black to gray, flat white, or reflecting surfaces (e.g. aluminium) often makes it impossible to compare studies in terms of the actual amount of light falling on the S. The light values given here are those reported by the author/s. Despite the problems outlined it appears that some tentative conclusions can be drawn if it is remembered that levels of illumination in ft.c. will always be slightly higher than the same units reported in mL.

1.51. Light Intensity Preferences in Rats

In the main, it is on evidence from the preference procedure that Lockard, the chief proponent of preference theory, bases his argument (Lockard, 1963). However, after a close inspection of the data from experiments using the preference procedure it can be seen that in some ways this evidence may oppose a preference theory of LCBP.

Most of the research using the preference procedure has been performed by Lockard himself. Typically, his strategy involves the continual testing, 24 hrs. a day, for at least 12 consecutive days, of albino rats in a double lever Skinner box. A bar press on one lever turns the light on, and a response on the other lever turns the light off.

In a series of papers, Lockard reports the duration of self exposure to luminance values ranging from .001 to 100 mL (Lockard, 1962a,b,c) and illuminations ranging from .001 to 116 ft.c. (Lockard, 1964a, 1966). In all experiments the animals were given a choice between darkness and one of the light values. (Lockard noted in his 1962 papers that by multiplying the mL value by 1.16, a measure in terms of ft.c. is obtained). The results he obtained from albino Ss can be summarised as follows. Initially, i.e. over at least the first 24 hrs., animals spend most of their time in light, irrespective of its intensity. With intensities of less than 1.0 mL this tendency persists over the whole test period. At 1.0 mL the animals may continue to remain mostly in the light if they have had a 12 day adaptation period in 100 mL (1962a [Experiment 1]). In all other cases a decline in the duration of self exposure to light occurs over trials, so that for example, in 10 or 100 mL the animals may eventually spend almost 100% of their time in darkness. However, the main point is that this preference shift usually takes several days to emerge. For example, Lockard (1966, Experiment 2) found no difference in preference between darkness and the six levels of illumination over the first 8 days of the experiment and all groups spent more than half the time in the light during this period.

As it takes several days of continuous testing before definite light intensity preferences emerge it is not obvious that light preferences should play a major role in the reinforcing value of short periods of light change when Ss are tested for only 10 mins. to 1 hr. each day, as in the LCBP research. Further weight is added to this question about the applicability of LCBP of the preference functions generated from experiments involving continuous testing over several days by the results of another study by Lockard (1966, Experiment 3). In this investigation albino rats were tested in the preference procedure for 25 daily 1 hr. trials. Lockard presented the data as a mean-daily-duration-of-exposure-to-light score over the whole 25 trials, presumably because there were no marked trends over trials. All groups spent approximately half the time, or more, in the light (from .001 to 100 ft.c.) rather than in the dark. Thus, over a 1 hr. trial no marked preferences were exhibited.

It is important to distinguish the strain of rat or mouse used as Ss. The preference functions of one strain may not be generalisable to another strain. It is especially important to distinguish strains with pigmented eyes and strains with nonpigmented eyes (the albino). Rats and mice with pigmented eyes (the hooded rat is the most commonly used) are not as sensitive to light as albinos.

Consequently, the results from experiments using the "preference procedure" with hooded rats are even more damaging to Preference theory than those using albino rats.

Lockard (1962b, Experiment 2), once again testing continuously over 12 days, reports that hooded rats showed "no tendency to decrease duration of self-exposure across days as did albinos.....[and]..... no tendency to select shorter durations as luminance increased" (p.1120). The hooded rats spent most of the time in the light rather than in the dark. Lockard (1964a) reports that rats with pigmented eyes, obtained by crossing male rats of the MAC1/F1 strain with Sprague-Dawley females, showed some preference for darkness over 11.6 and 116 ft.c. during the last 7 days of a continuous 15 day test period. Glow (1970) tested his hooded rats in the preference procedure over 6 x 30 min. trials with an intertrial interval of 48 hrs. immediately after 50 trials of LCBP experience with either light Onset or light Offset as the reinforcer. There was no overall preference for light (6.6 ft.c.) or darkness, but animals previously reinforced by light Onset spent more time in the light than animals previously reinforced with light Offset. In another experiment in the same laboratory (Glow, Roberts & Russell, unpublished) preference for either light (6.6. ft.c.) or darkness in naive hooded rats was examined over 18 x 20 min. trials with an intertrial interval of 48 hrs. Initially there was no preference for either light or darkness, but by the end of the experiment there was a tendency for the animals to spend about 70% of the trial in the light. Thor & Hoats (1968) examined light intensity preferences (darkness versus 1-2 ft.c.) in the hooded rat over 44 days of continuous testing. They obtained a 58% overall preference for light over darkness but noted that on successive days this percentage showed extensive variability, which they interpreted as "a further indication of the relative lack of significance for any precise duration of daily light or dark required" (p.2).

In summary, there is little evidence from procedures designed specifically to examine light intensity preferences which lead of necessity to the prediction that preferences, in both hooded and albino rats, will be a major determinant of responding in the LCBP situation, where sessions are typically less than 1 hr. and run with an intertrial interval of 24, or sometimes, 48 hrs. In addition, the preference data suggest that preferences are more likely to affect the LCBP behaviour of albino rats than hooded rats and that if preferences do play a part with albino rats their effects should only emerge after extended testing with higher levels of illumination.

Attention will now turn to the actual LCBP data with a view to evaluating Preference and Stimulus-Change theory.

1.52. Some Predictions from Stimulus-Change and Preference Theory

To facilitate discussion of the Stimulus-Change and Preference theories of LCBP some predictions from the two theories will be outlined.

Preference theory predicts that if the consequent intensity of the light change is preferred to the initial intensity the change will be reinforcing. But, from the evidence presented in the previous section it is clear that there is no satisfactory way of determining precisely the preferred level of illumination. The preferred level has been found to vary as a function of the prior light exposure history of the animal, the length of the test period, the strain of animal and so on. Consequently, exact predictions from Preference theory about which light changes will be reinforcing cannot be made. Nevertheless, if Preference theory is taken in its strongest form it would predict that if a change between two intensities in one direction is reinforcing a change in the other direction will not be rewarding. In this way Preference theory would predict that either light Onset to, or Offset from, a given light intensity may be reinforcing, but not both.

It also follows from Preference theory that the initial and consequent light levels should make a greater contribution to the reinforcing value of response-contingent light change than the magnitude of change. In albinos at least, this should be reflected in light increases with relatively high consequent intensities being less reinforcing than increases to dim illuminations i.e. in general, the larger the magnitude of light increase the smaller its reward value.

Stimulus-Change theory predicts that light changes in both directions between two light values, e.g. light Onset and Offset, should be reinforcing. Some authors (e.g. Lockard, 1966; Kish, 1966) have claimed that Stimulus-Change theory predicts that Onset and Offset will be equally reinforcing. In principle then, it should be possible to separate Stimulus-Change and Preference theory on the basis of the reinforcing value of light Onset and Offset, since the two theories generate different predictions about the reward value of Onset and Offset.

Stimulus-Change theory also predicts that, within certain limits, the larger the magnitude of light change the greater its reinforcing value. Over the whole range of light changes there should be an inverted U relationship between the magnitude of change and reinforcing value. Therefore, the Stimulus-Change and Preference theories also differ with respect to predictions about the effects of the magnitude of change and the initial and consequent light intensities. Stimulus-Change theory asserts that the initial and consequent intensities are of secondary importance and the magnitude of change is the vital factor.

Preference theory holds that the reverse is the case. Several studies enable at least some separation of the effects of the magnitude of change and the initial and consequent intensities.

Experimental evidence bearing on these two sets of predictions from Stimulus-Change and Preference theories will now be presented and discussed. Because of the obvious strain difference, noted in the work on light preferences, separate analyses will be made of data from rats and mice with nonpigmented eyes and those with pigmented eyes. In the light of the evidence and conclusions reached from these data an examination will be made of the results of experiments in which the magnitude of light increase only has been systematically varied. This kind of experiment, in its own right, does not permit a clear separation of the two theories.

1.530. The Reinforcing Effects of Light Onset and Offset

As noted, it may be possible to separate Stimulus-Change and Preference theory on the basis of the reinforcing effects of light Onset and Offset. If it can be shown that Onset and Offset are reinforcing, then the data would support Stimulus-Change theory. On the other hand, if it is consistently found that only one direction of change is reinforcing a case might exist for Preference theory.

1.531. Albino Ss

Several researchers have investigated the reinforcing effects of Onset and Offset to albino Ss when the change occurs for the "duration of the bar press" (DBP)[8]. With this type of change, Eacker (1967, Experiment 2) found Onset reinforcing, but little effect for Offset. Leaton, Symmes & Barry (1963) found both Onset and Offset reinforcing if animals were given 2 or 7 operant pretest trials, with response rates for Onset approximately three times those for Offset. When no operant pretest trials were allowed Leaton, Symmes & Barry report that neither Onset nor Offset was reinforcing initially, but that whereas Onset developed a reinforcing effect over trials, Offset never became reinforcing. Lockard (1966, Experiment 3), also for a DBP change, reports Onset reinforcing, but not Offset (except by very liberal criteria, and most of the Offset effect was due to a high response rate for Offset from 100 ft.c.). In other experiments using a DBP change, Tapp, Mathewson & Simpson (1968) also found only Onset rewarding, and Roberts, Marx & Collier (1958) obtained greater reinforcing effects for Onset than Offset. In contrast to these data, Barry & Symmes (1963) observed that Onset and Offset were about

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[8] As a rough estimate for present purposes the average DBP can be taken at about 1 sec. or less.

equally reinforcing over the initial LCBP trials, but whereas the response rate for Onset declined over trials, the response rate for Offset increased.

The reinforcing effects of light Onset and Offset to albino Ss has also been studied when the change occurs for a fixed time interval. For example, Eacker (1967, Experiment 3) used a 2 sec. change and found Onset highly effective, but little reinforcing value for Offset. For a 0.75 sec. change Singh, Johnston & Maki (1969) obtained more responding for Offset than Onset. A longer change (3 sec.) was used by Goodrick (1970). He reports that both Onset and Offset were reinforcing at the commencement of LCBP, with an initial tendency for more responding for Onset. However, over trials Offset eventually became more reinforcing than Onset.

In the main then, the results of studies in which the duration of the change is coincident with the duration of bar press (DBP) are clearly in conflict with Stimulus-Change theory - usually Onset is reinforcing and Offset is not. It might be argued from Preference theory that these results arise from a preference for light over darkness. This proposition seems possible but unlikely. Moreover it is not supported by the findings of Goodrick (1970), Singh, Johnston & Maki (1969) and Barry & Symmes (1963). Rather, it is argued here that the Onset and Offset data suggest that the duration of the light change is a determinant of the reinforcing value of response-contingent light change, in the following way. When a DBP change is used, light Onset is highly effective as a reinforcer but light Offset is either not reinforcing or much less reinforcing. When longer fixed durations of change (e.g. 2 or 3 sec.) are used, light Onset becomes less effective as a reinforcer and light Offset becomes more effective. At this stage the argument is based on two pieces of evidence.

The first comes from a comparison of the results of Eacker's (1967) Experiments 2 and 3. In these two experiments the procedure was the same except that in Experiment 2 the change occurred for the DBP and in Experiment 3 it occurred for 2 sec. The mean response rates for Onset and Offset in Experiment 2 were 18.18 and 4.53 respectively, while in Experiment 3 they were 7.74 and 4.63. Therefore, for a 2 sec. change the difference between Onset and Offset is markedly reduced. Secondly, the results of Goodrick (1970) which show that a 3 sec. Offset change can be reinforcing immediately and eventually may be more reinforcing than Onset. The postulated effect of the duration of light change is not in agreement with all of the data presented above (cf. Singh, Johnston & Maki, 1969; Barry & Symmes, 1963), but additional support for it arises from research on animals with pigmented eyes.

1.532. Pigmented Ss

In line with the data from albinos, a number of workers have found Onset, but not Offset reinforcing to hooded rats when the change occurred for the DBP (Hurwitz, 1956; Robinson, 1957, 1959). Sackett (1965) who also used a DBP change, found both Onset and Offset reinforcing. However, in this case the animals were tested 24 hrs. a day, with 12 hrs. of light Onset reinforcement and 12 hrs. of light Offset for the same animals. For this reason it is difficult to make direct comparison with other research on Onset and Offset.

In the study by Glow (1970), which is in many ways comparable to that of Goodrick (1970) with albinos, 3 sec. Onset and Offset changes were used. Both directions of change were reinforcing on the initial LCBP trials with little difference between them. With continued testing the reinforcing effects of Onset declined while responding for Offset increased over trials. A comparison of Glow's results with those of the DBP studies provides further support for the view that the duration of change may be an important determinant of the relative reinforcing value of Onset and Offset, as well as whether or not Offset is reinforcing.

1.533. Conclusions

Rather than providing support for either Stimulus-

Change or Preference theory the data reviewed suggest that the present formulations of both theories are incapable of accounting for the apparent discrepancies in results. The evidence suggests that both Onset and Offset can be reinforcing to hooded and albino rats, but that their relative reinforcing effectiveness may vary in ways not predicted by either theory. It is argued that one of the factors which affects the relative reinforcing value of Onset and Offset is the duration of change.

If the two studies using a 3 sec. change, one with hooded rats (Glow, 1970), and one with albino rats (Goodrick, 1970), are considered in isolation, it seems that they (1) provide strong support for a Stimulus-Change interpretation, and (2) suggest that the change effect might be slightly modified by light preferences. In contrast, the evidence from research using a DBP change does not provide consistent support for either theory.

Despite the variations in the duration of light change used in LCBP research there seems to have been little attempt made to investigate the role of this variable. Thomas, Appel & Hurwitz (1958) mention an unpublished experiment by Appel & Hurwitz (1958) in which it was found that the duration of light change did not systematically affect responding. No mention is made of the durations used, and further, it seems that only light Onset was examined. In another experiment (Crowder & Crowder, 1961) responding in extinction was tested after 10 response-light Onset pairings, with four durations of Onset from ⅓ sec. to 9 sec., but no differences between the durations were found. It seems that a parametric investigation of the effects of duration of change, including at least DBP and 3 sec. changes is necessary to sort out this problem. This may enable a more satisfactory evaluation of Preference and Stimulus-Change theory.

1.540. The Role of the Magnitude of Light Change: Light Changes in Both Directions

Although there is some evidence from hooded rats, the majority of experiments in which the reinforcing effects of different magnitudes of light change in both directions have been studied have used albino rats. Several of these experiments have involved attempts to separate the effects of the magnitude of change from the effects of the initial and consequent intensities by taking the same magnitudes of change with different initial and consequent intensities. Findings that the magnitude of change is systematically related to response rate and operates independent of the light intensities used would provide substantial support for Stimulus-Change theory.

1.541. Albino *Ss*

There are five relevant experiments using albino *S*s. A brief summary of each and the results obtained follows.

Firstly, Berlyne & Koenig (1965) studied the effects of three magnitudes of light Increment (x2, x4, x8) combined factorially with three consequent intensities (2.0, 4.0 and 8.0 mL) (Experiment 1), and three magnitudes of light Decrement (x⅛, x¼, x½) produced by inverting the initial and consequent intensities of Experiment 1 (Experiment 2). 15 min. daily trials were run in both experiments using the technique of "training" on the first trial and "testing" on the second i.e. trial 1 was a LCBP trial and trial 2 an extinction trial, and so on. No effects of variations in consequent level, or degree of change on reward value were found in either experiment. These results can be interpreted in two ways; either they indicate no preferences within the range used and no differences in the magnitude of change large enough to be differentially reinforcing, or some interaction between preference and magnitude of change. It is also possible that the procedure of alternating reinforcement and extinction trials may have reduced the resolving power of the experiment, so that any differences in reinforcing value of the changes were obscured.

The second experiment (McCall, 1965) selected four light intensities between 8.93 and 0.26 mL on a $\log_{10}$ scale and tested all possible combinations of Increments and Decrements. Over the five LCBP trials response rate was "a negatively increasing function of the amount of change, symmetrical about the zero point" (McCall, 1965, p.261). This is in accord with Stimulus-Change theory, and is not consistent with the Preference hypothesis of Lockard.

However, McCall (1966) noted that in his 1965 experiment the amount of change and the initial and consequent intensities were inseparable factors. "Hence, any given amount of change was inextricably associated with a unique set of initial and consequent intensities; and, therefore, comparisons between varying amounts of change were confounded with differences between these unique sets of intensities" (p.35). To overcome this McCall (1966) examined the entire initial-consequent-change matrix bounded by nine intensities (0.10, 0.18, 0.31, 0.54, 0.94, 1.64, 2.87, 5.03 and 8.80 ml). During the first two LCBP trials the symmetrical relationship between response rate and magnitude of change predicted by Stimulus-Change theory occurred. Over the remaining seven LCBP trials more responding for larger magnitudes of light Decrement occurred, but the response rates for Increments declined to about the level for no change. Therefore, the magnitude of change effect seems to have been increasingly modified by preferences for dim luminances as LCBP trials continued. These two experiments by McCall indicate that Stimulus-Change theory can account for much of the response rate data from albinos, especially over the initial LCBP trials.

The fourth and fifth experiments were performed by Lockard (1966, Experiments 3, 4). In Experiment 3 the reinforcing effects of light Onset to, and Offset from 0.001, 0.01, 0.1, 1.0, 10, and 100 ft.c. were studied. As already noted, the change occurred for the DBP and light Offset was not reinforcing, except perhaps in the 100 ft.c. group. In the Onset groups there was a tendency for greater reinforcing effects for larger magnitudes of change up to 1 ft.c., but then a reversal occurred for the highest illuminations. It seems reasonable to interpret the Onset results as a Stimulus-Change effect modified at higher consequent intensities by a preference for darkness over bright lights.

In Experiment 4 Lockard examined the reinforcing effects of all possible combinations of change between the six levels of illumination used in Experiment 3. Probably the most striking aspect of the results is the minimal overall reinforcing effects. In this experiment the strain of animal was changed from the Sprague-Dawleys used in his other work, and the animals were tested at a much earlier age (66 days) than usual. The apparatus consisted of double lever Skinner boxes with one lever producing a light change (F) and the other an operant lever (NF). Lockard noted that responding on the F lever for animals receiving no change was not significantly less than F responses of groups receiving either Increments or Decrements in light intensity. Much of the analysis is done in terms of F responses. In addition, after subtracting responses on the F lever from those on the NF lever a reinforcing effect during LCBP was detected for Decrements, but not for Increments. His results can be viewed mainly in the context of large reinforcing effects when a response produced a Decrement from either 10 or 100 ft.c. and virtually no reinforcing effects (in some cases negative) when the consequent intensity was 10 or 100 ft.c. Principally because of the contribution of the two highest light values, it seems that these results may support a Preference interpretation. It might be expected that changes involving the intensities other than 10 and 100 ft.c., where it could be argued that preference would be less prepotent, would support a Stimulus-Change interpretation. But all of these involved changes within the range of from 0.001 to 1.0 ft.c. There is little evidence that any of these were reinforcing, and even if they were, magnitude differences may not have been sufficiently large to reveal a magnitude effect.

The evidence from these five experiments seem to justify the following conclusions. Change *per se* seems to play an important part in the reinforcing value of light change to albino rats, especially when the change is novel. However, preferences may modify the change effect, with preferences making greater contributions at higher consequent intensities for light increases and higher initial intensities for decreases, and the longer LCBP testing is continued.

1.542. Pigmented Ss

There is little published research using pigmented rats and mice as Ss which deals with the effects of the magnitude of light change in both directions. One such study was performed by Sackett (1965). In an experiment which already has been outlined, he used either a large or small Onset or Offset change in each of his three environments (flat black, flat white, or black and white checkered). The actual luminance values differed for the three environments. He reports an overall tendency for more responding for the larger magnitude of change except in the checkered environment for light Offset, where there was no difference between bright light and dim light Offset. In general these findings are in agreement with a Stimulus-Change account.

Before continuing it is worth noting that in contrast to the findings when a duration of bar press change (DBP) is used for light Offset - several researchers failed to find reinforcing effects of Offset - it seems that when a DBP change has been used with light Decrements, reinforcing effects do occur (McCall, 1965, 1966; Lockard, 1966; Robinson, 1961). This does not obviate the suggestion, made on the basis of the Offset data, that the duration of change is related to its reinforcing value. If it is, the relationship should hold for all increases and decreases. As the literature on the duration of stimulus change for light Increments and Decrements is incomplete, there is no way of evaluating the hypotheses concerning the effects of duration with such changes.

1.550. The Role of the Magnitude of Light Change: Light Increases only

Experiments in which the magnitude of light increase only has been varied confound the possible effects of larger magnitudes of change with possible preferences for brighter lights. However, given the foundation of the argument from the previous section that for albino _Ss_ change _per se_ is an important determinant of the reinforcing value of light changes, but that with stronger lights preferences may modify this effect, the evidence from studies in which magnitude of light increase only has been studied can be evaluated. Data from hooded rats, which are generally consistent with the view that Stimulus-Change theory provides the most satisfactory account of the LCBP behaviour of these strains, are also presented.

1.551. Albino Ss

Most of the research from albino Ss seems to be consistent with the conclusion reached at the end of the previous section. For example, Henderson (1957) investigated the effects of five magnitudes of light Onset (0.02, 0.24, 2.24, 16.56, and 50.32 mL) and reported a positive relationship between magnitude of change and reinforcing value up to 16.56 mL, after which a reversal occurred and response rate declined. The 50.32 mL group responded at about operant level. These data can be taken to indicate a stimulus-change effect up to 16.56 mL with the reinforcing effect of the 50.32 mL change being modified by light preferences.

The results of Levin & Forgays (1959, Experiments 1, 2) also seem to indicate a stimulus-change effect up to certain intensities after which negative preferences modify the reward value. In Experiment 1 they used Onset changes of 0.01, 1.78 and 33.04 mL and included the age of the animal as an additional variable. In some groups, for example, the 110 days of age group, more responses were made for larger magnitudes of Onset over the whole range of light values. In other groups the 33.04 mL change was the least reinforcing (e.g. the 70 days of age group, Experiment 1). In their second experiment only the smallest and largest changes were used and the age and LCBP experience of the animals were manipulated. There was an overall tendency for more responding for the smallest change, in this experiment. Nevertheless, animals tested at 32 days of age responded slightly more for the larger change. When the same animals were tested again at 80 days of age the smallest change was the more reinforcing. This effect was even more pronounced when they were tested again at 130 days of age.

Tapp (1965, Experiment 1) studied the reinforcing effects of 0.05, 0.45, 3.15 and 18.5 ft.l. Onset changes and obtained no overall effect for the magnitude of change. This finding is not directly consistent with either Stimulus-Change or Preference theory and suggests a possible interaction of the effects of change *per se* and decreasing preferences for more intense luminances.

1.552. *Pigmented Ss*

Consistent with the general paucity of data on pigmented animals there appears to be only one study in which the magnitude of light Onset was studied with pigmented animals as *S*s. Stewart (1960) investigated the reward properties to hooded rats of four magnitudes of light Onset from 0.01 to 8.5 ft.c. There were no differences in response rate for the four magnitudes of change under continuous reinforcement conditions, but a positive relationship, as predicted by Stimulus-Change theory, occurred with fixed ratio schedules. It seems that the magnitude of change was related to reinforcing value of the change, but that the continuous reinforcement situation was not sensitive enough to reveal the relationship.

1.553. Conclusions

Once again, the evidence points toward an interaction of the effects of change *per se* and light intensity preferences when albinos are used as *S*s, with a suggestion that at comparatively low light intensities light change may function largely as a change *per se*.

Overall there is little evidence that light intensity preferences play an appreciable part in the LCBP behaviour of hooded rats. On the other hand, there is some evidence that light change may function predominantly as a change *per se* with pigmented rats and mice. But conclusions concerning the latter strains are made difficult by the paucity of evidence. Undoubtedly what is required here is a clear demonstration that the magnitude of change in both directions is related to the reward value of response-contingent light change to hooded rats in the way predicted by Stimulus-Change theory. In an attempt to provide additional support for the proposition that in the LCBP of hooded rats the light change can be considered simply as a change *per se*, further evidence bearing on this proposition will be presented.

1.56. Change per se in the LCBP of Hooded Rats: Additional Evidence

Apart from varying the magnitude of light intensity change there are other ways of evaluating the hypothesis that a response-contingent change *per se* in the visual modality is reinforcing. Most of this research has been performed with hooded rats as *Ss*. The results seem to be in accord with the theory that a response-contingent light change *per se* can be reinforcing to hooded rats. In the main, the relevant research here has been conducted by either Donahoe or Lowe & Williams.

Donahoe (1965, Experiment 1) studied the reinforcing effects to hooded rats of light Onset for the duration of the response (DBP) when the light which came on was in either a fixed position in the box or a variable position. Four panel lights were positioned around the bar at the corners of a three-by-five and three quarter inch rectangle, with the centre of the bar at the intersection of the diagonals. His three basic experimental groups were:
SP- light Onset from a single invariant position,
AP- each response led to light Onset from one of two light positions in alternating fashion, and RP- each response led to light Onset from one of two random, equiprobable light positions. In addition, a fourth group had been run earlier. In this group (DP) the position of the Onset light was the same within any one trial, but varied from

trial to trial. The findings were: the DP and AP groups did not differ in response rate, but both of these groups responded significantly more than the SP group; the RP group did not differ significantly from any other group. A feature of the RP group was a much greater variability of response rate.

In his second experiment Donahoe (1965, Experiment 2) again looked at the SP, AP and RP conditions, but in this case operant pretest trials were omitted. Once again extreme variability was observed in the RP group. In confirmation of the first experiment, the AP group responded more than the SP group, but the RP group responded significantly less than the AP group. The results from these two experiments by Donahoe indicate that change _per se_, when this consists of shifts in the position of the Onset light, can be reinforcing to the hooded rat. Further, when the uncertainty of change is increased it seems that response rate variability is increased and there may be a decrease in the reward value of light change. The results of both experiments might therefore be taken as indicative of an inverted U relationship between the amount of change and its reinforcing value.

Donahoe (1967) subsequently reported that the stimulus-change effect obtained in his 1965 work seems to be confined to certain conditions of the duration of change.

The AP condition was not significantly more reinforcing than the SP condition when the Onset change lasted for 1 sec. or when it occurred for a variable interval set equal to the duration of change as determined by animals receiving the change for the DBP. In the former two groups the duration of change was independent of the animal's response duration, while in the DBP group the change lasted for the duration of the response. Although the AP condition produced more responses than the SP condition (mean responses per trial of 67.1 and 49.7 respectively) when the duration of change was independent of the animals response, the difference was not significant. When Onset occurred for the duration of the response the AP group (mean 66.4) responded significantly more than the SP group (mean 42.9). Therefore, while the same tendency existed in both duration conditions it was significant only in the latter group.

The reinforcing effects of flickering light Onset as opposed to steady light Onset was investigated in two experiments (Lowe & Williams, 1969; Williams & Lowe, 1967). Williams & Lowe (1967) first gave animals 10 daily 30 min. operant trials. These were then followed by 5 daily LCBP trials. Flickering light was more reinforcing than steady light, as would be predicted by Stimulus-Change theory. This difference did not occur until the second LCBP trial. In fact, on the first LCBP trial flickering light was slightly less reinforcing than steady light. These results suggest an interaction between the "amount" of stimulus-change and its novelty. So that, the maximum reinforcing effect for steady light occurred on the first LCBP trial when it was novel, but the maximum reinforcing effect for the flickering light occurred on the second LCBP trial after some habituation to the stimulus. It seems that on the first LCBP trial there was an inverted U relationship between amount of change and its reinforcing value. After the first trial this relationship became a general positive one.

This kind of interpretation is supported by the results of their later experiment (Lowe & Williams, 1969). In this study only one 15 min. operant trial was given and the steady light was more reinforcing than the flickering light, although the difference was not reliable. The steady light animals responded significantly more than control animals, but not so the animals in the flickering light group. These results suggest an inverted U relationship between the "amount" of change and reinforcing value throughout all five LCBP trials. It is clear from the results of these two experiments that amount of stimulus-change is related to the reinforcing value of the change, and probably in a way consistent with Stimulus-Change theory. The experiments also indicate that the reinforcing value of a given amount of change may vary according to the number of operant pre-test trials run. The number of operant pre-test trials seems to be an important determinant of the initial reinforcing value of any given light change. For this reason its effects will be discussed in the next section of this review.

Notwithstanding the operant pre-test variable, the evidence reviewed here seems to provide substantial additional support for the proposal that a response-contingent light change *per se* is reinforcing to the hooded rat.

1.60. LCBP Response Rate Trends over Trials

Throughout this review it has been noted repeatedly that the response frequency in LCBP often varies systematically over successive trials. An analysis of these trends is important for at least two reasons. Firstly, because changes in the LCBP rate over trials may indicate something about the nature of light change reinforcement and its determinants. Secondly, because it is important for theoretical accounts of the behaviour that light change reinforcement is not a transitory phenomenon.

As a preliminary point it should be noted that the trends over trials cannot be taken, in the strictest sense, as learning curves. It is generally accepted that the response-light change contingency is learned almost instantaneously, i.e. after one or at most a few response-light change pairings. This can be attributed to the spatio-temporal relationships between response and reward in the LCBP situation. Reward and response occur almost concurrently and the animal does not have to learn an association between a bar press and reward located somewhere else in the environment. For this reason the response rate trends over trials in LCBP can be taken, in the main, as due to shifts in the incentive value of the response-contingent light change reward.

With respect to response rate trends over trials in LCBP, several points can be made. Firstly, the usual finding for a light increase change is for a decline in response rate over the initial trials, although in some cases the decline is not statistically significant (e.g. Appel & Hurwitz, 1959; Hurwitz, 1956; Stewart, 1960; Glow, 1970; Goodrick, 1970; McCall, 1965, 1966, Lockard, 1966). Secondly, this trend may be enhanced if apparatus habituation or familiarisation trials (which usually take the form of operant pretests) are run before LCBP commences. Such habituation trials have been shown to increase the reward value of light change at the commencement of LCBP, with the largest effects occurring over the range of from 0 to 3 habituation trials (Girdner, 1953b; Leaton, Symmes & Barry, 1963; McCall, Weiffenbach & Tucker, 1967; Appel & Hurwitz, 1959). Explanations of this phenomenon have been principally in terms of habituation trials allowing competing stimuli to habituate. If no habituation trials are included, responding for a light increase may show a rise over the initial LCBP trials, presumably because of the effects of competing stimuli (Hurwitz, 1956; Leaton, Symmes & Barry, 1963; Levin & Forgays, 1959; Forgays & Levin, 1958, 1961), although this is not an invariant finding (Henderson, 1957; Roberts, 1962). Further, it appears that if the normal 24 hr. intertrial interval is shortened the tendency for a decline over the initial trials in responding for a light increase may be accentuated (Forgays & Levin, 1961; Premack & Collier, 1962), while if the interval is lengthened the reverse may occur, even to the extent of producing a rise over trials (Premack & Collier, 1962). When a light decrease change is used as the reinforcer the usual response rate trend is a rise over the initial trials (Barry & Symmes, 1963; Roberts, Marx & Collier, 1958; Glow, 1970; Goodrick, 1970; McCall, 1966), although some workers have obtained a decline (Lockard, 1966, Experiment 4; Eacker, 1967, Experiment 3).

With respect to the durability of the LCBP phenomenon it can simply be stated that a large number of researchers have continued their experiments for a sufficient number of trials to establish asymptotic response rates. These experiments show that following the initial trends response rate stabilizes at a level indicating that a light change can have persistent and long term reinforcing effects (Glow, 1970; Goodrick, 1970; Stewart, 1960; Sackett, 1965). Of course it is not expected that all light changes will be of sufficient incentive value to sustain responding over long periods. This will depend on the magnitude of the change and light intensity preferences.

1.61. Evaluation

The evidence presented here demonstrates clearly that while the response rate for a light change may vary over the initial LCBP trials, given a constant intertrial interval and a sufficient number of trials, responding will eventually stabilize at an asymptote. The way in which this asymptote is reached varies according to a number of factors, including the direction of light change and the number of apparatus habituation trials. Undoubtedly other variables are involved as well. The crucial point seems to be that because of the response rate changes over the initial trials a reliable estimate of the incentive value of a given light change can only be obtained by allowing the response rate to stabilize. The fact that many researchers terminate their experiments before this point accounts for some of the apparent discrepancies in the literature. In addition, it seems that whereas the response rate over the initial LCBP trials might be a product of a host of variables, such as the novelty of responding for light change, the novelty of the light change, its magnitude, competing stimuli, visual scanning and so on, many of these variables would be expected to habituate, and therefore, the asymptotic response rate is probably mainly a function of the stimulus-change value of the response-contingent light change and, to a lesser extent, light preferences, with the latter playing a much larger part with albino Ss than with hooded rats.

Lastly, sufficient evidence was presented here to show that light change reinforcement is not a transitory phenomenon. Because of its durability LCBP therefore provides a valid foundation on which to base detailed analyses of a class of reinforcer unrelated to the common biogenic reinforcers.

1.70. The Nature of the Motivational State[4] underlying LCBP

The fact that a response-contingent light change is reinforcing justifies the assumption that some motivational

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[4] The term "motivational state" is used here only insofar as the name given such a state is a convenient way of summarising possible sets of empirical relationships and predicting others.

state mediates reinforcement. It was argued that in large part, and especially with hooded rats, light change in LCBP functions as a change _per se_. The major task of the present section is to analyse the possible motivational state upon which the reinforcing effects of a response contingent change _per se_ may be based.

Not a great deal of attention in the area of LCBP has been directed to this problem. Nevertheless, a notion which has been made more or less explicit by a number of workers is that LCBP belongs to a class of behaviour which arise from a general need or drive for sensory input or change. For example, after reviewing the area of sensory reinforcement Kish (1966) concluded that the most parsimonious way of viewing this behaviour is in terms of "a single "stimulus hunger" or drive for stimulation rather than a series of drives specific to different test situations, or sensory modalities, or perhaps both" (p.127). Frieman (1967) and Isaac (1962) both make similar claims on the basis of their research with mice and monkeys respectively, while Thor & Hoats (1968) speak of a "need for stimulus change" in discussing their data on response-contingent light changes.

The existence of such a need or Drive seems to have gained wide acceptance in the psychological literature. The sensory deprivation research with humans, which shows that a certain amount of sensory input or variation is necessary for normal functioning (Bexton, Heron & Scott, 1954; Brownfield, 1965) and that restricting sensory input, especially early in life, can have deleterious effects on the organism (e.g. Newton & Levine, 1967; Rieson, 1961, 1966), provided considerable impetus in this direction. Several authors draw parallels between the sensory deprivation studies and the research on curiosity-exploratory behaviour, and see both phenomena as stemming from a general need for exteroceptive stimulus change (e.g. Jones, 1966; Rieson, 1966; Hebb, 1955; Schultz, 1965, 1967). Schultz (1965, 1967) postulates a general Drive "for stimulus variation". This is seen as a homeostatic Drive comparable to that for food or water and is designated "sensoristasis".

A nonspecific need for stimulus change appears to form the foundation of theories of curiosity, exploration, or stimulus change reinforcement based on (1) a "boredom drive" - where it is claimed that unchanging stimulation produces a drive reducible by sensory change (Myers & Miller, 1954; Fowler, 1965, 1967), (2) "stimulus satiation" (Glanzer, 1953), and (3) the proposition that organisms engage in curiosity or exploratory behaviour to effect an optimal level of sensory input or arousal (e.g. Leuba, 1955; Fiske & Maddi, 1961; Berlyne, 1960; Hebb, 1955; Hebb & Thompson, 1954; Glickman, 1958) - which is typified by the postulation of a "general or basix motive to optimize amount of stimulus change or complexity" (Dember, 1961, p.231). The specific aim of this section is to evaluate the notion of a need or drive for stimulus change as it applies to LCBP.

This will be attempted by looking at the effects on the reward value of response-contingent light change of two kinds of antecedent manipulation: deprivation of stimulus change, and exposure to stimulus change. In the first case, if the reinforcing effectiveness of light change can be potentiated by depriving the organism of sensory change it could be argued that the crucial motivational state underlying LCBP is a general need for stimulus change. In the second case, if exposure to stimulus change reduces the reinforcing effectiveness of light change this might again provide support for the proposition that a general need for stimulus change is operative in LCBP.

1.71. Sensory Change Deprivation and LCBP

The obvious difficulty with testing for the potentiating effects on LCBP of deprivation of sensory change is arranging for such deprivation. The typical approach here has been to deprive the animal of light and then test the reinforcing effect of light Onset. Clearly these results must be viewed with caution because they confound the possible effects of light deprivation with sensory change deprivation.

This problem can be illustrated by the report published as an abstract by Premack, Collier & Roberts (1957). They found that the reinforcing effect of light Onset was a monotonic increasing function of light deprivation, at the values of 12, 24, and 48 hrs. of deprivation. They then conclude, "these results suggest that use of concepts such as novelty, or curiosity to explain the reinforcing effects of puzzles, mazes, lights, sounds etc. is misleading. Rather, these effects are, perhaps, better treated as a drive for stimulus change, drive being defined as a functional relation between deprivation for X and responding for X" (emphasis added). A conclusion concerning stimulus change is not wholly justified by these data as they confound the effects of light deprivation with any effects of stimulus change deprivation. This kind of conclusion must be based on a demonstration that the deprivation potentiates the reinforcing effects of other sensory changes, such as light Offset, as well.

Fox (1962, Experiment 1) came to a similar conclusion as Premack, Collier & Roberts after finding that confinement in a dark box increased responding for light Onset in monkeys with confinement periods up to 4 hrs. Fox interpreted his results as showing a compensation "for the lack of sensory input experienced during the deprivation period" (p.440). Another experiment in which light deprivation was found to increase the reward value of light Onset to monkeys is reported by Wendt, Lindsley, Adey & Fox (1963). These authors were more guarded in their conclusions and seem to attribute their results to light deprivation rather than to sensory change deprivation.

However, in contrast to these results there are several experiments with rats as Ss which have found that short term light deprivation is either not related to responding for a light Onset change, or actually reduces the reinforcing value of light Onset (Robinson, unpublished data reported by Kish, 1966; Premack & Collier, 1962, Experiments IID, IIIA, IIIC; Ochocki & Premack, 1958). Morrison (1965) found that light deprivation increased the total duration of the response for light Onset reinforcement, but did not affect the response rate. In the main, these results from rats seem to support the conclusion advanced by Premack & Collier (1962) that "there appears to be no stimuli, additional to the light contingent bar itself, that can be absented from the rat with the effect of increasing frequency of this response" (p.17). This conclusion is based in part on their finding that the longer the intertrial interval between LCBP trials the more reinforcing the light change.

If it is assumed that light deprivation also constitutes stimulus-change deprivation, then a test of the effects of stimulus-change deprivation can only be legitimately made if the reinforcing effects of light changes in both directions, e.g. Onset and Offset, are tested following deprivation. An extensive review of the literature failed to yield an experiment in which a satisfactory test was made of the effects of sensory deprivation on LCBP.

Two points seem to emerge from the present review. Firstly, there has been no clear demonstration that deprivation of sensory change can potentiate the reinforcing effects of response-contingent light change. Secondly, that in most studies of LCBP, light change operates as a reinforcer in the absence of any specific deprivation conditions. In the latter respect light change reinforcement seems to be like EBS (Trowill, Panksepp & Gandelman, 1969). Further, it seems that any attempt to demonstrate that sensory change deprivation can potentiate the reinforcing effects of light change is faced with several difficulties. For example, long term sensory restriction could have relatively permanent detrimental effects on the organism which may reduce tolerance of change. What constitutes "long term sensory restriction" is unclear at this stage. Further, the effects of sensory deprivation are likely to be complex and could affect subsequent LCBP in quite different ways. In albino rats light deprivation may modify the tolerance of light and therefore affect responding for light Onset.

Sensory deprivation may also affect the level of general activity and/or arousal and thereby modify subsequent LCBP. With respect to this, Premack & Collier (1962) noted that "protracted icebox maintenance appeared to reduce the home-cage activity level..... icebox Ss when removed for testing appeared to be sluggish, and also, their food and water consumption appeared to be below that of colony Ss" (p.15).

In conclusion; there does not appear to be any extant literature dealing with stimulus-change deprivation which leads of necessity to the conclusion that a drive or need for sensory change underlies the reinforcing effects of light change. In fairness it should also be pointed out that neither does the evidence indicate unequivocally a conclusion that a drive or need for stimulus change does not underly LCBP. More definite conclusions cannot be drawn because of the kind of research performed to date and the difficulties associated with such research, many of which have yet to be resolved.

1.72. LCBP and the Effects of Immediate Prior Exposure to Stimulus Change

Apart from deprivation procedures the nature of the presumed motive state underlying LCBP can also be investigated by examining the effects of exposure to stimulus change *immediately* before testing the reinforcing value of a light change. This method does not seem to suffer from the obvious difficulties associated with the deprivation of stimulus change technique and therefore is probably a much sounder method of investigating the problem at hand. However, despite the apparent advantages of exposure techniques in elucidating certain aspects of LCBP there are comparatively few research reports dealing with the effects on LCBP of various kinds of prior exposure to sensory change.

With respect to the effects on LCBP of immediate prior exposure to stimulus change it seems there exists a continuum in terms of the similarity of the exposure stimulus change and the stimulus change subsequently tested for reinforcing value. The continuum extends from exposure to precisely the same light change which is used as the reinforcer, to exposure to different light changes through to exposure to changes in a different sensory modality. A-general-need-for-stimulation hypothesis would predict that the reinforcing value of a given light change will be diminished by exposure to that change, and also that exposure to other light changes and changes in other sensory modalities will diminish the reinforcing value of a given light change.

Immediate prior exposure to the same light changes as subsequently used as a reinforcer has been shown to diminish the reinforcing value of that light change (Kish & Baron, 1962; Berlyne, Koenig & Hirota, 1966, Experiment

1 quiet maintained group, Experiment 2 saline injected animals). Kish & Baron interpret their results as supporting "the inference of a drive underlying light reinforcement" (p.1010). They mention that their results are consistent with the view (Berlyne, 1960) that "a curiosity drive is aroused by novel stimulation and reduced by continued commerce with such stimulation" (p.1009). However, they also claim their results are consistent with the position that LCBP is mediated by a "boredom drive". The point to be stressed here is that if LCBP is to be explained in terms of a "boredom drive" it must be shown that immediate prior exposure to one kind of sensory change will reduce the reinforcing effectiveness of a different sensory change (in this case a light change). The Kish & Baron experiment does not do this.

In contrast to these results, Berlyne, Koenig & Hirota (1966) found that prior exposure to a light change (or sound change) actually increased the reinforcing value of that change (in comparison with a novel change) to some groups (Experiment 1 noisy maintained group, Experiment 2 amphetamine injected animals). They claim this result is due to a supranormal level of arousal in these animals. Arousal interacted with the novelty of the change used as the reinforcer with the less novel change being most reinforcing to these animals. In view of this finding it appears that arousal level may be an interfering variable in exposure research and that care should be taken to control its contribution to the behaviour.

There is another way of looking at the effects of exposure to one light change on the reinforcing value of the same light change, namely by considering the within trial response rate trends in normal LCBP work. It would be expected that if exposure to the light change reduced its reinforcing value there would be a decline in responding throughout any one trial. Almost invariably this is the obtained result (McCall, 1965; Roberts, Marx & Collier, 1958; Glow, 1970). But, there is no way of determining in this situation whether this indicates satiation to stimulus change in general, or only to the particular change used as the reinforcer. In addition, it could be argued that reactive inhibition is the crucial factor mediating the decline in response rate. Little attempt has been made to investigate the role of reactive inhibition on within trial response rate trends in LCBP and there is no general agreement on its possible contribution (cf. Roberts, 1962; Forgays & Levin, 1961). Further, there appears to have been no attempt made to investigate the role of the response light change contingency in producing stimulus-satiation. It is conceivable that stimulus satiation will be greater when the light change is response contingent than when it is non-contingent. There is some indirect evidence to support this proposition (Fox, 1964).

An extensive review of the literature did not reveal a study in which the effects on the reinforcing value of one light change of exposure to a different light change was investigated. This is undoubtedly a vital and necessary research undertaking before valid conclusions can be drawn about the presumed motive state underlying LCBP. This is especially so since there is evidence that exposure to stimulus change in one sensory modality may have no effect on the reinforcing value of changes in another sensory modality, at least in the modalities of vision and audition (Berlyne, Koenig & Hirota, 1966, Experiment 1). While further research on this problem is necessary, the latter finding questions the validity of a notion of a general need for stimulation. For this reason it seems important to determine whether, or to what extent, exposure to a particular light change affects the reinforcing value of a different light change. Findings that different light changes do not operate independently may require a formulation in terms of a need for stimulation in separate sensory modalities, with one modality unrelated to another. Prescott's (e.g. 1971) theoretical position might predict such an organisation of the sensory modalities. On the other hand, if different changes in the one modality operate independently, the whole concept of a need or drive for stimulus change may have to be discarded in favour of other formulations.

1.80. Dependent Variables other than Responses

Besides the number of responses some other dependent variables have been recorded in LCBP studies. The most common of these is the mean duration of the response, i.e. a bar press. The latency period before the first response (McCall, Weiffenbach & Tucker, 1967), and, when a response-contingent light change occurs for a fixed time interval, the number of responses which are reinforced and the number not reinforced (Eacker, 1967) have also been recorded. In addition, some workers have reported their subjective impressions of the interresponse time distribution.

Principally, recordings of the duration of the bar press in LCBP have been taken when the light change duration is coincident with the response duration. Interest centred on whether animals would make longer responses for more reinforcing changes. In part this is based on the assumption that the consequent light intensity makes an important contribution to the reward value of the change, with this being reflected in an attempt to prolong the consequent intensity. On the other hand, if change *per se* is the crucial factor it seems there should be little relationship between the reinforcing value of the change and the response duration. The latter is the usual finding (McCall, 1965, 1966; Roberts, 1962; Sackett, 1965; Glow, Russell & Kirby, in press; Barnes & Baron, 1961b).

However, it appears that in comparison to the response duration under operant conditions, when a light change is response contingent there may be a general tendency for a lengthening of the response duration (Hurwitz, 1956; Robinson, 1961; Barnes & Baron, 1961b; McCall, 1966). It has also been found that the mean duration of bar press declines over LCBP trials (McCall, Weiffenbach & Tucker, 1967; McCall, 1966), although this decline did not occur when albino rats responded for light Decrement (McCall, 1966). It is fair to say that there is as yet no clear picture on the relationship between shifts in the response duration and responding for light change.

A number of researchers have reported subjective impressions about the inter-response time distribution in LCBP. They note that animals tend to respond in "bursts" with periods of inactivity between bursts (Hurwitz, 1956; Berlyne, Salapatek, Gelman & Zener, 1964). But there does not seem to have been any attempt made to quantify this topographical aspect of responding, or to investigate possible changes in the topography of responding with repeated LCBP trials.

1.90. Overview

Some of the more salient points which emerge from this review can now be summarised. A light change contingent on bar pressing is undoubtedly reinforcing to rats and mice. This is due mainly to the operation of light change as a change _per se_. However, in albino _S_s this effect is likely to be modified by light preferences, the more so as LCBP trials continue.

It seems that the duration of change may be an important determinant of the reinforcing value of light change. This parameter has not been rigorously tested. An examination of its effects may clear up some of the apparent conflicts in the literature concerning the relative reinforcing value of light changes in different directions. The latter have provided some difficulty for a Stimulus-Change theory of LCBP.

The reinforcing value of light change varies systematically over trials. Whereas responding over the initial trials may be determined by a variety of factors, the asymptotic response rate, which eventually emerges as trials continue, is probably mainly a function of the "stimulus change value" of the light change. This point is of most relevance to hooded rats, as in albinos it seems that light intensity preferences markedly affect the asymptotic response rate.

There is some consensus that the motive state underlying LCBP could be a general need or drive for sensory stimulation. While there are several difficulties associated with testing this hypothesis by investigating the effects of deprivation of sensory change, extant evidence seems to provide little support for the general need formulation. Probably the most satisfactory way of examining the nature of the presumed motive state is by testing the effects of immediate prior exposure to sensory change on the reinforcing value of light change. Little attempt has been made to investigate this. However, there is some evidence that stimulus change in different sensory modalities may operate independently. This raises the question of whether, or to what extent, changes in any one sensory modality, such as the visual, will also operate independently. An investigation of this question would make a significant contribution to the understanding of the LCBP phenomenon.

Other problems, as yet largely unresearched, were also noted. These include the contribution of reactive inhibition to response rate trends in LCBP and the role of the response-light change contingency in stimulus-satiation.

The research program reported here was designed to elucidate several of the issues and apparent conflicts noted throughout this review. The principal aim was to examine the effects of immediate prior exposure to light change on the reinforcing value of light change as a means of evaluating the presumed motive state underlying LCBP. As noted, this type of research is based on the assumption that change *per se* is the major factor in the reinforcing value of light change. To maximise as far as possible the contribution of change *per se* and to reduce the probable confounding effects of light intensity preferences, hooded rats rather than albinos were used in this research. In order to establish the contribution of change *per se* for the purposes of this research, and to obtain light changes in both directions which are indisputably reinforcing, a parametric examination of the effects of the magnitude and duration of change in both directions was first undertaken. Apart from providing further information on several aspects of LCBP this investigation was intended to provide a foundation on which subsequent research on the effects of prior exposure to light change on the reinforcing value of light change could be based.

2. RESEARCH METHODOLOGY AND STATISTICAL PROCEDURES

2.10. Research Methodology

In the final analysis, many of the apparent discrepancies noted in the research literature (section 1) can be attributed to methodological differences, and especially differences in the strain of animal; apparatus specifications; and a number of procedural differences, such as trial length, inter-trial interval and the number of trials included in the experiment.

Unless one is interested in investigating the strain as such, a good case would appear to exist for using hooded rats rather than albinos in LCBP research. The LCBP behaviour of albinos seems to be a complex function of the light change functioning as a change *per se* and the light intensity preferences of the animals. Moreover, these preferences vary as a function of a number of additional factors, e.g. the age of the *Ss* and the prior light exposure history of the animals. On the other hand, there is evidence that, within the range of light intensities typically used in LCBP research, the LCBP of hooded rats is largely uncontaminated by light preferences. In short, there are many advantages to using hooded rats in LCBP research. For this reason the research reported here used hooded rats exclusively.

One of the problems associated with investigating LCBP is the comparatively weak reinforcing value of a response-contingent light change. Because of this there is not a great deal of scope for obtaining statistically reliable effects over a wide spectrum of independent variables. One way of increasing the sensitivity of the experiment, or in other words, the ability of the experiment to detect effects on behaviour attributable to the independent variables, is by increasing the number of responses per trial. It has been found that the response rate is higher when a 48 hr. intertrial interval is used than when the usual 24 hr. intertrial interval is employed. Therefore, to increase the resolution in the series of experiments reported here the intertrial interval was 48 hrs. in all cases.

The trial length in LCBP research is usually in the range of from 6 min. to 1 hr. Periods of between 10 min. and 30 min. are favoured most often because of the convenience of the comparatively short test period and because it has been found that a large percentage of responses are made immediately following the commencement of the trial and consequently, little is gained from a longer test period. In the present research a constant trial length of 20 min. was used. This length was chosen partly because it was amenable to easy division into four quarters of 5 min. each for an examination of intra-trial responding.

A serious criticism which can be levelled at many studies of LCBP is that testing is terminated after only 1 or at most a few trials, i.e. before the behaviour has been allowed to stabilize at an asymptotic level. In some studies data from 1 or 2 trials is all that is required and meaningful to the problem at hand. But in other research, conclusions can only be validly drawn after the behaviour has reached an asymptote. As already noted (section 1.60) many variables (some of them confounding) determine responding over the initial LCBP trials. The present argument is that valid conclusions about the effects of independent variables often can be drawn only after confounding and transitory variables contributing to the behaviour have been allowed to habituate. For this reason, all experiments reported here were continued until it was apparent that the responding had reached an asymptote.

In all experiments performed here five trials were run prior to the actual start of LCBP. These trials were largely intended to (1) allow habituation to the apparatus and other experimental conditions, and (2) in several experiments, enable a determination of the operant response level.

Finally, whereas a number of researchers have used food and/or water deprived Ss in their research as a matter of course (i.e. not as an independent variable), the animals used in the present research were all on ad libitum food and water prior to and throughout the experiment. In this way the possible confounding effects of food and water deprivation were avoided. A large body of data has now accumulated on the effects of food and water deprivation on LCBP. It is fair to say that no clear picture has emerged from these data. In some studies deprivation has been found to raise LCBP or the operant response level while in others no effects have been obtained (see Tapp, Mathewson & Simpson, 1968; Tapp, Mathewson & Jarrett, 1968; and reviews: Kiernan, 1964; Kish, 1966). The use of nondeprived Ss enables conclusions to be drawn about the intrinsically motivated behaviour of animals under "normal" conditions.

To summarise, the main points to be noted about the research methodology used throughout the series of experiments reported here are:

(1) the use of hooded rats rather than albinos as Ss,

(2) all trials were of 20 min. duration, divided into four 5 min. quarters,

(3) the intertrial interval was 48 hrs.,

(4) LCBP trials were continued until a clear response asymptote had been established,

(5) five operant and/or apparatus habituation trials were run prior to the commencement of LCBP, and

(6) Ss were maintained on ad libitum food and water prior to and throughout the experiment.

2.20. Statistical Procedures

In the main, the experiments reported here were designed and analysed as complete factorial studies for the main experimental variables, with repeated measures over trials. In these respects, the present experiments parallel most of the LCBP research reported in the literature. The repeated measures analysis followed Winer (1970, chapter 7). The assumptions underlying this analysis are linear summation of effects and multivariate normal distributions. Analyses of variance for uncorrelated observations have been shown to be robust with respect to violations of the assumption that distributions are normal with equal error variances (Winer, 1970; Box, 1953). However, in cases of correlated observations, such as the "Within Ss" factors in repeated measures designs, "heterogeneity of both the variances and covariances..... will generally result in a positive bias in the usual F test" (Winer, 1970, p.123). Therefore, as far as possible, an attempt was made throughout this research to approximate the assumptions of the analysis. This necessitated the application of a transformation to the raw data in several experiments. A square root transformation was used for this purpose. In general, the transformation was used in experiments in which treatment conditions were applied from the commencement of LCBP (Experiments 1, 3, 4, 6 & 7). On the other hand, the raw data from experiments in which treatments were administered after responding for a light change had been established and in which animals were matched in terms of their response rate largely satisfied the assumptions without need for any transformation of the raw data (Experiments 2 & 5).

Furthermore, the main overall analysis of variance is frequently supported by ancillary analyses using blocks of trials. In this way, any doubts about the repeated measures analysis (c.f. Rouanet & Lépine, 1970) may be avoided. Appropriately pooled error terms are used in all F ratios. A pooled error term is used because (1) the assumptions underlying its use were largely satisfied and (2) it increased the power of the statistical test.

The principal dependent variable was responses. This was recorded in each quarter of each trial. The main analyses were performed on the total number of responses during each 20 min. trial. The overall analyses of variance of the response data did not include the within trial data as a factor. The reason for this was that in most experiments the size of the data array precluded the inclusion of the four quarters in the analysis. This was due to the limitations of available computer storage space (the data were analysed using computer facilities). Consequently, the within trial response data were analysed by (1) calculating the percentage of total responses which occurred in each quarter of the trial for every treatment condition, and (2) taking the data from each quarter of the trial and subjecting it to precisely the same analyses of variance as applied to the total number of responses - in order to determine whether the relationships between treatment groups obtained for the total number of responses held throughout each quarter of the trial.

When the analysis of variance of total responses yielded significant trends over trial or treatment x trials interaction effects, these were further analysed to indicate the orthogonal polynomial trend components in the changes in responding over trials. The orthogonal polynomials, up to the 5th order, were applied to the data for each animal. The resultant coefficients (see Winer, 1970, pp. 353-369 for procedure) were subjected to a one-way analysis of variance for all treatment groups to determine whether or not that trend component was homogeneous across treatments.

When the analyses of variance of the total number of responses indicated significant differences between treatments, the data were further analysed to determine precisely which treatments were significantly different and over which trials these differences occurred. The procedure here involved the calculation of the best fit regression equation up to the 5th order orthogonal coefficient for each treatment. The variance on each trial was determined and from this the least significant difference (LSD) on each trial was calculated. The LSD method was chosen because it was considered that in the context of significant F ratios it gives a satisfactory balance between type I and type II errors for present purposes.

Finally, to facilitate the analyses, if an animal died during the course of an experiment the data for that animal were estimated (2 animals died throughout the research program reported here). The procedure used for estimating missing data was adapted from the technique outlined by Winer (1970, p.283) in which possible interaction effects are taken into consideration. Thus, the data for an animal in one treatment cell was estimated by a weighted combination of the data from other animals in that treatment cell and data from animals in related treatment cells in the design.

3. STIMULUS-CHANGE THEORY AND THE EFFECTS OF THE MAGNITUDE, DIRECTION AND DURATION OF LIGHT CHANGE ON LIGHT-CONTINGENT BAR PRESSING

3.10. Introduction

The overall impression gained from a review of the data pertaining to Stimulus-Change and Preference theory (section 1.5) is that change *per se* is the major determinant of the reinforcing value of light change. This determinant is particularly evident in the behaviour of pigmented rats. Nevertheless, there are two aspects of the data which have posed some difficulty for Stimulus-Change theory. The first is that light Offset was generally not found to be reinforcing. The second is that light changes of equal magnitude, but in opposite directions, are rarely found to be equally reinforcing. However, the difference in reinforcing value of light increase and decrease changes is not always in the same direction. Sometimes a decrease is found to be more reinforcing than a comparable increase, and sometimes the reverse occurs. To some extent this may be related to the number of trials run in the experiment as responding for light increase usually declines over trials while responding for light decrease usually increases over trials. It was argued that the discrepancies in the literature with respect to both (1) whether or not light Offset is reinforcing and (2) the relative reinforcing value of changes in opposite directions, may be parametrically related to the duration of the change used (see section 1.53). The research reported here was designed to test this proposition.

In addition, although the evidence reviewed provides substantial support for a Stimulus-Change theory of the LCBP behaviour of hooded rats, it appears that there has been no clear demonstration that larger magnitudes of light change are more reinforcing to these strains. This relationship follows directly from Stimulus-Change theory, and a demonstration that it holds for hooded rats would add weight to a Stimulus-Change formulation. Amongst the data from albinos are several parametric studies of the relationship between the magnitude of light change and reinforcing value (e.g. McCall, 1965, 1966; Lockard, 1966; Berlyne & Koenig, 1965). No comparable research has been reported for hooded rats. Therefore, the first experiment reported here was designed to investigate the relationship between the magnitude of light change and reinforcing value in hooded rats.

3.20. EXPERIMENT 1: An Investigation of the Effects of the Magnitude, Direction and Duration of Light Change on the LCBP of Hooded Rats

INTRODUCTION

This experiment was designed to investigate the effects of the magnitude, direction, and duration of light change on the LCBP of hooded rats. It therefore tests the predictions from Stimulus-Change theory that (1) within certain limits at least, there will be a positive relationship between the magnitude of change and reinforcing value, and (2) that light changes in both directions will be reinforcing. The duration parameter was included to examine (1) the effects of the duration of change on the relative reinforcing value of light changes in different directions, and (2) to specifically compare the reinforcing value of light decrease changes which occur for the duration of the bar press (DBP) with fixed interval changes of 3 sec. The experiment was intended to provide an indication of the parameters of light changes in both directions which are clearly reinforcing and remain so with repeated trials.

The main dependent variable was responding. Other aspects of LCBP were examined by recording (1) the mean duration of bar press, (2) the number of reinforced responses, and (3) the inter-response time distribution during LCBP.

METHOD

Subjects The *S*s were 96 female Wistar hooded rats, approximately 140 days of age at the commencement of the experiment. They were obtained from the University colony at about 100 days of age, routinely handled, and maintained on *ad libitum* food and water prior to and throughout the experiment. The animals were singly caged in an air conditioned room at 70°F on a 12 hour light-dark cycle.

Apparatus The apparatus consisted of four light tight, air conditioned and sound insulated chambers containing single lever Skinner boxes 8½ x 8 x 9 ins., constructed from unpainted aluminium panels with a perspex door and ceiling. Two lights (Philips 0.8V, 0.82A) were mounted ¾" below the top of the box and 2" from the sides on the wall facing the lever. A 2" x ½" metal lever protruded ½" from a wall 3" above the floor. Approximately 20 gms weight was required to operate the lever. Four magnitudes of light change were selected on a log scale (factor 0.605): 0.10 ft.c., 0.40 ft.c., 1.62 ft.c., and 6.53 ft.c. The four magnitudes were presented either as Increments from 0.032 ft.c. or as Decrements from 6.56 ft.c. The light values were measured in the vicinity of the lever by a Lunasix photometer. The values were adjusted to the required level by potentiometers in the circuit. The equipment operated through a voltage stabilized supply.

The control apparatus, located in a separate room, was programmed so that light changes could occur for either the duration of the bar press (DBP), ½ sec., or 3 sec., as required. The inter-response times were recorded by a digital counter-timer (Glow & Parkanyi, 1968).

PROCEDURE

Design The experiment was designed as a three way complete factorial study for 4 magnitudes, 3 durations and 2 directions of light change. Four animals were randomly assigned to each of the 24 treatment conditions. All trials were of 20 min. duration, with an intertrial interval of 48 hrs. The animals in Increment and Decrement treatments were run on alternate days. The frequency of bar pressing in each of the four 5 min. quarters of the trial and the mean duration of bar press over the whole trial were recorded throughout the experiment which was run in two phases. Phase I consisted of operant responding, Phase II of LCBP. During the LCBP phase, records were also taken of the inter-response time, and in those treatments in which the light change occurred for a fixed time interval (½ sec. or 3 sec.), the number of reinforced responses.

Phase I (Operant Level)

During this phase animals in the Increment treatments were placed in the apparatus in 0.032 ft.c. and the animals in the Decrement treatments in 6.56 ft.c. A bar press did not produce a change in light intensity. This phase was included to habituate the animals to the apparatus and to obtain an estimate of the operant response rate. 5 trials were run.

Phase II (LCBP)

Commencing with the 6th trial one of the 24 combinations of light change was made contingent on bar pressing, according to treatment allocation in the design. For animals receiving a fixed duration of change a response during the period of light change was recorded, but did not affect the change. For this reason the number of reinforced responses as opposed to the total number of responses was recorded in these treatments. Trials were continued until inspection of the data and tests for trends indicated that responding had reached an asymptote. A total of 15 trials were run in this phase.

RESULTS

The main analyses were done on the total number of responses on each 20 min. trial. Separate analyses of responding on each quarter of the trial were made to see whether the relationships observed for total responses obtained for each quarter of the trial. A repeated measures analysis of variance procedure was used (Winer, 1970, chapter 7). To obtain homogeneity of variance a square root transformation was made of the response data. The basic analyses of the total responses in each phase are presented first, followed by the within trial responding.

TOTAL RESPONSES

Phase I (Operant level)

The analysis of responding during the operant phase was done in terms of treatment assignment in Phase II. There were no significant main effects or interactions, indicating that animals were adequately matched for operant responding and that the base level of illumination had no effect on operant responding. There was a decline in response frequency over trials ($F = 43.87$, df 4,288, $p < .01$). An estimate of the operant level for each animal was obtained from the mean on trials 4 and 5 (see Table 1).

Phase II (LCBP)

It was apparent from the data (see figs. 1, 2, 3) that the principal changes in response rate occurred over the first 7 or 8 trials of this phase, thereafter responding appeared asymptotic. This was confirmed by an analysis of trials 13-20, which showed no trends over these trials. Because of this, for the purpose of presentation, the data have been summarized into mean response rate over trials 6-12 and trials 13-20 for each treatment (see Table 1). The

TABLE 1: Mean Number of Responses per 20 min. Trial

LIGHT INCREMENTS

Magnitude of Change

		0.10 ft.c.			0.40 ft.c.			1.62 ft.c.			6.53 ft.c.			All magnitudes		
Duration of change	trials	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20
	½ sec.	4.4	8.6	7.2	2.2	8.4	4.5	2.5	15.7	9.4	2.0	23.7	12.4	2.8	14.1	8.4
	DBP	1.7	5.5	4.8	1.1	5.3	4.5	5.7	17.8	8.6	1.7	20.3	12.0	2.6	12.2	7.5
	3 sec.	1.2	3.2	2.9	2.2	10.9	3.5	3.6	13.9	6.2	1.6	14.9	8.5	2.1	10.7	5.3
	All Durations	2.4	5.8	5.0	1.8	8.2	4.2	3.9	15.8	8.1	1.8	19.6	11.0			

Table 1. (contd.)

LIGHT DECREMENTS

Magnitude of Change

		0.10 ft.c.			0.40 ft.c.			1.62 ft.c.			6.53 ft.c.			All magnitudes		
Duration of change	trials	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20
	½ sec.	2.2	0.9	0.8	1.2	2.6	1.9	2.5	2.6	1.9	1.4	4.1	4.1	1.8	2.3	2.4
	DBP	3.6	2.5	1.6	4.0	3.0	5.1	0.6	1.4	1.7	1.5	8.0	5.9	2.4	3.7	3.6
	3 sec.	4.2	5.9	3.2	3.0	2.1	2.5	1.5	2.8	2.7	1.5	9.2	13.5	2.6	5.0	5.5
	All Durations	3.3	3.1	1.9	2.7	2.2	3.5	1.5	2.3	2.1	1.5	7.1	7.8			

main features of the data as indicated by the repeated measures analysis of variance of all 15 trials and the several supporting analyses are as follows.

Direction of change The analysis of variance showed that more responses were made for light Increments than Decrements (F = 84.41, df 1,72, p < .01). This result is examined in more detail by looking at the magnitude and duration effects.

Magnitude of change There was a general tendency toward more responding for larger magnitudes of change (F = 17.97, df 3,72, p < .01). However, a significant magnitude x direction interaction suggests this is due mainly to the light Increment treatments (see Table 1). To determine whether the four magnitudes of change in both directions were reinforcing a series of 't' tests on the difference between response rate on the last two operant trials and the first two LCBP trials were performed. All four magnitudes of light Increment were reinforcing (p < .01 in all cases, 2 tailed test). None of the Decrements was reinforcing. There was a tendency for the 6.53 ft.c. Decrement to raise responding but this was confined to two animals and therefore not significant. Repeated testing of the 6.53 ft.c. Decrement showed it to be first reinforcing on trials 8-9 (t = 2.21, p < .05). The same series of 't' tests performed on the difference between responding on the last two operant trials and the last 5 LCBP trials revealed that all four magnitudes of light Increment remained reinforcing, while the only light Decrement found to be reinforcing was the 6.53 ft.c. change ($p < .02$ in all cases, 2 tailed test).

The effect of the magnitude of change on responding for light Increment is illustrated in fig.1, where the best fit regression curves[5] up to the 5th order orthogonal coefficients are presented, together with the least significant difference on each trial. In general, if the difference between any two magnitudes of light change is larger than the least significant difference given at the bottom of fig.1, the difference is significant. It can be seen from this figure that over the initial trials there were reliable differences between all four magnitudes of change, but that after responding had stabilized the major difference is between the two smallest and the two largest changes.

To investigate further the prediction from Stimulus-Change theory of a positive relationship between the magnitude of change and reinforcing value, linear regression analyses of the magnitude variable were performed on the mean response rate over trials 6-12 and trials 13-20 for

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[5] The close approximation of the best fit curves to the actual data can be seen by a comparison of the present fig.1 with fig.1 of Russell (in press) contained in Appendix I.

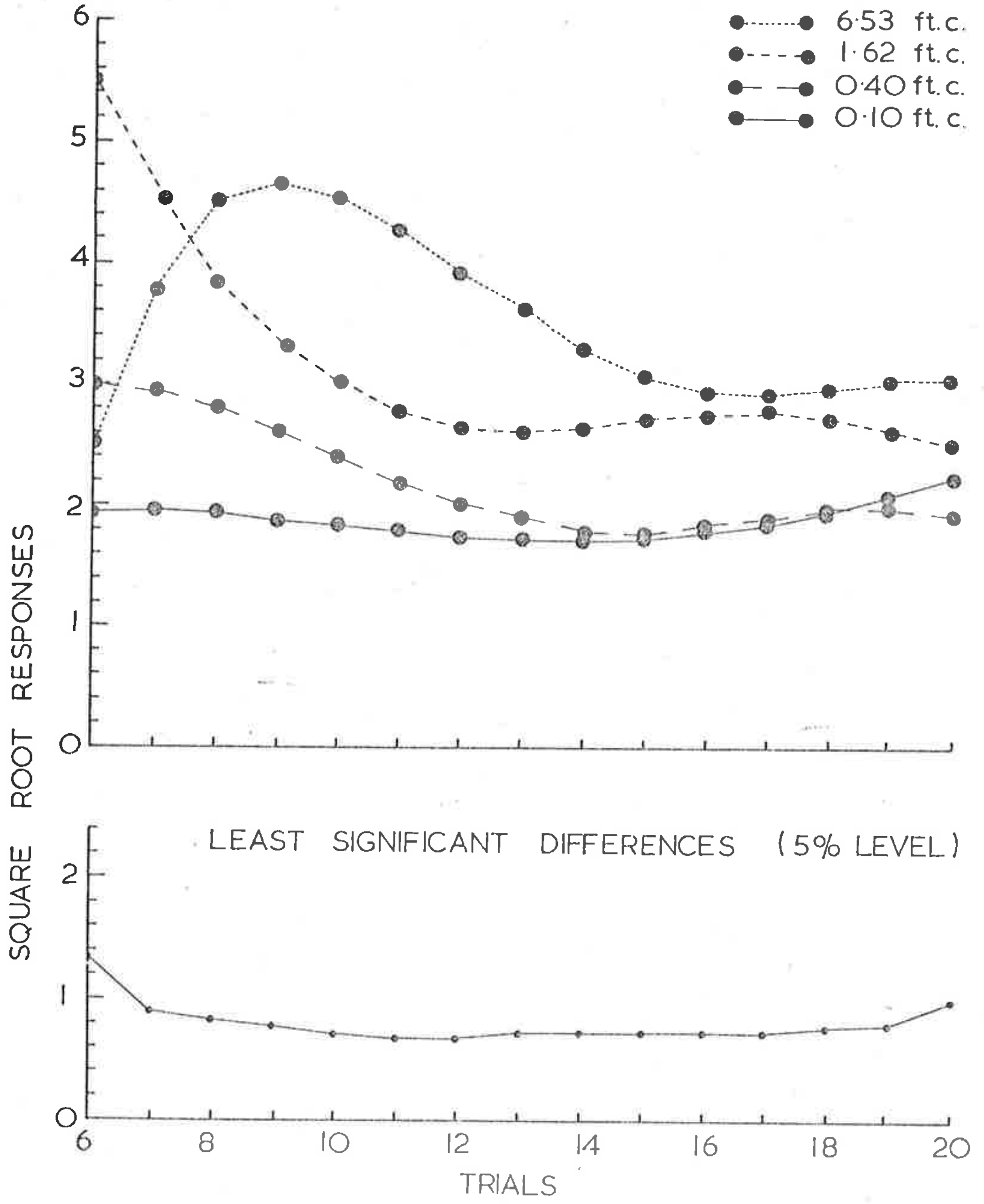


Fig.1. Responding in Phase II for light Increment as a function of the magnitude of change: Best fit curves and least significant differences (see text).

each magnitude of change with the four magnitudes taken as equally spaced units. A significant linear trend for light Increments occurred over both sets of trials. For trials 6-12 ($\underline{F} = 40.29$, $\underline{df}$ 1,10, $\underline{p} < .01$, slope 4.93, with nonsignificant residuals) the trend accounted for 76.4% of the variance. For trials 13-20 ($\underline{F} = 18.02$, $\underline{df}$ 1,10, $\underline{p} < .01$, slope 2.20, with nonsignificant residuals) it accounted for 59.9% of the variance. Of course, it can be seen from fig.1 that at first there was an inverted U relationship between the magnitude of change and response rate. Following the increase in response rate for the 6.53 ft.c. change a general positive relationship emerged, which accounts for the linear relationships (see Table 1). These results are in accord with Stimulus-Change theory. Further, they show that the magnitude effect is not transitory. It is also evident when responding has stabilized at an asymptote.

An examination of the four magnitudes of light Decrement, in the same way as was done for Increments in fig.1, revealed that there were no differences between any of the three smallest changes throughout phase II. On the other hand, the 6.53 ft.c. Decrement was reliably above the three smallest changes from trial 11 to trial 20. This would explain why the test for a trend in the mean response rate for the four magnitudes of Decrement over trials 6-12 revealed no trend. The same analysis of responding over trials 13-20 showed some evidence of a linear trend ($F = 4.79$, *df* 1,10, $p < .054$, slope 1.65, with nonsignificant residuals) which accounted for 25.2% of the variance. This indicates a tendency for more responding for larger magnitudes of light Decrement but the effect is not nearly as pronounced as for light Increments.

Duration of change The analysis of variance did not produce a significant main effect for duration of light change. However, there was an interaction between the direction and duration of change ($F = 7.21$, *df* 2,72, $p < .01$). This seems to reflect the fact that the duration of change had most effect in the light Increment treatments - where more responding occurred for the ½ sec. change, followed by the DBP and 3 sec. change. From fig.2 it is apparent that the difference between only the ½ sec. and the 3 sec. change was reliable. From Table 1 it is evident that there is little overall difference between the three durations of light Decrement. Nevertheless, when the 6.53 ft.c. Decrement is taken alone, it can be seen that after about the 11th trial more responses were made for the 3 sec. change than for the two shorter changes (see fig.3), thus reversing the relationship obtained for light Increments. An estimate of the average duration of light change for the DBP *Ss* can be obtained from fig.4. This indicates that the duration of light

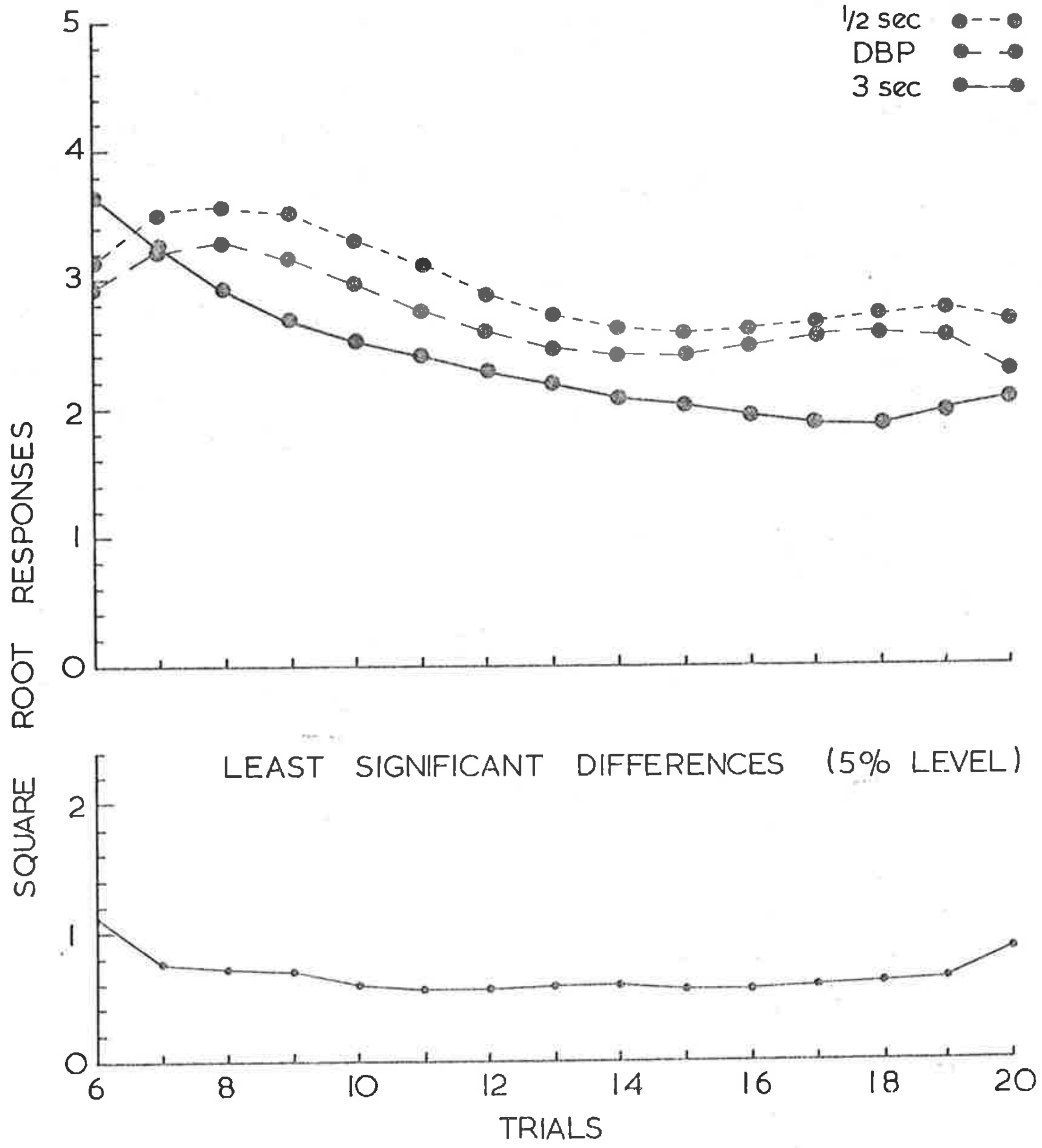


Fig.2. Responding in Phase II for light Increment as a function of the duration of change: Best fit curves and least significant differences.

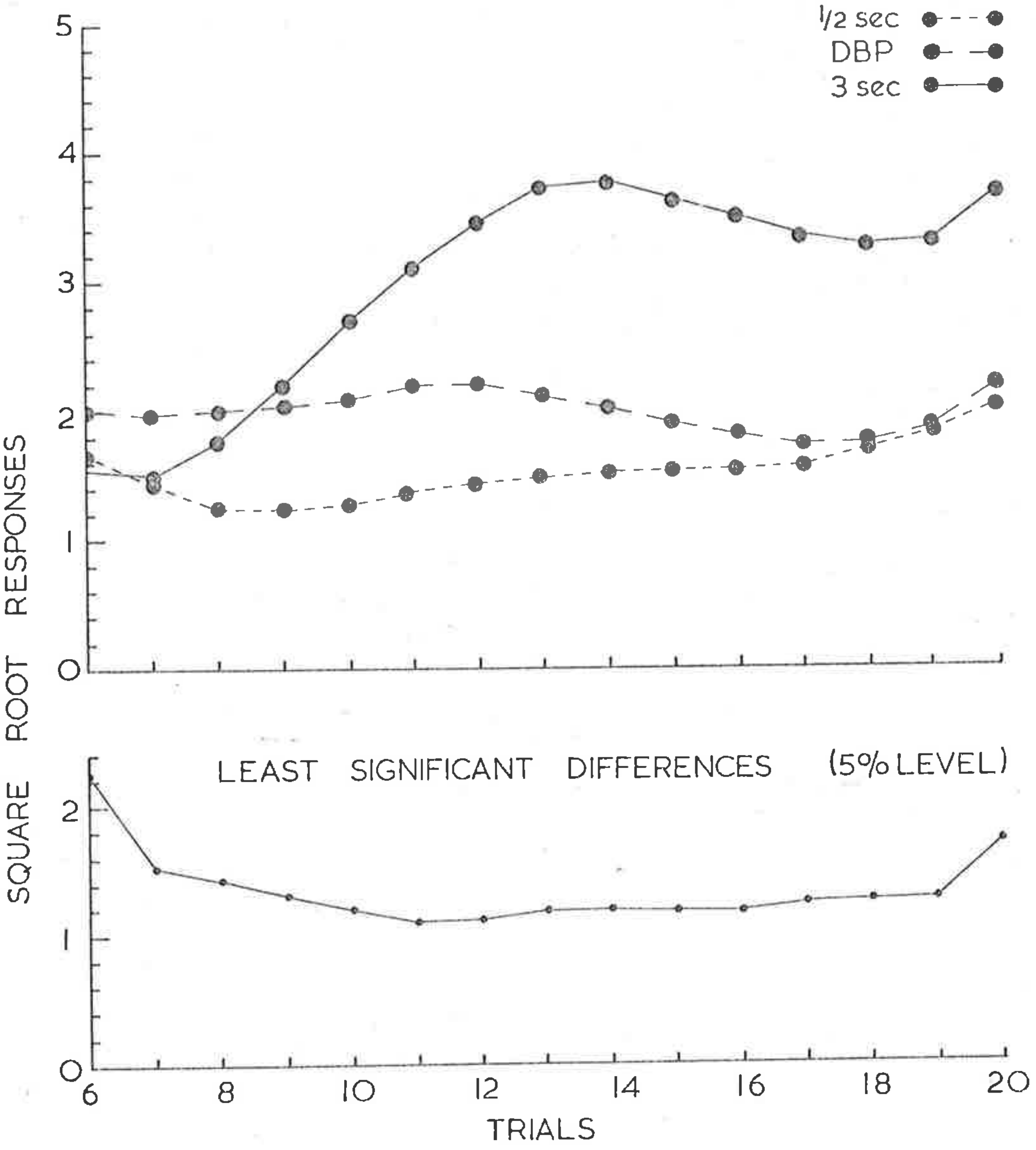
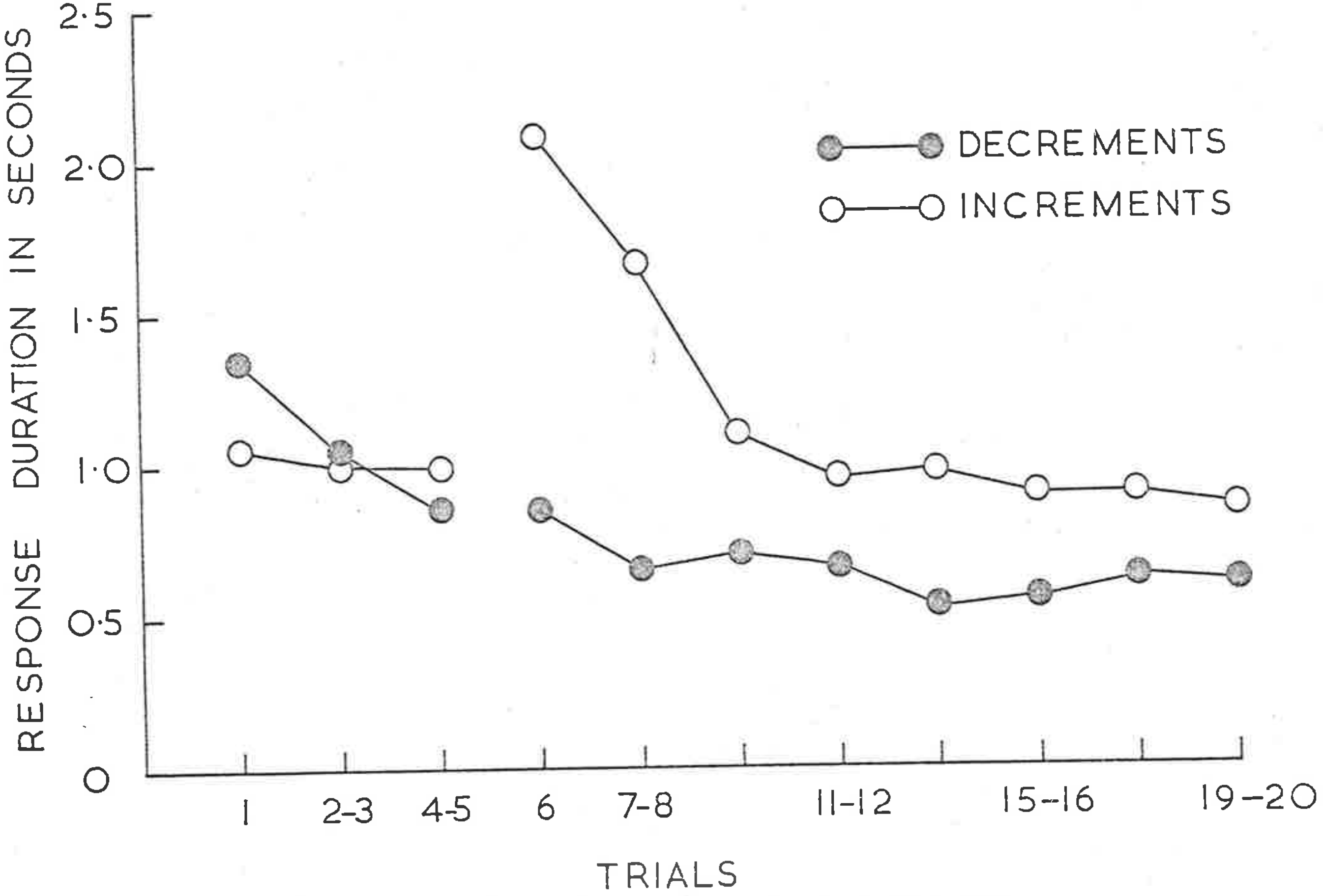


Fig.3. Responding in Phase II for 6.53 ft.c. Decrement as a function of the duration of change: Best fit curves and least significant differences.



<u>Fig.4.</u> Mean duration of bar press as a function of the direction of light change.

change for the DBP *Ss* lay between the ½ sec. and the 3 sec. groups throughout the experiment. Therefore, the duration effect for light Increments is one of shorter durations of change being more reinforcing, while it seems that the reverse holds for light Decrements. The duration and magnitude effects presented here did not interact ($F < 1$).

Trials The main effect of trials ($F = 2.23$, *df* 14,1008, $p < .01$), and the trials x magnitude ($F = 2.43$, *df* 42,1008, $p < .01$), the trials x direction ($F = 5.25$, *df* 14,1008, $p < .01$) and the trials x magnitude x direction ($F = 2.62$, *df* 42,1008, $p < .01$) interactions were significant. These results seem to arise from the minimal changes over trials in the Decrement treatments, the tendency for the 1.62 ft.c. Increment to decline rapidly over the initial trials, and the immediate increase and then decline in responding for the 6.53 ft.c. Increment. Further analysis of the trends over trials 6-12 using orthogonal polynomials revealed significant differences in the linear ($F = 2.37$, *df* 23,72, $p < .05$) and quadratic ($F = 1.79$, *df* 23,72, $p < .05$) components.

WITHIN TRIAL RESPONSE DISTRIBUTIONS

Responding declined rapidly throughout each trial in all treatments in both phases of the experiment. There were no noticeable differences in this trend between treatments and the distribution was relatively stable over trials. The overall percentage of responses in each quarter during the operant trials were 53, 24, 15, and 8 respectively (*F* = 139.40, *df* 3,285, $p < .01$) while in the LCBP phase they were 50, 24, 14 and 12 respectively (*F* = 170.60, *df* 3,285, $p < .01$). In general the analyses of variance of responding in the four quarters of the trial yielded the same results as the analysis of total responses. The major exceptions were in the trends over trials in the third and fourth quarters, where trends were less evident. For example the analysis of responses in the fourth quarter of the trial failed to produce any significant trends, in either the operant or LCBP phase. This seems to reflect the decline to a low response rate in the latter portions of the trial.

THE NUMBER OF REINFORCED RESPONSES

Animals receiving a fixed duration of change made a certain number of responses during the period of light change. The number of such nonreinforced responses was greater when the change occurred for 3 sec. than when it lasted for ½ sec., as would be expected. The proportion of total responses which were reinforced in these treatments, over the whole of phase II, were 87 and 96 respectively. These proportions were strikingly consistent from one magnitude of change to another and from trial to trial. The results of the analyses of variance of the number of reinforced responses during phase II precisely paralleled those for total responses, with the same relationships between treatment groups. This shows that when a fixed interval change, such as 3 sec., is used as the reward the total response measure provides a valid estimate of the reinforcing value of the light change.

INTER-RESPONSE TIME

Throughout phase II the inter-response time, to the nearest half second, was recorded in all treatments. To examine the nature of the distribution of inter-response times the following descriptive scores were calculated: mean (and SD), median, and mode, a measure of skewness and a measure of kurtosis. The main differences in the inter-response time distributions occurred between light Increment and light Decrement treatments (which seems to arise from the differences in the reinforcing value of Increments and Decrements), and over trials. To illustrate these effects a summary of the descriptive scores for light Increments and Decrements over the first and last five LCBP trials is presented in Table 2. These data show for light Increments that (1) the distribution is positively skewed and markedly leptokurtic, with a mode of either 1 sec. or ½ sec. - showing that animals tend to respond in "bursts", with one response followed immediately by another, and (2) from trials 6-10 to trials 16-20 the modal inter-response time remains about the same, but the distribution

TABLE 2: Summary of Descriptive Statistics for Inter-Response Time Distributions (with half-second units).

Trials	Mean	SD	Median	Mode	Skewness	Kurtosis
		LIGHT INCREMENTS				
6-10	50.0	103.0	11.0	2.0	3.8	34.7
16-20	104.0	162.0	21.0	1.0	2.3	5.7
		LIGHT DECREMENTS				
6-10	120.0	214.0	15.0	2.0	2.2	4.5
16-20	105.0	157.0	23.0	2.0	1.7	2.70

is much less positively skewed and leptokurtic - suggesting that animals still respond in bursts over trials 16-20, but that these are less prolonged with a greater incidence of "spasmodic responding" between bursts. In contrast, the data for light Decrements show that while these animals also tend to follow one response with another immediately after, this tendency is less pronounced - a result which is undoubtedly related to the comparatively low response rate in these treatments.

In general then, the inter-response time data indicate that not only does the response rate change from the initial LCBP trials to asymptotic performance, but the temporal characteristics of responding also changes.

MEAN DURATION OF BAR PRESS

The mean duration of bar press for each animal for trials 1-5, 6-12 and 13-20 were analysed as a 3 way factorial design. A repeated measures analysis was precluded by the fact that several animals failed to respond on every trial, this being most pronounced in the smaller Decrements as trials continued.

The analysis of the operant phase produced a significant interaction for the dummy magnitude and duration variables ($\underline{F} = 4.64$, $\underline{df}$ 3,72, $\underline{p} < .01$). This result is clearly due to individual differences as this phase involved operant testing for all animals. A correlation (Pearson r) of 0.56 ($\underline{p} < .01$) between mean duration of bar press over trials 1-5 and trials 6-20 for the light Increment animals suggests that these individual differences contaminate the results for the LCBP phase. Therefore, covariance analyses were run on the data for trials 6-12 and trials 13-20 with the duration for trials 1-5 as the covariate. The mean duration of bar press was longer in the light Increment treatments than the Decrement treatments over trials 6-12 ($\underline{F} = 5.48$, $\underline{df}$ 1,72, $\underline{p} < .02$) and trials 13-20 ($\underline{F} = 7.49$, $\underline{df}$ 1,72, $\underline{p} < .01$). No other effects were significant. These results indicate that except for the difference between Increments and Decrements, the duration of bar press is not related to the reinforcing value of a light change and that the duration of response does not differ according to whether the light change occurs for the duration of the response or for a fixed interval. A feature of the data not apparent from these results is the lengthening of response duration at the commencement of the LCBP phase by the light Increment animals. The rise from trials 1-5 to 6-12 ($t = 3.93$, $\underline{p} < .001$) and the fall from trials 6-12 to 13-20 ($t = 7.17$, $\underline{p} < .001$) for these animals was significant. This trend is illustrated in fig.4. Inspection of the duration of bar press data for the 6.53 ft.c. by 3 sec. Decrement animals revealed that the increase in reinforcing value of this light change across trials was not associated with any shift in the response duration. Therefore fig.4 seems to be illustrating a phenomenon restricted to novel events.

DISCUSSION

In general, these results support the predictions from Stimulus-Change theory that light changes in both directions will be reinforcing and that, within a range, larger magnitudes of change will be more reinforcing. It is reasonable then to claim that the light changes used here functioned as change *per se*. Given this, the present results have important implications for a Stimulus-Change theory of LCBP. The nature of a light change as a change *per se* seems to be determined not only by the magnitude of change, the parameter which has been typically emphasised, but also by the direction of change and the duration of change. The importance of the direction and duration is aptly illustrated by the results from the 6.53 ft.c. Increment and Decrement treatments. These changes have the same initial and consequent light intensities and therefore are of the same "magnitude", but they occur in different directions. Here the relative reinforcing value of an Increment and a Decrement shifted from the Increment being much more reinforcing than the Decrement when the change lasted for ½ sec., to the reverse when the change lasted for 3 sec. This might be interpreted as due to shorter durations of light Increment being of greater apparent brightness, with the reverse holding for Decrements. Consistent with this view is the finding with humans (Stevens, 1966; Katz, 1964) that shorter light flashes, up to 1.0 sec., are of greater apparent brightness. According to the interpretation placed on the present data, if light changes in different directions are not found to be equally reinforcing this does not mean, ipso facto, that factors other than change _per se_ are involved.

Several more specific comments on the present response rate results need to be made. Firstly, the failure of the three smallest light Decrements to be reinforcing seems to be due to their not being of sufficient incentive magnitude. The fact that the same changes were reinforcing when they occurred as Increments from 0.032 ft.c. appears consistent with the principles underlying Weber's law.

Secondly, the duration effect obtained for the 6.53 ft.c. light Decrement is in agreement with the argument of section 1.53 that the failure of several researchers to find a reinforcing effect for light Offset when the change lasted for the DBP may be a function of the duration of change. However, as the latter is not an invariant finding (Leaton, Symmes & Barry, 1963) and light Decrements (in contrast to Offset) which last for the duration of the bar press are frequently found reinforcing (McCall, 1965, 1966; Lockard, 1966) additional evidence on the duration parameter is required before definite conclusions can be drawn about when a light decrease which lasts for the DBP will be reinforcing and when it will not be reinforcing. Nevertheless, the present results suggest that a 3 sec. light decrease will be more reinforcing than a shorter duration of change.

Thirdly, the response rate trends within and across trials obtained here also appear consistent with a stimulus change interpretation. For a novel light change there was an inverted U relationship between the magnitude of change and reinforcing value. As animals habituated to the largest change (in both directions) over the initial trials its reinforcing value increased. With this increase the inverted U relationship between the magnitude of change and reinforcing value became a general positive one. Alternatively, these data could be interpreted, in terms of the proposal by Dember & Earl (1957) as reflecting an upward shift in the "psychological complexity" of the organism brought about by experiencing light change. In many ways these data are consistent with findings of preferences for more complex stimuli following experience in humans (Munsinger & Kessen, 1964) and animals (Thomas, 1969a,b). For the smaller magnitudes of change there appeared to be a simple relationship between the decline of novelty and reinforcing value. Novelty here probably involves two factors: the novelty of the response-contingent change, and the novelty of responding for a sensory change. But, responding stabilized at a level which indicates that even after novelty has habituated a response-contingent light change can still be reinforcing. That the relationships between the independent variables and responding were largely maintained throughout each trial and were still evident at the asymptote across trials shows further than the properties of a response-contingent light change as a reinforcer are not transitory.

No precise evaluation of the contribution of visual scanning of the environment (see section 1.40) to the obtained reinforcing effects can be made, but it does seem that if scanning were important the longer periods of light Increment should be the most reinforcing. Since the reverse occurred it appears that visual scanning was not a major factor in the determination of the reinforcing value of response-contingent light change in the present experiment.

Finally, the response rate data reported here seems to be consistent with other research on hooded rats, where it has been found that changes in both directions are reinforcing and remain so with prolonged testing (Glow, 1970; Sackett, 1965; Robinson, 1961), that after a number of trials a 3 sec. light Offset change is more reinforcing than a comparable Onset change (Glow, 1970), and that the magnitude of light Onset is positively related to reinforcing value, albeit only when fixed ratio schedules of reinforcement were used (Stewart, 1960). Further, the present results add weight to the distinction between albino and hooded rats with respect to the role of light intensity preferences made in section 1.5. It was noted there that studies of the effects of the magnitude of light increase using albinos have frequently found a break down of the positive relationship with higher consequent intensities, with this being more pronounced as trials continue (see McCall, 1966; Lockard, 1966). In contrast to these findings with albinos, in the present experiment all magnitudes of light Increment were reinforcing throughout the whole experiment and the positive relationship between magnitude of change and reinforcing value persisted. This suggests that whereas the reinforcing effect to albinos of light increases is modified by preferences for dim illuminations, no such preferences are operative with hooded rats.

The inter-response time data reported here gives a quantitative foundation to the subjective impressions of a number of researchers that animals tend to respond in bursts. Further, inspection of these data for the first LCBP trial confirms the proposition (section 1.60) that learning in LCBP is of the "one trial" variety. That is, the first reinforced response was typically followed with a burst of responding, thus showing the contingency had been learned.

The present results for the mean duration of bar press are largely in accord with other experiments in which shifts in the mean duration of bar press in LCBP have been found (Robinson, 1961; Hurwitz, 1956; McCall, 1966; Barnes & Baron, 1961b; McCall, Weiffenbach & Tucker, 1967). They may also shed some light on the fact that the mean duration of bar press is usually found to be a poor index of the reinforcing value of light change (e.g. McCall, 1965, 1966; Roberts, 1962; Glow, Russell & Kirby, in press). The data on different durations of change (DBP, ½ sec., 3 sec.) obtained here suggests that an increase in the mean duration of bar press at the commencement of LCBP is a general effect. It occurs whether or not the animal has direct control over the duration of change. This indicates that, in the main, the lengthening of the response duration was not due to an attempt to prolong the consequent light intensity. An increase in response duration therefore appears to be associated with any novel and reinforcing response contingent light change. As novelty habituates the response duration then declines.

This experiment demonstrates that light change reinforcement can be subjected to the same kinds of parametric analyses which have been applied to the organically based reinforcers. It therefore provides a basis for more detailed considerations of the nature of sensory change as a reinforcer and its relationship to other types of reward.

3.30. EXPERIMENT 2: Some Additional Evidence on the Significance of the Duration of Change Parameter in LCBP

INTRODUCTION

In Experiment 1, shorter durations of light Increment were found to be the most reinforcing, at least within the range of from ½ sec. to 3 sec. On the other hand, whereas a 3 sec. light Decrement was reinforcing, there was some evidence that a ½ sec. or DBP Decrement was not reinforcing. The present experiment was designed to investigate a wider range of durations and to examine the robustness of the relationships observed in Experiment 1. The study involved shifting the duration of change to either duration of the bar press (DBP), ½ sec., 1½ sec., or 6 sec. after first establishing responding for a 3 sec. change. It was considered that by first establishing responding for a reinforcing light decrease before shifting to a DBP or ½ sec. change the experiment may provide a clearer indication of the reinforcing value of the latter durations of light decrease. Further, in the case of light increases, if the effects observed in Experiment 1 are due to the greater apparent brightness of shorter durations, as suggested, it would be expected that shorter durations would again be more reinforcing under the conditions of the present experiment.

METHOD

Subjects The Ss were 120 female Wistar hooded rats, approximately 130 days of age at the start of the experiment. Other conditions were the same as in Experiment 1.

Apparatus The apparatus was the same as used in Experiment 1, except that an additional Skinner box was included, making a total of five. The light changes used were: light Onset, a change from darkness to 6.65 ft.c., and light Offset, a change from 6.65 ft.c. to darkness. The control apparatus was programmed so that light change could occur for either the DBP, ½ sec., 1½ sec., 3 sec., or 6 sec., as required. A response made during a period of light change for the fixed durations of change was recorded but did not affect the change.

PROCEDURE

The basic conditions of the experiment were the same as in Experiment 1, that is, the trial duration was 20 min. and the intertrial interval was 48 hrs. Animals in the Onset and Offset treatments were run on alternate days and Ss were run between approximately 9 a.m. and 2 p.m. each day. The frequency of bar pressing in each quarter of the trial, the mean duration of bar press over the whole trial and the number of reinforced responses in those groups receiving a fixed duration of light change were recorded throughout the experiment. The study was conducted in two phases.

Phase I

This experiment was run with the same animals used in Experiment 7. Therefore, phase I of this experiment is in fact phase II of Experiment 7. Half the animals received a response-contingent 3 sec. light Onset light change and half received a response-contingent 3 sec. light Offset change. Trials were continued until a performance asymptote was established. 16 trials were run.

Phase II

Animals in the Onset and Offset treatments were ranked according to their response rate over the last five trials of phase I and divided into 5 matched groups of 12 animals. Each group received one of the 5 durations of response-contingent light change (DBP, ½ sec., 1½ sec., 3 sec., and 6 sec.). Nine trials were run in this phase.

RESULTS

TOTAL RESPONSES

The main analyses were performed on total responses on each trial using the repeated measures procedure (Winer, 1970). The factors analysed were direction of change and duration of change. A summary of the total response data is presented in Table 3.

Phase I

As the animals were matched there were no differences between the treatment groups over the last five trials of phase I. Further, there were no trends over trials, indicating that responding had reached an asymptote. The matching data are presented in Table 3. The only difference in this phase was between light Onset and light Offset. More responding occurred for light Onset ($F = 26.20$, df 1,110, $p < .01$).

Phase II

The analysis of all nine trials showed no effect for the duration of change and no interaction between direction and duration. However, as is evident from Table 3, more

TABLE 3: Summary of Actual Mean Number of Responses per 20 min. Trial in Phases I and II.

DURATION OF LIGHT CHANGE	LIGHT ONSET			LIGHT OFFSET		
	PHASE I	PHASE II		PHASE I	PHASE II	
	Last 5 Trials	Trials 1-4	Trials 5-9	Last 5 Trials	Trials 1-4	Trials 5-9
DBP	26.2	28.8	16.0	13.9	14.0	9.0
½ sec.	24.3	21.2	17.5	15.0	11.3	9.0
1½ sec.	24.7	23.4	17.2	14.7	13.0	12.1
3 sec.	25.4	26.7	25.4	15.8	15.8	15.7
6 sec.	27.0	22.1	21.1	14.7	13.5	11.9

responses were made for light Onset than Offset ($F = 35.03$, *df* 1,110, $p < .01$). In addition, trends over trials were significant ($F = 8.83$, *df* 8,880, $p < .01$) and they interacted with the duration of change ($F = 2.67$, *df* 32,880, $p < .01$). Further analysis of these trends showed the treatments differed in linear trends ($F = 3.02$, *df* 9,110, $p < .01$). Separate analyses of the first four and last five trials of phase II showed that while the duration of change had no effect over the first four trials ($F < 1$), there were differences between the durations over the last five trials ($F = 3.81$, *df* 4,110, $p < .01$). The latter did not interact with the direction of change ($F < 1$). Finally, whereas the main effect of trials ($F = 4.19$, *df* 3,330, $p < .01$) and the trials x duration interaction ($F = 2.84$, *df* 12, 330, $p < .01$) were reliable over the first four trials, there were no trends over the last five trials.

A more detailed assessment of these results can be made from fig.5 where the best fit curves and least significant differences are presented. The data in this figure show that whereas responding for the 3 sec. change remained constant, there was a general tendency for responding for the other durations of change to decline slowly throughout the experiment. So that by about the 5th trial the 3 sec. change was the most reinforcing in

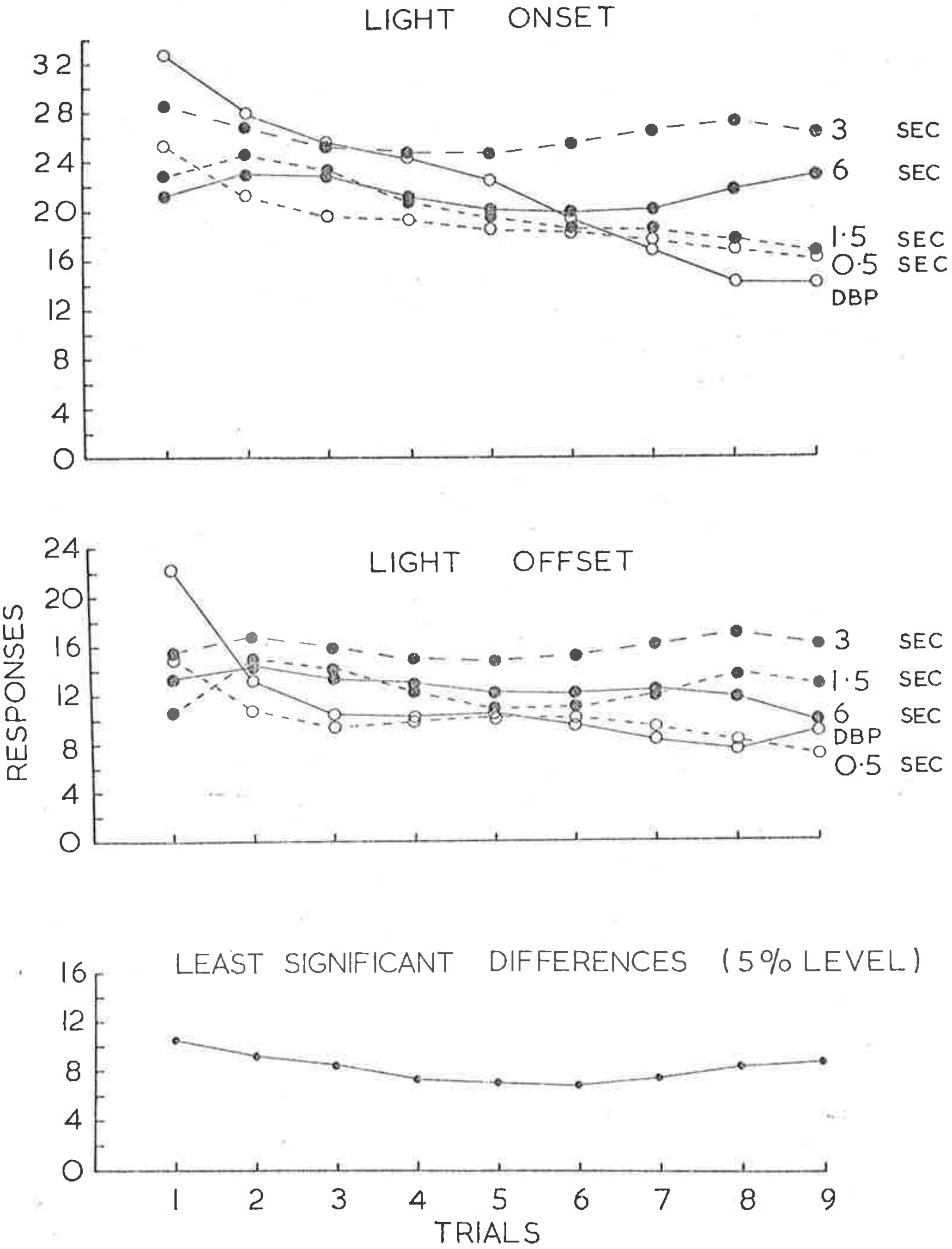


Fig.5. Responding in Phase II for light Onset and Offset as a function of the duration of light change: Best fit curves and least significant differences.

both directions. Over the terminal 2 or 3 trials it can be seen that the DBP and ½ sec. changes in both directions were the least reinforcing, and significantly below the 3 sec. change in each case.

WITHIN TRIAL RESPONSE DISTRIBUTION

A within trial decline in response rate occurred in all treatments throughout the experiment. There were no marked differences in this trend either between treatment groups or over trials. The overall percentage of responses in each quarter of the trial was 45, 28, 15 and 12 respectively ($F = 94.38$, $df\ 3,357$, $p < .01$). The separate analyses of variance of responding in each quarter of the trial throughout the experiment showed that the difference between light Onset and Offset persisted throughout the trial and that trends over trials were confined mainly to the first and second quarters (with no trends in the last quarter). In contrast to the analysis of total responses (see above) the analyses of the first and second quarters yielded a significant duration effect when all nine trials were analysed. This suggests that because most responding occurs in the early portions of the trial, analyses of these portions may in some cases provide a more sensitive test of treatment effects than an analysis of total responses.

THE NUMBER OF REINFORCED RESPONSES

As in Experiment 1 animals receiving a fixed duration of change made a certain number of responses during the light change. More nonreinforced responses were made the longer the duration of change, but the proportion of total responses which were reinforced was strikingly constant throughout the experiment for each duration of change. The respective overall proportions for the ½ sec., 1½ sec., 3 sec., and 6 sec. changes were 97.0, 90.0, 81.0, and 80.0. The analyses of variance of the number of reinforced responses paralleled those for the total responses, with the relationships between the durations of change essentially the same. Animals in the 3 sec. groups received the most reinforcements and animals in the DBP and ½ sec. groups the fewest reinforcements. This shows that the data presented in fig.5 and Table 3 are reliable estimates of the reinforcing value of the respective light changes.

MEAN DURATION OF BAR PRESS

As all animals in all treatments responded throughout phase II the mean duration of bar press scores were able to be analysed by the repeated measures procedure. The analysis of all nine trials yielded significant effects for the duration of change ($\underline{F} = 4.59$, $\underline{df}$ 4,110, $\underline{p} < .01$) and the trials x direction interaction (F = 1.94, df 8,880, $p < .05$). An examination of the data revealed that the DBP and ½ sec. groups had longer response durations than the other groups. The mean duration of bar press in the five duration groups over the whole of phase II were 0.48, 0.48, 0.53, 0.68, and 0.71 sec. for the 3 sec., 6 sec., 1½ sec., ½ sec., and DBP changes respectively. Inspection of the data pertaining to the trials x direction interaction revealed that this reflects differences in trial to trial variations rather than systematic trends over trials (see Table 4).

DISCUSSION

Insofar as altering the parameter of the duration of change affected the reinforcing value of a response-contingent light change in the present experiment, these results support the finding of Experiment 1 that the duration of change is related to the reward value of light change.

The present experiment was concerned with the effect of shifting the duration of light change following the establishment of responding for a 3 sec. light change. Consequently, the present discussion is concerned only with this aspect of the data and not, therefore, with the overall difference between light Onset and Offset.

TABLE 4: Mean Duration of Bar Press Over Trials in Phase II for all Light Onset and Offset Treatments (in seconds).

TRIALS IN PHASE II	LIGHT ONSET	LIGHT OFFSET
1	.54	.56
2	.56	.52
3	.57	.71
4	.54	.58
5	.66	.55
6	.56	.60
7	.56	.60
8	.55	.54
9	.57	.53

Clearly, the results obtained here are not wholly in agreement with the data from Experiment 1. For example, whereas a ½ sec. light Increment was found to be more reinforcing than a 3 sec. Increment in the latter study, the reverse occurred in the present experiment. It is unlikely that this discrepancy can be accounted for by the use of light Increments and Decrements in Experiment 1 and light Onset and Offset here. The Onset and Offset changes differ little from the largest Incremental and Decremental changes from Experiment 1, where the initial intensity for the Increment and the consequent intensity for the Decrement was only 0.032 ft.c., a value marginally different from darkness.

Despite the rather puzzling results of the present experiment the data from both Experiments 1 and 2 might be partly reconciled if the duration of change is construed to affect LCBP in the following way. Firstly, for light Offset or Decrement shorter durations of change, at least within the range of from ½ sec. to 3 sec., are less reinforcing than longer changes. The present results are open to interpretations other than this, but the claim is not inconsistent with the findings. Further, because responding for the DBP and ½ sec. Offset changes did not decline rapidly to about an operant level it seems that it is not the case that these changes are not reinforcing at all. It is more likely that they may have some reward value, but are not rewarding to the same extent as a 3 sec. change.

Secondly, shorter durations of light Onset or Increment are more reinforcing to animals naive to LCBP, again at least within the range of from ½ sec. to 3 sec. However, for animals not naive to LCBP the relative reinforcing value of various durations of light Onset or Increment will depend on the nature of the prior LCBP experience of the animals. By reinterpreting the light Increment results of Experiment 1 an explanation of the results of both Experiments 1 and 2 emerges.

It was suggested in discussing Experiment 1 that shorter durations of light Increment may be more reinforcing because they are of greater apparent brightness. But it is possible that that effect arose for another reason. The shorter the duration of change the quicker the light returns to the initial level, thereby providing an opportunity to initiate another light change. Therefore, because the response duration is usually more than ½ sec., when a change lasts for either the DBP or ½ sec. the animal is in a position to produce another change immediately after completing a response. The fact that animals tend to respond in bursts suggests that this is what happens. In contrast, when a change lasts for 3 sec. there is an enforced delay following one response before another reinforced response can be made. Since about 80% of the responses of animals bar pressing for a 3 sec. change are reinforced it seems that in the main this is the pattern of responding exhibited by Ss responding for these changes. It was noted in Experiment 1 that the modal inter-response time of animals in the 3 sec. treatments did not differ from those in the ½ sec. and DBP treatments and was 1 sec. or less. The nonreinforced responses in the 3 sec. treatments undoubtedly accounts for this result. According to the present argument, different behaviour patterns will develop for different durations of change. It is further assumed that over many LCBP trials the particular pattern of responding for the 3 sec. change, for example, will become fairly well established. If then, a shorter period of light change is made response-contingent it appears that for the latter change to raise response rate the existing pattern of responding would have to be broken and another one established. It seems that the 1½ sec., ½ sec., and DBP light Onset changes here could not do this. But why should they be less reinforcing than the 3 sec. change?

There is no readily available answer to this question. Little more can be said than that once animals adapt to a certain duration of change a different duration, and especially a shorter one, may be less reinforcing. Further explication of this possibility must await additional research.

The differential effect of the duration of light change on the mean duration of bar press obtained here was not striking. It seems to show that because there is not a great deal of variability in the duration of bar press from animal to animal statistically significant differences may occur when the effects are not terribly profound. Nevertheless the duration of bar press results further illustrate the effects of shifting the duration of change by showing that not only does this affect the response rate, but it may also affect the duration of the response. The significance of the latter for a theoretical analysis of LCBP behaviour is not immediately apparent.

3.40. Conclusions

The research reported here supports an interpretation of the light change in the LCBP or hooded rats as a change *per se*. The present data also go a long way in explicating the apparent discrepancies in the reported research with respect to the relative reinforcing value of light changes in different directions. Experiment 1 showed that the relative reinforcing value of changes in opposite directions differs according to the duration of change. For this reason it was argued that the duration of change as well as the magnitude of change is an important factor in the determination of the reinforcing value of response-contingent light change.

In addition, it was shown that short durations (½ sec. and DBP) of light Offset or Decrement are much less reinforcing than a 3 sec. change. This might explain the failure of several researchers to obtain a reinforcing effect when using a DBP light Offset change. The results of Experiment 1 also indicate the importance to the estimation of the reinforcing value of a given light change of running sufficient LCBP trials to allow responding to stabilize.

In view of the present results, many of the reported findings of light Onset being more reinforcing than light Offset, or light Offset not being reinforcing at all, cannot necessarily be taken as opposing a Stimulus-Change theory. It seems that Stimulus-Change theory should take into account parameters of the light change other than its magnitude, and especially the duration and direction of change.

Experiment 2 confirmed that the duration of change can modify the reward value of a given magnitude of change.

The results of this experiment were somewhat unexpected. They seem to indicate that prolonged experience of bar pressing for one duration of change involves a complex adaptation to the particular duration, so that if the duration is then altered the new duration is less reinforcing.

Finally, Experiment 1 was successful in revealing the parameters of light changes in both directions which have long term reinforcing effects. On the basis of this experiment the light changes selected for the subsequent research on the nature of the presumed motivational state underlying the reinforcing effect of a response-contingent change *per se* were 3 sec. light Onset and Offset changes, with a consequent and initial intensity respectively of 6.65 ft.c. This research is presented in section 4.

4. THE "MOTIVATIONAL STATE" UNDERLYING LIGHT-CONTINGENT BAR PRESSING.

4.10. Introduction

The results obtained in Experiment 1 and the reported data from LCBP studies using hooded rats reviewed in section 1.50 support the proposition that in LCBP the light change functions mainly as a change *per se*. The research reported in this section was directed towards the question: what is the nature of the "motivational state" which mediates the reinforcing effect of a response-contingent change *per se*? Special attention was given to the possibility that LCBP might be amenable to a Drive theory explanation. Within this context, several authors have stated or implied that stimulus change reinforcement arises from a need or Drive for stimulation (see section 1.70). This notion appears to have attained a position of prominence as a means of "explaining" curiosity-exploratory behaviour. The initial aim of the research to be reported here was to test directly the hypothesis that a need or Drive for stimulation underlies light change reinforcement.

4.20. EXPERIMENT 3: The Nature of Satiation in LCBP: Does a "Drive for Stimulus Change" underlie LCBP?

In Experiments 1 and 2, within each LCBP trial more responses were made at the start than at the end of the trial. This intratrial trend is characteristic of LCBP and indicates that 'satiation' of some kind occurs as a result of responding for light change. However, little can be said about the nature of the 'satiation' from these data. Since the reinforcing stimulus is constant throughout the trial it could be that a specific satiation to that stimulus mediates the response rate decline. On the other hand, the satiation may be nonspecific, i.e. a general satiation to stimulus change. Finally, the response rate decline could be due to response satiation or reactive inhibition rather than a form of stimulus satiation. A detailed examination of the satiation processes mediating the within trial decline of LCBP so clearly evident in Experiments 1 and 2 was undertaken here, with the experiment designed to separate these three possible types of satiation.

The determination of whether responding for light change reinforcement can result in a nonspecific satiation for stimulus change is of considerable theoretical significance. Nonspecific satiation follows directly from a Drive for stimulus change explanation of LCBP (see section

1.70). According to this view, responding for one light change should reduce the Drive for stimulus change, and therefore, the reinforcing value of not only that light change, but other light changes as well. To test this hypothesis the LCBP trial was divided into two equal periods and two light changes (Onset and Offset) were used as reinforcers. Either the same light change was used as the reinforcer in both halves or a different change was the reinforcer in the first and second half of the trial. If stimulus satiation is nonspecific the reinforcing value of light change should decline from the first to the second half of the trial in all cases.

To evaluate the possible contribution to within trial response rate trends in LCBP of response satiation, Ss were allowed to respond throughout the whole trial or only in the second half of the trial. If response satiation is an important factor in LCBP Ss which respond in the first half of the trial should respond less in the second half than Ss which respond only in the second half.

In summary then, the present experiment was designed to determine (1) whether satiation for "stimulus change in general" underlies the within trial decline of responding obtained in Experiments 1 and 2, and thus, the validity of a Drive-for-stimulus-change-explanation of LCBP, and (2) to what extent reactive inhibition affects LCBP.

METHOD

Subjects The subjects were 80 female Wistar hooded rats, approximately 160 days of age at the start of the experiment. Other conditions were the same as for Experiment 1.

Apparatus The apparatus was the same as used in Experiment 2. The light changes were light Onset, a change from darkness to 6.65 ft.c., and light Offset a change from 6.65 ft.c. to darkness. All changes lasted for a fixed duration of 3 sec. A response during the period of change was recorded, but did not affect the change.

PROCEDURE

Design The experiment was designed as a complete 2 x 2 x 2 factorial study with repeated measures over trials. A summary of the design is set out in Table 5. Each trial lasted for a total of 20 min. This was divided into two 10 min. periods, the first, the "exposure" period, the second, the "test" period. During the exposure period half the Ss bar pressed for light change and half received light changes independent of their behaviour. These two conditions are designated response-contingent prior exposure (R-C) and nonresponse-contingent prior exposure (N-C) respectively (factor 1, the method of prior exposure - N-C or R-C). In the case of the N-C treatment the lever

TABLE 5

SUMMARY OF EXPERIMENTAL TREATMENT CONDITIONS FOR EXPERIMENT 3.

EXPOSURE PERIOD	TEST PERIOD
R-C LIGHT ONSET	ONSET
	OFFSET
N-C LIGHT ONSET	ONSET
	OFFSET
R-C LIGHT OFFSET	OFFSET
	ONSET
N-C LIGHT OFFSET	OFFSET
	ONSET

was covered with an aluminium panel which prevented responding and the Ss were yoked to the R-C Ss for light change, each N-C S yoked to the same R-C animal throughout the experiment. Therefore, in the exposure period each time an R-C S produced a light change by responding, its N-C partner also received the light change. Half the Ss in each of the method of exposure conditions was "exposed" to light Onset, and half to light Offset (factor 2, the type of exposure light change).

At the commencement of the test period the panel covering the lever in the N-C treatments was removed and all Ss responded for either light Onset or Offset (factor 3, the type of test light change).

The intertrial interval was 48 hrs., with half the Ss run on any one day. The experiment was conducted between approximately 9 a.m. and 2 p.m. each day. The dependent variables were: the frequency of bar pressing in each quarter of both the exposure period (for R-C treatments) and the test period, the mean duration of bar press in the exposure period and in the test period, and the number of reinforced responses in the exposure period and in the test period. The experiment was conducted in two phases.

Phase I (Operant)

The animals were randomly assigned to one of the eight treatment groups. During this phase the animals were not exposed to any light changes and did not respond for light change. Throughout the 10 min. exposure period the lever was covered with an aluminium panel in all cases and therefore unoperative. At the completion of the exposure period the cover was removed from the lever, but a bar press did not produce a light change. The cover was removed manually by E by opening the Skinner box. The light conditions (i.e. 6.65 ft.c. or darkness) in the test and exposure periods were the same as those scheduled for the LCBP phase of the study. For example, Ss assigned to treatments receiving prior exposure to Onset and test with Onset were in darkness throughout the 20 min. trial and Ss assigned to treatments receiving prior exposure to Onset and test with Offset were in darkness for the first 10 min. and in 6.65 ft.c. for the second 10 min. The phase lasted for 5 trials.

Phase II (LCBP)

Commencing with the 6th trial animals received prior exposure to light Onset or Offset changes by one of the two methods (R-C or N-C) in the first 10 min. of the trial, and responded for either Onset or Offset in the second 10 min., according to treatment allocation in the design. To control for possible effects of opening the Skinner box and removing the cover over the lever after 10 min. in the N-C treatments, the Skinner box was opened at the end of the exposure period and the cover placed over the lever and immediately removed again in the R-C treatments. Trials were continued until a performance asymptote was established, as determined by inspection of the data and tests for trends.

RESULTS

Several animals were removed from the experiment because they failed to satisfy the essential condition of the experiment, namely the condition of prior exposure to light change before responding for light change. The prior exposure of the N-C animals was dependent upon the R-C animal to which it was yoked. Over the initial trials of phase II a number of R-C animals did not respond and therefore their yoked partners did not receive light change prior exposure. Consequently, if a N-C S commenced responding in the test period before its R-C partner started responding during the exposure period, both Ss were removed from the experiment. Of the four treatment combinations of type of exposure - type of test light change, three pairs of animals from three of the treatment combinations had to be removed for this reason. Two pairs had to be removed from the fourth treatment combination. To facilitate analysis a third pair of animals was removed (randomly selected) from the latter. This left seven animals in each of the 8 treatments. The data analysed were for these 56 animals.

The main analyses were performed on total responses in the exposure and test periods using repeated measures procedures. To match the assumptions of the repeated measures analysis of variance (Winer, 1970), all the response data were subjected to a square root transformation.

TOTAL RESPONSES

Phase I (Operant)

The analysis of total responses in the 10 min. test period over all trials in phase I yielded a significant effect for the dummy type of exposure x type of test light change interaction ($\underline{F} = 13.22$, $\underline{df}$ 1,48, $\underline{p} < .01$). This indicates that when the ambient light condition was constant throughout the trial fewer operant responses were made than when the ambient light condition changed from light to darkness, or vice versa, after 10 min. Close inspection of the data revealed that the mean response rate in all treatments was about 1 response per trial (see Table 6). This low rate arose because on any one trial a large proportion of animals did not respond. The significant effect obtained reflects the fact that a larger proportion of animals responded if the ambient light condition changed after 10 min. of the trial. The analysis also showed that the operant rate declined over the five trials ($\underline{F} = 3.12$, $\underline{df}$ 4,192, $\underline{p} < .05$).

TABLE 6: Summary of Mean Number of Responses in Phases I and II for all Treatments.

			PHASE I		PHASE II					
			TRIALS 1-5		TRIALS 6-10		TRIALS 11-15		TRIALS 16-20	
METHOD OF EXPOSURE	TYPE OF EXPOSURE	TYPE OF TEST	EXPOSURE PERIOD	TEST PERIOD	EXPOSURE PERIOD	TEST PERIOD	EXPOSURE PERIOD	TEST PERIOD	EXPOSURE PERIOD	TEST PERIOD
R-C	ONSET	ONSET		0.5	9.0	2.8	15.0	5.9	13.6	3.9
N-C	ONSET	ONSET		1.2		3.3		3.2		3.2
R-C	OFFSET	OFFSET		0.6	12.8	4.4	12.7	3.2	14.3	3.6
N-C	OFFSET	OFFSET		1.0		1.1		4.0		4.2
MEAN				0.8	10.9*	2.9**	13.8*	4.1**	13.9*	3.7**
R-C	ONSET	OFFSET		1.5	17.8	6.2	14.8	10.8	12.6	13.4
N-C	ONSET	OFFSET		1.8		6.9		6.2		17.0
R-C	OFFSET	ONSET		2.1	14.6	7.0	13.2	6.5	14.8	9.1
N-C	OFFSET	ONSET		2.3		7.6		7.9		9.7
MEAN				1.9	16.2*	6.9**	14.0*	7.8**	13.7	12.3

Exposure versus test period; Comparisons*-** p < .001 in all cases (2 tailed t test).

Phase II (LCBP)

Responding in the exposure period and in the test period were first analysed separately. An analysis was then made of the difference between responding in the exposure and test periods to determine whether the reinforcing value of light change declined from the exposure to the test period.

The exposure period A summary of the response data from the exposure period for all treatments is presented in Table 6. The analysis of variance showed that there were no significant differences between treatments or trends over trials. This indicates that light Onset and Offset were equally reinforcing and that the amount of prior exposure to light change (i.e. the frequency of light change in the exposure period) did not differ from treatment to treatment, or over trials.

The test period The analysis of responding in the test period over all trials in phase II showed that there were no differences according to either the method of exposure ($F < 1$), the type of exposure light change ($F < 1$), or the type of test light change ($F < 1$). This indicates (1) that the effects of prior exposure to light change were the same for R-C and N-C exposure, a result which suggests that reactive inhibition did not affect responding, (2) light Onset and Offset did not differ in reinforcing value, and

(3) there were no differential effects according to whether the prior exposure was to light Onset or Offset.

The only treatment effect to emerge was an interaction between the type of exposure light change and the type of test light change ($F = 11.41$, *df* 1,48, $p < .01$), demonstrating that more responses were made if the test light change was different to the exposure light change (see fig. 6, Table 6).

In general, the response rate increased over trials ($F = 6.29$, *df* 14,672, $p < .01$). However, trends over trials differed according to the method and type of exposure ($F = 2.18$, *df* 14,672, $p < .05$) and the type of exposure and type of test light change ($F = 2.11$, *df* 14,672, $p < .05$). More detailed analyses of the differences in trends using orthogonal polynomials revealed that the treatments differed in terms of both linear ($F = 2.36$, *df* 7,48, $p < .01$) and quadratic trends ($F = 2.40$, *df* 7,48, $p < .01$) over trials.

To further analyse the differences between treatments and the nature of the response rate trends over trials the best fit regression equations up to the 5th order orthogonal coefficients were calculated, together with the least significant difference on each trial. A summary of these data is presented in fig.6 where it can be seen that

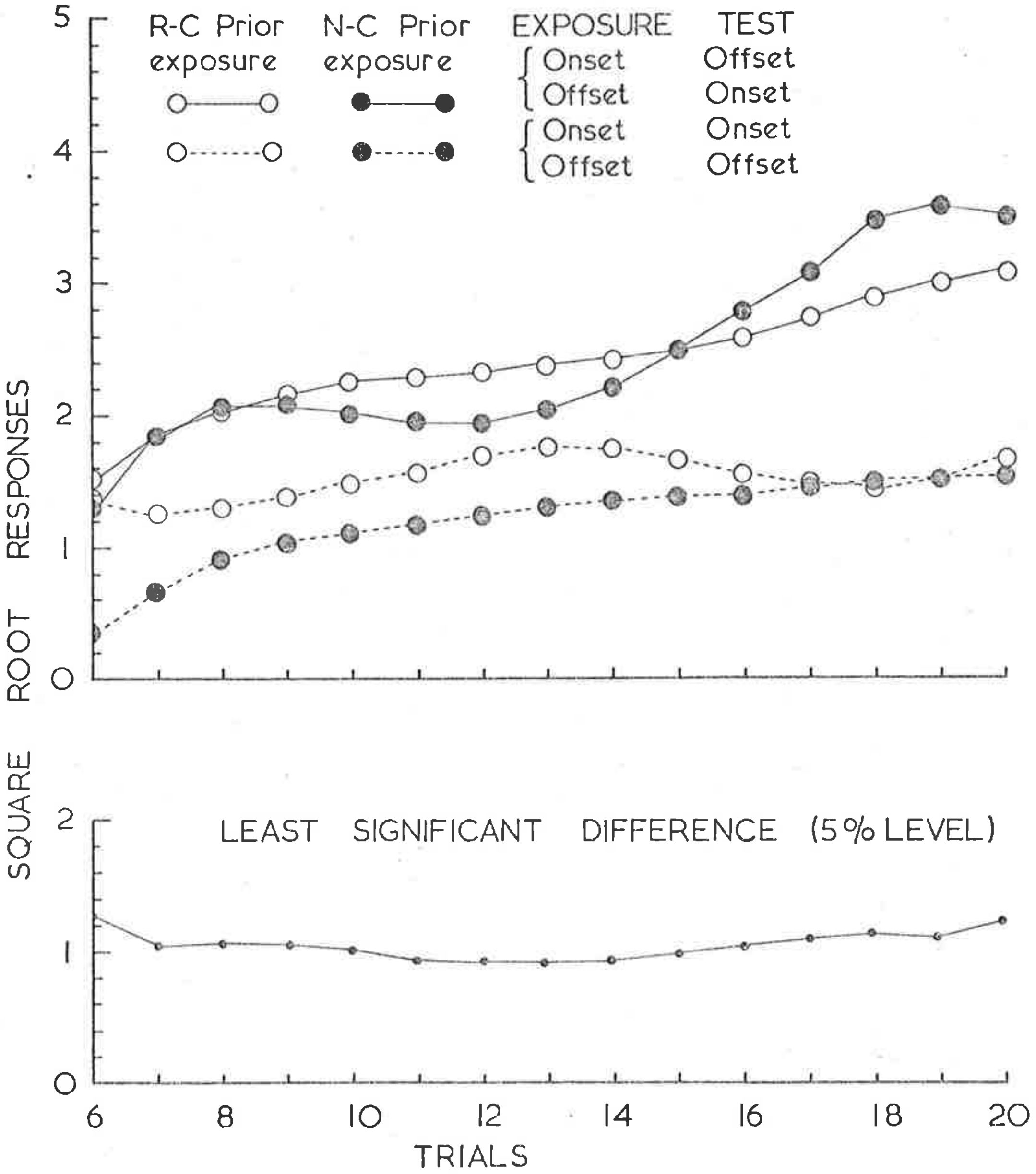


Fig.6. Responding in the test period during Phase II for response-contingent (R-C) and nonresponse-contingent (N-C) prior exposure groups as a function of whether the exposure and test light changes were the same or different: Best fit curves and least significant differences.

(1) the N-C treatments tested with a light change different to the exposure light change showed a more pronounced delay before increasing their response rate in the test period than the comparable R-C treatments, (2) the treatments in which the exposure and test light change were the same exhibited a fairly constant response rate over trials, and (3) for both the R-C and N-C treatments, Ss which received a different direction of light change in the test and exposure periods responded more than Ss which received the same light change in both periods, throughout all trials in phase II, but the difference was significant only over the later trials.

The decline in the reinforcing value of light change from the exposure to the test period. The difference between the total number of responses in the exposure and test periods were analysed by difference 't' tests to determine whether there was a decline in the reinforcing value of light change when (1) the same light change occurred in both periods, and (2) a different light change occurred in the exposure and test periods. Because of the obvious shifts in this difference over trials, separate analyses were performed on the data for trials 6-10, trials 11-15 and trials 16-20. To include the N-C treatments in these analyses the difference between the number of responses of the N-C S in the test period and the number of responses in the exposure period of the R-C S to which it was yoked was taken. The results of these analyses are presented in Table 6. From Table 6 it can be seen that (1) the reinforcing value of light change declined markedly from the exposure to the test period when the same light change occurred in both periods, as expected, but (2) while the reinforcing value of light change over trials 6-10 and trials 11-15 significantly declined from the exposure to the test period when a different change occurred in the two periods, there was no reliable decline over trials 16-20.

NUMBER OF REINFORCED RESPONSES

The percentage of reinforced responses differed little according to whether light Onset or light Offset was the reinforcing stimulus and from the exposure period to the test period. As a result, the analyses of the number of reinforced responses paralleled those for total responses. However, there was a general tendency for more nonreinforced responses to be made on the first one or two LCBP trials than on later trials.

The percentage of reinforced responses on trials 6 to 9 respectively was 71, 74, 82, and 86. The percentage then remained fairly stable over the rest of the trials, with a value for trials 16-20 of 87%.

WITHIN TRIAL RESPONSE DISTRIBUTION

Within the exposure period more responses were made in the first quarter of the 10 min. than in later quarters in all treatments, but this trend of a decline over the period was not pronounced (see Table 7). In contrast, the distribution of responses within the test period differed from treatment to treatment. This is shown in Table 7, where it can be seen that responding throughout the test period was relatively constant in treatments involving nonresponse-contingent prior exposure to a different light change and in treatments involving response-contingent prior exposure to the same light change. When the prior exposure to a different light change was response-contingent a larger proportion of responses were made in the fourth quarter of the test period than in other quarters. Finally, when the prior exposure to the same light change was non-response-contingent the response rate declined rapidly throughout the test period.

Despite these differences the results from the separate analyses of the four quarters precisely replicated the analyses of total responses in terms of the Between Ss treatment effects. Therefore, the type of exposure x type of test light change interaction was reliable in all four quarters of the test period. In addition, the trends over trials obtained for total responses in phase II were also largely present in each quarter of the test period.

TABLE 7

PERCENTAGE OF RESPONSES IN EACH QUARTER OF THE EXPOSURE AND TEST PERIODS FOR ALL TRIALS IN PHASE II.

		EXPOSURE PERIOD	TEST PERIOD			
	Method of Exposure	R-C	R-C		N-C	
	Same or Different Light Change in Exposure and Test	All Treats.	Same	Different	Same	Different
QUARTER	1st	30	27	21	47	26
	2nd	27	26	24	18	24
	3rd	20	19	23	17	26
	4th	23	28	32	18	24

MEAN DURATION OF BAR PRESS

The failure of all animals to respond on all trials in phase I and phase II precluded the analysis of the mean duration of bar press data by the repeated measures procedure. Therefore, the mean duration of bar press for each animal over trials 1-5 and trials 6-20 was calculated and analysed as a three way complete factorial design.

There were no significant differences during the operant phase. The mean duration of bar press in phase I, for all animals, was 1.29 sec. In phase II, the analysis of the mean duration of bar press during the exposure period for the R-C treatments also showed no differences (see Table 8). Contrariwise, the analysis of all treatments for the test period yielded a significant effect for type of test light change ($\underline{F} = 7.95$, $\underline{df}$ 1,48, $\underline{p} < .01$), and a significant method of exposure x type of exposure x type of test light change interaction ($\underline{F} = 4.58$, $\underline{df}$ 1,48, $\underline{p} < .05$). These results are presented in Table 8. Further analysis of the data in Table 8 revealed a significant tendency for animals in the R-C treatments to have a longer duration of bar press in the test period than in the exposure period if the test light change was different to the exposure change ($t = 3.53$, $\underline{df}$ 13, $\underline{p} < .01$). There was no correlation between the mean duration of bar press in the operant and LCBP phases (Pearson r).

TABLE 8

MEAN DURATION OF BAR PRESS FOR ALL TRIALS IN PHASE II (in sec.)

METHOD OF EXPOSURE	EXPOSURE LIGHT CHANGE	TEST LIGHT CHANGE	MEAN DURATION IN EXPOSURE PERIOD	MEAN DURATION IN TEST PERIOD
R-C	ONSET	ONSET	.78	.72
N-C	ONSET	ONSET		.98
R-C	ONSET	OFFSET	.63	.77
N-C	ONSET	OFFSET		.60
R-C	OFFSET	ONSET	.60	1.32
N-C	OFFSET	ONSET		.93
R-C	OFFSET	OFFSET	.55	.52
N-C	OFFSET	OFFSET		.74

A feature of the data not apparent from these analyses is the general decline in the mean duration of bar press over the initial trials of phase II. There was no difference between the mean response duration for all Ss in the operant trials (1.29 sec.) and trials 6-10 (1.04 sec.), but there was a general decline from trials 6-10 to trials 16-20 (0.69 sec.) ($t = 4.50$, df 45, $p < .001$).

DISCUSSION

Three major points emerge from the data. The first is that the number of responses in the test period made by animals which responded for light change in the exposure period did not differ from the number made by animals prevented from responding in the exposure period. This demonstrates clearly that response satiation or reactive inhibition is not an important factor in the normal within trial decline in responding in LCBP (as in Experiments 1 and 2), at least within the limits of a 20 min. trial. This finding is not in agreement with the general hypothesis that the decline in responsiveness to novel stimuli is mainly due to reactive inhibition (e.g. Stretch, 1960a,b; Broadhurst & Eysenck, 1964). Consequently, this result is not in agreement with the proposition that the within trial response decline in LCBP "is a function of the occurrence of the operant rather than its consequences"

(Roberts, 1962, p.379). On the other hand, this result is in accord with data showing the inadequacy of the reactive inhibition concept in accounting for spontaneous alternation in a T-maze (e.g. Montgomery, 1951; Glanzer, 1953; Walker, Dember, Earl & Karoly, 1955).

The second is that prior exposure to a given light change (Onset or Offset) diminishes the reinforcing effectiveness of <u>that</u> light change. This is in line with the results of Experiments 1 and 2. The finding that N-C prior exposure diminished the reinforcing effectiveness of that light change corroborates the results of Kish & Baron (1962). This kind of evidence has been used in support of a Drive for stimulus change interpretation of not only LCBP (Kish & Baron, 1962; Kish, 1966), but also other behaviour reinforced with stimulus change (Fowler, 1965, 1967). The point of the present experiment has been that this is necessary but not sufficient evidence for such an interpretation.

The third is that after a number of LCBP trials prior exposure to one direction of light change had little effect on the reinforcing value of a different direction of light change. This effect emerged only after several LCBP trials, being preceded by a reduction in the reinforcing value of light change following prior exposure to a light change in the opposite direction. The latter reduction gradually disappeared, so that over the terminal four or five LCBP trials light Onset and Offset could be considered to have largely independent reinforcing effects. In principle, these results represent an extension of those reported by Berlyne, Koenig & Hirota (1966). They found that immediate prior exposure to stimulus change in one sensory modality (auditory or visual) did not affect the reinforcing value of a response-contingent change in another modality. Taken overall, the present results and those of Berlyne, Koenig & Hirota suggest that in the main the satiation which occurs in LCBP is not a general satiation for stimulus change. In short then, the present results do not support a need or Drive for stimulus change explanation of LCBP.

An elegant explanation of LCBP should be able to accommodate all aspects of the phenomenon. A Drive for stimulus change formulation cannot do this. As an alternative it is postulated that response-contingent light change is reinforcing because positive motivational effects occur when there is a contingency between behaviour and an environmental change. The argument here is that light change as a stimulus in its own right has no rewarding properties, i.e. it does not satisfy a need of any kind and is essentially an indifferent stimulus biologically. The reinforcing effect therefore arises from the fact that the light change comes under behavioural control when it is made contingent upon bar pressing. In other words, it is the control over an environmental change which is rewarding in LCBP, and not the light change as such.

The model of LCBP as control over an environmental stimulus change proposed here can be developed further by a consideration of the present results. It was suggested that the reduction in the reinforcing value of light change following prior exposure to that light change obtained here was due to stimulus satiation. In terms of the hypothesis that the reward in LCBP arises from the control over the light change, it might be expected that the satiation of this reward would occur only through responding for the change. It can be seen that a distinction is being made between stimulus satiation and the satiation of the control of a stimulus. However, it seems likely that both kinds of satiation will contribute to the within trial decline in LCBP. The present data do not permit a clear separation of these two possible kinds of satiation. It might be argued, from the absence of any difference between the effects of N-C and R-C prior exposure, that stimulus satiation is the most important factor. However, it is possible that N-C prior exposure to the same light change as responded for in the test period diminished LCBP because of a reduction in the sense of control over the light change. One effect of N-C light changes could be a diminution in the sense of control over the light change because of repeated experience of the light change as a stimulus occurring independent of behaviour.

There is also the problem of accounting for the fact that over about the first 10 trials in phase II prior exposure to light change in one direction diminished the reinforcing value of responding for a light change in the other direction. It is suggested that this result is due to limitations on the capacity of the organism to accommodate novelty and stimulus change. There are no powerful constraints on the organisms in the LCBP situation to continue to respond. It appears that the amount of stimulus change and novelty in treatments involving both directions of light change was of a level close to the upper limit of the capacity of the rats to accommodate such novelty and stimulus change. The repeated experience of both directions of light change seems to have raised the capacity of the organisms to accommodate novelty and change so that by the last 4 or 5 trials of phase II responding in the exposure period for one direction of change was about the same as responding in the test period for the opposite direction of change. This effect of experience is consistent with theory (Dember & Earl, 1957) and data

(Munsinger & Kessen, 1964; Thomas, 1969a,b) from other research areas in the field of intrinsic motivation. In part then, the motivational properties of control over the environment must operate within the context of certain biological restraints, one being the capacity of the organism to accommodate novelty and change, a point given explicit recognition in Stimulus-Change theory by the postulation of an inverted U relationship between the novelty and magnitude of change, and reinforcing value (cf. the effects of magnitude in Experiment 1).

Finally, the model of LCBP in terms of the positive motivational properties of control over an aspect of the environment proposed here envisages that in the generic sense bar pressing for a light change does not reduce the positive effects of control over the environment. Rather, responding for a particular light change only satiates the positive effects from controlling that change. The same point was made by Woodworth (1958) in referring to exploratory behaviour: "what becomes satiated...... is not the exploratory tendency in general, but the exploring of a particular place or object" (p.83). So it is also with controlling an aspect of the environment, an argument which is clearly in opposition to a drive formulation of LCBP.

The operant response rate differences reported here would follow from a view that operant responses are mainly epiphenomenal and occur in the course of the exploration of the Skinner box. Such exploration is most vigorous when the animal is first placed in the apparatus. After 10 min., when the lever was made available, it would be expected that exploration of the box would be less pronounced. This could account for the much lower operant rate obtained here than in earlier experiments (Experiment 1; Glow, Roberts & Russell, in press). The higher operant rate in groups in which the ambient light condition changed after 10 min. of the trial suggests that this change may have the effect of initiating renewed exploration, thus causing more animals in these groups to make operant responses. Because phase II was continued long enough for all animals to develop stable LCBP behaviour, the operant differences cannot be invoked to account for the results of phase II. This is also supported by the fact that the operant differences seem of little relevance to treatments in phase II which responded in both the exposure and test periods.

Other aspects of the present data worthy of note are firstly the increase in the proportion of reinforced responses over the first 2 or 3 LCBP trials. This suggests animals learn that responses within the 3 sec. period of light change are not reinforced and therefore, to a certain extent, to inhibit such responses. This agrees with the analysis of the effects of the duration of change parameter made in the Discussion of Experiment 2. The reason this effect did not emerge in Experiment 1 may be related to the greater number of animals responding for a highly effective light change, and the associated increase in power, in the present case. Secondly, the mean duration of bar press results. Most of the obtained differences are not easily interpreted. Nevertheless, the general increase in mean response duration when a different light change was made response-contingent after 10 min. probably represents a response to novelty. In addition, as with Experiment 1 the mean duration of bar press declined to an asymptote in the LCBP phase of the present study. Thirdly, the within trial response rate distributions. In the exposure portion of the trial the response rate declined over the four quarters. This decline was not as marked, however, as in the 20 min. trial of Experiment 1, a result undoubtedly due to the shorter time period here. Furthermore, the data from the four quarters of the test period indicate: (a) that the exposure experience immediately before the test period may disrupt the normal inclination to respond most in the first quarter of a LCBP period, and (b) that if the exposure and test periods had been longer, the response rate in the test period for a different direction of change may even have been above that for the exposure period, because there was no tendency for responding to decline over the test period in these treatments. However, the precise effects of the duration of the test and exposure periods could only be revealed by a parametric analysis.

To recapitulate, the results obtained here cannot be reconciled with a model of LCBP which claims that the reinforcing effects of light change is due to the reduction of a need for varied exteroceptive stimulation. As an alternative it was suggested that so long as the light change or changes do not exceed the capacity of the organism to accommodate novelty and change, light change _per se_ is an indifferent stimulus and biologically neutral. Given this proposition, it was argued that a response-contingent light change is rewarding because of the positive motivational effects of control over an environmental stimulus change.

The conclusions advanced here are predicated on the assumption that it is the light changes which occurred during the exposure period that were of crucial importance and related to responding for light change in the test period. However, a close examination of the exposure period shows that a light change occurred, on the average, only every 40-45 sec. Therefore, more than 90% of the 10 min. exposure period was spent in the "background" or ambient illumination which constituted the initial level of illumination for the light change. In this way, the major portion of the exposure experience consists of constant illumination which, obviously, is different for light Onset and Offset. As it is possible that the latter may be itself related to responding for light change in the test period, the validity of the present conclusions can only be established by an investigation of the effects of prior exposure to continuous light or darkness before responding for light Onset and Offset. This was the aim of Experiment 4.

4.30. EXPERIMENT 4: Immediate Prior Exposure to Continuous Darkness or Light and the Reinforcing Value of Response-Contingent Light Onset and Offset.

INTRODUCTION

In the discussion of the effects of the "exposure" experience in Experiment 3, emphasis was placed on the exposure to light change. However, as a light change only occurred, on average, every 40-45 sec. most of the time in the "exposure" period was spent in the initial light intensity i.e. the prevailing ambient illumination, which in the case of light Onset and Offset was darkness and 6.65 ft.c. respectively. Therefore, the exposure experience of Ss which received a different direction of light change in the exposure and "test" periods contrasts with that of Ss which received the same light change in the exposure and test periods in two ways: the light change and the ambient or background illumination. It is possible that the ambient illumination in the exposure period may have affected subsequent LCBP independently of the light changes which occurred. The aim of the present experiment was to test this hypothesis by exposing Ss, in the test environment, to either continuous light or continuous darkness before testing the reinforcing value of light Onset and Offset. If the prevailing ambient illumination in the exposure period of Experiment 3 affected subsequent LCBP it would be predicted that the reinforcing value of Onset and Offset will differ according to whether the exposure period is spent in continuous light or darkness.

METHOD

Subjects The Ss were 20 female Wistar hooded rats, about 165 days of age at the start of the experiment. Other conditions were the same as in Experiment 1.

Apparatus The apparatus was the same as used in Experiment 2, except that only one Skinner box was used here. The light changes were light Onset and Offset, as in Experiment 3. A light change lasted for 3 sec. and a response during a period of light change was recorded, but did not affect the change. The ambient light conditions in the exposure period were either darkness or light (6.65 ft.c.).

PROCEDURE

Design The experiment was designed as a complete factorial study for two types of ambient light exposure (light or darkness) and two types of response-contingent light change (Onset or Offset), with repeated measures over trials. The intertrial interval was 48 hrs. Total trial length was 20 min., divided into a 10 min. exposure period and a 10 min. test period. During the exposure period the lever was covered and the ambient light condition was either light or darkness. The lever was covered with an aluminium panel, as in Experiment 3, and the same procedure was used for removing it. For the test period, the lever cover was removed and light change was response-contingent. The experiment was run between approximately 9 a.m. and 2 p.m. each day, with half the Ss run on any one day. The number of bar presses in each quarter of the test period and the mean duration of bar press and the number of reinforced responses over the whole test period were recorded throughout the experiment, which was conducted in two phases.

Phase I (Operant level)

The animals were randomly assigned to one of the four treatment groups. During Phase I the lever was covered for the exposure period and uncovered for the test period. A bar press in the test period did not produce a light change. The ambient light conditions were the same as those scheduled for the experimental phase. Thus, the ambient light conditions in the exposure and test period for the four treatments were darkness-darkness, darkness-light, light-light and light-darkness. Five trials were run.

Phase II (LCBP)

Commencing with the 6th trial, light change (Onset or Offset) was made response-contingent during the test period, according to treatment assignment. For the sake of exposition the treatments are designated as follows:

Treatment 1: exposure to darkness and test with light Onset.
Treatment 2: exposure to darkness and test with light Offset.
Treatment 3: exposure to light and test with light Offset.
Treatment 4: exposure to light and test with light Onset.

Trials were continued until it was clear from inspection of the data and tests for trends that responding had reached an asymptote, or for a minimum of 15 trials. 15 trials were run in this phase.

RESULTS

TOTAL RESPONSES

The major analyses were performed on the total responses in the test period. The response rate distribution within the test period is presented separately. A repeated measures analysis of variance (Winer, 1970) was used. To match the assumptions of the analysis all response data were subjected to a square root transformation. One animal died after four trials in phase II. To facilitate analysis, data for the missing animal were estimated by the procedure outlined in section 2.20.

Phase I (Operant level)

There were no significant differences between the four treatments on response rate in phase I, showing that the ambient light conditions had no effect on operant rate. In general, response rate declined over the five trials ($F = 4.57$, *df* 4,64, $p < .01$). This trend seems to have been most marked in treatment 1, as suggested by the trials x exposure illumination x test light change interaction ($F = 3.44$, *df* 4,64, $p < .05$) (see fig.7).

Phase II (LCBP)

The analysis of all 15 trials in phase II revealed no significant differences between treatments ($F < 1$) in all cases. The main effect of trials was significant ($F = 3.13$, *df* 14,224, $p < .01$), indicating an increase in responding over the initial trials (see fig.7). To an extent this trend reflects the fact that an increasing proportion of *S*s responded over the initial trials (all *S*s responded by the 12th trial), but inspection of the data showed that apart from this there was a tendency for responding to increase over the first few trials. There were no differences between treatments in trends over trials. Separate analyses were performed on the data for trials 6-10, trials 11-15 and trials 16-20. There were no differences between the treatments on any of these.

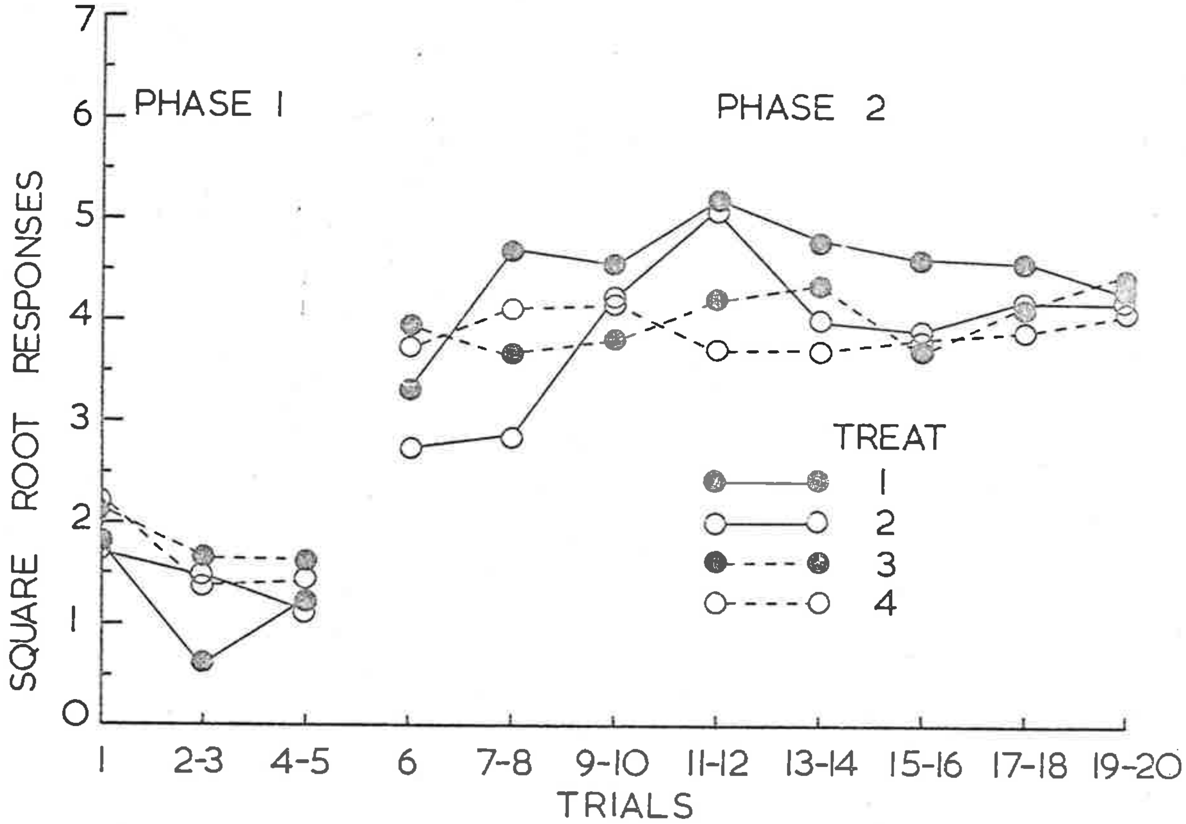


Fig. 7. Responding in Phases I & II for all treatments.

Furthermore, they yielded a trend over trials for trials 6-10 only ($F = 3.30$, df 4,64, $p < .05$), which indicates that after about trial 10 responding had stabilized.

WITHIN TRIAL RESPONSE DISTRIBUTION

Responding showed a general decline over the four quarters of the test period in both phases. There were no pronounced differences in this trend between treatments and little change over trials. The percentage of responses in each quarter of the test period for all Ss in phase I was 37, 18, 27, and 18 respectively, while in phase II it was 40, 24, 18 and 18 respectively. The results of the analyses of variance of each quarter of the trial in phase I generally paralleled the analysis of total responses, with the exceptions that the decline over trials was confined to responding in the first quarter and animals exposed to light made more responses than animals exposed to darkness in the first quarter of the test period ($F = 5.08$, df 1,16, $p < .05$). The separate analyses of each quarter of the test period in phase II revealed no differences between treatments in any quarter of the trial and showed that the trends over trials obtained for total responses was confined to responding in the first quarter ($F = 7.11$, df 14,224, $p < .01$).

NUMBER OF REINFORCED RESPONSES

The analyses of the number of reinforced responses on each trial precisely paralleled those for total responses. There were no differences between treatments in the proportion of reinforced responses. On trials 6, 7, 8, and 9 respectively the overall proportion of reinforced responses was 79, 86, 87, and 85. This proportion then remained at about 86% for the remainder of the experiment.

MEAN DURATION OF BAR PRESS

The failure of several animals to respond over the initial trials precluded a repeated measures analysis of the mean duration of bar press scores. Consequently, the mean duration of bar press for each animal for trials 1-5 and trials 6-20 were calculated and analysed. These analyses showed no differences between treatments in phase I. The mean duration of bar press for all animals in phase I was 1.50 sec. In phase II, the mean duration of bar press for Ss responding for Onset was longer than for Ss responding for Offset ($F = 5.27$, df 1,16, $p < .05$). The respective means for these treatments were 1.03 sec. and 0.79 sec. An examination of the changes in mean duration of bar press over trials indicated that there was no change from trials 1-5 to trials 6-10, but that there was a general decline from trials 6-10 (mean 1.10 sec.) to trials 16-20 (mean 0.76 sec.) ($t = 3.77$, df 17, $p < .01$). The mean duration of bar press in phase I was not correlated with the mean duration in phase II (Pearson $r = 0.02$).

DISCUSSION

In demonstrating that immediate prior exposure to different ambient light conditions has no significant effect on subsequent LCBP, the present experiment has done several things. It has confirmed that the results obtained in Experiment 3 can be attributed to the effects of the light change to which the Ss were "exposed", and not to differences in the ambient level of illumination. The present results also demonstrate that exposure to the consequent level of illumination involved in a light change (e.g. darkness in the case of light Offset) does not affect the reinforcing value of that light change. This provides further evidence that light change in LCBP functions as a change *per se*. Furthermore, the present findings add weight to the argument (see review, section 1.40 and the Discussion of Experiment 1) that visual scanning of the environment is not a major determinant of the reinforcing value of light change. If scanning were important, light Onset should have been less reinforcing following exposure to light than following exposure to darkness, since light provides an opportunity to visually scan the environment.

The present results are in agreement with those of Premack & Collier (1962) dealing with the effects of prior exposure to light or darkness in the test environment on the reinforcing value of light Onset. They found that the longer the time spent in the test environment before LCBP commenced the greater the reinforcing value of light Onset, but no systematic effects for exposure to light versus darkness prior to responding for light Onset. On the other hand, the data reported here conflicts with the findings of Kish & Baron (1962). Kish & Baron also used only light Onset as the reinforcer and found it less reinforcing following a period of pre-exposure in the test environment to continuous light than following a period of pre-exposure to continuous darkness. However, the reliability of their findings are open to question since the experiment lasted for only one trial.

Finally, the decline in the mean duration of bar press in phase II obtained here essentially replicates the results of Experiments 1 and 3. This trend seems to be a reliable feature of LCBP behaviour.

4.40. EXPERIMENT 5: Some additional evidence bearing on a Drive theory interpretation of LCBP.

INTRODUCTION

It was concluded on the basis of the results of Experiment 3 that a "Drive for stimulus change" model is not applicable to LCBP. This argument was founded on the observed independent reinforcing effects for light Onset and Offset when one direction of light change was the reinforcing stimulus in the first half of the trial and the other direction of light change was the reinforcing stimulus in the second half of the trial. However, if light Onset and Offset are taken separately and alone, it could be argued that responding for one direction of light change alone does function according to a Drive model. In support of this, nonresponse-contingent immediate prior exposure to a given light change reduces the reinforcing value of that light change when it is response-contingent. Also, under normal LCBP conditions responding for a given light change typically declines within the trial.

It can be postulated that separate Drives are aroused by different light changes. Such an approach would be in line with the notion that in curiosity-exploratory behaviour a Drive ("curiosity") is aroused by exteroceptive stimulation and reduced by commerce with the source of stimulation (e.g. Berlyne, 1960; Berlyne & Slater, 1957; Harlow, 1953a, Montgomery, 1953). Kish & Baron (1962) mention this kind of Drive explanation as a possible means of accounting for their LCBP results. According to this approach, in the case of LCBP it would be hypothesised that light Onset arouses a "curiosity Drive" which is satiated by experiencing light Onset (whether as a nonresponse-contingent light change or by responding for it), and that independent Drives are aroused by different light changes, such as light Offset.

The aim of the present experiment was to investigate the possibility that a Drive model can be applied to LCBP if it is considered that light Onset (or Offset) arouses a Drive which is reduced by commerce with light Onset (or Offset). Toward this end, the experiment was designed to analyse two aspects of the effects of nonresponse-contingent prior exposure to light change on the reinforcing value of response-contingent light change, when the nonresponse-contingent and the response-contingent light changes are the same (e.g. Onset).

The first was the relationship between the amount (frequency) of nonresponse-contingent prior exposure to light change and subsequent responding for that light change.

If a Drive model is applicable the greater the amount of prior exposure the less reinforcing should be the response-contingent light change. This kind of analysis was not feasible in Experiment 3 because of the relatively small number of Ss in each treatment (seven) and the fact that the amount of light change exposure was determined by the responding of the response-contingent (R-C) animals and therefore varied from trial to trial. The second was, in terms of responding on successive trials, the rapidity and extent to which LCBP is affected by the introduction of nonresponse-contingent prior exposure to light change, and the rapidity and extent to which LCBP is affected when nonresponse-contingent light change prior exposure is terminated. To investigate the second question Ss were first allowed, over several trials, to acquire a stable LCBP rate in the absence of any immediate prior exposure to nonresponse-contingent light change. Then each LCBP trial was preceded by a certain number of nonresponse-contingent light changes of the same kind for which the S was responding. Several trials were given with light change exposure followed immediately by LCBP. Finally, the prior exposure to light change was terminated and several additional trials were run with only LCBP. According to a Drive formulation the introduction of the exposure experience should reduce responding for light change immediately and when the prior exposure is terminated the LCBP rate should show an immediate recovery.

METHOD

Subjects The Ss were 110 female Wistar hooded rats. Ss were about 190 days of age at the commencement of the experiment. All other conditions were the same as in Experiment 1.

Apparatus The apparatus was the same as used in Experiment 2. The light changes were light Onset and Offset, as in Experiment 3. The light change lasted for a fixed duration of 3 sec. A response made during a period of light change was recorded, but did not affect that change. A Random Function Generator was used to produce the nonresponse-contingent light changes. It was programmed to produce at randomly determined times during the trial 5, 10 or 20 light changes, as required by the design.

PROCEDURE

The experiment was conducted in four phases. An outline of the experimental conditions in each phase is presented in Table 9. Throughout each phase the total trial length was 20 min. and the intertrial interval was 48 hrs. Ss were run between approximately 9 a.m. and

TABLE 9: Outline of Experimental Conditions in each Phase of Experiment 5.

PHASE I	PHASE II		PHASE III		PHASE IV	
LCBP FOR FULL 20 MIN.TRIAL	EXPOSURE PERIOD	TEST PERIOD	EXPOSURE PERIOD	TEST PERIOD	EXPOSURE PERIOD	TEST PERIOD
			20 N-C ONSET	ONSET	CONTINUOUS DARKNESS	ONSET
					20 N-C ONSET	ONSET
			10 N-C ONSET	ONSET	CONTINUOUS DARKNESS	ONSET
					10 N-C ONSET	ONSET
			5 N-C ONSET	ONSET	CONTINUOUS DARKNESS	ONSET
					5 N-C ONSET	ONSET
ONSET	CONTINUOUS DARKNESS	ONSET	CONTINUOUS DARKNESS	ONSET	CONTINUOUS DARKNESS	ONSET
OFFSET	CONTINUOUS LIGHT	OFFSET	CONTINUOUS LIGHT	OFFSET	CONTINUOUS LIGHT	OFFSET
			5 N-C OFFSET	OFFSET	5 N-C OFFSET	OFFSET
					CONTINUOUS LIGHT	OFFSET
			10 N-C OFFSET	OFFSET	10 N-C OFFSET	OFFSET
					CONTINUOUS LIGHT	OFFSET
			20 N-C OFFSET	OFFSET	20 N-C OFFSET	OFFSET
					CONTINUOUS LIGHT	OFFSET

2.30 p.m. on each day, with half the Ss run on any one day. The frequency of bar pressing in each quarter of the LCBP period, the total number of reinforced responses and the mean duration of bar press, were recorded throughout each phase.

Phase I. (20 min. LCBP)

For half the Ss light Onset was contingent on bar pressing and for the other half light Offset was contingent on bar pressing. This light change contingency operated throughout the whole 20 min. trial. The purpose of this phase was to firmly establish LCBP in all Ss. Ten trials were given in this phase.

Phase II. (10 min. LCBP)

The response-contingent light change for each S was the same as in phase I. However, during phase II the lever was covered with an aluminium panel, which prevented responding, for the first 10 min. of each trial (designated the exposure period). The panel was then removed (by the same procedure used in Experiment 3) and LCBP was permitted in the second 10 min. of the trial (designated the test period). Trials were continued until it was clear, from inspection of the data and tests for trends over trials, that a response asymptote had been established. The criteria for a response asymptote were satisfied clearly after 8 trials in this phase. Ss in the light Onset and Offset treatments were then ranked according to their mean response rate over trials 4-8 in this phase and divided into 4 matched groups of 13 Ss, 4 groups for light Onset and 4 for light Offset. The three animals with the lowest response rate in both the light Onset and Offset treatments were discarded, thus leaving 104 animals in the experiment. In preparation for phase III the running schedule for Ss was reorganised so that the application of the experimental conditions in phase III was possible. This involved running a number of animals at a different time of the day. To check that the matching was satisfactory and not disrupted by the alteration in running schedule, an additional 3 trials were given. Therefore a total of eleven trials were given in phase II.

Phase III. (Prior exposure)

Phase III was designed as a complete factorial study for 2 directions of light change (Onset and Offset) and four amounts of nonresponse-contingent (N-C) prior exposure (0, 5, 10 and 20 light changes), with repeated measures over trials. The experimental treatment groups are set out in Table 9.

During the first 10 min. of each trial (designated the exposure period) the lever was covered and Ss received either

0, 5, 10 or 20 N-C light changes (Onset or Offset). For the second 10 min. of the trial (designated the test period) the lever was uncovered and light change (Onset or Offset) was made response-contingent. In all cases the "exposure" light change was the same as the response-contingent light change. In the case of treatments receiving no light change prior exposure the ambient level of illumination during the exposure period was the same as in the test period (e.g. if Onset was response-contingent in the test period the ambient level of illumination in the exposure period was darkness). Trials were continued until a response asymptote had been established, or for a minimum of 15 trials. A total of 15 trials were given in phase III.

Phase IV. (Removal of prior exposure)

Ss in all treatment groups receiving N-C light change prior exposure in phase III (i.e. the 5, 10 and 20 exposure groups) were divided into two matched groups of 6 Ss on the basis of their mean response rate over the last 5 trials of phase III. The lowest responder in all cases was discarded. For one of these groups N-C exposure was continued as in phase III. For the other group, the prior exposure to light change was terminated. In the latter treatment groups the lever was still covered during the exposure period of the trial, but no light changes occurred. The conditions in the test period were the same as in phase III. In summary, the 0 exposure groups of phase III continued unaltered, but the treatments which had received N-C exposure to light change were divided into a group which now received no prior exposure to light change and a group which continued under the same conditions operative in phase III. Trials were continued until a response asymptote had been established or for a minimum of 15 trials. 15 trials were run in phase IV.

RESULTS

All the results from each phase of the experiment will be presented together, with each phase taken separately. The principal analyses of the data were performed on the total responses in the LCBP period using a repeated measures analysis of variance procedure (Winer, 1970, chapter 7).

Phase I.

The response rate data from phase I (total responses in the 20 min. and responses in the second 10 min. of each trial) are presented in fig.8. It is apparent from this figure that both light Onset and Offset were reinforcing and that after the first few trials there was little difference in the reinforcing value of Onset and Offset.

During phase I the mean duration of bar press for

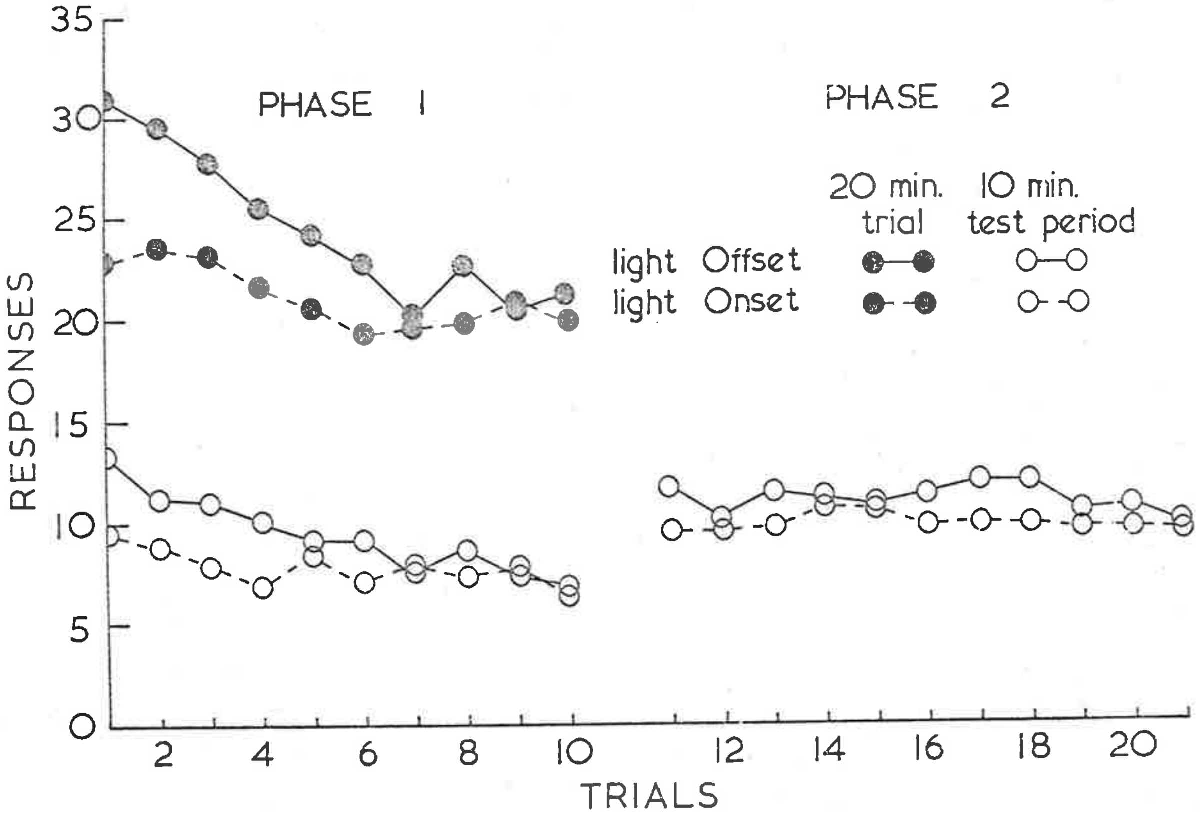


Fig.8. Responding in Phases I & II for light Onset and Offset.

light Onset (0.73 sec.) was longer than for Offset (0.59 sec.). There were no changes in the mean duration of bar press over trials.

The intra-trial distribution of responses was essentially the same for light Onset and Offset. The overall proportion of responses in each quarter of the 20 min. trial, for Onset and Offset combined, was 38, 27, 19 and 16 respectively.

The proportion of total responses which were reinforced was reasonably constant over the 10 trials, showing only slight variations around a mean of 85%. There were no marked differences in the proportion of reinforced responses for light Onset and Offset.

Phase II.

The total response data for phase II are presented in fig.8. From fig.8 it can be seen that the effect of reducing the LCBP period from 20 min. (phase I) to only the second 10 min. of the trial (phase II) was to approximately halve the response rate. This reduction in responding occurred immediately and the response rate then remained essentially unaltered. It can also be seen from fig.8 that the effect of preventing responding in the first 10 min. of the trial was to raise the response rate in the second 10 min. of the trial. The increase in responding in the second 10 min. of the trial, from the last 2 trials of phase I to the first two trials of phase II, was significant for both light Onset ($t = 3.49$, *df* 54, $p < .01$) and light Offset ($t = 3.85$, *df* 54, $p < .01$).

Particular analyses were made of the last 3 trials of phase II with animals divided into the matched groups which were to be subjected to different experimental conditions in phase III. The groups were found to be satisfactorily matched ($F < 1$). The response rate in each of the groups is indicated in Table 10. However, a similar analysis of the mean duration of bar press yielded a significant effect for the dummy amount of exposure variable ($F = 2.84$, *df* 3,96, $p < .05$). The mean duration of bar press in the 0, 5, 10 and 20 light change exposure groups was 0.57 sec., 0.68 sec., 0.58 sec., and 0.56 sec. respectively. The mean duration of bar press of animals responding for light Onset (0.66 sec.) was longer than for animals responding for light Offset (0.58 sec.), but this difference was not significant.

An examination of the intra-trial distribution of responding over the last 3 trials of phase II showed that responding declined from the first to the last quarter in all cases. The overall proportion of responses in each quarter for all animals was 55, 18, 12 and 15 respectively.

The proportion of total responses which were

TABLE 10: Summary of Mean Number of Responses in the test period for Phase III (n = 13)

		PHASE II	PHASE III		
	AMOUNT OF EXPOSURE	TRIALS 19-21	TRIALS 22-26	TRIALS 27-31	TRIALS 32-36
LIGHT ONSET	0	10.2	10.3	10.9	10.8
	5	9.6	8.9	7.5	6.1
	10	9.4	6.8	5.6	4.4
	20	9.2	5.4	5.0	4.8
LIGHT OFFSET	0	10.8	9.7	8.3	8.0
	5	10.8	7.4	6.7	6.2
	10	9.9	6.1	6.1	4.7
	20	10.2	7.6	6.6	5.2

reinforced differed little between the groups. The overall proportion of responses reinforced during the last 3 trials of phase II was 86%.

Phase III.

A summary of the response data from phase III is presented in Table 10. The analysis of total responses in the test period over all trials in phase III yielded a significant effect for amount of exposure ($\underline{F} = 6.03$, df 1,96, $\underline{p} < .01$) and trials ($\underline{F} = 2.85$, df 14,1344, $\underline{p} < .01$). From Table 10 and fig.9 it is clear that these reflect the fact that the response rate was lower following immediate prior exposure to N-C light change than following no light change prior exposure, and that there was a tendency for the response rate to decline over trials. Further analysis of the trends over trials failed to yield significant differences for any of the trend components from the linear to the quintic.

To analyse the differences between the treatments in more detail the best fit regression equations up to the 5th order orthogonal coefficient, together with the least significant difference on each trial, were calculated. These data are presented in fig.9. From fig.9 it is apparent that immediate prior exposure to 10 and 20 N-C light changes reduced responding on the first trial and that the response rate in these treatments was significantly below that of the

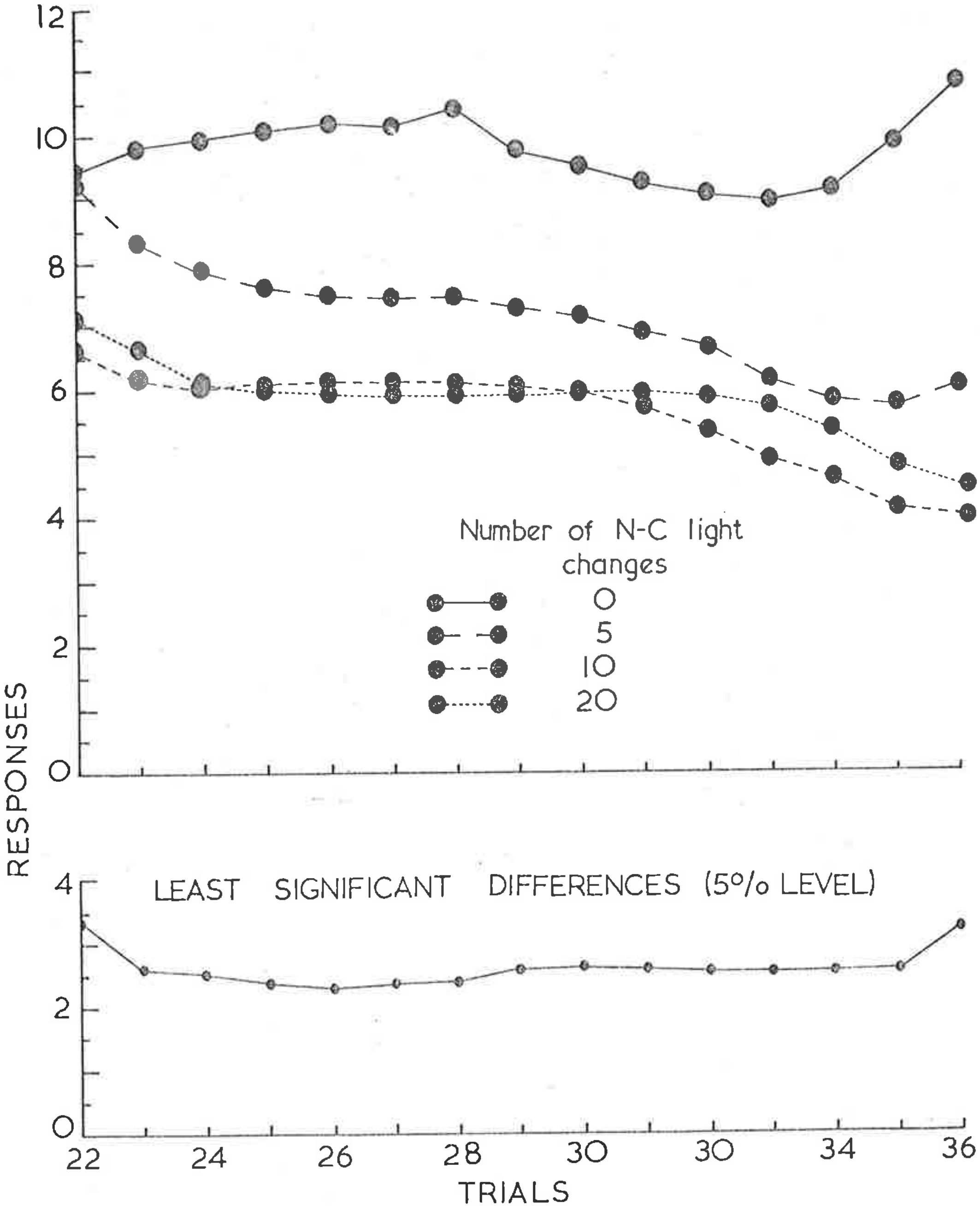


Fig.9. Responding in Phase III as a function of the amount of nonresponse-contingent (N-C) light change prior exposure: Best fit curves and least significant differences.

treatments which received no light change prior exposure, throughout all of phase III. On the other hand, prior exposure to 5 N-C light changes had little effect on responding for light change on the first trial. As trials continued responding in the latter treatments slowly decreased. Finally, there were no reliable differences between the 5, 10 and 20 light change prior exposure treatments.

An examination of the intra-trial distribution of responding (i.e. in the four quarters of the test period) revealed that most responses were made in the first quarter of the test period in all cases. Furthermore, there was a tendency for this trend to become more pronounced as trials continued. For example over the first 3 trials of phase III the overall proportion of responses in each quarter was 57, 17, 12 and 14 respectively, while over the last 3 trials of phase III the proportions were 64, 15, 11 and 10 respectively. The separate analyses of responding in each quarter of the test period showed significant differences between the four exposure treatments, in the same way as obtained for total responses, in the first and second quarter of the period but not in the third and fourth quarters.

The proportion of total responses which were reinforced was relatively constant from treatment to treatment and over trials. The overall proportion of total responses which were reinforced was 85%. The results of the analyses of variance of the number of reinforced responses precisely paralleled those for total responses.

The analysis of the mean duration of bar press over all trials in phase III revealed that the mean response duration was longer for animals responding for light Onset (0.68 sec.) than for light Offset (0.57 sec.) ($F = 6.44$, df 1,96, $p < .05$). This tendency was also present in both phase I and phase II. There were no differences between the four exposure treatments. The differences between the latter treatments which occurred over the last 3 trials of phase II were present over the initial trials of phase III, but they became less marked as phase III continued.

Phase IV.

The total-response data for phase IV were analysed to determine whether the response rate of Ss which had received prior exposure to N-C light change during phase III, but now received no light change prior exposure, was above that of Ss which continued to receive prior exposure to light change. The orthogonal factors subjected to analysis of variance were (1) present N-C light change prior exposure versus previous N-C light change prior exposure, (2) the amount of

N-C light change prior exposure and (3) the direction of light change. As the treatment groups were matched in terms of their response rate over the last 5 trials of phase III there were no differences between them before phase IV commenced. A summary of the mean response rate data for phase IV, plus the mean response rate for each treatment over the last 5 trials of phase III is presented in Table 11.

The analysis of variance of total responses for all trials in phase IV yielded a significant effect for present versus previous exposure ($\underline{F} = 10.41$, $\underline{df}$ 1,60, $\underline{p} < .01$), indicating fewer responses were made in treatments receiving light change prior exposure. No other significant differences occurred and there were no significant trends over trials. More detailed analyses were performed to determine if this difference between present and previous light change exposure emerged at the start of phase IV, or if it took several trials to emerge. The best fit regression equations up to the 5th order orthogonal coefficient, together with the least significant difference on each trial were calculated. A summary of the results of this analysis is presented in fig.10 where the results for the present N-C prior exposure $\underline{S}$s (n = 36), the $\underline{S}$s for which N-C light change prior exposure was removed (n = 36)

TABLE 11: Summary of Mean Number of Responses in the Test Period for Phase IV (n = 6)

			PHASE III	PHASE IV		
	AMOUNT OF EXPOSURE	EXPOSURE PRESENT OR REMOVED	TRIALS 32-36	TRIALS 37-41	TRIALS 42-46	TRIALS 47-51
LIGHT ONSET	0*		10.1	9.1	9.5	9.1
	5	PRESENT	6.6	7.1	6.1	4.8
	5	REMOVED	6.5	6.6	9.4	8.1
	10	PRESENT	4.9	4.3	4.9	5.0
	10	REMOVED	4.2	7.3	9.3	9.1
	20	PRESENT	5.4	3.8	3.0	3.8
	20	REMOVED	5.1	6.2	5.1	5.1
LIGHT OFFSET	0*		8.4	8.4	9.0	10.3
	5	PRESENT	7.3	6.0	4.7	4.8
	5	REMOVED	5.7	6.3	6.5	8.3
	10	PRESENT	5.1	2.4	3.6	3.9
	10	REMOVED	5.1	5.2	8.3	7.6
	20	PRESENT	5.6	6.0	4.6	6.7
	20	REMOVED	5.3	6.7	7.1	8.3

*These data are based on 6 Ss only. The Ss in the 0 exposure groups of Phase III were divided into 2 matched groups of 6 on the basis of their response rate over the last 5 trials of Phase III. The data here are for the group with the lowest mean response rate after matching.

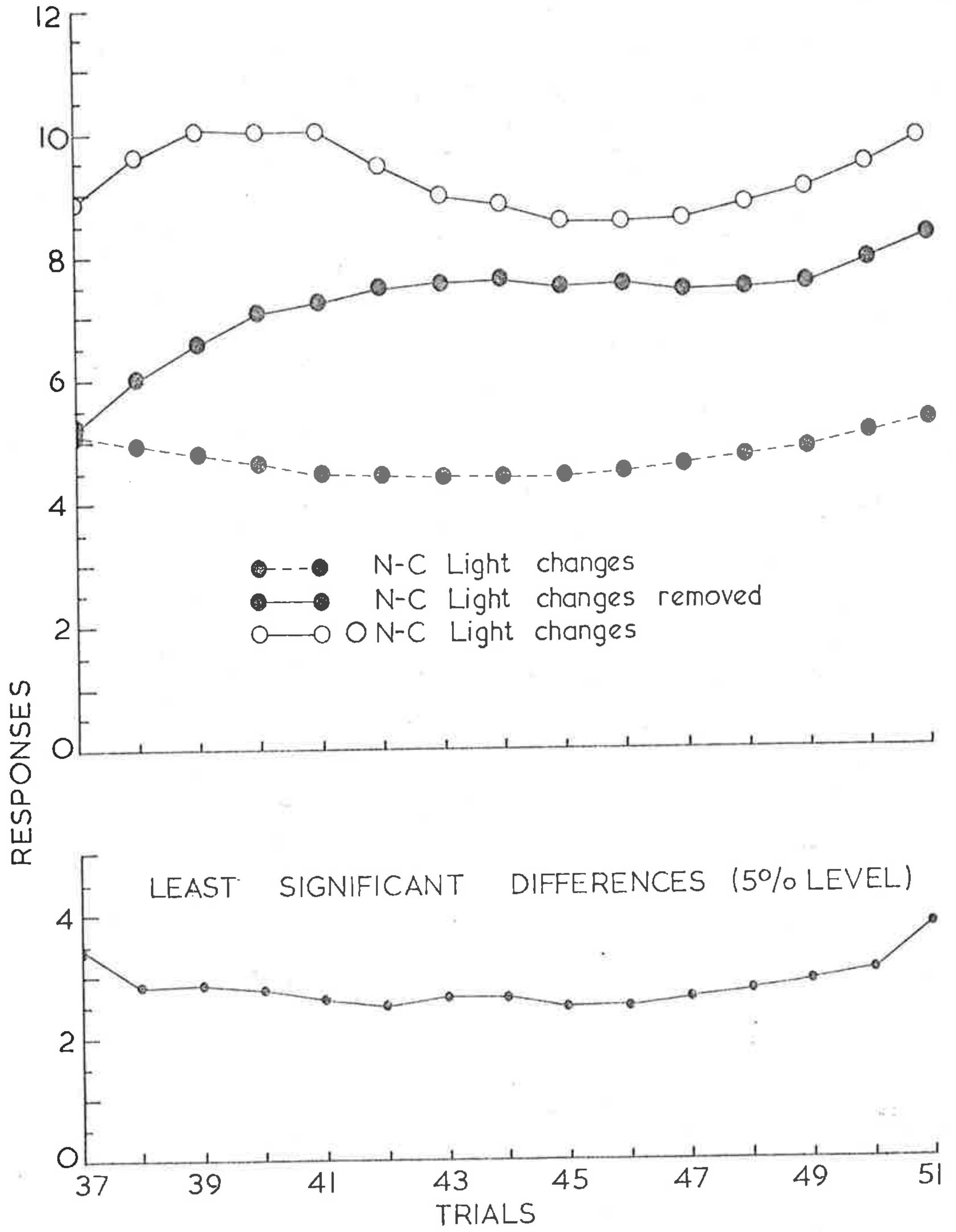


Fig.10. Responding in Phase IV as a function of present or previous nonresponse-contingent (N-C) light change prior exposure: Best fit curves and least significant differences (see text).

and the Ss which received no N-C light changes in either phase III or IV (n = 12) are outlined. The latter data is for the two 0 exposure groups of 6 Ss presented in Table 11. The least significant differences given in fig.10 refer to the two groups with n = 36. It can be seen that the removal of the N-C light change prior exposure did not have the effect of producing an immediate "recovery" of responding. Rather, responding in these treatments increased slowly over the initial trials of phase IV, so that by the 5th trial the difference between the present and previous light change exposure treatments was significant. The results presented in fig.10 were also confirmed by analyses of variance. They showed no significant difference between the present and previous light change exposure treatments over trials 37-41 in phase IV, but a significant difference over trials 42-46 and trials 47-51 .

An examination of the intra-trial distribution of responding revealed that most responses were made in the first quarter of the trial in all cases. There was little difference in this trend between treatments and over trials. Overall, the proportion of responses in each quarter of the test period were 68, 13, 10 and 9 respectively. As a result of the preponderance of responses in the first quarter of the test period, the separate analyses of the four quarters showed that the difference between the present and previous N-C light change exposure treatments was significant in the first quarter ($\underline{F} = 14.29$, $\underline{df}$ 1,60, $\underline{p} < .01$), but not over the rest of the trial.

There was little variation in the proportion of total responses which were reinforced, either between treatments or over trials. Only slight variations around a mean of 85% occurred throughout phase IV. The analyses of the number of reinforced responses precisely paralleled those for total responses.

The mean duration of bar press in phase IV differed little from that in phase III. The only significant effect to emerge from the analysis of the mean duration of bar press for all trials in phase IV was for the direction of light change ($\underline{F} = 7.57$, $\underline{df}$ 1,60, $\underline{p} < .01$). As in phases I, II and III the mean duration of bar press was longer for animals responding for light Onset than for light Offset.

DISCUSSION

Prior exposure to N-C light changes (prior exposure) reduced the reinforcing value of responding for that light change. This confirms the results of Experiment 3. Also, when the prior exposure was terminated, responding for light change increased. Nevertheless, when the results are viewed in detail they do not support an interpretation of LCBP in terms of a Drive aroused by a particular light change. Firstly, there was no difference between the effects of 5, 10 and 20 N-C light changes. Insofar as only 5 N-C light changes reduced the reinforcing value of responding for light change it seems that the crucial factor here may well be not how much prior exposure is given, but whether any is given. Secondly, responding for light change was not immediately reduced by prior exposure to 5 N-C light changes. This treatment slowly reduced LCBP over the initial trials of phase III. Thirdly, when the prior exposure was terminated, LCBP did not recover immediately as would have been predicted had the prior exposure simply reduced the Drive for that light change. Instead, responding increased slowly over the first few trials, which suggests that the prior exposure had a more durable effect than if the light changes in the exposure period had simply diminished a Drive on each trial.

In the Discussion of Experiment 3 it was argued that LCBP is not amenable to a "Drive for stimulus change" interpretation. Extending this further, it is argued here that neither is LCBP amenable to interpretation in terms of a specific Drive aroused by a particular light change. In other words, it appears that despite the apparent concordance with expectations from a Drive model of several features of LCBP, there is more involved in responding for light change than can be accounted for by any type of Drive explanation.

The proposition advanced to account for the results of Experiment 3 was that it is control over an environmental stimulus change which is the reinforcing factor in LCBP. If this is accepted, the data reported here suggest several things about the nature of the reward associated with the control of a light change.

Firstly, it seems that prior exposure reduces the reinforcing effect of responding for that light change. But, on the one hand it appears that very little such prior exposure to a light change is necessary to reduce the reinforcing value of responding for that light change - responding in the test period of phases III and IV was slightly lower following 5 N-C light changes in the first 10 min. of the trial than in phase I where 12-15 response-contingent light changes occurred in the first 10 min. of the trial. On the other hand, it seems that even after large amounts of prior exposure <u>some</u> reward value is associated with having that light change under response control.

Secondly, it seems that under the conditions of repeated trials involving prior exposure followed by LCBP the reinforcement arising from responding for light change is directly affected, so that after the termination of the prior exposure some trials are necessary before the reward value of the stimulus control "recovers". It is worthy of note here that with the termination of response-contingent "exposure" in the first 10 min. of the trial, i.e. from phase I to phase II, there was an immediate increase in responding in the second 10 min. of the trial. This indicates a difference between the effects of response-contingent exposure to light change and N-C prior exposure, a difference which cannot be accommodated by any Drive model and which seems to arise because in one case the light change is under response control all the time while in the other case it is under response control for only half of each trial. When the light change is under behavioural control for only half the trial it seems feasible to argue that eventually the sense of control over that stimulus will be diminished by the random presentations of the light change. In fact, this might partly explain the slow decline in responding over the initial trials of phase III of treatments prior exposed to only 5 N-C light changes.

Stimulus satiation is likely to be the other important factor contributing to the effects of the N-C light changes (these two possible effects of N-C light changes were advanced in Experiment 3). With the removal of the N-C light changes and the re-instatement of the light change as an event produced only by bar pressing, it seems that the reinforcing value of controlling the light change increased as the sense of complete control was re-established. This possibility is examined in more detail in Experiments 6 and 7.

In summary, the present experiment provides further evidence that many features of LCBP are not amenable to interpretation in terms of a Drive model. On the other hand, most features of the data can be incorporated into an account of LCBP based on the positive motivational effects associated with having control over an indifferent environmental stimulus change.

4.50. EXPERIMENT 6: The Effects of Experience of a Light Change as a Stimulus not under Behavioural Control on Subsequent LCBP.

INTRODUCTION

It has been argued (Experiments 3 and 5) that the reinforcement in LCBP is mediated by the control over an environmental change that arises when a light change is made response-contingent. According to this view it is the contingency between a response and a light change and not the light change itself which constitutes the reinforcement. An implication of this proposition is that the motivational effects associated with the control of a light change should be greater if the initial experience of that light change is mediated by such control than if the organism is adapted to the light change as a stimulus beyond its control before it is made response-contingent. In other words, if control over a light change is the factor which mediates reinforcement in LCBP it would be expected that the "sense" of control would be diminished if Ss are first subjected to experience of the light change as an externally imposed environmental stimulus change, i.e. as a nonresponse-contingent (N-C) change. The present experiment was designed to test this hypothesis.

The study reported here, as with previous experiments (Experiments 1, 3 and 4) consisted of five apparatus habituation trials followed by several (15) LCBP trials with a constant inter-trial interval of 48 hrs. throughout. During the apparatus habituation trials N-C light changes were introduced on each trial for some Ss. In these cases the light change responded for in the LCBP phase was the same as that introduced in the apparatus habituation trials. With a constant inter-trial interval such as used here the stimulus satiation effects (cf. Experiments 3 and 5) produced within each trial are largely dissipated between trials. Consequently, it cannot be claimed that the N-C light changes during the apparatus habituation trials will diminish the reinforcing value of that light change when it is made response-contingent in the LCBP trials because of stimulus satiation. If the N-C light changes diminish the reinforcing value of responding for that light change it would be due mainly to the adaptation to the light change as a stimulus which is not under behavioural control, a result which would provide substantial support for the hypothesis that the reinforcement in LCBP is provided by the control over the light change.

METHOD

Subjects The Ss were 60 female Wistar hooded rats about 150 days of age at the start of the experiment. All other conditions were the same as in Experiment 1.

Apparatus The apparatus consisted of 5 Skinner boxes and control apparatus as in Experiment 2. The light changes were either 3 sec. of light Onset or 3 sec. light Offset, as in Experiment 3. A response during a period of light change was recorded but did not affect the light change. N-C Onset and Offset light changes were introduced by a random function generator set to produce either 10, 20 or 40 light changes over the 20 min. trial as required.

Procedure The experiment was conducted over two phases with an inter-trial interval of about 48 hrs. and a trial length of 20 min. throughout each phase. Half the Ss were run on each day. Animals were usually run between about 11.30 a.m. and 2 p.m. each day, but due to circumstances beyond the control of E the experiment was frequently conducted much later in the day. In phase II the number of responses in the 5 min. quarters of the trial and the mean duration of bar press and the number of reinforced responses over the whole trial were recorded.

Phase I. (Apparatus and light change habituation)

Throughout phase I the lever was covered with an aluminium panel which prevented responding. The 60 Ss were randomly assigned to one of 10 treatment groups.

The treatment conditions applied to each of these groups is set out in Table 12. Half the Ss were assigned to light Onset and half to light Offset treatments. Three of the treatment conditions for both light Onset and Offset consisted of the random introduction of 10, 20 or 40 N-C light changes on every trial. In the fourth pair of treatments the ambient level of illumination changed from darkness to light, or vice versa, for 2 min. in the middle of each trial. Therefore the latter treatments did not experience the light change for which they responded in phase II, but they were equated with the 40 3 sec. N-C light change treatments in terms of the total time spent in light or darkness for the light Onset and Offset changes respectively. The fifth pair of treatments consisted of operant control groups. In these groups no light changes occurred and the ambient illumination was either darkness (light Onset operant control) or light (light Offset operant control). This phase lasted for 5 trials.

Phase II. (LCBP)

At the commencement of the 6th trial the aluminium panel was removed from the lever. The operant control group was not reinforced with a light change. All other treatments were reinforced with either light Onset or Offset according to the design. The light change was contingent on bar pressing throughout the whole 20 min. trial and no N-C light changes occurred at any time. 15 trials were given in this phase.

RESULTS

The principal analyses were performed on the total number of responses on each trial using a repeated measures analysis of variance (Winer, 1970). All ten treatment groups were placed into a two way analysis of variance for the orthogonal factors of direction of change (Onset versus Offset) and five treatment conditions. To approximate the assumptions of the analysis all response data were subjected to a square root transformation. An animal in the light Onset operant control group died after 5 trials in phase II. To facilitate analysis the missing values for this animal were estimated according to the procedure outlined in section 2.20.

TOTAL RESPONSES

A summary of the actual total response data from phase II is presented in Table 12. The analysis of variance showed significant differences between the five treatments ($\underline{F} = 4.64$, $\underline{df}$ 4,50, $\underline{p} < .01$), but no effect for the direction of light change ($\underline{F} < 1$), or for the direction of change x treatment interaction ($\underline{F} < 1$).

TABLE 12.

Summary of Mean Response Rate Data for all Treatments.

TREATMENT CONDITION PHASE I	RESPONSES IN PHASE II		
	Trials 6-10	Trials 11-15	Trials 16-20
10 N-C LIGHT ONSET	11.0	18.2	18.4
20 N-C LIGHT ONSET	11.3	10.8	9.2
40 N-C LIGHT ONSET	4.7	2.9	6.8
2 MIN. CHANGE FROM DARKNESS TO LIGHT	18.5	14.9	11.6
CONTINUOUS DARKNESS (OPERANT CONTROL)	3.4	2.0	2.0
10 N-C LIGHT OFFSET	5.2	7.6	9.2
20 N-C LIGHT OFFSET	3.8	8.7	11.0
40 N-C LIGHT OFFSET	7.9	12.9	12.9
2 MIN. CHANGE FROM LIGHT TO DARKNESS	25.7	20.6	21.1
CONTINUOUS LIGHT (OPERANT CONTROL)	4.8	2.5	3.2

In addition, the main effect of trials was reliable ($F = 2.31$, df 14,700, $p < .01$) and the trends over trials differed according to the treatment condition ($F = 1.58$, df 56,700, $p < .01$). Further analysis of these trends revealed that the ten groups differed in terms of only the linear trends over trials ($F = 3.19$, df 9,50, $p < .05$). In order to examine these results in more detail the best fit regression equations up to the 5th order orthogonal coefficient, together with the least significant difference on each trial, were calculated. The results of these calculations are presented in figs. 11 and 12.

From fig.11 it is apparent that responding for light Offset was markedly reduced by the introduction of N-C light changes during the apparatus habituation trials and that it was only towards the end of phase II that responding in these treatments was significantly above the operant group. In addition, over most of phase II the response rate in the treatments which had received N-C light changes in phase I was significantly below that of the treatment which had experienced a 2 min. period of darkness on each trial. There was little difference between the 10, 20 and 40 N-C light Offset treatments. From fig.12 it can be seen that the results from the light Onset treatments are not as clear cut as for the light Offset treatments. There was some tendency for the

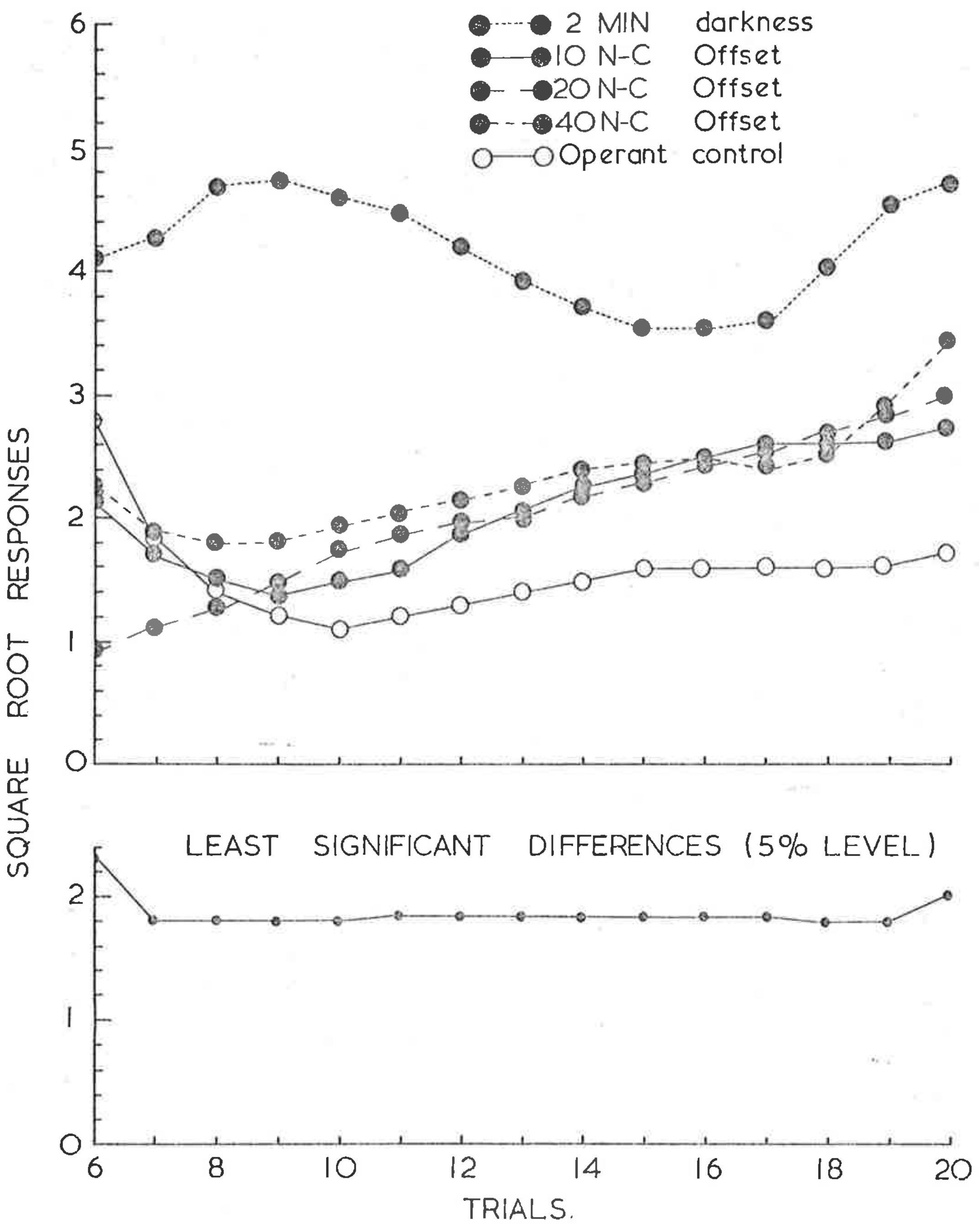


Fig.11. Responding for light Offset in Phase II as a function of treatment in Phase I: Best fit curves and least significant differences.

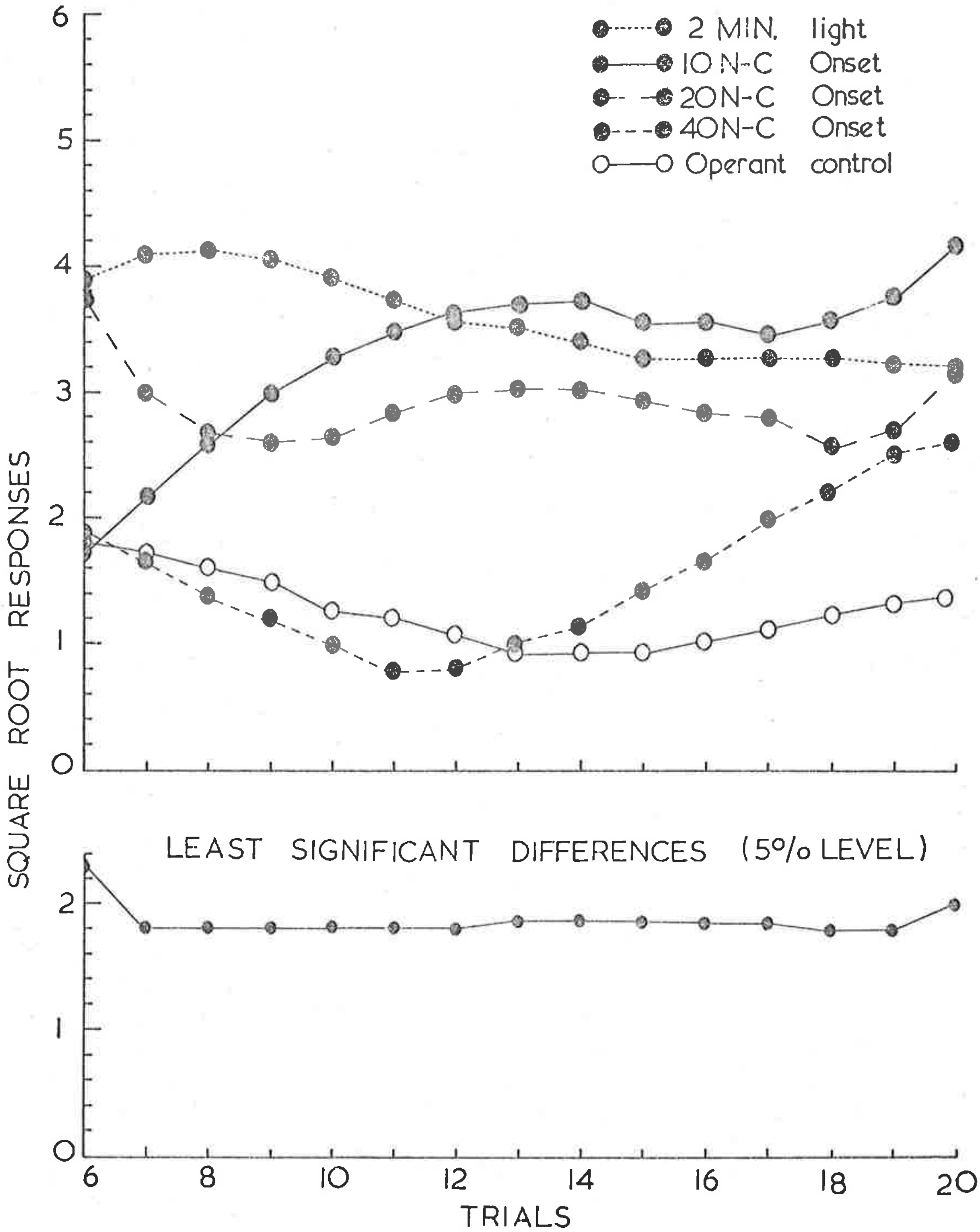


Fig.12. Responding for light Onset in Phase II as a function of treatment in Phase I: Best fit curves and least significant differences.

N-C light Onset treatments to respond less than the 2 min. light treatment over the initial trials, especially in the case of the 40 N-C light Onset treatment. In fact, over all of phase II the latter treatment responded little more than the operant treatment. In contrast to the results for light Offset, there were large differences in the responding of the three N-C light Onset treatments. Whereas there was only an initial reduction in the response rate of the 10 N-C light Onset treatment, there was a marked and relatively permanent reduction in the 40 N-C light Onset treatment. Furthermore, the 20 N-C light Onset treatment showed little reduction in responding.

The response data obtained here, especially for the N-C light change treatments, differs in one important way from those obtained in earlier experiments. The N-C treatments exhibited an extreme variability, both within _S_s and between _S_s. This feature of the data is somewhat obscured by the best fit functions presented in figs. 11 and 12 and by the data in Table 12. The variability does not negate the impressions gained from the data as indicated in figs. 11 and 12 and Table 12, but it does preclude an interpretation of responding over the terminal trials of phase II as a reasonable estimate of the asymptote in most of the N-C light change treatments. In view of the variability, the experiment was terminated after 15 trials in phase II because it seemed unlikely that if the experiment was continued a clear response asymptote would emerge in most treatments.

WITHIN TRIAL RESPONSE DISTRIBUTIONS

The responding declined within the trial in all cases. There was little difference between the eight treatments responding for light change in terms of this trend. However, responding in the operant treatments exhibited a more pronounced intra-trial decline than in the LCBP treatments. Overall, the percentage of responses in each quarter of the trial for all treatments responding for light change was 35, 29, 22 and 14 respectively, while for the operant treatments the proportions were 50, 25, 16 and 9 respectively. The separate analyses of variance of the responses in each quarter of the trial revealed significant differences between the treatments, in the same way as obtained for total responses, in all four quarters of the trial. However, trends over trials were confined to the first and second quarter.

NUMBER OF REINFORCED RESPONSES

The proportion of total responses which were reinforced (for Ss responding for light change) varied little over trials and between treatments. The mean proportion for all trials and all Ss was 85.

MEAN DURATION OF BAR PRESS

The failure of several animals to respond during the initial trials of phase II precluded an analysis of the mean duration of bar press scores using the repeated measures procedure. Therefore, the mean duration of bar press over all trials in phase II was calculated for each animal and analysed as a 2 way factorial design, the factors being the same as the orthogonal factors in the response analyses. The analysis showed that the mean duration of bar press in the light Onset groups (0.94 sec.) was longer than in the light Offset groups (0.69 sec.) ($F = 8.81$, df 1,50, $p < .01$). There was no treatment effect (the mean duration for the operant treatments was 1.02 sec., and 0.76 sec. for all Ss responding for light change). For all Ss combined, the mean duration of bar press declined from the first five (0.99 sec.) to the last five trials (0.69 sec.) in phase II ($t = 4.76$, df 56, $p < .001$).

DISCUSSION

In general, the introduction of N-C light changes during phase I reduced responding for that light change in phase II, at least over the first few trials. This reduction is interpreted as due to adaptation to the light change as a stimulus beyond the control of the animal, with the result that when it was made response-contingent the sense of control over the light change was attenuated. In this way the higher response rate at the start of phase II in treatments which had not experienced the 3 sec. light change as a N-C stimulus is interpreted as due not so much to the novelty of the light change as such, but rather to the fact that the only experience of the light change in these treatments was as a stimulus under behavioural control - that the light change here is completely novel simply functions to increase the sense of control over it by strengthening the response-light change contingency. If anything, the higher response rate on the initial trials in LCBP, for *S*s with no previous experience of the light change, is a function of the control over a hitherto unexperienced stimulus, rather than to the novelty of the light change *per se*. An animal in this situation may respond more on the first trial than on later trials, not for exposure to a novel light change, but because *responding for light change is novel* and it has had no other experience with the light change which might weaken the sense of contingency or control.

The control aspect of the behaviour is emphasized because it is clear from the data that even after many

LCBP trials, involving considerable experience with the light change, responding in those treatments which did not receive N-C light changes in phase I at no stage declined to the level of responding observed in most of the N-C treatments over the initial trials of phase II. Consider, for example, a comparison of the 10 N-C light Offset treatment with the 2 min. darkness treatment. After 5 trials of phase II the latter treatment had received the light change over 100 times, yet the response rate was still more than four times that of the 10 N-C treatment (which had experienced only 50 light Offset changes over the 5 trials of phase I) at the start of phase II. In short, the response rate in LCBP is not so much a function of whether the light change has been experienced on previous trials, but whether the experience is mediated by responding or independent of behaviour, i.e. of whether or not the light change is under response control. If the experience is by N-C means the animals seem to learn that they have no control over the light change. This learning appears to diminish the efficacy of control when the light change is made response-contingent.

While this is the overall picture to be gained from the present results there are more detailed aspects of the data which require further comment. The light Offset data show that it makes little difference how many N-C light changes are given - the effect is the same, to diminish responding for light Offset. This finding adds weight to the point made above that the novelty of the light change as such, in the context of experience from trial to trial, has little effect on LCBP. On the other hand, there were fairly substantial differences between the three N-C light Onset treatments. In this case, the largest and most durable reduction in responding for light Onset followed 40 N-C light changes on each trial in phase I. There was an initial reduction in responding following 10 N-C light changes, but little reduction in the 20 N-C light Onset treatment. There is no apparent explanation of this difference between the effects of N-C light Onset and Offset.

Another question of some importance concerns the durability of the reduction in responding for light change following earlier N-C light change experience. The major question here seems to be whether the asymptotic response rate will be the same for all treatments, regardless of whether N-C light changes had been introduced. It might be expected, from the model of LCBP proposed here, that the reinforcing value of responding for light change in the N-C treatments would eventually increase as LCBP trials continued (cf. Experiment 5). As noted, the within and between Ss variability in the present data preclude conclusions about the response asymptote in most of the N-C treatments. However, there is a suggestion in figs. 11 and 12 and Table 12 that the reduction in responding is still evident over trials 11-15 in some treatments, while in others there is a suggestion of a "recovery" of responding. Further research is necessary to clarify this point.

The variability evident here may be a direct result of the N-C light change experience. But it may have arisen because of the possible disruptive effect of running the experiment at widely different times of the day. In any event the difference in results for light Onset and Offset, the obvious theoretical significance of the present findings and the much larger response rate variability than usually associated with LCBP all suggest that additional support for the present position on LCBP as control over an environmental stimulus change would be provided by a replication of the present results. Consequently, the next experiment to be reported consists of a replication and extension of the experiment reported here.

Finally, the mean duration of bar press results obtained here are in agreement with previous experiments (Experiments 1, 3 and 4) on the decline in the response duration from the first five LCBP trials to the last five LCBP trials . The present data are also in agreement with Experiments 1 and 5 with respect to a longer mean duration of response for light Onset than light Offset.

4.60. EXPERIMENT 7: Further Evidence concerning the Effects of Experience of a Light Change as a Stimulus not under Behavioural Control on Subsequent LCBP.

INTRODUCTION

It was concluded that the findings of Experiment 6 provide substantial support for viewing the reinforcement in LCBP as arising from the control over an environmental stimulus change. A persistent problem with much of the psychological research reported in the literature is that results fail to be replicated when (more often, if) the experiment is repeated. Partly to establish the reliability of the results of Experiment 6, and therefore to strengthen the conclusions drawn from them, the present experiment consists, in the main, of a replication of that study. All experimental conditions of Experiment 6 except for the operant control groups were included here. A particular aim of the present study was to determine the durability of any effects of the introduction of N-C light changes during the apparatus habituation trials. The response rate variability which occurred in Experiment 6 did not allow satisfactory conclusions about this durability. In an attempt to reduce the within treatment response rate variability a particular effort was made to ensure that Ss were run at the same time each day. Also, the power of the experiment was increased by including 10 Ss in each treatment.

Apart from examining the effects of N-C light changes on trials prior to the start of LCBP, additional treatment conditions were included in the present experiment to determine the possible effects of different ambient light conditions, during trials prior to the start of LCBP, on responding for light change. Specifically, the aim was to determine if responding for light Onset and Offset is affected by whether the apparatus habituation trials are spent in continiuous light or continuous darkness.

In summary, the experiment reported here was designed to examine the effects of N-C light change experience and ambient light change experience, during trials prior to the commencement of LCBP, on responding for light Onset and Offset.

Attention was focussed mainly on (1) whether the results of Experiment 6 showing a reduction of responding for light change following N-C light change experience would be replicated, (2) the durability of any such reduction and (3) following from (2), whether clear asymptotic response rates are established, and if so, the extent to which they vary according to the treatment condition prior to the start of LCBP.

METHOD

Subjects   The Ss were 120 female Wistar hooded rats about 130 days of age at the start of the experiment. All other conditions were the same as in Experiment 1.

Apparatus   The apparatus specifications are the same as for Experiment 6.

Procedure   The experiment was conducted in two phases. A constant inter-trial interval of 48 hrs. and a trial length of 20 min. were used throughout both phases. Half the animals were run on each day. The experiment was run between 9 a.m. and 2 p.m. each day, with no variations in running time from trial to trial. Throughout phase II the number of responses in each 5 min. quarter of the trial and the mean duration of bar press and number of reinforced responses over the whole trial were recorded.

Phase I. (Apparatus and light change habituation).

Throughout phase I the lever was covered with an aluminium panel, which prevented responding, in all cases. The animals were randomly divided into 12 treatment groups of 10 Ss. The treatment conditions applied to the various groups are set out in Table 13. One pair of treatments received 10 N-C light changes on each trial in phase I, another pair 20 N-C light changes and a third pair 40 N-C light changes. In phase II Ss in these treatments

TABLE 13.

Treatment Conditions in Phases I and II of Experiment 7.

PHASE I (LIGHT CHANGES NON RESPONSE-CONTINGENT)	PHASE II (LIGHT CHANGES RESPONSE-CONTINGENT)
40 N-C LIGHT ONSET	LIGHT ONSET
20 N-C LIGHT ONSET	LIGHT ONSET
10 N-C LIGHT ONSET	LIGHT ONSET
CONTINUOUS DARKNESS	LIGHT ONSET
CONTINUOUS LIGHT	LIGHT ONSET
2 MIN. CHANGE FROM DARKNESS TO LIGHT	LIGHT ONSET
40 N-C LIGHT OFFSET	LIGHT OFFSET
20 N-C LIGHT OFFSET	LIGHT OFFSET
10 N-C LIGHT OFFSET	LIGHT OFFSET
CONTINUOUS LIGHT	LIGHT OFFSET
CONTINUOUS DARKNESS	LIGHT OFFSET
2 MIN. CHANGE FROM LIGHT TO DARKNESS	LIGHT OFFSET

responded for the same light change as they had experienced in phase I. The 2 min. change from darkness to light (6.65 ft.c.) or from light to darkness occurred in the middle of each trial, as in Experiment 6. The final four treatments experienced either continuous light or continuous darkness throughout phase I. This phase lasted for five trials.

Phase II. (LCBP).

After the 5th trial the lever was uncovered and either light Onset or light Offset was made response-contingent, according to treatment allocation in the design. No N-C light changes occurred and responding was reinforced with a light change over the whole 20 min. trial. Trials were continued until it was clear from inspection of the data and tests for trends that a response asymptote had been reached in all treatments. 16 trials were given in phase II.

RESULTS

The principal analyses of responding were performed on the total number of responses in the 20 min. trial using a repeated measures analysis of variance (Winer, 1970). The orthogonal factors analysed were the direction of change (Onset and Offset) and the six treatment conditions (as set out in Table 13). To satisfy the assumptions of the analysis of variance all response rate data were subjected to a square root transformation.

TOTAL RESPONSES

A summary of the actual total response rate data from all treatments for both directions of light change is presented in Table 14. The analysis of all trials in phase II showed that more responses were made for light Onset than light Offset ($\underline{F} = 35.90$, $\underline{df}$ 1,108, $\underline{p} < .01$), but no significant differences between the six treatment conditions. The main effect of trials was not significant but trends over trials differed according to treatment condition ($\underline{F} = 1.64$, $\underline{df}$ 75,1620, $\underline{p} < .01$). Further analysis of these trends failed to yield significant differences between the treatments on any of the trend components from the linear to the quintic.

Because it seemed from the data (see Table 14, fig.13) that there were differences between the treatments over the initial trials of phase II which largely disappeared as trials continued, separate analyses were performed on responses over trials 6-10, trials 11-15, and trials 16-21. These showed that the difference between light Onset and Offset held in all three sets of trials. In addition, there were significant differences between the six treatments over trials 6-10 ($\underline{F} = 4.00$, $\underline{df}$ 5,108,

$\underline{p} < .01$), but not over trials 11-15 ($\underline{F} < 1$), or trials 16-20 ($\underline{F} < 1$). The direction x treatment interaction was not significant in any analysis. Significant trends over trials occurred in the analysis of trials 11-15 ($\underline{F} = 2.64$, $\underline{df}$ 4,432, $\underline{p} < .05$), but not in the analyses of either trials 6-10 or trials 16-21. The latter suggests that a response asymptote occurred over the last 6 trials of phase II.

In order to examine the differences between the treatment conditions in more detail the best fit regression equations up to the 5th order orthogonal coefficient, together with the least significant difference on each trial were calculated. These data indicated that almost exclusively, for both directions of light change, the only significant differences were between the three treatments which had not received N-C light change in phase I (the continuous light, continuous darkness and 2 min. treatments) and the three N-C light change treatments. The results from these sets of three treatments combined are presented in fig.13. It can be seen from fig.13 that the N-C light change treatments responded less during the initial trials of phase II than the treatments which had not experienced N-C light changes. This tendency was most pronounced for light Offset. It can also be seen that the reduction in responding in the N-C treatments was

TABLE 14.

Summary of Mean Number of Responses
per 20 min. Trial in Phase II.

	MEAN NUMBER OF RESPONSES		
TREATMENT	Trials 6-10	Trials 11-15	Trials 16-21
40 N-C LIGHT ONSET	14.7	23.1	22.2
20 N-C LIGHT ONSET	25.4	31.7	30.0
10 N-C LIGHT ONSET	29.6	26.6	25.3
CONTINUOUS DARKNESS	41.5	33.1	27.2
CONTINUOUS LIGHT	24.3	24.2	21.5
2 MIN. CHANGE FROM DARKNESS TO LIGHT	34.9	25.3	23.8
40 N-C LIGHT OFFSET	9.9	12.1	14.5
20 N-C LIGHT OFFSET	9.6	10.7	13.0
10 N-C LIGHT OFFSET	7.2	14.4	13.2
CONTINUOUS LIGHT	19.6	16.1	14.8
CONTINUOUS DARKNESS	24.5	21.4	17.2
2 MIN. CHANGE FROM LIGHT TO DARKNESS	21.6	17.6	17.9

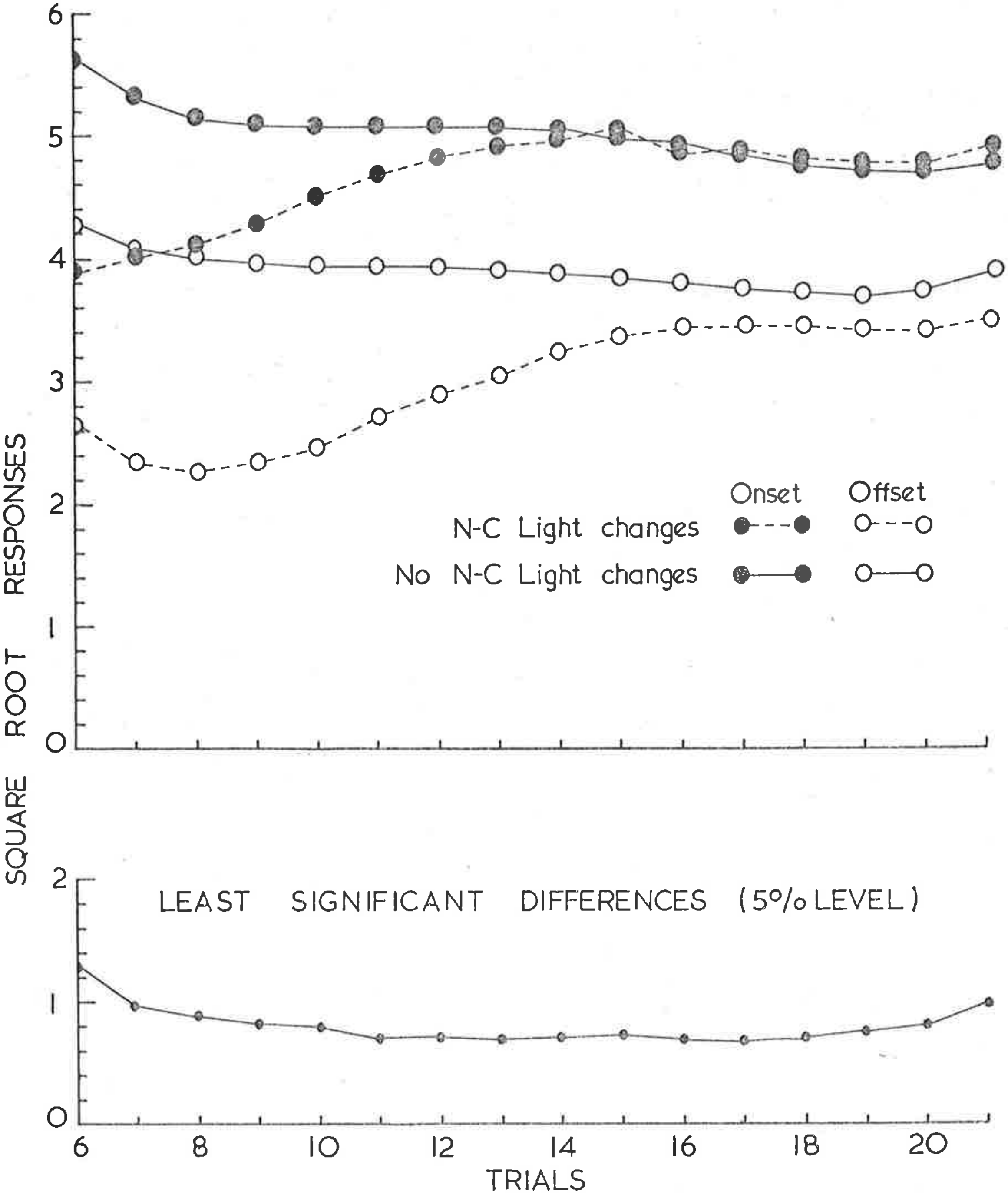


Fig.13. Responding in Phase II for light Onset and Offset as a function of whether or not nonresponse-contingent (N-C) light changes occurred in Phase I: Best fit curves and least significant differences.

temporary - responding increased over trials so that the asymptotic response rate did not differ from that reached by the other treatment groups. Responding here did not show marked fluctuations from trial to trial as in Experiment 6. Therefore, the rates over trials 16-21 in Table 14 can be taken as a reasonable estimate of the response asymptote.

Closer inspection (from the best fit curves and least significant differences) of the 10, 20 and 40 N-C treatments for light Onset and Offset showed that (1) there was little difference between the three N-C light Offset treatments (see Table 14), but (2) for light Onset, the 40 N-C treatment had by far the lowest response rate over the first few trials. In fact, as is suggested by the data in Table 14, there was no reliable reduction in the response rate of either the 10 or 20 N-C light Onset treatments. Responding in these two treatments was significantly above that of the 40 N-C light Onset treatment over the first 4-5 trials of phase II.

A closer examination was also made of the continuous light, continuous darkness and 2 min. ambient light change treatments. It revealed (1) no significant differences between these three treatments for light Offset, and (2) in the case of light Onset, the continuous light treatment responded reliably less than the "2 min. of light" and the continuous darkness treatments during the first two trials of phase II.

WITHIN TRIAL RESPONSE DISTRIBUTIONS

A general intra-trial decline in responding occurred in all treatments. There was little difference between treatments or trials in terms of this trend. The overall proportion of responses in each quarter of the trial, for all treatments combined was 43, 26, 17 and 14 respectively. In contrast to the analysis of all trials in phase II for total responses, the separate analyses of each quarter revealed reliable differences between the six treatments in the second ($F = 2.31$, df 5,108, $p < .05$), third ($F = 2.48$, df 5,108, $p < .05$) and fourth ($F = 2.45$, df 5,108, $p < .05$) quarters of the trial. The difference between light Onset and Offset was reliable in all quarters of the trial. Significant response trends over trials were confined to the first three quarters.

THE NUMBER OF REINFORCED RESPONSES

The proportion of total responses which were reinforced differed little from treatment to treatment. On trials 6, 7 and 8 this proportion, for all Ss combined, was 80, 83, and 85 respectively. It then showed slight variations around a mean of 86% for the remainder of phase II. The analyses of variance of the number of reinforced responses precisely paralleled those for total responses in all cases.

MEAN DURATION OF BAR PRESS

The failure of several animals to respond, especially on the first few trials of phase II, precluded an analysis of the mean duration of bar press data with the repeated measures procedure. Therefore, the mean duration of bar press, averaged over all trials, was calculated for each animal and analysed as a 2 way complete factorial design (Direction of change and Treatment condition). The analysis showed that the mean duration of bar press was longer for light Onset (0.68 sec.) than for Offset (0.57 sec.) ($F = 5.41$, df 1,108, $p < .05$). There was a general tendency for the mean duration to decline from trials 6-10 (0.77 sec.) to trials 16-21 (0.57 sec.) ($t = 7.88$, df 117, $p < .001$).

DISCUSSION

The present results concerning the effects of N-C light changes during the apparatus habituation trials on subsequent responding for light change replicates the findings of Experiment 6 i.e. the general effect is for the N-C light changes to reduce the subsequent reinforcing value of responding for that light change, at least over the initial LCBP trials. In fact, the present results replicated those of Experiment 6 even to the extent of showing (1) little difference between the effect on LCBP of 10, 20 or 40 N-C light Offset changes on every trial in phase I, and (2) for light Onset, a pronounced reduction in LCBP in the 40 N-C light change treatment, with less evidence of a reduction in the 10 and 20 N-C light change treatments.

In contrast to Experiment 6 the response rate here did not fluctuate widely from trial to trial. In part this may have been due to the increase in the number of Ss here and in part to the variations in the time of day at which Ss were run in Experiment 6. Either way, the present results enable valid conclusions about the durability of the reduction in LCBP following N-C light change experience. Overall, (i.e. as in fig.13) the N-C light change treatments had a significantly lower response rate than those treatments which did not receive N-C light changes, for 4 trials in the case of light Onset and 8 trials for light Offset. Equivalent asymptotic response rates were reached independent of the presence or absence of N-C light changes in phase I.

The interpretation placed on the present findings are the same as those outlined in Experiment 6. That is, the data reported here indicate that the initial reinforcing value of controlling a light change is diminished by prior experience of that light change as a stimulus beyond the control of the organism. They also show that with repeated trials involving responding for light change the reinforcing value of controlling or manipulating a light change then increases, i.e. as familiarity with the light change as a stimulus under response control increase, thereby neutralising the earlier experience of it as an externally imposed stimulus change. This finding is comparable to the slow increase in responding following the removal of prior exposure to N-C light changes in Experiment 5.

The present data show clearly, once again, that the differences in responding over the initial LCBP trials cannot be accounted for by the novelty *per se* of the light change - overall, there was little decline in responding over trials of treatments which had no N-C light changes introduced during the apparatus habituation trials. The crucial aspect here is whether the first occurrences of the light change are as a N-C event or as a response-contingent event. If the first occurrences are as a N-C event then the initial reinforcing value of responding for that light change is low, but increases as familiarity with the light change as a stimulus under behavioural control increases. This increase occurs while the light change as such is becoming even less "novel" with each trial. On the other hand, if the first occurrences are as a response-contingent event the initial reinforcing value of responding for that light change is high and declines only slightly as the light change as such becomes less "novel" over trials. The results provide substantial support for viewing the reinforcement in LCBP as stemming from control over an environmental stimulus change.

The differences in results for N-C light Onset and N-C light Offset are difficult to interpret. The light Offset data (from both Experiments 6 and 7) suggest that the N-C light change experience, rather than the number of such light changes, is what is important. In contrast, in both Experiments 6 and 7 40 N-C light Onset changes diminished LCBP more than 10 or 20 N-C light Onset changes. This might suggest that responding for light Onset, especially on early trials, is reinforced by more than just controlling an environmental stimulus change. Although not consistent with other data (Experiments 1 and 4) one such additional source of reinforcement may be the opportunity to visually scan the environment. Nevertheless, this is consistent with the present finding that fewer responses were made for light Onset on the first two LCBP trials by Ss which had spent all the apparatus habituation trials in continuous light than Ss which had spent these trials in continuous darkness or in darkness apart from a

2 min. period of continuous light on each trial, a result which is in general agreement with the findings of Hurwitz (1960). The continuous light group would have had greater opportunities to visually scan the environment during the apparatus habituation trials. This may have reduced the relative reinforcing value of light Onset in this group over the first two LCBP trials.

Finally, the mean duration of bar press results once again confirm the results of previous experiments in terms of a decline in mean duration from the commencement of LCBP to the terminal trials (Experiments 1, 3, 4 and 6), a longer mean duration for light Onset than Offset (Experiments 1, 5 and 6) and no systematic relationship between other treatment conditions and the mean duration (Experiments 1, 3, 4, 5 and 6).

In summary, the data obtained here (and in Experiment 6) demonstrate a difference between the effects of a light change which is contingent on responding and random light changes which are independent of behaviour. A comparable difference was also noted in Experiment 5. It is concluded that these data support the proposition that the reward in LCBP arises from the control over a light change which occurs when it is response-contingent.

4.70. CONCLUSIONS

On the basis of the data obtained in Experiments 3 and 4 it was concluded that the reinforcing effect of a response-contingent light change cannot be explained in terms of a general need or Drive for stimulus change. The possibility that LCBP could be conceived in terms of specific Drives aroused by light Onset and Offset was then examined (Experiment 5), and rejected. Despite the apparent agreement with a Drive theory model of many features of LCBP it is concluded that sufficient evidence has been presented here to reject a Drive interpretation (whether a general Drive for stimulation or a Drive for stimulation from a particular source) as a necessary and sufficient account of the LCBP phenomena.

It was proposed that the reward in LCBP is not the light change as such, but the contingency between the response and a light change. This reward was described as "control over an indifferent environmental stimulus change". This notion appears consistent with the findings of Experiments 3 and 5 which Drive theory could not satisfactorily accommodate. Furthermore, it was concluded that the results of Experiments 6 and 7 provide substantial direct support for viewing the reward in LCBP as control over the light change. The conjunction of the data from

Experiments 1-7 indicate several things about the nature of the reinforcement arising from control of the environment. Many of these have been noted. A detailed consideration of the nature of control over light change as a reward, especially as indicated by the present data, is undertaken in the following, and concluding, section.

5. CONCLUSIONS.

5.10. Introduction

The purpose of this section is to (1) examine some of the more salient experimental findings presented in sections 3 and 4 in the context of evidence and theories discussed in section 1, and (2) outline an alternate theory, concerning LCBP as control over an environmental stimulus change.

5.20. Theoretical Appraisal of LCBP

5.21. Scanning Theory

After a review of the literature in section 1 it was concluded that while the opportunity to visually scan the environment may affect the reinforcing value of response-contingent light change, in comparison with other factors scanning makes a relatively weak contribution. The experimental evidence presented in sections 3 and 4 (especially Experiments 1, 4 and 7) is wholly consistent with this conclusion. The only experiment in which there was evidence that visual scanning of the environment might significantly affect the reinforcing value of responding for light change was Experiment 7, where the reinforcing value of light Onset was reduced when the apparatus habituation trials were spent in continuous light. In most of the studies (Experiments 3, 4, 5 and 6) there was no difference between the reinforcing value of light Onset and light Offset. Scanning theory would predict a greater reinforcing effect for Onset. Light Onset was more reinforcing than Offset in Experiment 7, and for 3 sec. changes there was some evidence in Experiment 1 that light Increment may be more reinforcing than a comparable light Decrement, but only over the initial LCBP trials.

Overall then, the experimental data obtained here suggests that the opportunity to visually scan the environment does not make a substantial (or consistent) contribution to the reinforcing effectiveness of response-contingent light change.

5.22. Stimulus-Change Theory

It has been claimed that according to Stimulus-Change theory "the crucial reinforcing event in LCBP is stimulus change", i.e. change *per se* (e.g. Lowe & Williams, 1968, 1969; Williams & Lowe, 1967, 1970). In this way, the Stimulus-Change position has been construed to mean that the organism is responding *for* a change *per se*. If this is accepted, then the question arises as to what mediates the reinforcing effect of a change *per se*. Two possibilities are a general need for change (incorporating the positions that change *per se* will be attractive to the extent that it produces an optimum level of arousal or stimulation) or a specific curiosity Drive aroused by a particular change. Both possibilities were examined, and on the basis of experimental evidence (Experiments 3, 4 and 5) largely rejected. It was therefore proposed that the crucial reinforcing factor in LCBP is the control of the light change and not the light change itself. Either way it is necessary to determine if the light change functions as a change _per se_.

It was concluded in section 1, after a review of the literature, that in the main, and especially with hooded rats, light change does function as a change _per se_. The experimental data reported here provide additional support for this conclusion. In Experiment 1 there was a positive relationship between the magnitude of light change and reinforcing value. In all experiments both directions of light change were reinforcing. In Experiment 4 the ambient illumination to which the animal was "exposed" immediately prior to LCBP had no significant effect on responding for light change. These findings follow directly from Stimulus-Change theory.

While light Onset and Offset were equally reinforcing in several studies (Experiments 3, 4, 5 and 6) it was argued (section 3.40) that such a result does not follow of necessity from Stimulus-Change theory. Nevertheless, it still leaves the problem of accounting for the fact that in Experiment 1 the response asymptote for a 3 sec. light Increment (6.53 ft.c.) was lower than that for a comparable light Decrement, while in Experiment 7 light Onset was much more reinforcing than light Offset. That is, for a 3 sec. change, a light Increase was more reinforcing than a comparable Decrease in Experiment 7, the reverse occurred in Experiment 1, and in the other experiments there was no difference between an Increase and a Decrease. Any attempt to explain these differences would be largely speculative. One point is fairly certain, the differences are inherent in the animal populations and not in apparatus or procedural differences. The nature of such population differences and their origins is not apparent. Notwithstanding this, the sum total of the experimental evidence accumulated here points to the conclusion that the light changes used functioned predominantly as a change *per se*.

An important result to emerge from the present research was that the duration of light change was related to responding for light change (Experiments 1 and 2). Undoubtedly the finding, in Experiment 1, that a 3 sec. light Decrement was an effective reinforcer whereas a duration of bar press (DBP) or ½ sec. Decrement had virtually no reinforcing value, was the most important aspect of the results dealing with the duration of change parameter. This, together with the fact that in all subsequent experiments a 3 sec. light Offset change had clear reinforcing effects is fairly conclusive evidence that other research in which light Offset, for the DBP, was not found reinforcing (e.g. Barnes & Kish, 1957; Barnes, Kish & Wood, 1959; Hurwitz, 1956; Robinson, 1959) is a function of the duration of change and not the direction of change or the consequent level (darkness). The latter failures seem to have provided difficulties for the development of theories about LCBP (cf. Kish, 1966) and have certainly influenced research on LCBP by the fact that many experimenters investigate only light Onset (e.g. Donahoe, 1965; Morrison, 1965; Premack & Collier, 1962; Tapp, Mathewson & Jarrett, 1968; Davis, 1958).

Mainly because of the obtained effect for the duration of light change it was argued (see Experiment 1 and section 3.40) that the qualities of a light change, as a change _per se_, are determined by the magnitude of change (the difference between the initial and consequent intensity), the direction of change and the duration of change. It is not possible to integrate these three parameters into a comprehensive formulation on the basis of the present experimental findings. The major point is that differences between the reinforcing effects of response-contingent light changes in opposite directions do not, ipso facto, require the postulation of other factors, such as light intensity preferences to explain them.

5.23. Drive Theory

In many ways classical Drive theory has satisfied the criteria of a good theory. It has helped describe, systematise and "explain" a great deal of data. It has been of unquestionable heuristic value. But the results of many of the experiments which it generated are now contributing to the growing dissatisfaction with Drive theory. This dissatisfaction seems, at this stage, to be more pronounced within the area of the homeostatic and biogenic behaviours such as those dealing with food, water and sexual rewards (Bolles, 1958, 1967; Cofer & Appley, 1964; Appley, 1970; Beach, 1956) where the theory first arose, than in the area of curiosity-exploratory behaviour to which it was, possibly without reasonable justification, subsequently applied.

There is no doubt that a Drive formulation is a popular means of "explaining" curiosity-exploratory behaviour (e.g. Fowler, 1965, 1967; Berlyne, 1960, 1969a;

Berlyne & Slater, 1957; Nicki, 1970; Harlow, 1953a; Harlow, Harlow & Meyer, 1950; Schultz, 1967). Insofar as LCBP is intrinsically motivated behaviour involving stimulus change it belongs in this class, and indeed it has been so grouped by most reviewers (e.g. Fowler, 1965, 1967; Berlyne, 1960; Kish, 1966).

Drive theory has been applied to curiosity-exploratory behaviour i.e. behaviour apparently reinforced by stimulus change, in two ways. On the one hand (Myers & Miller, 1954; Fowler, 1965, 1967; Schultz, 1967) and in line with the theory as applied to the biogenic Drives, it is argued that Drive is aroused by constant and unchanging stimulation, that this Drive energises behaviour and that Drive reduction reinforces behaviour. The Drive here can be conveniently labelled "boredom Drive". Fowler combines the Drive construct with an Incentive-motivational construct (K). K is determined mainly by the magnitude of change and the number of times the change has been experienced. Nevertheless, Fowler considers it crucial that the Drive in curiosity-exploratory behaviour be anchored in antecedent deprivation conditions. With respect to the effects of unchanging stimulation or "boredom" this theory has much in common with Glanzer's (1953) theory of stimulus satiation.

On the other hand (e.g. Berlyne, 1955; Montgomery

& Segal, 1955; Montgomery & Zimbardo, 1957; Harlow, 1953a) it is argued that Drive (usually called a curiosity Drive) is aroused by "(novel) external stimulation rather than by the internal state of the organism, and it is satiated quickly by continuous exposure to the same stimulus situation" (Bindra, 1957, p.408). Berlyne (1960, 1963, 1965), Berlyne & Peckham (1966), and some of his associates (e.g. Nicki, 1970) have gone one step further and suggest that both kinds of Drive model are necessary to account for curiosity-exploratory behaviour. That is, constant and unchanging stimulation may arouse a "boredom Drive" and induce stimulus seeking behaviour, but also, in the absence of a boredom Drive, a specific perceptual or curiosity Drive may be "aroused by the exposure of the organism to novel, ambiguous, incongruous or surprising stimuli" (Nicki, 1970). These two types of exploration were labelled diversive exploration and specific exploration respectively.

The application of both types of Drive theory to LCBP was examined, on strictly empirical grounds, in Experiments 3 and 5 respectively. The results of Experiment 3 (and 4) demonstrate that LCBP cannot be considered to be motivated by a "boredom Drive". In other words, LCBP is not motivated by a general need for stimulus change where such a need is due to stimulus change deprivation. Additional support for this argument is provided by (1) the finding that twice as much responding occurred when a light change was made response-contingent on two levers in the Skinner box than when a light change was response-contingent on only one lever (Levin & Forgays, 1959) and (2) the results of another experiment from the present laboratory (Glow & Russell, 1971, unpublished) in which it was found that rats placed in an environment of continually fluctuating light (light or darkness, with a phase time of ½ sec.) would bar press for short periods of time out from the continuous stimulus change. To a certain extent the review of the literature dealing with stimulus change deprivation and LCBP (section 1.71) also supports the present argument. Notwithstanding the possibility that general sensory deprivation may potentiate LCBP, although this has yet to be satisfactorily demonstrated, the point made in section 1.71 was that, typically, responding for light change is reinforcing in the absence of any kind of general sensory deprivation. As Premack & Collier (1962) noted, the only kind of deprivation which can reliably increase LCBP is LCBP deprivation (as shown by the effects of inter-trial interval - see Premack & Collier, 1962; Forgays & Levin, 1961). It was mainly this feature of most curiosity-exploratory behaviour - that it occurs in the absence of a specific deprivation condition - which influenced Bolles (1958, 1967) and others (Brown, 1953; Estes, 1958) to reject Drive theory as a means of explaining such behaviour. In summary, there seems little evidence which would support an analysis of LCBP, as sensory change reinforcement, "in terms of a single "stimulus hunger" or Drive for stimulation" (Kish, 1966, p.127) where this hunger is assumed to be due to antecedent deprivation conditions. Accordingly, as the data do not provide evidence that LCBP is motivated by a Drive for stimulus variation, LCBP cannot be viewed within the framework of a homeostatic Drive (e.g. the "sensoristasis" Drive of Schults, 1965).

Does this leave the only alternative as being "a series of drives specific to different test situations, or sensory modalities [different directions of change within each modality should also be added], or perhaps both" (Kish, 1966, p.127)? If it is argued that any alternative <u>must be</u> of a Drive theory kind, then the evidence presented here (Experiment 3) and other data (e.g. Berlyne, Koenig & Hirota, 1966) would indicate an affirmative answer. From a theory construction viewpoint there seems little to recommend this approach. Nevertheless, the possibility of "explaining" LCBP by a specific curiosity Drive aroused by a novel stimulus and which is sated by exposure to that stimulus will be examined. Experiment 5 was directed toward this possibility. The results of that experiment, together with other data from LCBP research, provide empirical grounds for rejecting the exteroceptively aroused Drive formulation as a means of accounting for LCBP. There are also theoretical grounds for such a rejection. Firstly the empirical grounds.

The results of Experiment 5 failed to support the proposition under consideration in three ways. Firstly, the number of light changes experienced immediately prior to the start of LCBP was not related to the number of responses made for light change. Secondly, responding for light change in all treatment groups did not decline immediately the prior exposure to light change experience was commenced. Thirdly, when the immediate prior exposure to light change was terminated, responding for light change did not "recover" immediately. An important difference between the effects of light change which are randomly introduced independent of behaviour and those which occur as response-contingent changes was noted in Experiment 5. Similar differences occurred in both Experiments 6 and 7 and were interpreted as showing the importance of the response-light change contingency in LCBP rather than the simple occurrence of the light change.

Therefore, it is argued that there are several features of the results of Experiments 5, 6 and 7 which fail to support an explanation of LCBP in terms of a Drive aroused by novel stimuli. This point is well illustrated by the fact that in Experiment 7 responding for light change in those treatments which had received N-C light changes during the apparatus habituation trials actually increased over trials as the light change was becoming less "novel".

Another aspect of LCBP which seems to oppose this type of Drive explanation of LCBP is the durability of the phenomenon, both within trials and across trials. As noted by Bindra (1957) an exploratory or curiosity Drive is typically claimed to be aroused by NOVEL stimuli and quickly satiates as the stimulus loses its novelty. If this were so in LCBP it would be expected that responding for light change would rapidly habituate out, leaving a virtually zero level of responding. But on the contrary; within trials responding declines to an asymptotic involving some responding. This was evident in all experiments reported here, where a 20 min. trial was used. Responding was fairly constant over the last 10 min. of each trial when Ss responded for the same light change over the full 20 min. trial. The same result emerges when longer trials were used, for example a one hour trial (Glow, 1970). Across trials responding reaches an asymptote which indicates a stable, long term reinforcing effect. Moreover, when hooded rats were tested continually, 24 hrs. a day, for several weeks, responding for light change not only remained rewarding, but actually increased in reinforcing value (Sackett, 1965). There is obviously more to the reinforcing effect in LCBP than exposure to a novel stimulus. For this reason it seems that LCBP is beyond the scope of the general theories which claim "that new stimuli are attractive" (O'Connell, 1965, p.170), whether or not the theory postulates that a Drive is aroused by such stimuli. The latter have been termed "titillation theories" and are distinguished from "tedium theories" which are those theories based mainly on "stimulus satiation" or "boredom" (see review, O'Connell, 1965).

The theoretical criticisms of the exteroceptively aroused curiosity Drive formulation have been outlined by Fowler (1965, 1967) and others. Firstly, it has been noted that this is a circular argument and therefore does little by way of explanation. The Drive is both inferred from and used to explain the behaviour. This point has been made by several critics (e.g. Brown, 1961;

Estes, 1958). Secondly, Fowler (1965, 1967), Brown (1961) and Brown & Farber (1968) note that a feature of curiosity-exploratory behaviour is that organisms will perform an instrumental response to obtain exposure to a stimulus change. This suggests that the Drive or motivational force is present before the exposure to the novel stimulus occurs. Such instrumental responses, as in LCBP, demonstrate that a simple proposition that "when a novel stimulus affects an organism's receptors, there will occur a drive-stimulus-producing response.... which we shall call "curiosity" ....." (Berlyne, 1950, p.79) cannot account for the occurrence of most curiosity-exploratory behaviour, including LCBP. The point is well taken: the motivation underlying LCBP is present before the response is made and serves to energise the response.

The conclusion reached is that LCBP cannot be reasonably interpreted in terms of either form of Drive theory discussed here.

5.24. Optimum Level of Arousal or Stimulation

Principally in an attempt to provide a unifying concept for a large variety of behaviour, several authors have argued that organisms strive for an optimum level of arousal[6] or stimulation (Hebb, 1955; Hebb & Thompson, 1954; Leuba, 1955; Berlyne, 1960; Fiske & Maddi, 1961; Dember & Earl, 1957). This notion also forms a part of the formulations of Schultz (1967) and Glanzer (1958).

When examined closely, there are several detailed differences amongst the various "optimum level" positions. Most of these are beyond the scope of the present discussion. However, worthy of note is the direction from which arousal is claimed to approach the optimum in curiosity-exploratory behaviour. Whereas most theorists conceive exploratory behaviour and stimulus change as increasing arousal or stimulation, Berlyne (e.g. 1965) has argued that such activity reduces arousal (Drive). In Berlyne's formulation "boredom", or curiosity aroused by a specific stimulus, produces an increase in arousal or Drive which is reduced by stimulus change and exploration[7].

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[6] To relate the present discussion and the previous section on Drive theory, it should be noted that there is some agreement that Drive and arousal or activation can be roughly equated (Berlyne, 1963, 1965, 1969a; Fiske & Maddi, 1961; Malmo, 1958, 1959).

[7] However, Berlyne's position has varied from one publication to another and sometimes within a particular publication. In recent articles (1969a,b) for example, it is not clear that he adheres to this viewpoint. The apparent contradictions in some of Berlyne's views also have been noted by Appley (1970).

Despite this difference it is possible to consider the general question: is LCBP mediated by an attempt to attain an optimum level of arousal or stimulation? If LCBP is to be accounted for in this way the assumption must be made that prior to LCBP the level of stimulation was below the optimum (which produced a level of arousal either above or below the optimum, depending in one's theoretical position). Most of the evidence relevant to this assumption has been outlined under the heading of Drive theory (section 5.23). The data pertaining to the notion of a "boredom Drive" presented in that section indicates that it is unlikely that such an assumption can be justified. The optimum level is rarely defined precisely, but this conclusion is strengthened further if the optimum level is defined "as the normal or characteristic level" (Fiske & Maddi, 1961, p.45).

Rather than an optimum level of arousal or stimulation it seems more reasonable to postulate an optimum <u>range</u>. There is considerable evidence showing the aversive nature of both very low levels of arousal or stimulation (e.g. the sensory deprivation studies - Schultz, 1965; Brownfield, 1965) and very high levels of arousal or stimulation (Berlyne, 1960, 1969a; Schultz, 1967). Within these two limits there would appear to be a <u>range</u> of arousal or stimulation levels which are not disruptive of normal functioning, and which in fact, are "characteristic" in the sense that the level of arousal or stimulation will fluctuate within a range under normal circumstances. It is argued that the levels of arousal or stimulation, prior to and during LCBP, are above the lower limit of the optimum range. In the main, the levels of arousal or stimulation involved in LCBP would also appear to fall below the upper limit of the optimum range. However, there is evidence that in some cases LCBP may result in levels of stimulation at or above the upper limit of the optimum range. The postulation of an inverted U relationship between the magnitude or novelty of light change and its attractiveness in Stimulus-Change theory appears to be based on the notion of an upper limit to the capacity of the organism to accommodate novelty and change. Central to the notion of an optimum range proposed here is the proposition that the upper limit will be raised as experience with novelty and change accumulates. The latter is also central to most optimum level theories, where it is claimed that such experience will raise the optimum level (Dember & Earl, 1957; Glanzer, 1958).

The combination of an upper limit to the optimum range of stimulation and a shift in this limit with experience of novelty and change was invoked to account for the results obtained in Experiment 3. The results for the largest light Increment and Decrement in Experiment 1 could also be accounted for in this way. Other experimental data on LCBP which suggests the operation of an upper limit to the capacity of the organism to accommodate novelty and change have been reported by Donahoe (1965, 1967) and by Lowe & Williams (1969).

The present argument can be developed further by an examination of the possible arousal effects of light change. Any theory of LCBP which claims that responding for light change is reinforcing because of shifts in the arousal level must be based on a demonstration that light change does in fact affect arousal. One method of investigating this is by measuring the various autonomic and central components of the orienting reflex (OR) (Sokolov, 1963) to light change. The evidence from this type of investigation indicates that not only do the general components of the OR, e.g. GSR, habituate quickly to such stimuli as light change (Lyn, 1966; Maltzman, Harris, Ingram & Wolff, 1971), but also the specific components, e.g. the visual evoked potential, also habituate quickly

(Fox, 1964). These data suggest that light change in LCBP has little effect on the arousal level of the organism. Therefore, it would appear that the optimum range hypothesized here is, in LCBP, primarily a function of the stimulation, its novelty, magnitude, etc. and not of the possible effects on arousal that such stimulation may have.

The conclusion reached is that LCBP behaviour usually occurs within the optimum range of stimulation and that to the extent that it does, light change can be considered to be an indifferent stimulus which is, in large part, biologically neutral. The light change is no longer an indifferent stimulus when the amount of novelty or change resulting from the occurrence of the light change reaches the upper limit of the optimum range. When the level of stimulation which is produced by LCBP does not exceed the upper limit of the optimum range, the light change can be considered an indifferent stimulus. The indifference refers to the fact that the light change does not serve to satisfy a need of any kind and is of no direct biological consequence to the organism either through effects on arousal or through the production of a level of stimulation which is conducive to "normal functioning".

5.250. Control of an Environmental Stimulus-Change[*]

It has been argued (Experiments 3, 5, 6 and 7) that the reward in LCBP is provided by the control over a light change which arises when the light change is made response-contingent, and not by the light change itself. This notion is favoured to alternatives (as already discussed) largely for three reasons. Firstly, the light change cannot be considered to satisfy a need for stimulus change, whether this need is claimed to arise from a "boredom Drive" or a need to maintain a so called optimum level of arousal or stimulation. In this way it is argued that the light change can be considered an indifferent stimulus. Therefore, it is unlikely that organisms will respond for light change because of any reward value associated with the light change as such. Secondly, the durability of the LCBP phenomenon suggests

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[*] Following the completion of this thesis, the publications of Kavanau (e.g. 1966, 1967, 1968), who is working outside the mainstream of psychology, came to the attention of the author. In essential respects, the theoretical position of Kavanau, a zoologist, is the same as that advanced here, although the two accounts do differ in several details. The latter do not place the two theories in conflict, rather, they serve to complement each other.

that the animals are not responding simply for exposure to a novel stimulus[9]. Therefore, it is questionable whether the long term reinforcing efficacy of LCBP can be accounted for in this way. Thirdly, the apparent differences between the effects of response-contingent and nonresponse-contingent light change (Experiments 5, 6 and 7) i.e. between a light change which is under behavioural control and a light change which randomly occurs independent of behaviour.

5.251. An Outline of a Theory

The proposed theory of LCBP as control over a stimulus change involves five sets of postulates, which can be seen as tentative generalisations based mainly on the present findings.

1. The behavioural control of a discriminable environmental stimulus change, and in particular a light change, is attractive, pleasurable and rewarding. To a certain extent this proposition appears to follow of necessity from the observed reinforcing effects of bar pressing for light change. Nevertheless, it also predicts that responding for other sensory changes will be reinforcing. In support of this, reinforcing effects have

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[9] This point is also emphasized by Kavanau.

been reported for bar pressing for sound changes (Glow, Roberts & Russell, in press; Andronico & Forgays, 1962; Barnes & Kish, 1961), vibration (Hunt & Quay, 1961), odours (Tapp & Long, 1968) and other sensory changes (see reviews, Kish, 1966; Hinde, 1970, pp.594-602). The relative reinforcing efficacy of controlling changes in different sensory modalities may be a function of the evolutionary history of the animal, with greater reinforcing effects associated with sensory modalities predominantly used as sources of information about the environment.

The reinforcing effects of control of a stimulus change also seems to be indicated by the fact that in the preference procedure (see section 1.51) rats will continue to respond when by responding they place themselves in an aversive level of illumination (Lockard, 1962a) or in a nonpreferred sound intensity level (Glow, Roberts & Russell, in press). The results of Neuringer (1970) could also be interpreted as demonstrating the reward value of exercising control of an aspect of the environment. He found that under some conditions animals would respond many times to obtain one food reward while identical food was freely available.

That control of the environment has rewarding effects would appear to be of importance biologically.

The biological significance of an appreciation of relationships between behaviour and the consequences of that behaviour on the environment are obvious. If there were no consistent perception of the relationships between behaviour and its consequences an organism could not survive in its natural habitat, or probably in any habitat for that matter. It seems that this feature of all living organisms, their capacity to, and the necessity of, interacting effectively with their environment, forms the basis for the pleasurable or positive motivational effects of a contingency between behaviour and an environmental change.[10]

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[10] Kavanau (1967, pp.1623-1624) points out that

> "animals in the wild exercise a relatively high degree of control over the environment, for example, by selection of nest site, territory, food, and time and degree of activity and social contacts and by manipulation of many objects. But the activities of captive animals and their opportunities to interact with and modify the environment are restricted severely, with the consequence that their behaviour becomes markedly distorted. A large amount of activity becomes channelled into "controlling the environment", that is, into manipulating, and altering relationships with, any susceptible environmental features. The most rewarding of several alternative outlets for activity (that is, the one engaged in most) presumably is the one that substitutes best for (or possibly even would be preferred to) the spectrum of activities in the wild. However, when outlets are highly restricted, as is usual, virtually any opportunity to modify environmental variables is exercised repeatedly, in little apparent relation to the appropriateness of the act as a substitute activity."

2. The larger the magnitude or "amount" of light change the greater the reward value associated with controlling that change.

In essence, the suggestion is that greater control over the environment is associated with a larger response-contingent environmental change. The magnitude of light change refers to the difference between the initial and consequent light intensity. The "amount" of change refers to such factors as whether the light is steady or flickering (e.g. Williams & Lowe, 1967; Lowe & Williams, 1969), whether the light source shifts from one point in the environment to another (Donahoe, 1965, 1967) or whether light changes of different magnitudes or directions are response-contingent for the same Ss (Experiment 3). A small light change represents only a minor change in the environment, whereas a larger light change constitutes a greater environmental change. This is borne out by the results of Experiment 1. Other experiments in which a larger magnitude or amount of change was associated with more LCBP have already been mentioned in the review of the literature (section 1.5).

It would be helpful if the duration of light change could be meaningfully included here as a parameter of the magnitude of light change. But, as noted above, little more can be said than that the duration of light change is related to the number of responses for light change, with a tendency for shorter durations of light Increase and longer durations of light Decrease to produce the most responses, at least in naive _S_s.

3. _The reward value of responding for a particular light change increases with the sense of control over that change._

One way of manipulating the sense of control over a given light change is by introducing nonresponse-contingent (N-C) light changes. It was argued (Experiments 3, 5, 6 and 7) that because N-C light changes are not under behavioural control they reduce the sense of control over that light change when it later occurs as a response-contingent event. Given that this is so, the results of these experiments provide evidence that if the sense of control is reduced by N-C light changes there is a diminution of the reward value of responding for that change. Experiments 5 and 7 also demonstrate that when the N-C changes are no longer introduced, the reinforcing value of responding for light change increases, i.e. as the sense of complete control over the change is either re-established or established.

Further, it is likely that the sense of control would also be related to the nature of the response. This might be expected to operate in two ways. Firstly, to maximise the sense of control, the response required to produce a light change should be specific, discrete and relatively unique. If the light change occurred as a result of ambulation or movement in one part of the Skinner box or similar apparatus for example, it could be argued that the sense of control over the light change would be less than if a bar pressing response is used. An ambulatory response, and therefore the contingency between behaviour and an environmental change, is less clearly defined than for a bar press response. Secondly, if the response necessary to produce a light change is complex or requires considerable effort it might again be expected that the sense of control would be diminished. In both respects a bar press seems ideal. It is simple, discrete and a comparatively unique and distinct response requiring little effort. These suggestions are somewhat conjectural. Nevertheless, it is reasonable to expect that the nature of the response would be an important factor in determining the sense of control over an environmental change. This expectation is supported by data reported by Thomas, Appel & Hurwitz (1958) and is in agreement with Johnson's (1965) speculations concerning the effects of the type of response on response-contingent light change behaviour.

4. Within each trial a particular light change will be subjected to stimulus satiation and therefore there will be a decline in the reward value of controlling that light change. If two light changes have sufficiently different parameters the rewarding effect of controlling one will be independent of the rewarding effect of controlling the other. In the generic sense then, the reward value of control of an environmental change does not satiate. Satiation will dissipate between trials, with greater dissipation associated with longer inter-trial intervals.

The data reported here provide ample evidence of a within trial decline in the reinforcing value of a particular response-contingent light change. In view of the results of Experiments 3 and 5 this decline would seem to be due in part to stimulus satiation. That is, as a stimulus is repeatedly experienced in a short period the organism becomes sated for that stimulus and as it does so the reward value of controlling it declines. This conclusion is based mainly on the obtained effects of immediate prior exposure to nonresponse-contingent (N-C) light change in Experiments 3 and 5. However, as already mentioned, these results are open to the interpretation that the N-C light changes reduced the sense of control over that light change. If the latter interpretation is accepted then it might be argued that a decline in the reinforcing value of controlling a particular light change is not due to stimulus satiation, but rather to the satiation of control of that stimulus. It is not possible to separate these two alternatives on the basis of the present data. It is likely that both factors contribute to the characteristic within trial decline in LCBP.

The point that, in the generic sense, the rewarding effects of controlling an environmental change will not satiate is the same as that made by Woodworth (1958) with respect to exploration, i.e. that exploration in general does not satiate, only exploration of a particular object etc. The results of Experiment 3 substantiate this argument by demonstrating that the reinforcing effect of control of a light Onset change is independent of the reinforcing effect of control of a light Offset change. Between these two extremes it might be expected that the satiation associated with a 3 sec. light Onset change, for example, would generalise to other light Onset changes of different durations, or to light Onset changes to a different consequent light intensity. The precise extent to which generalisation from one light change to another will occur can only be established by further research.

With a 48 hr. inter-trial interval, as used throughout the research reported here, the satiation which occurs within each trial is largely dissipated between trials. If a shorter inter-trial interval had been used, the recovery of LCBP from one trial to another would have been less complete, as indicated by the data of Premack & Collier (1962) and Forgays & Levin (1961).

5. Control of a light change has comparatively weak but persistent reinforcing effects.

Response-contingent light change reinforcement is certainly not as powerful a reinforcer as any of the more biologically based reinforcers such as food, water, sex, or the avoidance of pain. In a normal environment if an animal is deprived of food, for example, a large portion of its behaviour is directed toward the satisfaction of this need. Once the immediate need is satisfied the organism returns to interacting with and dealing with its environment in other ways. The latter is undoubtedly the way most of the time of humans is spent. This would seem to apply to animals. Therefore, most of the behaviour of humans and animals is behaviour not directly related to the satisfaction of immediate biological needs. This point seems to be reflected in the persistent reinforcing effect of controlling a light change. While responding declines within any one trial, it stabilises at a rate above zero. This is clearly shown in Experiment 6 where the reinforcing effect of LCBP was still evident in the last 5 min. of the trial. Within this context, the results of Glow (1970) and Sackett (1965) have already been mentioned (see section 5.23). Across trials as well, it is clear that responding for light change has a persistent rewarding effect. Results of experiments using the preference procedure (where a unidirectional light change is response-contingent) which have involved testing Ss 24 hrs. a day for several days also support this proposition (see Lockard, 1962a,b,c, 1964, 1966; Thor & Hoats, 1968).

It is not suggested that all response-contingent sensory changes will have persistent reinforcing effects. The durability of any reward value will be dependent upon the magnitude and other characteristics of the sensory change within the context of the species and strain of animal. The main point is that, given a change of the appropriate dimensions the reinforcing effect of responding for that change appears to be remarkably resistant to complete satiation.

5.252. Some Limitations of the Theory

This theory, as just outlined, is based on the assumption that the light change, or indeed any response-contingent sensory change, has no positive or negative reinforcing effects in its own right. As argued throughout this thesis, especially for hooded rats responding for light change, this assumption can be largely substantiated. Nevertheless, to provide the theory with a greater generality and to indicate more clearly the context within which the theory is considered to operate, several additional points need to be made. In some cases the light change, or any other sensory change, may have positive or negative properties in its own right. These will serve to modify the basic reinforcing effect of control over an environmental stimulus change.

Firstly, the positive reinforcing effects of the light change. It is possible that some additional reinforcing value will be associated with responding for light Onset or Increment because of the opportunity to visually scan the environment that such changes provide. This factor may have measurable effects in visually complex test environments (see section 1.42). Additional reinforcing effects may also occur if the light change places the animal in a preferred level of illumination or allows it to escape from a less preferred level of illumination. This aspect of LCBP is chiefly of relevance to albino _S_s. Finally, if an animal is deprived of stimulus change, or the level of arousal or stimulation prior to the start of LCBP is below the optimum range, the light change as such may provide an additional source of reinforcement because it represents a form of stimulation.

Secondly, the negative properties of the light change. A factor of some importance here is whether the novelty of the light change, or the level of stimulation produced by responding for light change, reaches or exceeds the upper limit of the optimum range. In short, an animal will not continue to respond for light change if the level of novelty or stimulation involved is beyond its capacity to easily accommodate such. In LCBP the animal is not under any powerful biological constraints to respond. This aspect of the behaviour was invoked to account for certain features of the results obtained in Experiments 1 and 3. It could also be used to account for some of the data of Lowe & Williams (1969) and Donahoe (1965, 1967). Furthermore, there is evidence to suggest (Berlyne, 1969a,b) that the optimum range of stimulation will shift with the "base level" of arousal, as determined for example, by the injection of arousal producing drugs or traumatic experiences prior to the LCBP trial. The effect of the "base level" of arousal could be used to account for the effects of apparatus habituation trials (see section 1.60), where it might be argued that the initial experiences of the test environment evoke fear and arousal.

Another limitation of the present theory is that the frequency of responding for light change is partly a function of the strength of competing stimuli and responses. The strength of such competing stimuli and responses will depend on many things, including the complexity of the test environment and the past experience of the animal with novelty, change, etc. However, it seems likely that competing stimuli and responses will largely habituate as the test environment becomes more familiar.

5.253. Some Advantages of the Theory

Stimulus-Change theory has been the most popular theory of LCBP. The difficulty here is whether this so called theory can be reasonably classified as a comprehensive theory of LCBP. As a descriptive summary of LCBP, the assertion that "a response-contingent stimulus change is reinforcing" is fairly satisfactory. But if it is claimed that stimulus change is the crucial reinforcing event, then the question arises as to *why* stimulus change is reinforcing. To account for the reinforcing effect in LCBP, Stimulus-Change theory must be supplemented. Two possible ways of explaining the reinforcing effect of stimulus change are that it represents a novel stimulus and is therefore attractive, or that stimulus change satisfies a need for stimulation or stimulus change. Both possibilities were examined within the framework of Drive theory and found not substantiable.

The main advantage of the present formulation is that it provides a comprehensive account of LCBP behaviour. It therefore, (1) incorporates all that Stimulus-Change theory purports to explain, and (2) provides an account of those aspects of the behaviour beyond the scope of Stimulus-Change theory. With respect to the latter, it provides an alternative to Drive theory which has been found unsatisfactory.

Furthermore, it can be seen that the present theory generates several unique predictions about LCBP behaviour. Some of these are based on a recognition of the nature of the response as a determinant of the S's sense of control over the environment via its effect on the response-light change contingency. It also clearly distinguishes between the effects of response-contingent sensory changes and nonresponse-contingent sensory changes. The predictions which are generated by this distinction appear unique to the present theory.

Sensory reinforcement primarily involves reinforcement through an interaction of the animal with the environment. The present theory emphasises that the nature of this interaction is crucial. Consequently, the reward value associated with this interaction is determined by a number of factors which are obscured when the reward is predominantly a function of what is produced by the response, as with food for a deprived animal, or the termination of electric shock. In large part this is where Stimulus-Change theory and any Drive theory explanation of LCBP fail: too much attention is given to the event produced by the response, i.e. the light change, and not enough is given to the nature of the interaction with the environment.

5.254. A Need for Control?

Does the contention that control of the environment is reinforcing require the postulation of a need to control the environment? Not necessarily, and especially not if the need is considered to operate in the same way as a need for food, for example (with an absence of control increasing a need for control and the exercising of control reducing the need, and therefore the reward value of control). The point has already been made (Experiment 3) that in the generic sense the reinforcing value of control of the environment does not decline, only the reward value associated with controlling a particular aspect of the environment.

Some control over the environment is obviously necessary for the continued survival of the organism. In addition, it seems that organisms have evolved so that control of the environment may be attractive and rewarding for its own sake. Probably, there is justification for assuming the existence of a basic predisposition to control the environment inherent in all organisms. It would be expected that learning and experience throughout ontogeny would modify the strength of this predisposition from one member of a species to another. This is likely to be one of many factors contributing to individual differences. Given this predisposition, behaviour of controlling the environment is seen as being aroused by appropriate external stimulus conditions. With respect to the view that motivation is determined by some interaction of intra-organismic factors and external stimulus (or incentive) conditions, the behaviour of controlling the environment appears to be comparable to behaviour directed toward other rewards (e.g. Bindra, 1968, 1969). The difference between controlling the environment and the biogenic reward such as food seems to lie in the nature of the intra-organismic factors contributing to the behaviour. For food reinforcement, food deprivation produces a deficit condition which can be conveniently described as a need.

With reward from controlling the environment there is no comparable deficit condition. Therefore, it is argued that it would be misleading to claim that the theory and data presented here support the proposition that there is a need to control the environment. The same point would probably apply to curiosity: it is unlikely that there is a general need to be curious, but, on the other hand, there is probably a general (non deficit) predisposition to be curious, which is aroused by the appropriate external stimulus conditions.

It should be apparent from these points that the position upheld here is that, of the general theories of motivation, an incentive-motivational theory (Bindra, 1969; Bolles, 1967; Black, 1965; Logan, 1960) would provide the most satisfactory account of the mechanisms whereby LCBP behaviour is energised. Provided that magnitude of the incentive conditions in LCBP could be adequately specified, an incentive-motivational theory might also provide a reasonable account of performance levels in LCBP. However, the first and major task at this stage involves determining the factors which affect the incentive value of control of an aspect of the environment and their effect on the behaviour. The research reported here represents a substantial contribution in this direction.

5.255. Some Theoretical Affiliations

The assertion that control of the environment is rewarding is not a novel one. Several authors have argued along comparable lines,[11], while others have espoused theories which can be meaningfully related to the present formulation of LCBP.

White's (1959) concept of competence is in many ways comparable to the present concept of control. Competence refers to "the process whereby the animal or child learns to interact effectively with its environment" (White, 1959, p.329). The motivation associated with competence is designated "effectance" and the experience so produced is characterised as a feeling of "efficacy". White envisages that his concept is relevant to a wide range of behaviour and in so doing probably extends his theory beyond the limits intended for the present notion of control (cf. section 5.252). Aspects of Woodworth's (1958) behaviour-primacy theory of motivation, which holds that "all behaviour is directed primarily to dealing with the environment", which, as White (1959, p.316) notes, "means a good deal more than receiving stimuli and making responses", also appears consistent with the concept of control as a reinforcer.

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[11] The close affiliation of the present theory and that of Kavanau (e.g. 1967) has already been noted.

Analyses of play behaviour in animals and humans (e.g. Gross, 1898; Jewell & Loizos, 1966; Hinde, 1970) seem to have much in common with the present formulation of control over the environment as a reinforcer. This is shown, for example, in the analysis of play behaviour by Gross in 1898 where emphasis was placed on "pleasure in being a cause".

However, most of the theories which have affiliations with the present theory of control come from the area of human motivation. It has long been recognised that most of the behaviour of humans is outside the range of Drive theory, especially with respect to Drive theory analyses of behaviour as based on homeostatic biological needs. Among the notions applied to human motivation which can be compared with the present theory are mastery; Hendrick (1942) postulates an instinct to master, which is indicated by "pleasure in exercising a function successfully, <u>regardless of its sensual value</u>". (emphasis added) and power; Minton (1967) defines power as "the ability to cause environmental change so as to obtain an intended effect".

Developments in Ego psychology away from Freud's original view that the Ego evolves out of the Id, toward the view that the Ego is an autonomous entity and develops independently of the Id (e.g. Hartmann, 1958; Rapaport, 1959), have yielded a psychology of the Ego which can be related to the present interpretation of LCBP. In the "new Ego psychology" emphasis is placed on the autonomy of the Ego and on the development of mastery and control of oneself and the environment as an integral part of Ego development and function. This aspect of Ego development also seems to be reflected in the postulation of a tendency toward self-actualisation (Maslow, 1954, 1955; Goldstein, 1940).

Finally, the present theory concerning the rewarding effects of control can be related to Piaget's notions of the pleasure and satisfaction gained from exercising an existing cognitive schemata (assimilation) or in accommodating information so as to form a higher level schemata (Flavell, 1963). This aspect of the behaviour of children is shown in the work of Schultz & Zigler (1970).

This is far from a comprehensive outline of the theoretical affiliations of the present theory with other theories of human and animal motivation. But, it serves to show the general alliance of the theory of LCBP as control of the environment with other interpretations of motivation.

5.30. Dependent Variables other than Response Rate

Three dependent variables other than response rate were recorded in the course of the present research: inter-response time, duration of bar press, and the number of reinforced responses.

The analysis of the inter-response times in LCBP (Experiment 1) provided a quantitative demonstration that animals tend to respond in "bursts". It also showed that the response-light change contingency is learned almost immediately, i.e. after the first, or at the most a few, response-light change pairings.

The mean duration of bar press data revealed one consistent result; a decline in the duration of bar press over the initial LCBP trials with a reasonably constant response duration over the remaining trials. In Experiment 1, the response duration at the commencement of LCBP was longer than during the last two operant trials. This shift in the response duration is opposite to that reported by Margulies (1961) for water reinforcement. However, there was no difference between the mean duration of bar press over the last two operant trials and the initial LCBP trials in Experiments 3 and 4. This is in line with the fact that some researchers report a rise in the response duration from operant to LCBP trials (e.g. Robinson, 1961;

Hurwitz, 1956; McCall, 1966), while others report no increase (e.g. McCall, 1965). When independent operant and LCBP groups were included (Experiment 6) there were no differences between the mean response duration for operant and LCBP groups.

In several experiments there was a tendency for the duration of bar press to be longer for a light Increment or light Onset than for a light Decrement or light Offset (Experiments 1, 4, 5, 6 and 7). In general, the response duration was a poor index of the reward value of the response-contingent light change, a result which is generally consistent with the findings of other researchers (see section 1.80). There is also some evidence from research with primary reinforcers that the response duration is not a sensitive dependent variable (Millenson, Hurwitz & Nixon, 1961).

The decline in the response duration during the LCBP trials could be taken as evidence that, with experience, an optimum response strategy is acquired by Ss. This would be in agreement with the interpretation of data from animals responding for primary reinforcers (Di Lollo, Ensminger & Notterman, 1965; Notterman & Mintz, 1965; Hurwitz, 1954). However, features of the stimulus change which is contingent on the response also affect the response duration e.g. the present difference for a light increase and decrease. The effect of the stimulus change also has been shown clearly in the data of Glow, Roberts & Russell (in press) where Ss responding for a decrease in sound intensity had a much longer duration of bar press than Ss responding for an increase in sound intensity and showed no decline in the duration of the response over 18 trials. Similarly, McCall (1966) found that albino rats responding for a light decrease maintained a comparatively long response duration over several trials while rats responding for a light increase exhibited a decline in response duration. Beyond pointing out the systematic changes in the duration of bar press observed here, little more, by way of theoretical appraisal, can be said at present about this dependent variable.

Another dependent variable recorded throughout the research reported here was the number of reinforced responses. When a 3 sec. light change was used, the percentage of total responses which were reinforced was fairly constant at between 80 and 86%. There was a tendency in Experiments 3 and 4 for the percentage of reinforced responses to increase over the initial LCBP trials. The percentage of reinforced responses did not vary with the response rate and the analyses of the number of reinforced responses almost invariably paralleled precisely those for total responses. These results suggest that the fact that a certain number of responses occur during the period of light change cannot be accounted for by response facilitation (Eacker, 1967). If facilitation were important it would be expected that more responses would be made during the period of light change than found here, and also that the proportion of reinforced responses would decline as the response rate increased. It seems more reasonable to emphasise the fact that a high proportion of responses are reinforced, especially in view of the tendency of animals to respond in "bursts"[12]. In a situation where there are no powerful constraints on the animal either to respond or not respond, the data pertaining to the number of reinforced responses indicate a consistent response strategy substantially appropriate to the contingencies operating. The appropriateness of the response strategy is commensurate with the lawfulness of LCBP behaviour apparent from other data reported here.

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[12] Kavanau (1967) interprets such nonreinforced responses as obtained throughout the present the present research in terms of the adaptive value of a certain degree of variability of behaviour in the wild.

APPENDIX I

RUSSELL, A. The Effects of Magnitude and Duration of Change on the Light-Contingent Bar Pressing of Hooded Rats, Australian Journal of Psychology (in press).

(This paper reports some of the data contained in Experiment I of the thesis).

Abstract

A prediction from a Stimulus-Change theory of light-contingent bar pressing (LCBP) is that within a range, larger magnitudes of change will be more reinforcing. This was tested with hooded rats for light intensity Increments and Decrements. In addition to magnitudes, the effect of the duration of change was also investigated. The response results for light Increments showed an initial inverted U effect for magnitudes, followed by a general positive relationship over the remaining trials. Only the largest light Decrement was reinforcing. It was argued that these results support a Stimulus-Change explanation of LCBP. The magnitude effect was contrasted with comparable data from albino rats. While shorter durations of light Increment were the most reinforcing, there was a suggestion that a longer duration of light Decrement was the most effective. Therefore, the relative reinforcing value of Increments and Decrements differed according to the duration of change.

INTRODUCTION

The stimulus-change theory of light-contingent bar pressing (LCBP) attributes the reinforcing effects of a short period of light intensity change to the reward value of change *per se* (e.g. Forgays & Levin, 1959; McCall, 1965, 1966). Recent reports have presented evidence consistent with a stimulus-change interpretation of the LCBP of hooded rats by showing that novel and familiar light onset and offset changes can be reinforcing (Glow, 1970; Sackett, 1965), that flickering light is more reinforcing than steady light (Williams & Lowe, 1967) and that light onset from an alternating position in the box is more reinforcing than onset from a fixed position (Donahoe, 1965). The experiment reported here was designed to test the prediction from stimulus-change theory of a positive relationship, at least within certain limits, between the magnitude of light change and its reinforcing value.

Secondly, the experiment investigated the relationship between reward value and the duration of light change. Various durations have been used in LCBP research. They range from the duration of the response (Robinson, 1961; Sackett, 1965; McCall, 1965, 1966) to fixed intervals of 1 sec. (Berlyne & Koenig, 1965), 2 sec. (Eacker, 1967; Wilson, 1962), 3 sec. (Glow, 1970; Goodrick, 1970) and 5 sec. (Levin & Forgays, 1959). It appears that little attempt has been made to study the role of this parameter, despite indications in the literature of its relevance. For example, Meyer (1968) found a tendency for shorter durations of light onset to be more reinforcing to chicks. In addition, several studies using a light offset change duration coincident with the duration of bar press, report no reinforcing effects (Barnes & Kish, 1957; Barnes, Kish & Wood, 1959; Hurwitz, 1956; Robinson, 1959), whereas experiments using a 3 sec. change have found substantial effects (Glow, 1970; Goodrick, 1970). These apparently discrepant results cannot be satisfactorily accommodated by any extant theory of LCBP. The effects of three durations of light change were investigated here; a change for the duration of the bar press (DBP), ½ sec., and 3 sec.

In summary, the experiment reported here investigates the effects of the magnitude and duration of light intensity Increments and Decrements on the LCBP behaviour of hooded rats.

METHOD

Subjects The Ss were 96 female Wistar Hooded rats, approximately 140 days of age at the commencement of the experiment. They were obtained from the University colony at approximately 100 days of age, routinely handled, and maintained on *ad libitum* food and water prior to and throughout the experiment. The animals were caged singly in an air conditioned room at 70°F on a 12 hour light-dark cycle.

Apparatus. The apparatus consisted of four light tight, air conditioned and sound insulated chambers containing single lever Skinner boxes 8½ x 8 x 9 ins., constructed from unpainted aluminium panels with a perspex door and ceiling. Two lights (Philips 0.8V, 0.82A) were mounted ¾" below the top of the box and 2" from the sides on the wall facing the lever. A 2" x ½" metal lever protruded ½" from a wall 3" above the floor. Approximately 20 gms weight was required to operate the lever. Four magnitudes of light change were selected, 1.076 lx (converted from 0.10 ft.c.), 4.306 lx (from 0.40 ft.c.), 17.437 lx(from 1.62 ft.c.) and 70.288 lx (from 6.53 ft.c.). The ft.c. values are equally spaced on a log scale (factor 0.605). The four magnitudes were presented as either Increments from 0.344 lx (from 0.032 ft.c.) or as Decrements from 70.611 lx (from 6.56 ft.c.). The light intensities were measured in the vicinity of the lever by a Lunasix photometer. The values were adjusted to the required level by potentiometers in the circuit. The equipment operated through a voltage stabilized supply.

The control apparatus, located in a separate room, was programmed so that light changes could occur for either the duration of the bar press (DBP), ½ sec., or 3 sec., as required.

PROCEDURE

Design. The experiment was designed as a three way complete factorial study for 4 magnitudes, 3 durations and 2 directions of change. Four animals were randomly assigned to each of the 24 treatment conditions. All trials were of 20 min. duration, with an intertrial interval of 48 hours. The animals in Increment and Decrement treatments were run on alternate days. The frequency and duration of bar pressing was recorded throughout the experiment which consisted of 2 phases. Animals were run between approximately 9 a.m. and 2 p.m. each day.

PHASE I (Operant Level).

During this phase animals in the Increment treatments were placed in the apparatus in 0.344 lx and animals in the Decrement treatments in 70.611 lx. A bar press did not produce a change in light intensity. 5 trials were run.

PHASE II (LCBP).

Commencing with the 6th trial one of the 24 combinations of light change was made contingent on bar pressing, according to treatment allocation in the design. For animals receiving a fixed duration of change a response during the period of change was recorded, but did not affect the change. Testing was continued until inspection of the data and tests for trends indicated that responding had reached an asymptote. A total of 15 trials were run in this phase.

RESULTS

RESPONSES.

The data were analysed by repeated measures procedures (Winer, 1970, Chapter 7). To obtain homogeneity of variance a$\sqrt{}$ transform was made of the response data.

PHASE I (Operant Level). The analysis of responses during the operant phase was done in terms of treatment assignment in Phase II. There were no significant main effects or interactions, indicating that animals were adequately matched for operant responding and that the base level of illumination had no effect on operant responding. There was a decline in response frequency over trials (F = 43.87, df 4,288, $p < .01$) (see Fig.1). An estimate of the operant level for each animal was obtained from the mean on trials 4 and 5 (see Table 1).

Insert Table 1 about here

PHASE II (LCBP). It was apparent from the data (see Fig.1) that the principal changes in response frequency occurred over the first 7 or 8 trials, thereafter responding appeared asymptotic. Consequently, separate analyses were performed on the data for trials 6-12 and trials 13-20.

Insert Fig.1 about here

Trials 6-12. More responses were made for light Increments than Decrements (F = 96.14, df 1,72, $p < .01$). This effect accounted for 60.4% of the nonerror variance (estimated by setting the expected mean squares for the orthogonal components of the model equal to their computed values and solving the set of simultaneous equations). A series of 't' tests on the difference between response frequency on the last two operant trials and the first two LCBP trials for each magnitude of Increment and Decrement revealed all four Increments reinforcing ($p < .01$ in all cases, 2 tailed test), but no effect for any Decrement. There was a tendency for the 70.288 lx Decrement to raise responding but it was confined to two animals and therefore not significant. Continual testing of the 70.288 lx Decrement showed it to be first reinforcing on trials 8-9 ($t = 2.21$ $p < .05$).

More responses were made for the larger magnitudes of change ($F = 12.84$, df 3,72, $p < .01$; 16.10% of nonerror variance). A significant magnitude x direction interaction ($F = 6.67$, df 3,72, $p < .01$; 16.8% of nonerror variance) suggests the magnitude effect is more pronounced for Increments (see Table 1, Fig.1). This was confirmed by linear regression analyses performed on the mean number of responses over trials 6-12 for each magnitude of change, with the four magnitudes taken as equally spaced units. A linear trend ($F = 40.29$, df 1,10, $p < .01$, slope 4.93, nonsignificant residuals) accounted for 76.4% of the variance for Increment treatments. From Fig.1 it is apparent that an inverted U relationship occurred between magnitude of Increment and the number of responses over the initial trials. Following the increase in responding for the 70,288 lx change a general positive relationship between magnitude and reinforcing value emerged, which seems to account for the linear trend (see Table 1). There were no trends for Decrements.

There was little relationship between duration of change and responding in the Decrement treatments. In the light Increment treatments most responses were made for the ½ sec. change, followed by the DBP change and the 3 sec. change (see Table 1). These results seem to account for the significant direction x duration interaction (*F* = 3.56, *df* 2,72, *p* $< .05$; 6.7% of the nonerror variance). An estimate of the mean duration of change for the DBP animals can be obtained from Fig.2. These data show that the mean duration of change for these animals lay between the ½ sec. and 3 sec. groups throughout the experiment.

Significant trials effects were obtained for the trials x magnitude (*F* = 3.74, *df* 18,432, *p* $< .01$), trials x direction (*F* = 2.51, *df* 6,432, *p* $< .05$), and trials x magnitude x direction (*F* = 2.91, *df* 18,432, *p* $< .01$) interactions. These results seem to arise from an absence of trends over trials for Decrements, the tendency for the 17,437 lx Increment to decline rapidly over trials, and the immediate increase and then decline in responding for the 70,288 lx Increment.

Trials 13-20. The absence of significant effects over trials indicates that responding had stabilized. The relationships between magnitude and duration of light Increment and the number of responses observed over trials 6-12 were essentially maintained throughout trials 13-20. The only noticeable change in the twelve Decrement treatments was in the 3 sec. 70.288 lx treatment. Responding for this change increased to a maximum on trials 13-14 and then remained at a level more than twice that for the DBP and ½ sec. groups (see Table 1). 't' tests on the difference between mean numbers of responses on trials 4-5 and 16-20 confirmed that all Increments maintained their reinforcing properties ($\underline{p} < .02$ in all cases, 2 tailed test) and that the 70.288 lx Decrement was reinforcing ($\underline{p} < .002$).

The analysis of variance yielded significant effects for magnitude ($\underline{F} = 14.99$, df 3,72, $\underline{p} < .01$; 32.4% of the nonerror variance), direction ($\underline{F} = 38.10$, df 1,72, $\underline{p} < .01$; 41.2% of the nonerror variance) and direction x duration ($\underline{F} = 8.10$, df 2,72, $\underline{p} < .01$; 26.4% of the nonerror variance). The changes in the percentage of nonerror variance accounted for by each of the effects from trials 6-12 to trials 13-20 indicates a shift in the relative emphasis of treatment conditions from the initial trials to asymptotic performance. There is a drop in the contribution to nonerror variance of the direction effect and large increases in both the magnitude and duration x direction effects. These seem to arise from: a smaller difference in the number of responses for Increments and Decrements, more responding for larger magnitudes in both directions (supported as well by a nonsignificant magnitude x direction interaction, F = 1.85, df 3,72) and a different relationship between duration and response frequency for Decrements and Increments, over trials 13-20. The 3 sec. change was still the least effective for Increments but there was a tendency for it to be the most effective for Decrements (see Table 1).

A linear relationship for the magnitude variable for Increments (F = 18.02, df 1, 10, $p < .01$, slope 2.20, with nonsignificant residuals), accounted for 59.9% of the variance, while for Decrements (F = 4.79, df 1,10, $p < .05$, slope 1.65, with nonsignificant residuals), it accounted for 25.2% of the variance.

MEAN DURATION OF BAR PRESS.

The mean duration of bar press for each animal for trials 1-5, 6-12, and 13-20 were analysed as a 3 way factorial design.

The analysis of the operant phase produced a significant interaction for the dummy magnitude and duration variables (F = 4.64, df 3,72, $p < .01$). This result is clearly due to individual differences as this phase involved operant testing for all animals. A correlation (Pearson r) of 0.56 ($p < .01$) between mean duration of bar press over trials 1-5 and trials 6-20 for the light Increment animals suggests that these individual differences contaminate the results from the LCBP trials. Therefore covariance analyses were run on the data for trials 6-12 and trials 13-20 with the durations for trials 1-5 as the covariate. The mean duration of bar press was longer in the light Increment treatments over trials 6-12 ($\underline{F} = 5.48$, df 1,72, $\underline{p} < .02$) and trials 13-20 ($\underline{F} = 7.49$, df 1,72, $\underline{p} < .01$). No other effects were significant. These results indicate that except for the difference between Increments and Decrements, the duration of bar press is not related to the reinforcing value of a light change and that the duration of response does not differ according to whether the light change occurs for the duration of the response or for a fixed interval. A feature of the data not apparent from these results is the lengthening of response duration at the commencement of the LCBP trials by the light Increment animals. The rise from trials 1-5 to 6-12 ($t = 3.93$, $\underline{p} < .001$) and the fall from trials 6-12 to 13-20 ($t = 7.17$, $\underline{p} < .001$) for these animals was significant. This is illustrated in Fig.2. Inspection of the duration of

Insert Fig.2 about here

bar press data for 70.288 lx by 3 sec. Decrement animals revealed that the increase in reinforcing value of this change across trials was not associated with any shift in the response duration. Therefore Fig.2 seems to be illustrating a phenomenon restricted to novel events.

DISCUSSION

The four magnitudes of light Increment from 1.076 lx to 70.288 lx were reinforcing. At first there was an inverted U relationship between magnitude of change and reinforcing value which was followed by a general positive relationship after the 8th trial. The only light Decrement found to significantly raise responding above the operant level, a result which did not occur for several trials, was the 70.288 lx Decrement, and this was due mainly to the effectiveness of the 3 sec. change. The interpretation placed on these results is that overall they provide strong support for a stimulus-change explanation of the LCBP of hooded rats.

The results for the light Increments and the 70.288 lx light Decrement (only the 3 sec. change) corroborate the findings of Glow (1970), Sackett (1965) and Robinson (1961) that light changes in both directions can be reinforcing to the hooded rat and remain so with prolonged testing. Furthermore, the results for the 3 sec. 70.288 lx Increment and Decrement treatments are in agreement with Glow's (1970) finding with hooded rats that after several trials a 3 sec. light Offset change was more reinforcing than a 3 sec. light Onset. The absence of rewarding effects for the three smallest Decrements is probably due to their not being of sufficient incentive magnitude. The fact that the same magnitudes were reinforcing when they occurred as Increments from 0.344 lx seems consistent with the principles underlying Weber's law (Stevens, 1951).

Two aspects of the data suggest an initial suppression of responding due to excess novelty or change which dissipates with familiarity. Firstly, the increase in responding over trials for the 70.288 lx change in both directions. Secondly, the shift, in the case of light Increments, from an inverted U relationship between magnitude of change and reinforcing value to a general positive relationship. Alternatively, in terms of the theory proposed by Dember & Earl (1957) these data can be accounted for by an upward shift in the "psychological complexity" of the organism brought about by experiencing the light change. In many ways these data are consistent with findings of preferences for more complex stimuli following experience in humans (Munsinger & Kessen, 1964) and animals (Thomas, 1969,a,b).

In what appears to be the only other reported study of the effects of magnitude of change in hooded rats, Stewart (1960) investigated four light onset changes ranging from 0.01 to 8.5 ft.c. Whereas with continuous reinforcement no differences between the four magnitudes was found, a positive relationship analogous to the one reported here obtained with fixed ratio schedules. But Stewart's study may not be directly comparable to the present research because of several apparatus and procedural differences. For example, in Stewart's experiment the test environment was mat black and the animals were food deprived.

The present magnitude effect for light Increments contrasts with comparable data from albino rats reported by Lockard (1966) and McCall (1966). They found a tendency for larger magnitudes of light Increment to be more reinforcing when the change was novel, but as trials continued responding for all Increments declined to a little more than operant level, with no magnitude effect evident. In the present experiment the positive relationship between responding and magnitude of Increment was evident at the asymptote and all Increments remained reinforcing. This difference between albino and hooded rats may stem from the light intensity preference functions of the two strains. In situations where a unidirectional light change is made contingent on bar pressing and the change continues until another response is made, albinos have been repeatedly shown to prefer to spend most of their time in very dim illuminations (Lockard, 1962,a,b, 1964, 1966). On the other hand, hooded rats have exhibited no differential preferences for luminances from .1 mL to 100 mL (Lockard, 1962) and no overall preference for either darkness or 6.5 ft.c. (Glow, 1970).

There is no obvious way of accounting for the effects of duration of change on reinforcing value reported here. However, the light Increment data might be taken as indicative of shorter durations being of greater apparent brightness. This relationship has been observed with human subjects

(Stevens, 1966; Katz, 1964) for durations up to 1.0 sec. The present data suggests that the reverse may hold for Decremental light changes.

The fact that the two shorter durations of 70.288 lx Decrement sustained a comparatively low response rate might explain the failure of Hurwitz (1956), Barnes & Kish (1957), Robinson (1959), and Barnes, Kish & Wood (1959) to obtain an effect for light offset when the change lasted for the duration of the bar press. That the latter is not an invariant finding suggests that other factors may be involved as well. For example, in albinos the extent to which light offset allows escape from intense illumination may be important. The effect of the duration of light change obtained here does not follow from any extant theory of LCBP. If it is accepted that the light changes in the present experiment represented a change *per se* to the *S*s, then clearly stimulus-change theory should be modified to incorporate the duration of change as well as the magnitude of change. The duration of change seems to be a powerful determinant of the relative reinforcing value of light changes in different directions. This is shown by the present results for a 70.288 lx change: for a ½ sec. change an Increment was much more reinforcing than a Decrement but for a 3 sec. change the reverse occurred. However, more research is needed before the duration parameter could be incorporated readily into a stimulus change position.

The mean duration of bar press data presented here shows that the reinforcing effects of light changes may be reflected in dimensions of the operant other than the number of responses. The increase in mean duration of bar press at the beginning of the LCBP trials by the animals in light Increment treatments seems to be associated with a novel and reinforcing change. Robinson (1961), Hurwitz (1956), McCall (1966), and Barnes & Baron (1961) all report a longer duration of bar press in LCBP than under operant conditions. In McCall's experiment the longer durations were maintained over trials for light Decrements, but not for Increments. Similarly, McCall, Weiffenback & Tucker (1967) obtained a general decline in mean duration of response over LCBP trials for the light Increments. A feature of almost all studies in which the mean duration of bar press has been reported is that the light change occurs for the duration of the response. It has been reasoned that animals should make longer responses for more reinforcing changes. While there is some evidence for this in albinos, especially when they respond for a Decrement in light intensity (McCall, 1966), the more common result, in agreement with the present data, is that the mean duration of bar press is a poor index of the reinforcing value of the change (McCall, 1966, 1965; Roberts, 1962; Sackett, 1965; Glow, Russell & Kirby, in press; Barnes & Baron, 1961). The present data on different durations of change (DBP, ½ sec., 3 sec.) suggest that an increase in the mean duration of bar press is a general effect associated with any novel and reinforcing response contingent light change. It occurs whether or not the animal has direct control over the duration of change.

This experiment demonstrates that light change reinforcement can be subjected to the same kinds of parametric analyses which have been applied to the organically based reinforcers. It therefore provides a basis for more detailed considerations of the nature of sensory change as a reinforcer and its relationship to other types of reward.

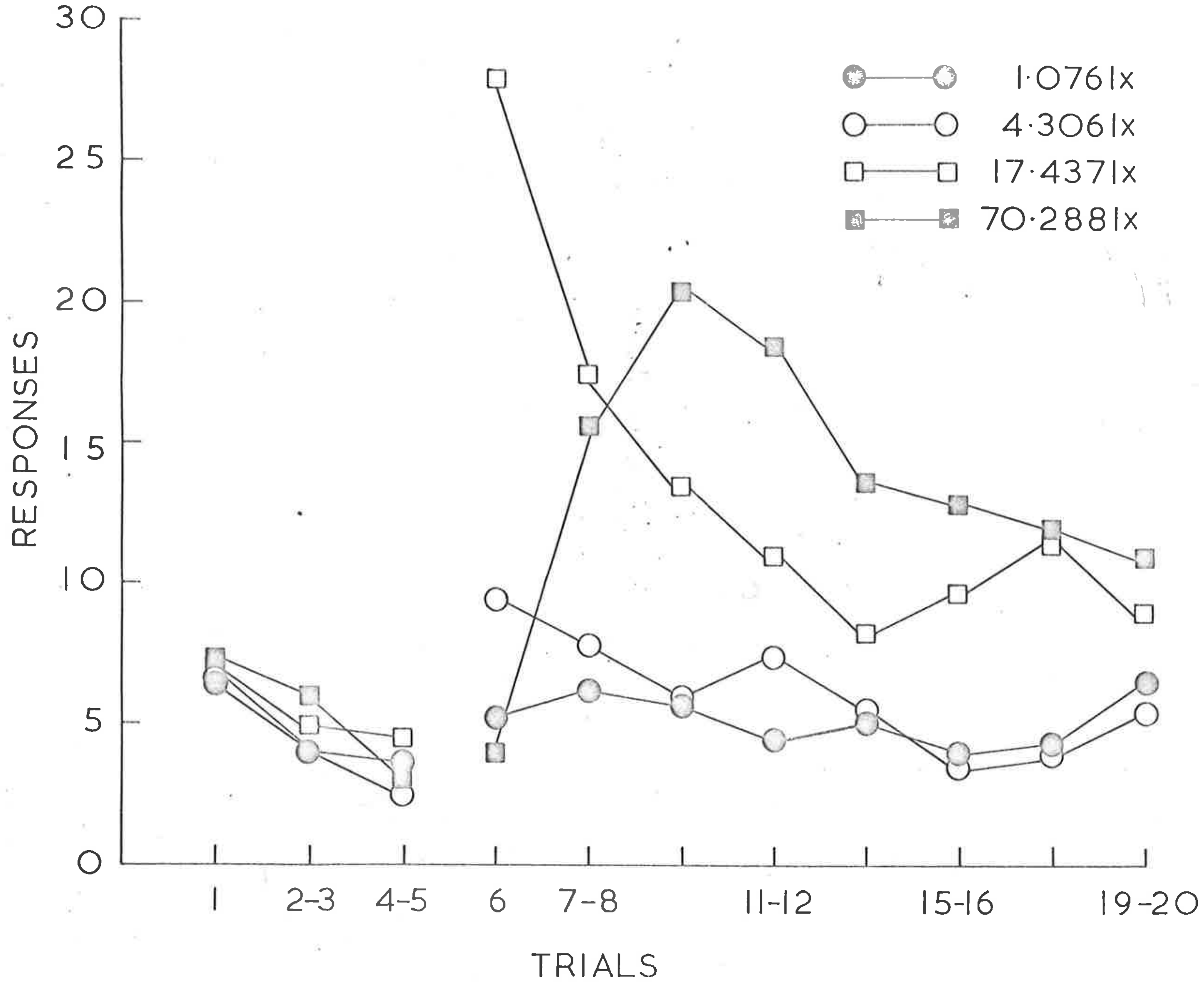

Fig.1. Mean Number of Responses per Trial for light Increments as a function of the magnitude of change.

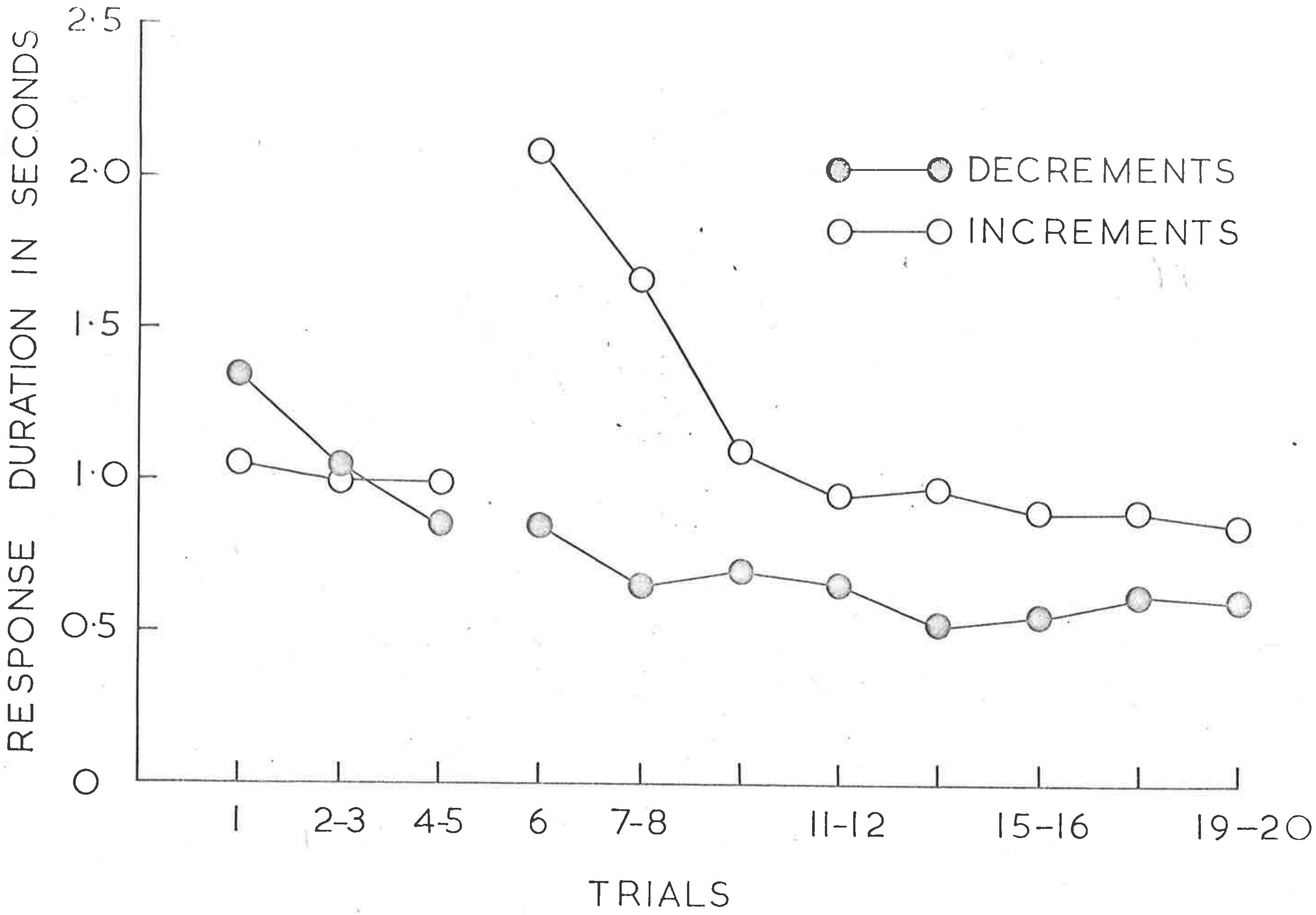

Fig.2. Mean duration of bar press as a function of the direction of change.

Table 1. Mean Number of Responses
per 20 min. Trial.

LIGHT INCREMENTS

Magnitude of Change

Duration of change	1,076 lx			4,306 lx			17,437 lx			70,288 lx			All magnitudes		
trials	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20
½ sec.	4.4	8.6	7.2	2.2	8.4	4.5	2.5	15.7	9.4	2.0	23.7	12.4	2.8	14.1	8.4
DBP	1.7	5.5	4.8	1.1	5.3	4.5	5.7	17.8	8.6	1.7	20.3	12.0	2.6	12.2	7.5
3 sec.	1.2	3.2	2.9	2.2	10.9	3.5	3.6	13.9	6.2	1.6	14.9	8.5	2.1	10.7	5.3
All Durations	2.4	5.8	5.0	1.8	8.2	4.2	3.9	15.8	8.1	1.8	19.6	11.0			

Table 1. (contd.)

LIGHT DECREMENTS

Magnitude of Change

Duration of Change	1.076 lx			4.306 lx			17.437 lx			70.288 lx			All magnitudes		
trials	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20	4-5	6-12	13-20
½ sec.	2.2	0.9	0.8	1.2	2.6	1.9	2.5	2.6	1.9	1.4	4.1	4.1	1.8	2.3	2.4
DBP	3.6	2.5	1.6	4.0	3.0	5.1	0.6	1.4	1.7	1.5	8.0	5.9	2.4	3.7	3.6
3 sec.	4.2	5.9	3.2	3.0	2.1	2.5	1.5	2.8	2.7	1.5	9.2	13.5	2.6	5.0	5.5
All Durations	0.3	3.1	1.9	2.7	2.2	3.5	1.5	2.3	2.1	1.5	7.1	7.8			

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Footnote

[1] This experiment represents part of a program of research being conducted for the Ph.D. degree at the University of Adelaide under the supervision of P.H. Glow. The author wishes to thank his supervisor for his continual encouragement and guidance throughout this project.

APPENDIX II

GLOW, P.H., ROBERTS, JEANNE, E. & RUSSELL, A. Response Contingent Auditory Reinforcement in the Rat, Australian Journal of Psychology (in press).

Abstract

The acquisition and performance levels of responding for auditory intensity changes in rats are presented. A sound decrease was found to be more reinforcing than an equivalent sound increase. A preference experiment ruled out the possibility that the differences found could be accounted for by an aversion for the higher sound intensity. Several parallels between the reinforcing properties of sound and light intensity changes are drawn. The results are interpreted as showing that a change *per se* in the auditory modality can be reinforcing.

A short period of changed light intensity, when made contingent upon bar pressing, has been repeatedly shown to act as a reinforcer for rats and other species (Glow, 1970; Kish, 1966). This phenomenon is known as light-contingent-bar-pressing (LCBP). Partly as a result of these observations Kish (1966) proposed a general concept of Sensory Reinforcement, the implication being that changes in any sensory modality may be reinforcing. However, to date little systematic work has been published on sensory modalities other than the visual. The series of experiments reported were designed to test the adequacy of Kish's notion by investigating the reinforcing properties of auditory intensity changes.

In method, the present experiments parallel a recent LCBP study by Glow (1970). This enables valid comparisons to be made between the sensory reinforcing properties of visual and auditory changes. It also permits an investigation of a number of questions about the reinforcing effects of auditory changes which have hitherto been neglected. These include: (a) What are the relative reinforcing properties of sound intensity changes of equal magnitudes but opposite in direction, and how do they change within and across trials?, and (b) What role do sound intensity preferences play in auditory contingent bar pressing (ACBP)?

METHOD

Subjects Subjects were 24 naive female Wistar hooded rats (280 days of age). The animals were caged singly in airconditioned quarters and routinely handled. All were maintained on *ad libitum* food and water prior to and throughout the experiments.

Apparatus The apparatus consisted of sound attenuating airconditioned chambers containing single lever Skinner Boxes 8½ x 8 x 9 ins. The Skinner Boxes were programmed so that a lever depression produced an auditory change. The auditory stimulus for each box was provided by a buzzer, (133.3 Hz) placed within the sound attenuating chamber but outside the Skinner Box. The sound intensity of the buzzer in the vicinity of the lever was measured by a Dawe sound level indicator on Scale A. The intensity of the buzzer for each box was adjusted to 86 ± 1 db (base 0.0002 dynes per sq. cm.). External background noises were masked by a white noise generator (Grayson Stadler). In the absence of the buzzer the ambient level within the box was 73 db.

Procedure and experimental design Trials were of 20 minutes duration with an intertrial interval of 48 hrs. Throughout the experiment the number of bar presses during each successive five minute period of the trial, and the mean duration of bar press over the whole trials were recorded.

Phase I (Operant). Five trials were run in order to habituate the animals to the apparatus and to establish the operant rate and duration of bar pressing.

<u>Phase II (A.C.B.P.).</u> Rats were randomly assigned to one of four treatments. Each of the groups received a different auditory change contingent upon bar pressing for 18 trials: <u>Treatment 1</u>, Sound ON for 3 secs; <u>Treatment 2</u>, Sound ON for duration of bar press; <u>Treatment 3</u>, Sound OFF for 3 secs; <u>Treatment 4</u>, Sound OFF for duration of bar press.

Sound ON consisted of an increase in the intensity of auditory stimulation from 73 db of background noise to 86 ± 1 db by the activation of the buzzer. Sound OFF consisted of a decrease in the auditory intensity from 86 ± 1 db to the background of 73 db by the inactivation of the buzzer.

<u>Phase III (Alternation).</u> The animals from each of the four treatments were randomly divided into two groups. Group I was placed in the Skinner Box with the Sound ON, Group 2 with the Sound OFF. The initial lever depression turned the sound OFF for Group 1 and ON for Group 2. The Sound ON or OFF condition persisted until another lever depression occurred which reinstated the initial condition, and so on. Response rate and amount of time spent with the Sound ON in successive 5 min periods of the trial, and the mean duration of bar press over the whole trial were recorded. After the 7th

trial in Phase III, additional timers were included to separately measure the duration of bar press according to whether the buzzer was being turned ON or OFF for a further 7 trials. A total of 14 trials were run.

Phase IV (A.C.B.P.). Animals in this phase received either 3 sec. Sound ON or Sound OFF contingent on bar pressing as in Treatments 1 and 3 of Phase II. Those animals which had responded for Sound ON (Treatments 1 and 2) in Phase II now received Sound OFF, and those which had previously responded for Sound OFF (Treatments 3 and 4) now received Sound ON. 14 trials were given in this Phase.

RESULTS

The data for each phase of the experiment were analysed by a repeated measure Analysis of Variance procedure (Winer, 1970). The analyses were performed on the number of responses in each five minute period of each trial.

Phase I. A decline in the rate of responding within trials ($F = 6.27$, df 3, 60, $p < .01$), and across trials ($F = 2.51$, df 4, 80, $p < .05$) occurred. There was no significant treatment variable effect.

Phase II. The mean scores over trials for each treatment are illustrated in Fig. 1. The main effects of the direction

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Insert Fig. 1 about here

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of change (ON or OFF) (*F* = 13.14, *df* 1, 20, *p* < .01), and trials (*F* = 2.33, *df* 17, 340, *p* < .01) were significant. The interaction between direction of change and trials was also significant (*F* = 4.10, *df* 17, 340, *p* < .01). This reflects the tendency apparent in Fig. 1 for the Sound ON groups to decrease their response rate over trials and for the Sound OFF groups to increase their response rate. There was no overall within trials effect for response rate (*F* = 1.71, *df* 3,60, *p* > .05); but the within trials x trials interaction (*F* = 1.84, *df* 51, 1020, *p* < .01), the within trials x direction of change interaction (*F* = 4.03, *df* 3,60, *p* < .05), and the direction x within trials x trials (*F* = 1.85, *df* 51, 1020, *p* < .01) interaction were significant. These interactions result from (1) an overall tendency for animals in the ON groups to make most of their responses in the early quarters of the trial, and for the OFF groups to distribute their responses more evenly throughout the trial (see Table 1); and (2) a tendency for both groups to change their within trial distribution over trials (see Table 1).

Insert Table 1 about here

The duration of stimulus change was not related to response rate (*F* < 1). It is apparent from Fig. 1 that no significant trend emerged after about the 8th or 9th trial. A test over trials 9 to 18 (F = 1.84, df 9, 180, p > .05) supported this observation. A test of the difference between response rate on the last two operant trials of Phase I and the first two A.C.B.P. trials of Phase II showed a significant increase for the Sound ON group (t = 2.32, df 11, p < .05), but not for the Sound OFF group (t = 0.10, df 11, p > .10).

Phase III. The response rate was related to the training history (ON or OFF) in Phase II (F = 7.84, df 1, 20, p < .05); animals which had responded for Sound OFF in Phase II made more responses than those which had responded for Sound ON. A significant within trial variation occurred (F = 4.92, df 3, 60, p < .01), as shown in Table 2.

Insert Tables 2 & 3 about here

As well as the main response measures, the average time spent with Sound ON in each quarter of the trial was recorded in this phase. The time spent with Sound ON declined within trials (F = 20.16, df 3, 60, p < .01), as shown in Table 3. The only other significant effect was the within trials x trials interaction (F = 1.94, df 39, 780, p < .01), reflecting the tendency for time spent in Sound ON to be more evenly distributed throughout each trial as trials continued (see Table 3).

Phase IV. An analysis of responding over all trials showed no significant effect for ON-OFF. The only significant effect was for within trials (*F* = 2.96, *df* 3, 66, *p* < .05). However, an analysis of total responses over the *last six* trials showed a significant difference for the ON, OFF treatment (*F* = 4.74, *df* 1, 22, *p* < .05); the mean number of responses per trial during this period was 4.6 for the Sound ON group and 12.5 for the Sound OFF group.

Mean Duration Bar Press. The only treatment condition which significantly affected this measure was the direction of change (ON or OFF) in Phase II (*F* = 5.20, *df* 1, 20, *p* < .05), and in Phase IV (*F* = 16.12, df 1, 22, *p* < .01); in both cases the mean duration of bar press was longer for the OFF group. In Phase IV the mean duration bar press varied over trials (*F* = 2.12, *df* 13, 286, *p* < .05); the trend was for the Sound OFF groups to show a gradual increase over the initial trials and for the ON groups to show a comparable decrease.

DISCUSSION

The results obtained show that a sound intensity change contingent upon bar pressing can act as a reinforcer, thus providing support for a general concept of Sensory Reinforcement. Comparing the present results and those of Glow (1970) demonstrates a number of parallels between the reinforcing properties of sound and light intensity changes. The acquisition and performance characteristics are comparable, and a decrease in intensity is more reinforcing than an equivalent increase.

Sound intensity preferences or aversions could be advanced as an explanation of the greater reinforcing value obtained in Phases II and IV for Sound OFF. However, an analysis of the Alternation Phase suggests that an account involving a combination of the effects of change *per se* and preference level is more satisfactory. During the Alternation Phase, animals demonstrated an overall 60% preference for the lower sound intensity. The question is, when does a preference become an aversion? Campbell (1955) has offered one criterion, 75% avoidance. The finding that animals continue to turn the higher sound intensity ON and OFF throughout each trial suggests that the onset of sound is not aversive. This is compelling evidence for a reinforcing effect for change *per se* in the auditory modality.

In view of this result, the initial reinforcing effect observed for Sound ON in Phase II can be interpreted as due primarily to the effect of change *per se*. Because the sound intensity consequent upon the response was less preferred than the background noise level, when the novelty of the change had habituated the response rate declined. Responding was not suppressed as would be expected if the sound were aversive. In a similar way the high response rate for Sound OFF can be accounted for in terms of a combination of the effects of change *per se* and a change to a more preferred sound intensity. The "latency period" before a repid increase in responding for Sound OFF (see Fig. 1) was also noted by Lavery & Foley (1965). This period can perhaps be attributed to an adaptation to the sound stimulus. The importance of change *per se* both for Sound ON and Sound OFF is further indicated by the absence of any differential reinforcing effect according to whether the change lasted 3 secs or for the duration of bar press (mean of .94 sec and 1.39 sec for Sound ON and OFF respectively).

The essential features of this explanation of the auditory contingent bar pressing data differs little from that proposed by McCall (1966) for light contingent bar pressing with albino rats. Both Lockard (1966) and McCall (1966) reported that change *per se* is an important determinant of response rate initially but that light intensity preferences eventually predominate.

Several additional aspects of the present results should be noted. In the Alternation Phase, preference for the higher sound intensity significantly declined within trials. This agrees with the result of Barnes & Kish (1957). Campbell does not seem to have considered this factor when attempting to establish aversion thresholds for various sound intensities in rats. This limits the generality of his conclusions about the aversive properties of sound based on the terminal 30 minutes of one 50 minute trial (Campbell, 1957), and the last 4 minutes of the final two 12 minute training trials (Campbell, 1955).

The differences between the within trial distribution of responses for Sound ON and Sound OFF in the A.C.B.P. Phases has obvious implications for comparisons between the relative reinforcing values of these changes. For example, if one hour trials had been used, a much larger relative difference between the two would be expected. The terminal A.C.B.P. Phase indicates that even after prolonged exposure to the sound levels and sound changes, animals do not respond at the same level for Sound ON as for Sound OFF.

The differences in mean duration of bar press observed in Phases II and IV are difficult to explain. In the case of food reward the amount of reinforcement seems to determine the precision with which the animal comes to approximate the criterion effort needed (Notterman & Mintz, 1965; Di Lollo, Ensminger & Notterman, 1965). In the present study the short durations, presumably indicating less effort, were associated with the less reinforcing change. This suggests that in this experiment features of the stimulus change other than its reinforcing value are related to the apparent effort expended to obtain reward.

FIG.1. AUDITORY CONTINGENT RESPONDING

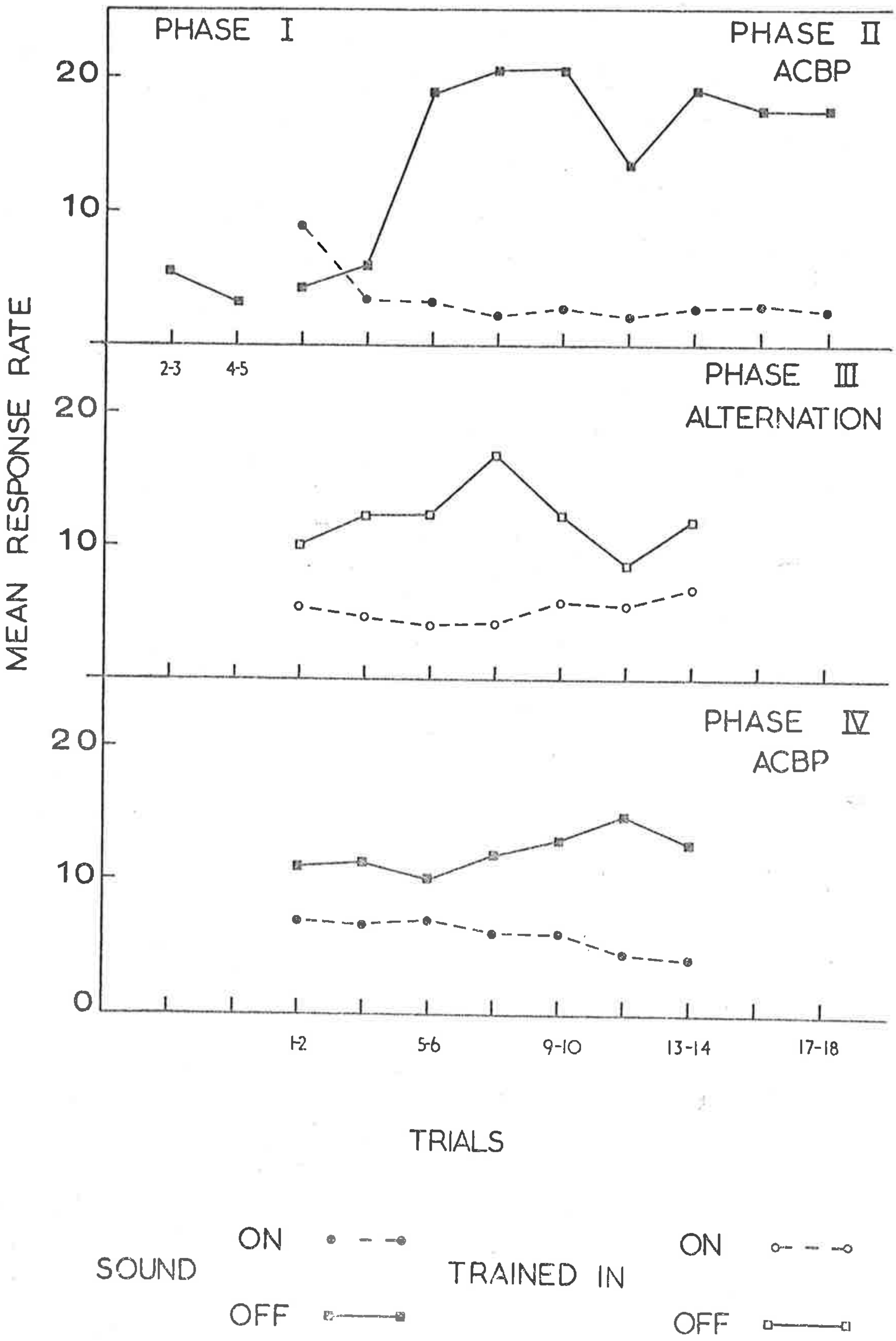

Table 1

Mean Intratrial Distributions of Responding
in Phase II.

		Quarters of 20 Minute Trial				
		1	2	3	4	Total
First 4 Trials						
Sound ON	Mean	1.90	1.95	.60	.98	5.43
	Proportion	35.1%	35.9%	11.1%	17.9%	100%
Sound OFF	Mean	1.50	1.95	1.78	2.0	7.23
	Proportion	20.8%	27.0%	24.5%	27.7%	100%
Last 4 Trials						
Sound ON	Mean	1.03	.88	.45	.30	2.65
	Proportion	38.7%	33.0%	16.9%	11.4%	100%
Sound OFF	Mean	2.54	7.60	4.90	5.95	20.99
	Proportion	12.20%	36.20%	23.3%	28.3%	100%
All Trials						
Sound ON	Mean	1.27	1.10	.49	.45	3.31
	Proportion	38.3%	33.2%	14.9%	13.6%	100%
Sound OFF	Mean	3.05	4.87	4.30	4.65	16.87
	Proportion	18.1%	28.9%	25.5%	27.5%	100%

Table 2

Mean distributions of responses and mean times (seconds) spent in Sound ON over all trials in Phase III.

		Quarters				
		1	2	3	4	Total
RESPONSES	Absolute	2.00	2.69	2.40	1.74	8.83
	% of the whole trial	22.5	30.5	27.3	19.7	100%
TIME IN ON	Absolute	137.70	131.60	110.30	91.30	470.9
	% of the whole trial	29.3	27.9	23.4	19.4	100%

Table 3

The Percentage of time spent in Sound ON in each quarter of the trials in Phase III (Alternation)

	Quarters of 20 Minute Trial			
	1	2	3	4
First 4 Trials	50.6%	46.3%	34.1%	27.1%
Last 4 Trials	44.2%	43.1%	39.9%	31.6%

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APPENDIX III

GLOW, P.H., RUSSELL, A. & KIRBY, N.H.
Sensory Reinforcement Using Paired
Stimuli from Different Modalities,
Australian Journal of Psychology
(in press).

Abstract

The effects of the concurrent presentation of two sensory changes contingent upon a bar pressing response of rats were investigated. Initially, a performance asymptote was established with one sensory reinforcer after which a second sensory reinforcer was added. When an asymptotic performance level was reached with the paired sensory reinforcers, one was deleted. The addition of a second sensory change initially produced a marked increase in the response rate. This rate declined to a new and only marginally elevated asymptote in subsequent trials. It was suggested that an early summation in the reinforcing effectiveness of two combined sensory changes gives way to a later interaction in their reinforcing effectiveness.

A sensory change in either of the modalities of vision or audition can be reinforcing. It has been argued that this reinforcing effect occurs when the values of the parameters governing the phenomenon, such as magnitude and duration of stimulus change etc. are appropriate (Glow, 1970, and Glow, Roberts and Russell, submitted for publication). Little is known of the effects of two such sensory changes from different modalities being paired concurrently. Baron and Kish (1962) using mice, paired an auditory and a visual change for one half hour period following immediately on a one half hour operant period. They claim that, "when visual and auditory stimuli were presented concurrently, their respective positive and negative effects summated rather than interacted since the auditory stimuli depressed response rates in about the same proportion when presented together with visual stimuli as when presented alone." However, only limited conclusions about the effects of pairing sensory stimuli from different modalities can be drawn from the Baron and Kish study. These authors used only one 30 minute test session and it has been shown in extended studies of both auditory and visual change that responding varies markedly over trials (Glow, 1970; Glow, Roberts and Russell, submitted for publication).

The aim of the present paper is to investigate the effects of pairing two, independently reinforcing, sensory changes from two modalities in an extended study.

METHOD

Subjects were 24 female Wistar hooded rats approximately one year old. The animals were singly caged in air conditioned quarters and maintained on _ad libitum_ food and water.

Apparatus. Four identical light-proofed, ventilated and sound-insulated Skinner boxes 8½ x 8 x 9" were used. Each box contained a single lever, a depression of which produced a 3 sec increase or decrease in the intensity of either sound or light, or sound and light paired together. The light change consisted of an increase from darkness to 6.5 foot candles (Light ON) or a decrease from 6.5 foot candles to darkness (Light OFF), measured level with and beside the lever with a Lunasix photometer. The sound change consisted of either a decrease from 86 ± 1 dbs to a background level of 73 dbs (Sound OFF) or alternatively, an increase from the background level to 86 dbs (Sound ON). The level of sound was measured by a Dawe sound level indicator on scale A from a base of 0.0002 dynes per sq. cm. Throughout the experiment, a white noise generator was used to mask external noises.

The total number of responses and total duration of bar presses were recorded for each trial.

Procedure and experimental design. The experiment was conducted over 3 phases. All trials were of 20 minutes duration with an inter-trial interval of 48 hours.

Phase 1

Equal numbers of animals were randomly assigned to two basic treatment conditions, either 3 seconds of Sound ON or 3 seconds of Sound OFF contingent on bar pressing. Trials were continued until a performance asymptote appeared to have been reached. The criteria used were visual inspection of the data and a trend analysis over the terminal 5 trials which did not produce a significant effect. Fourteen trials were given in this phase.

Phase II

Each Phase I group was randomly divided into two and a 3 second visual stimulus change was added to the contingency to form the following 4 treatments:

Treatment 1: Sound ON plus Light ON
Treatment 2: Sound ON plus Light OFF
Treatment 3: Sound OFF plus Light ON
Treatment 4: Sound OFF plus Light OFF

Using the same criteria as in Phase I trials were continued until a performance asymptote was reached. Thirteen trials were given in this phase.

Phase III

All sound contingent changes were deleted leaving only the respective light changes operating in Phase II contingent upon bar pressing. A total of nine trials were given.

RESULTS

The data were analysed by repeated measures analysis of variance or by other tests as indicated in the text.

The use of an operant control group was not thought to be necessary since the operant level of responding has been established in previous research (Glow, Roberts and Russell, in press). It was found to be 2.46 responses for each 20 minute trial.

Responses

Phase I. An analysis performed on the last 6 trials showed an effect for Sound ON-OFF ($F = 4.74$, $p < .05$) (see fig. 1), and no trend over trials ($F < 1$).

Insert Fig. 1 about here

Phase II. An immediate increase in response rate occurred as a result of the addition of the light changes (see fig. 1). The analysis showed an effect for trials ($F = 3.96$, $p < .01$) reflecting the subsequent decline in response rate apparent in all groups in fig. 1. The trials x light x sound interaction was also significant ($F = 1.89$, $p < .05$). An analysis of the last 9 trials of this phase failed to produce any significant main effects or interactions. The F value for trials was 1.18. Finally, a comparison of the last 5 trials of Phases I and II using a difference t test showed a significant increase in responding for the Sound OFF groups ($t = 3.81$, $p < .01$) but not for the Sound ON groups ($t = 1.44$, $p > .20$).

Phase III. An effect for trials occurred ($F = 3.34$, $p < .01$) reflecting the gradual downward trend of all groups in this phase (see fig. 1). Neither the main effects of sound or light nor any interactions were significant.

Mean duration of bar press

The analysis of the last 6 trials of Phase I showed that while there was no effect to the dummy light variables the mean duration of bar press for the Sound OFF groups (.99 seconds) was significantly greater than for the Sound ON groups (.67 seconds) ($F = 16.01$, $p < .01$). This effect was not significant in either of Phases II or III. Throughout both Phase II and Phase III the F values for light were significant ($F = 7.57$, $p < .025$ and $F = 5.18$, $p < .05$ respectively) (see Table 1).

Insert Table 1 about here

DISCUSSION

The data presented here extend the observations of Baron and Kish to the case of two independently reinforcing sensory changes, and show, after an immediate increase in responding, a gradual adjustment to the introduced stimulus.

The immediate increase and subsequent decline in responding for all groups in Phase II is directly comparable to the behaviour of naive animals responding for either Light ON or Sound ON alone (Glow, 1970; Glow, Roberts and Russell, in press). Naive animals responding for Light OFF alone have been reported to increase their bar pressing over trials (Glow, 1970). The present finding of a drop in rate over trials for groups receiving Light OFF as the second sensory change, may be due to the increased familiarity of these Ss with the Skinner box and contingent sensory changes.

Baron and Kish (1962) claimed that the conjunction of two sensory changes results in a summation of their separate effects, as distinct from an interaction of their reinforcing values. If summation occurs the response rate for the paired stimuli is a simple addition of the rates for each stimulus alone. If interaction occurs then response rate for the paired stimuli will be some value other than that obtained by simple addition. Our expectation is that this rate will normally be below that for summation. While the results do not provide unequivocal support for either of these processes, they do lend themselves to an interpretation incorporating both summation and interaction. Our model envisages that during the initial trials following the introduction of the novel stimulus summation of the effects of the two occurs. With continued exposure to the paired stimuli their effects eventually interact to determine response rate. This model accommodates the findings of

Baron and Kish and the notion of interaction is consistent with results obtained with food, water and sucrose reinforcement (Guttman, 1953; Dufort and Kimble, 1956; Kimble, 1961; Hutt, 1954). The latter are "in agreement on the point that performance increases as a negatively accelerated function with increases in the amount of reinforcement" (Kimble, 1961, p.138).

The results of Phase III demonstrate that the effect of removing one of the sensory changes following a number of trials with paired stimuli is minimal compared to the introduction of a second change. The Ss in this phase show only a slow adjustment to the new reinforcement conditions.

The present results also demonstrate the effect of pairing sensory reinforcers on a second dimension of bar pressing behaviour, namely the duration of bar press. These effects are not easily interpretable. However, they do indicate that the number of bar presses and the duration of bar press are not necessarily positively related. When light changes were added to Sound OFF, response rate increased but the mean duration of bar press decreased. It seems that for each stimulus or combination of stimuli there may be a characteristic duration of bar press that is partially independent of the rate. This notion is consonant with Gilbert's (1958) analysis of the fundamental dimensional properties of the operant, and with suggestions made by Glow, Roberts and Russell (in press) concerning the duration of bar press differences for Sound ON and Sound OFF groups.

FIG.1. SENSORY CONTINGENT BAR PRESSING

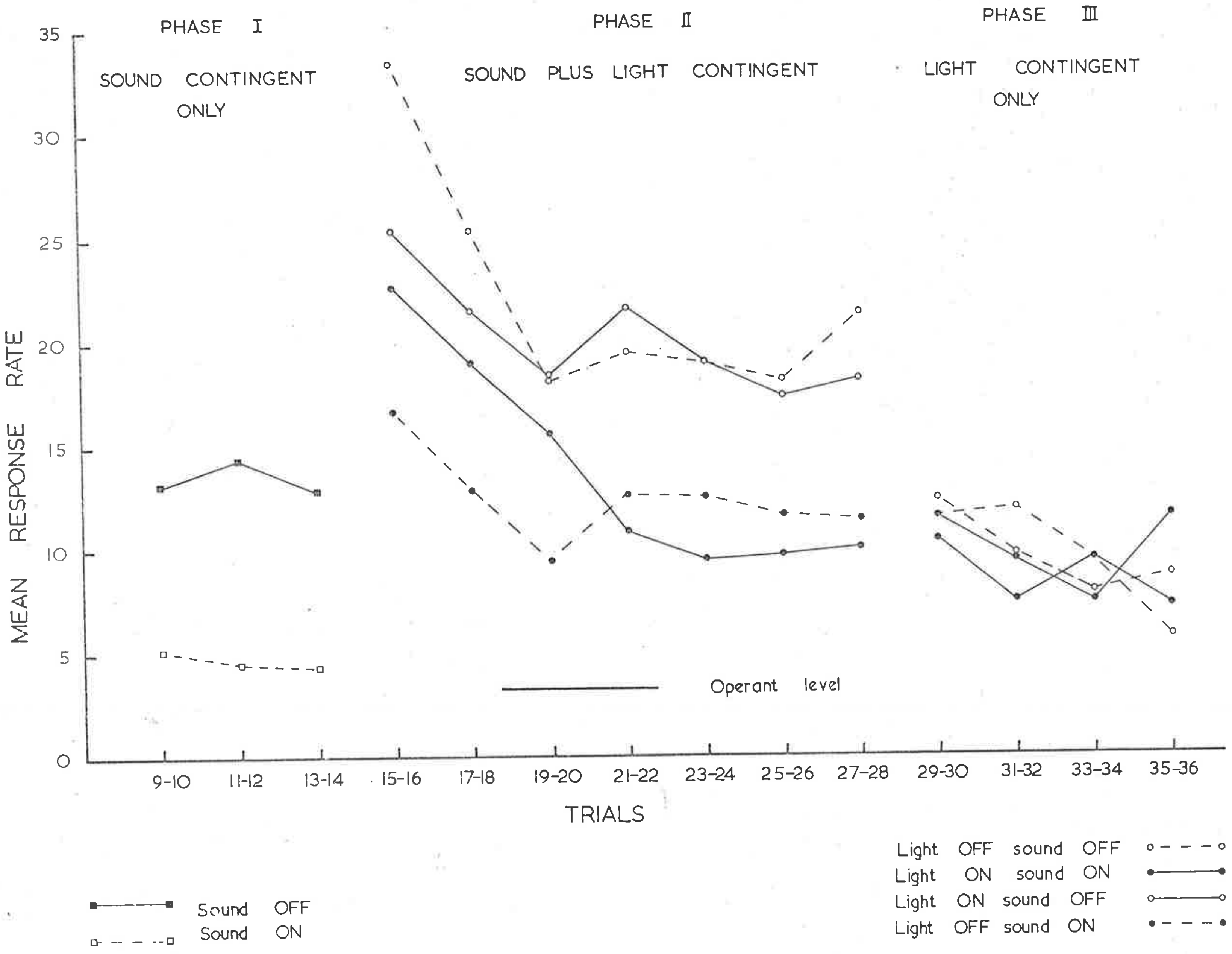

TABLE 1.

Mean duration of bar press

		PHASE I	PHASE II	PHASE III
	LIGHT ON*		.76	.64
SOUND ON		.67		
	LIGHT OFF*		.81	.76
	LIGHT ON		.68	.56
SOUND OFF		.99		
	LIGHT OFF		1.05	.72

*Light ON and Light OFF are dummy variables in Phase I.

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