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ABSTRACT

Six- and nine-month-old infants were exposed to contingent or non-contingent perceptual stimulation from a source which was spatially displaced at 60 from the infant's midline. Reliable operant acquisition was observed in the case of the nine-month-old infants, but not in the case of the six-month-old infants whose performance was similar to that of non-contingent controls. Examination of visual fixations of the feedback source coincidental with touching the manipulandum revealed the emergence of a strategy in the older infants which appeared to be critical for response acquisition. The emergence of this strategy is interpreted in terms of the older infants' increased capacity to remain oriented to task-relevant stimuli which are no longer immediately visually available and to regulate behavior on the basis of information derived from these stimuli. [Filmed from best available copy.] (Author)

Visual-manipulative Response Strategies in Infant Operant Conditioning with Spatially Displaced Feedback[1]

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Abstract

Six and nine-month-old infants were exposed to contingent or non-contingent perceptual stimulation from a source which was spatially displaced at 60° from the infant's midline. Reliable operant acquisition was observed in the case of the nine-month-old infants, but not in the case of the six-month-old infants whose performance was similar to that of non-contingent controls. Examination of visual fixations of the feedback source coincidental with touching the manipulandum revealed the emergence of a strategy in the older infants which appeared to be critical for response acquisition. The emergence of this strategy is interpreted in terms of the older infants' increased capacity to remain oriented to task-relevant stimuli which are no longer immediately visually available and to regulate behaviour on the basis of information derived from these stimuli.

Despite the wide ranging demonstrations of operant conditioning in early infancy, it is only recently that investigators have turned their attention to the role which spatial and temporal parameters play in infants' operant response acquisition (Millar, 1972; Millar and Schaffer, 1972; Ramey and Ourth, 1971; Watson, 1967). In particular, previous speculation as to the importance of spatial contiguity of response and feedback contingency components in early learning has produced divergent opinions. On the one hand, the "magico-phenomenalistic" procedures observed by Piaget in infants are interpreted as indicating that in the early months causality is not yet spatialized or objectified; efficacy is a "causality of action-at-a-distance" (Flavell, 1963, p. 142). Moreover, there is recent evidence which indicates that under specific circumstances spatial contiguity between response and feedback loci is not prerequisite to contingency acquisition (e.g. Kalnins, in Bruner & Bruner, 1968; Millar, 1972; Siqueland & DeLucia, 1969; Watson, 1967). On the other hand, there is other evidence to suggest that in fact infants do experience difficulty when confronted with remotely controled contingency events (Friedlander, 1965; Smith, Zwerg & Smith, 1963).

In order to examine this matter further, Millar and Schaffer (1972) investigated the influence of spatial displacement of perceptual feedback on operant response acquisition in six-, nine-, and twelve-month-old infants by systematically varying the extent of the displacement. Reliable acquisition was found for all three age groups when the audio-visual feedback emanated from the manipulandum itself, i.e. when response and reinforcement loci were spatially contiguous. Similar acquisition performance was obtained for all three age groups under a spatially displaced feedback condition, where the reinforcing stimuli emanated from a source 35.5-cm. removed from the infant and offset from the face-on position. Under a third condition, however, where the feedback source (though still only 35.5 cm. from the infant) was displaced 60° to the side, acquisition was demonstrated only in the two older groups. The performance of the six-month-old group did not differ in this situation from the performance of controls that had received non-contingent stimulation.

It is evident that an explanation of these results cannot be in terms of spatial displacement *per se*, for even the youngest infants had no difficulty in coping with the 5° task, despite the spatial separation of the manipulandum and feedback locus. In the 60° condition the two loci were no further apart than in the 5° condition; what did differentiate the tasks, however, was the relative *visual* accessibility of the stimuli. In the 5° displacement situation the manipulandum and feedback source were, despite the spatial separation, so close within the infant's visual field as to permit virtual simultaneous visual attention to both; by contrast, in the 60° condition visual attention to one locus effectively precluded focussing on the other. As, moreover, the auditory component of the reinforcing stimulus ensured adequate orienting to the displaced feedback source it is unlikely that the difficulties encountered by the six-month-old infants could be attributed to restricted visual sampling.

Incidental observations made in the course of the study suggested another possible interpretation. The older infants, it appeared, were capable of handling the 60° task by adopting a strategy of visually fixating the feedback source while at the same time repeatedly touching the manipulandum without, that is, having to attend visually to the latter. This strategy the younger infants could not accomplish because, it was argued, they were unable to bear in mind stimulus events that were no longer visually accessible and to regulate their behaviour accordingly.

The present investigation was designed primarily to provide empirical evidence for this interpretation. It does so by comparing the behaviour of six- and nine-month-old infants in the critical 60° condition; on this occasion, however, visual as well as manipulative responses were recorded. It was predicted that the older infants would show a greater amount of 'coincidental' behaviour than the younger infants, i.e. that the former would be more capable of tactually operating the manipulandum while at the same time visually fixating the spatially displaced reinforcement locus.

METHOD

Subjects

Forty-eight infants (26 males, 22 females) were divided into two age groups as follows: 5.5-6.5 and 8.5-9.5 months (mean ages: 6.38 and 9.30 months respectively). Infants were obtained through child welfare clinics and letters of invitation to participate in the study were sent to every parent in the clinic area who had an infant within the relevant age groups. No infant had previously been involved in any other study and each infant was tested on one occasion only. Within each age group subjects were matched across experimental and control conditions to within ± 14 days. Altogether 61 infants were examined, but of these 13 were excluded from the study because of persistent fretting or sustained disruptive behaviour (n=10) or prolonged distraction from the task (n=3).

Apparatus

The apparatus enabled preselected programming of audio-visual perceptual feedback to be presented contingently or non-contingently upon instrumental response emission. A matt-grey table-top, bordered along its far sides with 46-cm. high matt-grey screens, was employed. An adjustable infant seat was situated midway along the near-side of the table so that the table extended 53-cm. on either side of the infant and 55-cm. in front of him.

The manipulandum consisted of a 10-cm. tall cylindrical aluminium canister rigidly secured to the table top at 8-cm. from the table edge, directly in front of and within easy reach of the infant. In addition to the manipulandum, a second canister was used to provide displaced feedback. This was secured to the table top at a distance of 35.5-cm. from the infant and offset at 60° from his visual centre line, either to the left or the right side. Holes of 1-cm. diameter were cut out of the canister in order to house coloured lights that provided the visual feedback. The lid of the canister incorporated a miniature loudspeaker which provided variable frequency auditory feedback from a Philips cassette tape-recorder. Signal amplitude was sufficient to orient the infant's gaze to the source of feedback without producing any observable startle. The amplitude of the signal was constant for all subjects.

Control equipment provided the necessary switching gear to present the perceptual feedback contingencies to the responding infant. The duration of both auditory and visual feedback pulses was variable up to a maximum duration of 1.0 seconds depending on the duration of the infant's response on the manipulandum.

A portable Rustrak 4-channel event pen-recorder was used for recording manipulative and visual responses. All control and recording equipment was housed in high-density polyester foam-rubber and operated at a distance behind the infant. Operating noise was consequently negligible.

Experimental Design

A mixed experimental design permitted both between-group and within-group comparisons. Age (6 and 9 months) and Contingency conditions (contingent and non-contingent) constituted the between-subject variables, with repeated measures on Phases (baseline, conditioning and extinction) the within-subject variable. The seven-minute procedure began with a one-minute baseline period (Phase I) which enabled operant level of responding to be determined, and this was immediately followed by two consecutive three-minute periods (Phases II and III). During Phase II the feedback stimuli were presented at the 60^{o} displaced canister, contingently or non-contingently upon discrete touch-down on the manipulandum using either or both hands. Where the infant maintained contact with the manipulandum he was required to lift-off at least one hand before further touching of the manipulandum would produce response feedback.

Periods of non-contingent stimulation involved each yoked control subject being matched with his experimental partner in terms of the number of discrete units of feedback and the total duration of feedback per minute during Phase II. Under this condition stimulation was delivered on a pre-determined random time schedule, thereby controlling for potential eliciting effects of the feedback stimuli.

Twelve infants at each of the two age levels were assigned to each experimental condition. The only restriction on random assignment was that, for the purpose of matching the experimental and control groups, the contingent subjects were tested first.

Procedure

The infant was placed in the chair by the mother, the seat being adjusted to enable the infant to reach the manipulandum on the table-top directly in front of him. Until the procedure formally commenced the canisters remained concealed. The mother stood behind the table-top screens facing the infant so that she was potentially visually available to him. This served to reduce the incidence of upset among the older subjects which had been observed during preliminary testing. Once the infant was judged content, the two canisters were uncovered, permitting manipulative access to the manipulandum. Discrete touching of the manipulandum enabled the infant to produce feedback at the 60° displaced canister. Presentation of the displaced feedback at the 60° source was balanced across subjects for left and right positioning relative to the central manipulandum. Discrete manipulative responses were recorded by one experimenter (who stood out of sight and to the rear of the infant) by operating a silent push-button switch. In the case of the contingent conditions, this effectively triggered the feedback episode. Visual fixations of the manipulandum and of the 60° displaced canister were separately recorded by a second experimenter who observed through a 13.5 x 4 cm. observation aperture in the screen directly facing the infant. A gauze covered smoked-glass insert effectively provided one-way vision. Interobserver agreement for the recording of manipulative and visual behaviours, based on independent samples of $\underline{n}$=8 and $\underline{n}$= 6 infants were .98 and .85 respectively.

The baseline minute commenced with the infant's first manipulative response. Recording of visual behaviour commenced simultaneously. Phase II was defined as the three-minute period extending from the first response which occurred after the termination of the baseline period. Similarly, Phase III was determined as the three-minute period elapsing from the first response emitted after Phase II terminated. This operated for both contingent and non-contingent groups. The adoption of this procedure of timing-out each of the phases from the first response overcame the problem of individual differences in response latency at the beginning of phases being confounded with effective acquisition time.

RESULTS

The findings will be reported under the following headings: (a) response acquisition data, i.e., the number of contacts made with the manipulandum, (b) visual fixation data, referring to the number of visual fixations observed, and

(c) coincidental manipulative and visual data.

(a) Response Acquisition Data

Baseline Performance

An Ages x Contingency (2 x 2) analysis of variance undertaken on baseline response frequency scores revealed no significant differences in operant response levels across the four experimental conditions.

The Effect of Contingency on Response Acquisition

Figure 1 shows the curves for each age group across baseline (Phase I), contingency (Phase II) and extinction (Phase III) for contingent and non-contingent presentation of perceptual feedback.

Insert Figure 1 about here

An Ages x Contingency x Phases (2 x 2 x 3) analysis of variance, with repeated measures on Phases, was carried out on responce frequency data for baseline minute and for the means of the three minutes of Phase II and Phase III respectively. No reliable main effects were obtained for Age, Contingency or Phases. A reliable Contingency x Phases interaction effect, $F(2,88)=7.54$, $p < 0.01$, revealed in broad outline the effectiveness of contingency upon response acquisition. Selected comparisons of the Contingency x Phases interaction, with Ages collapsed, revealed no reliable difference between contingent and non-contingent stimulation groups during Phase I and Phase III, $F(1,132)=0.98$, $p > 0.05$, but did indicate a reliable difference during Phase II, $F(1,132)=5.03$, $p < 0.05$. An overall effect for response acquisition was thus demonstrated.

The Effect of Age on Response Acquisition

A significant second-order Contingency x Phases x Ages interaction effect, $F(2,88)=4.94$, $p < 0.01$, revealed a differential effect of contingency for age. Selected comparisons between the curves for the six- and nine-month-old contingent groups showed no difference in baseline performance or during Phase III, but did reveal a significant difference during Phase II ($p < 0.05$). In the case of non-contingent stimulation, no differences were observed between the two age groups. As can be seen from figure 1, the Contingency x Phases interaction effect clearly applies to the older infants only. Selected comparisons within groups for the older subjects showed that the reliable difference between contingent and non-contingent conditions ($p < 0.001$) was directly attributable to a two-fold effect. Firstly, exposure to response-contingent feedback produced a significant increase in responding from baseline to Phase II ($p < 0.01$), whereas exposure to non-contingent stimulation resulted in a significant decrease in responding ($p < 0.05$). Secondly, quite divergent patterns of responding emerged during Phase III depending on prior contingency scheduling. In the case of the contingent group, the withdrawal of feedback produced, as expected, a highly significant extinction effect ($p < 0.001$) in the nine-month-old infants. By contrast, the cessation of non-contingent stimulation produced no statistically discernible change in responding for this age group. However, the performance of the six-month-old infants under response contingent feedback was quite different. As Figure 1 illustrates, there was no reliable increase in response output either under contingent stimulation or during extinction. Non-contingent stimulation did, however, produce a suppression effect ($p < 0.01$) comparable to the performance of the older infants. Similarly, cessation of non-contingent stimulation did not alter responsiveness. Clearly, the older infants demonstrated response acquisition under contingent feedback when it was delivered at the 60° spatial displacement, whereas the younger infants failed to show acquisition under these circumstances.

(b) Visual Fixation to (i) the Manipulandum, (ii) the 60° Canister

An Age x Contingency x Phases (2 x 2 x 2) analysis of variance with repeated measures on Phases was carried out on frequency of visual fixation to the manipulandum during baseline and Phases II and III. Discussion is restricted only to those relevant interaction effects which include Contingency and Phases. A significant Age x Contingency x Phases interaction effect, $F(2,88)=3,84$, $p < 0.05$, revealed differential visual fixations by age with contingency. Selected comparisons revealed no age-related differences in frequency of visual fixation of the manipulandum during the baseline period. However, in the course of Phase II the younger infants under non-contingent stimulation, but not under the contingent stimulation condition, showed reliably more visual fixations of the manipulandum than the older infants($p < 0.01$). Furthermore, under extinction in Phase III, the younger contingent group showed more visual fixations of the manipulandum than their older counterparts ($p < 0.01$).

Similarly, an Age x Contingency x Phases (2 x 2 x 2) repeated measures analysis of variance was undertaken on frequency of visual fixation to the 60^{o} displaced canister. No significant interaction effects were observed, demonstrating that the younger infants looked no less at the 60^{o} canister than the older infants.

(c) Coincidental Visual and Manipulative Behaviour

In order to establish whether the strategy of touching the manipulandum while fixating the spatially displaced feedback source was, as predicted, associated with successful response acquisition, an Age x Contingency x Phases analysis for repeated measures was carried out on the frequency of manipulative responses coinciding with visual fixation of the 60^{o} displaced canister. Only those interaction effects which include Contingency and Phases are relevant to the present discussion. When the contingent groups for both ages were compared, selected comparisons showed no reliable differences in coincidental behaviour during baseline or Phase III, but did reveal a highly reliable difference during Phase II ($p < 0.001$) see figure 2. Selected comparisons within-groups indicated that this age difference was directly attributable to an increase in the adoption of the coincidental response strategy between Phases I and II for the older infants ($p < 0.001$).

Insert Figure 2 about here

No similar increase was observed for the six-month-old infants. Similarly, only the older infants showed a significant decrease in this type of responding during extinction ($p < 0.001$). Under non-contingent scheduling, no reliable changes were observed either across phases or between the two age groups. Thus, these data confirm the prediction that the increase in coincidental responding occurred only in the older group during response acquisition. By contrast, it may be noted that no age-related difference was observed in frequency of simultaneous visual and manipulative behaviour to the manipulandum. The Age x Contingency x Phases interaction effect was non-significant ($p > 0.05$), indicating in particular no differences between the two age groups in terms of their simultaneous visual-manipulative behaviour to the manipulandum during the acquisition phase.

DISCUSSION

The results of this investigation confirm those of our earlier study (Millar and Schaffer, 1972) in demonstrating the difficulties experienced by six-month-old infants in an operant learning situation, in which a substantial spatial displacement of feedback source from the manipulandum has been incorporated. Unlike nine-month-old infants, the younger subjects in both studies showed no increase in response level during the reinforcement phase when compared either with baseline performance or with the performance of a non-contingent control group. It has thus again been established that only after six months are infants capable of conserving the response feedback contingency through the 60° displacement employed here.

The main purpose of this study, however, was to throw light on the reasons for this age difference, and in particular to examine the suggestion, stemming from previously made incidental observations, that the success of the older infants was largely due to the adoption of a response strategy which the younger infants appeared unable to adopt. This consisted in visually fixating the feedback source while simultaneously making repeated manual contact with the manipulandum: a pattern which we have referred to as "coincidental behaviour" and which necessitated the collection of visual as well as manipulative data in this study.

The results obtained confirm our prediction that such coincidental behaviour characterises the older but not the younger group. There were no age differences in this respect during baseline performance, but a highly significant difference emerged during contingency exposure, with the older group showing a dramatic increase in coincidental responding. The incidence in the younger group, on the other hand, did not differ from baseline measures nor from that observed in the performance of both age groups under non-contingent stimulation. During extinction the coincidental behaviour of the older infants decreased once more. An unequivocal association is thus demonstrated between successful learning and the adoption of the coincidental response strategy. Although coincidental-type responding accounted for only approximately one third of the total manipulative responses observed in the nine-month-old group during the conditioning phase, it does appear to be critical if the infant is to succeed in conserving the contingency.

In attempting to understand the reason for the age difference, it is relevant to note that the two age groups did not differ either in the number of simultaneous visual-manipulative contacts with the manipulandum or in the number of visual fixations of the feedback source. The younger infants, that is, were as competent as the older infants in making the appropriate manipulative responses on the one hand and the appropriate orienting responses on the other; what did differentiate the two ages was the integration of these behaviour patterns. In an analagous manner Koslowski and Bruner (1972), studying the development of lever usage by infants in the second year of life, found that their younger subjects were already well aware of the various components of the situation, but that each one of these was so preemptive of attention that their effective combination could not yet occur. Similarly, the performance of the six-month-old infants in the present study suggested that they were responding to separate categories of events which they were unable to integrate into a unitary whole. The economical strategy adopted by the older infants, on the other hand, effectively overcame the difficulty of sequentially integrating response and feedback information, in that it derived from an ability to remain oriented to an object that was no longer within the visual field, thereby indicating the necessary cognitive competence to rely on stored information for the regulation of behaviour. As had been pointed out elsewhere (Schaffer, 1971), there are various indications that such an ability does not emerge until the third quarter of the first year; previous to this point different events must be experienced simultaneously in the same perceptual field if they are to be related to one another.

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FOOTNOTES

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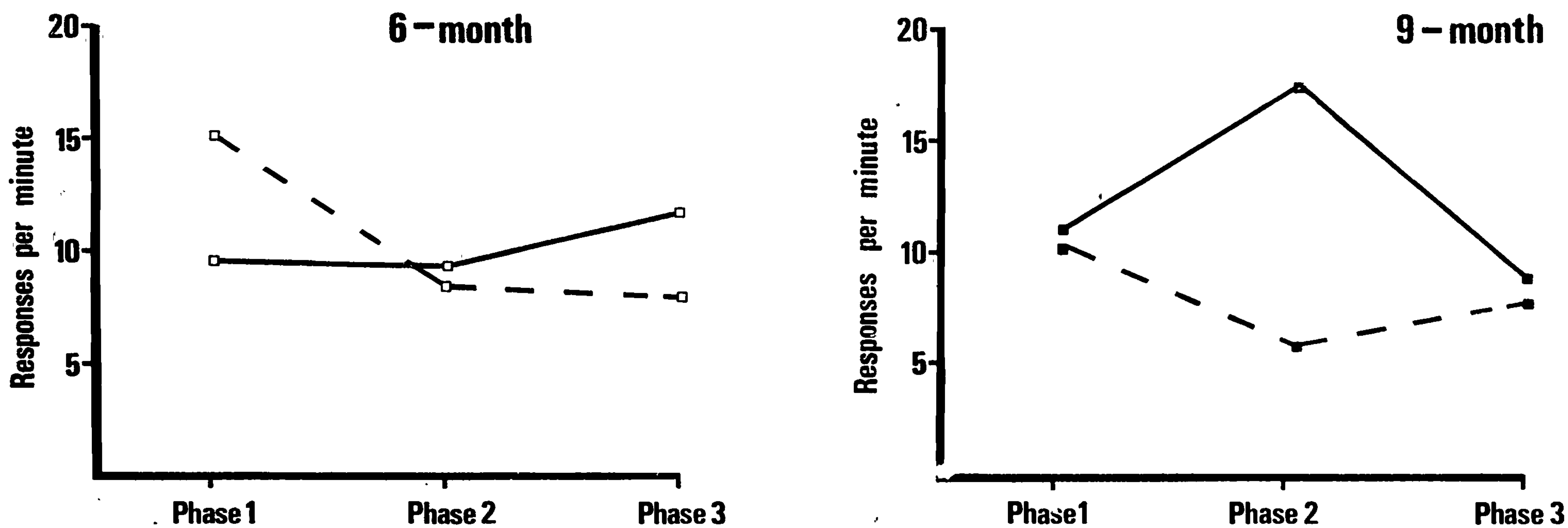
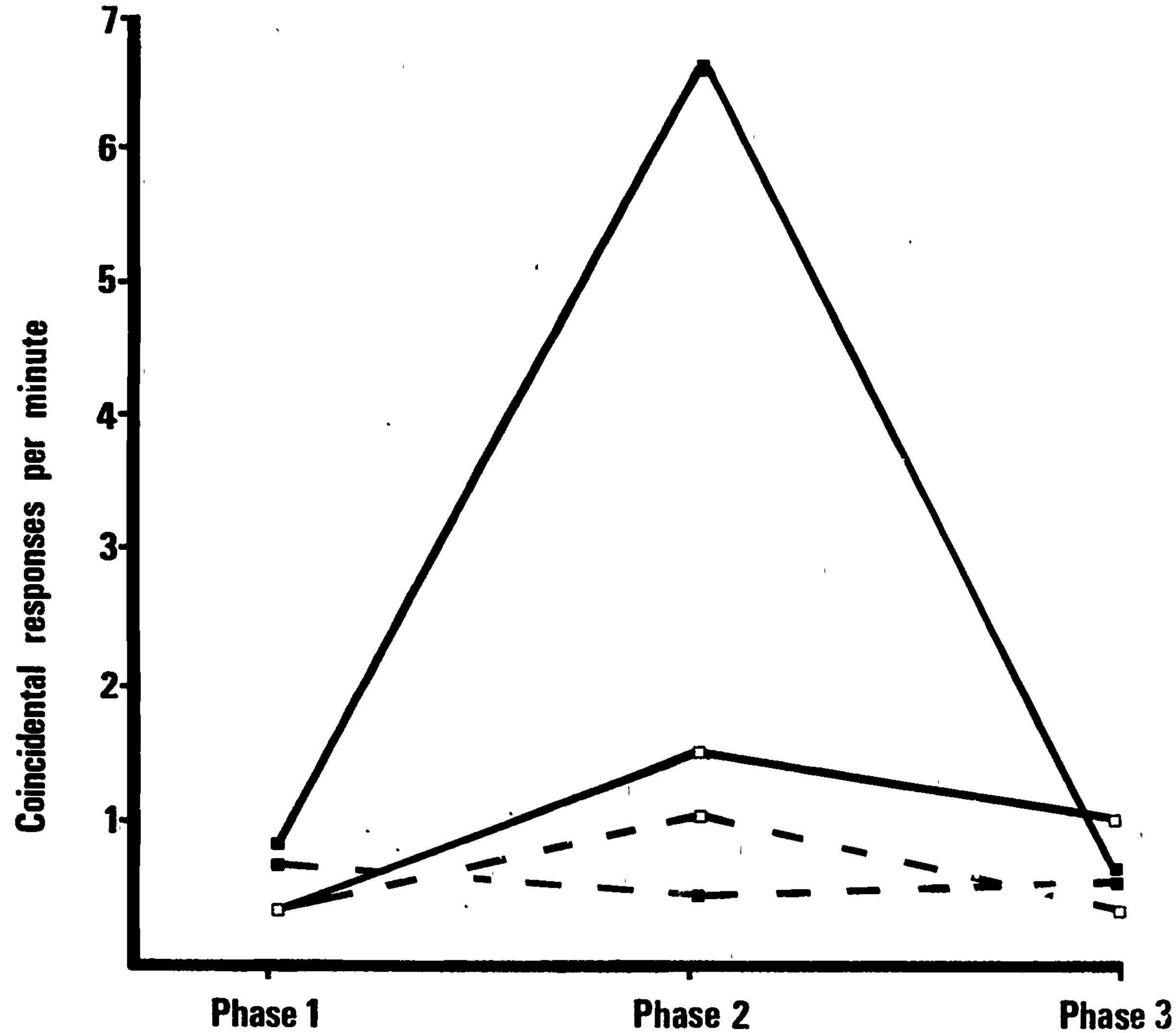
FIGURE CAPTIONS

Figure 1. Mean manipulative response frequency for 6-month groups under contingent □———□ and non-contingent stimulation □— — —□; and 9-month groups under contingent ■———■ and non-contingent stimulation ■— — —■.

Figure 2. Mean frequency of coincidental visual and manipulative responding to the displaced feedback source for 6-month groups under contingent □———□ and non-contingent stimulation □— — —□; and 9-month groups under contingent ■———■ and non-contingent stimulation ■— — —■.



6 – month
Responses per minute
20
15
10
5
Phase 1
Phase 2
Phase 3
9 – month
Responses per minute
20
15
10
5
Phase 1
Phase 2
Phase 3



7
6
5
4
3
2
1
Coincidental responses per minute
Phase 1
Phase 2
Phase 3