Blocking of Stimulus Control over Human Operant Behavior

by

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Abstract

The research was designed to demonstrate blocking of stimulus control over human operant behavior by employing basic, discriminated operant blocking procedures used with other animals. In operant conditioning, blocking occurs when a novel antecedent stimulus presented in compound with an S^D fails to condition. In Experiment 1 an A-B-C-D design was replicated across participants, with an additional between-groups comparison. Undergraduate introductory psychology students were randomly assigned to either the experimental blocking or control condition. The first 3 phases constituted the traditional blocking procedure: discrimination training between single stimuli (phase 1); discrimination training between 2-component compound stimuli, with one component from phase 1 plus one novel component for blocking group participants, but with two novel stimuli for control group participants (phase 2); and test for stimulus control to the novel stimulus elements (phase 3). A fourth phase consisted of discrimination training to the (former) novel stimuli but in reversed S^D and S^Δ roles. In Experiment 2 the control group procedure was changed by eliminating phase 1 altogether. In Experiment 1, data analysis by visual inspection of individually graphed data demonstrated apparent blocking in 8 of 11 blocking group participants, but 5 of 6 control group participants shared similar results. Experiment 2 produced apparent blocking in 10 of 11 blocking group participants but 7 of 11 control group participants performed similarly. Lack of conditioning to stimulus components by control group participants calls into question the role of (phase 1) preconditioning of a contiguously presented stimulus in the attenuation of conditioning. Between-subjects differences in suppression ratios on the first phase three test were not statistically significant for either experiment, although in the expected

direction for Experiment 2. Suppression ratios did vary reliably with response rate across both groups in Experiment 1, indicating that responding at higher rates was associated with a greater degree of conditioning to the novel stimulus elements. Differences between groups in phase 4 acquisition of discrimination were not statistically significant for Experiments 1 or 2. A number of variables were targeted for experimental control in the continuing quest to demonstrate blocking in humans.

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Blocking of Stimulus Control Over Human Operant Behavior

Under certain circumstances, an initially neutral antecedent stimulus presented contiguously with an unconditioned stimulus (UCS) in Pavlovian conditioning, or contiguously with a reinforced response in operant conditioning, fails to acquire conditioned stimulus (CS) or discriminative stimulus (S^D) properties, respectively. Failure to respond to the neutral stimulus may be due to prior training with another antecedent stimulus that is then presented in combination (as a compound CS or S^D) with the neutral stimulus during conditioning procedures. Kamin (1968, 1969) named this phenomenon the blocking effect.

Research on the blocking effect has relevance for two important issues: the conditions necessary and sufficient for learning to occur, and the generality of learning principles across species. The blocking effect undermines the notion that temporal contiguity between antecedent stimulus and UCS in the Pavlovian paradigm, and between antecedent stimulus and reinforced response in the operant paradigm, is sufficient for conditioning (Kamin, 1968, 1969; Rescorla & Wagner, 1972; Williams, 1996). Specifically, the amount of conditioning that will occur to a given antecedent stimulus over learning trials is dependent, among other things, on the conditioning history of *other* stimuli that are presented at the same time. Also, the relative ease of demonstrating blocking in infrahuman subjects compared with the difficulty in demonstrating blocking in humans, has raised doubts about the generality of learning principles across species, and supported speculations of fundamental differences between human and non-human animal learning in general, and between verbal and nonverbal learning in particular (Arcediano, Matute, & Miller, 1997). These implications have led Williams (1999) to state, "No empirical finding in the study of animal learning has been of greater theoretical importance than the phenomenon of blocking" (p. 618).

In his classic blocking experiment, Kamin (1968, 1969) used a conditioned suppression procedure whereby two Pavlovian conditioning phases and one test phase were superimposed on a stable base rate of operant bar pressing for food in rats. In phase one, a tone (CS-A) was paired with an electric shock UCS for 16 trials. In phase two, the tone was presented together with a neutral, light stimulus (CS-B), forming a simultaneous compound, tone-light stimulus (CS-AB). This compound stimulus then was paired with the shock UCS for 8 trials. In the test phase, the light stimulus (CS-B) was presented once in extinction, and the rate of operant responding was observed. The primary control group received the same phase two treatment and test trials as the experimental group, but phase one pretraining of the tone (CS-A) was omitted. Differences in responding between groups on the test trials therefore, were a function of between-group differences in phase one preconditioning (i.e., presence or absence thereof). Experimental group rats showed blocking. That is, operant bar pressing was much less suppressed during test presentations of the light (CS-B) in experimental group rats than in control group rats. Despite contiguous presentation of the light with the shock UCS, experimental rats showed impaired conditioning to the light relative to control rats. Kamin's three-phase blocking procedure remains the basic paradigm used in numerous subsequent studies of the blocking phenomenon (e.g., Martin & Levey, 1991; Rehfeldt, Dixon, Hayes & Steele, 1998; Williams, 1996).

Kamin (1968, 1969) also provided evidence for two methods of preventing the blocking effect, despite a history of prior conditioning to one element (A) of a compound stimulus. First, extinguishing the response to stimulus A *before* (but not after) compound AB conditioning trials, produced conditioning to stimulus B (1968, p. 19). Second, changing the UCS intensity at the onset of compound conditioning (phase two) also produced a conditioned response to stimulus B in the test phase (i.e., changing from a 1-ma electric shock UCS in phase one to a 4-ma shock UCS in phase two; 1968, p. 29).

Pavlovian studies demonstrating blocking in human participants have used Kamin's (1968, 1969) original three-phase design, but have varied the response measures, the stimulus modality, and the training procedures. Instead of conditioned suppression of operant bar pressing (Kamin), Kimmel and Bevill (1991) measured the skin conductance response. Martin and Levey (1991) measured blinking of the eyelid, to parallel blocking studies measuring responses of the rabbit's nictitating membrane (e.g., Giftakis & Tait, 1998). The stimulus modality in both of these studies was limited to the visual, rather than visual and auditory modalities (i.e., Kamin used a light and a tone). CSs were colored shapes, one or two of blue, yellow, red, and green. When Kimmel and Bevill earlier had used tone, light, and vibratory (finger) CSs (Experiment 1), no blocking was demonstrated. When only visual CSs were used (Experiment 3) blocking was demonstrated, possibly due to reduced response variability due to CS modality. Both the Kimmel and Bevill study and the Martin and Levey study ultimately produced statistically reliable blocking effects only when they made within-subject comparisons, which eliminated substantial "noise" found in between-subject comparisons (noise due to large individual variability in responding; Martin & Levey, p. 251). Their procedure involved "differential conditioning" (Kimmel & Bevill, p.134) between two CSs in phase one, whereby the CS+ was contiguously paired with the UCS and the CS- was not paired with the UCS. In phase two a novel stimulus was compounded with each of the preconditioned stimuli, but each compound stimulus then was paired contiguously with the UCS. Although blocking effects were found, the conditions under which they occurred appeared to be more complicated than for other animals.

Martin and Levey (1991) produced only weak blocking effects during extinction test trials until phase two compound stimulus presentations were changed from *adjacent* squares of colored light in a horizontal panel (CS-AB consisted of colors in positions one and two, and CS-CD of colors in positions three and four), to *separated* squares of colored light (CS-AB consisted of colors in positions one and three, and CS-CD of colors in positions two and four). The distance between elements of one compound stimulus was now 12 cm (each square was 12 cm x 12 cm in size). To improve detection of any blocking that might have occurred, Martin and Levey also re-analyzed their data to control for individual differences in discrimination between CS+ and CS- during phase one, and combined data from three separate experiments. The difference between the number of responses to the CS+ and the CS- on test trials was calculated for each individual participant (i.e., the difference value), and the sample was divided at the median difference value into a low differentiation group with a mean response frequency difference of 0.83, and a high differentiation group with a mean difference of 9.22. Only the high differentiation group produced a statistically significant blocking effect, indicating that strong discrimination performance in individual participants was prerequisite for demonstrating the blocking phenomenon.

Arcediano et al. (1997) set out to overcome the problems in blocking experiments with humans, by using a blocking procedure as similar as possible to procedures successful with other animals (e.g., Kamin with rats, 1968, 1969). A "behavioral" response measure and conditioned suppression procedure replaced physiological dependent measures such as the skin conductance response and eyelid conditioning of earlier human studies. Arcediano et al. superimposed conditioning trials on stable base rates of operant bar pressing using the space bar of a computer keyboard, with all stimuli presented to participants as part of a computer game. In a between-groups design, an experimental blocking group and a control group of participants learned to bar press to avoid individual Martian landings, which were occurring every 0.3 s. If the participant bar pressed immediately prior to an attempted landing by a Martian invader, an explosion symbol (i.e., ✱) would appear on the computer screen instead of a Martian symbol (i.e., ☺), indicating that a Martian landing had been prevented. After stable bar pressing rates were obtained, the schedule was increased so that Martian landings occurred every 0.2 s unless prevented by bar pressing responses (i.e., producing approximately five bar presses per second). This avoidance schedule remained in place for conditioning phases one and two.

Due to ethical constraints, the usual shock stimulus (as UCS; see Kamin, 1968, 1969) operative in non-human animal studies could not be employed as a punisher. Instead a visual stimulus, a white, intermittently flashing light, was given aversive qualities ("suppression value"; Arcediano et al., 1997, p. 192) through "verbal instructions and symbolic punishment" (p. 197). When the white, intermittently flashing light appeared on the computer screen, continued bar pressing by the participant would be punished by an immediate mass invasion of Martians. Participants were instructed that indicators would appear that would predict the white, flashing light, but that there also would be false indicators. If participants could determine which indicators predicted the white, flashing light, they would be able to avoid subsequent mass invasions by suppressing their operant bar pressing behavior before the light appeared. The aversive white light was therefore a conditioned punisher, and stopping the underlying bar-pressing behavior, prior to the light's appearance, was a conditioned avoidance response.

Phase one of Arcediano et al.'s (1997) blocking procedure consisted of discrimination training, replacing Kamin's (1968, 1969) single element conditioning. Presentations of S^Ds and S^Δs occurred during the ongoing bar-pressing task. In the presence of a blue background, the stimulus $S^D{}_A$, on the computer screen, stopping the ongoing key-pressing response was reinforced by the avoidance of a mass Martian invasion; in the presence of a yellow background, the stimulus $S^\Delta{}_X$, on the computer screen, stopping the key-pressing response was not reinforced – rather, individual Martian landings ensued at the rate of one per 0.2 s, if prior key presses did not prevent them. Similarly, in phase two ceasing to bar press was reinforced (by avoiding a mass invasion) in the presence of the compound stimulus, $S^D{}_{AB}$, consisting of the preconditioned blue background plus a novel high-frequency tone, stimulus $S^D{}_B$, but ceasing to bar press was not reinforced in the presence of the compound stimulus, $S^\Delta{}_{XY}$, consisting of the yellow background plus a novel low-frequency tone, stimulus $S^\Delta{}_Y$. Discrimination training was employed in order to "prevent excessive generalization" from one discriminative stimulus to other related stimuli (Arcediano et al., p. 192).

Participants in the experimental group were successful in discriminating the predictive and non-predictive stimuli (blue and yellow background colors) over 16 discrimination training trials for each color in phase one. In order to provide participants in the control group with equal exposure to both the conditioned aversive stimulus (white light) and the blue and yellow background colors, all three stimuli were presented 16 times by themselves, in an "explicitly unpaired" procedure (Arcediano et al., 1997, p. 192) (i.e., with no contingent relationships among them). Phase two conditioning trials consisted of four presentations each of the blue and yellow screens compounded with high- and low-frequency complex pulsed tones, respectively, presented through headphones (Arcediano et al.). The white, flashing light always followed, contiguously, the blue screen-high frequency tone compound, and never followed or was contiguous with the yellow screen-low frequency tone compound. The third, or test phase, consisted of a single unreinforced presentation of the target stimulus, the novel, high-frequency tone stimulus that had been combined with the preconditioned blue computer screen during phase two. A statistically significant between groups blocking effect was observed, attributed to the differential phase one preconditioning for experimental group participants, but also to the behavioral rather than physiological dependent measure that was used.

Several features of the design used by Arcediano et al. (1997) may have predisposed the lack of conditioning to novel stimuli when combined with preconditioned stimuli (i.e., to blocking), features that customarily may not be associated with demonstration of the blocking effect. First, the preconditioned stimuli, the blue and yellow background colors, were presented in the same sensory mode (visual) as the conditioned aversive stimulus (white, flashing light), whereas the novel stimuli added in phase two were auditory, and furthermore, emanated not from the computer, as did both preconditioned stimuli and the aversive stimulus, but from headphones. It is possible that this distinct separation in both sensory modality and physical source reduced the effectiveness of the contingency involving the auditory stimuli, and thus the amount of responding to these stimuli in the test phase. If both elements of the compound stimulus had been in the same sensory modality, and particularly the same modality as the aversive (white flashing light) stimulus, perhaps the blocking effect would not have been observed. Both previous studies that found blocking only when conditioned stimulus (CS) modalities were restricted to one (Kimmel & Bevill, 1991; Martin & Levey, 1991) nevertheless paired their CSs with a stimulus in a different sensory modality, tactile electric shock in the first, and a puff of air to the eye in the second. The effects of differing modalities of antecedent stimuli and consequent stimuli remain to be clarified.

A second potential confound concerns the verbal instructions to participants. Instructions informed participants that indicators of impending Martian invasions would appear, indicators that, if discerned, would allow participants to avoid bar pressing during the white, flashing light, and thereby also to avoid the Martian invasion. Participants were instructed to watch for both true and false indicators, so that they could discriminate when to continue bar pressing to avoid individual Martian landings, and when to stop bar pressing to avoid a major invasion. Subsequent responding by participants was likely controlled by instructions, rather than by the contingencies themselves (Kaufman, Baron, & Kopp, 1966). Once the true and false indicators were discriminated and effective performance was attained in phase one, no further discriminations were necessary to comply with instructions, and to avoid punishment, even after the transition to phase two. If no instructions had been given (or different instructions encouraging continuing vigilance for stimulus indicators), participants may have continued discriminating contiguous stimuli in phase two, and the tone stimulus then added might have produced a response in the test phase. Thus it is possible that the verbal instructions biased participants' responding in favor of blocking, and that different instructions would not have produced the blocking effect.

Suppression ratios for the novel stimulus in Arcediano et al.'s (1997) test phase were 0.39 for the blocking group and 0.27 for the control group (where 0.50 indicates no suppression, no conditioning, or complete blocking and 0.00 indicates conditioning, no blocking, and complete suppression). That is, the blocked group demonstrated less conditioning/suppression (i.e., blocking occurred) by higher bar pressing rates, and the control group demonstrated more conditioning/suppression by lower bar pressing rates, when tested with the novel stimulus. The difference, although statistically significant, is not large. As one comparison, Kamin (1968, 1969) obtained median suppression ratios of 0.45 and 0.05 for rats in blocked and unblocked groups, respectively.

A larger difference between groups, due to more conditioning/suppression in control group participants than reported, might have been expected in the Arcediano et al. (1997) study. For control group participants, stimulus A was unpaired in phase one but paired in phase two, with the white light UCS. That is, bar pressing was reinforced during stimulus A (i.e., individual Martian landings were prevented) in phase one, but punished during stimulus A (i.e., mass Martian invasion) in phase two. This manipulation provided the conditions for discriminating the novel stimulus element, by changing the consequences for responding during stimulus A in the transition from phase one to phase two (Kamin, 1968, pp. 15-16), and by the phenomenon of associative (conditioned) inhibition to the preexposed stimulus consequent to the explicitly unpaired phase one control procedure (Droungas & LoLordo, 1995), possibly making the novel stimulus more conditionable in comparison. Neither of these procedural differences occurs for the blocking group participants. Considering the potential confounding factors described above, in addition to the relatively small differences obtained between groups, it may be that a convincing demonstration of blocking in human participants has yet to occur.

Operant research with non-human participants has produced consistent evidence for blocking (Seraganian & vom Saal, 1969; vom Saal & Jenkins, 1970; Williams, 1996). Seraganian and vom Saal's procedure shared several characteristics with Kamin's Pavlovian animal studies. Rather than discrimination training between two stimuli, only a single stimulus was presented in phase one, and only a single compound stimulus was presented in phase two. Rats in both experiments learned to bar press for food on a variable-interval (VI) reinforcement schedule, and in each case, blocking was measured using a suppression ratio that compared response rate during stimulus presentation with response rate prior to stimulus presentation. Whereas Kamin's stimuli were paired with a shock UCS, Seraganian and vom Saal's stimuli were correlated with extinction. Seraganian and vom Saal presented 3-min noise stimulus periods without reinforcement in phase one, while a control group of rats continued responding on the VI 1-min reinforcement schedule without such stimulus periods. During phase two, both the blocking and the control group of rats received 3-min compound noise-light stimulus periods without reinforcement. The blocking group of rats learned to stop responding during noise stimulus periods during phase one, and both the blocking group and control group of rats learned to stop responding during compound noise-light stimulus periods in phase two. Subsequent test trials to the light stimulus alone resulted in statistically significantly greater suppression of responding in control group rats than in blocking group rats (suppression ratios of 0.08 vs. 0.19, respectively, with little overlap between groups), despite identical histories of light stimulus presentations.

A subsequent investigation by vom Saal and Jenkins (1970) differed from Seraganian and vom Saal's (1969) by instituting discrimination training between red and green lights in phase one, and between a red light-tone compound and a green light-noise compound in phase two, for the blocking group. The critical control group received no discrimination training or other stimulus presentations in phase one, but had the same phase two treatment as the blocking group. Discrete trials replaced free operant responding, for pigeons pecking keys for food. Pecks on the red key (phase one), or during the red key-plus-tone presentations (phase two) were reinforced, but pecks on the green key (phase one) or during green key-plus-noise presentations (phase two) were not reinforced. Phase three test trials with the tone during extinction again produced statistically significant blocking effects between groups, with discrimination indices of 0.57 vs. 0.77 for the blocking and control groups, respectively, where an index of 0.5 indicates no stimulus control (i.e., full blocking), and 1.0 indicates perfect stimulus control.

Williams (1996) replicated Kamin's blocking procedure in an operant paradigm, with a single discrete stimulus rather than with discrimination training between two stimuli in phase one (using a noise for the blocking group, and a clicker for the control group), and with a single compound stimulus in phase two (a noise plus a houselight for both groups; i.e., no S^{Δ}). Rats learned to lever press for food reinforcement in a discrete trials procedure and were reinforced on a VI schedule in effect only during stimulus presentation, but were not reinforced during the intertrial interval (ITI). Rats in both groups learned to discriminate by responding primarily during stimulus presentations in both phases one and two. Tests trials to the houselight during extinction produced a statistically significant blocking effect between groups. Control group rats demonstrated more stimulus control by the houselight than did blocking group rats (assessed by mean number of responses to the houselight, 61 vs. 29, for the control and blocking groups, respectively). Williams then proceeded to compound the houselight with a novel tone stimulus, which was presented to both groups of rats in a third conditioning phase, after which they were tested with the tone during extinction. Blocking group rats responded equally to both the houselight and tone tested singly, consistent with prior blocking of conditioning to the houselight. Conditioning to the tone was blocked in control group rats, but the houselight continued to control responding as expected, since this group of rats was preconditioned to respond to the houselight in phase two compound conditioning. The mean number of responses on the test trial to the tone stimulus was 38 for the control group (blocked) and 64 for the experimental blocking group (not blocked). Conditioning to stimulus elements of a compound, then, presumably also produces the required preconditions for subsequent blocking by either stimulus element when compounded with other novel stimuli.

Early investigations with humans produced only weak evidence for blocking of operant responses. Undergraduate students (Trabasso & Bower, 1968/1975) and primary school children (Lyczak, 1976; Lyczak & Tighe, 1975) participated in card-sorting tasks. Trabasso and Bower's results were confounded by overshadowing effects of one stimulus over the other, evident in the control group without preconditioning trials. (A stimulus that overshadows another evokes or controls a greater degree of responding, but without any differences between stimuli with respect to conditioning history; the overshadowing stimulus is identified as a "more salient" or "dominant" stimulus [p. 78]). Lyczak and Tighe demonstrated blocking only when obtrusive procedures during transitions between phases were minimized (i.e., instructions and observable manipulations by the experimenter that disrupted continuity between phases); and Lyczak showed blocking only when response latency was used as the dependent measure, rather than the less sensitive measure previously used, the number of errors made. Blocking appeared to be a "low-probability event" in humans as opposed to animals (Lyczak & Tighe, p. 121).

Applied researchers have examined the blocking effect in procedures used to teach reading skills to children with moderate mental retardation (Didden, Prinsen, & Sigafoos, 2000; Singh & Solman, 1990). Picture prompts shown together with written words may actually block learning to read the written words. Six of eight (Singh & Solman) and five of six (Didden et al.) children learned the correct spoken responses to written words more quickly when these words were trained without additional picture prompts, than when words were trained in compound with picture prompts. A rehearsal training procedure, requiring five oral repetitions of the correct response, was used on all trials with incorrect answers. Because pre-screening ensured correct recognition of picture prompts, errors were differentially made on word-only trials, likely resulting in implementation of the rehearsal training procedure predominantly in the word-only condition, when compared with picture-word compound conditions (data not reported). This procedure could very well have contributed to better word naming after word-only trials when compared to word naming after picture-word compound trials. Also, because there was no comparison group of children who were not preconditioned to the pictures, it is possible that poorer learning was due to the presentation of novel material in compounds rather than singly, and not due to blocking.

A somewhat more convincing demonstration of blocking was reported by Rehfeldt, Dixon, Hayes, & Steele (1998) in a stimulus equivalence paradigm. Undergraduate psychology students were trained on matching tasks for point reinforcers. Phase one consisted of matching (preconditioning) sample A with comparison stimulus B (and matching B with C). In phase two, the familiar stimulus sample A was combined with a new stimulus, X, to form the compound sample stimulus, AX, which was then matched with comparison stimulus B. Five of 10 participants demonstrated development of three-member equivalence classes (A, B, and C) on test trials during extinction. Four of these 5 participants also demonstrated blocking evidenced by decreased response accuracy on test trials with stimulus X (i.e., symmetry, B-X; transitivity, X-C; and equivalence, C-X) compared with accuracy on test trials with stimulus A (i.e., B-A; A-C; and C-A). Participants who demonstrated the blocking effect showed larger differences in response accuracy between tests of A relations versus tests of X relations. Using the median response measure across all 10 participants for each relation as a marker, blocking was most evident in four participants who performed at or above median accuracy on A relations and below median accuracy on X relations (e.g., accuracy on B-A vs. B-X trials; Rehfeldt et al., p. 657) on at least two of three equivalence relations. Five of 10 participants failed to establish stimulus equivalence between stimuli A, B, and C. These latter 5 participants and 1 who established equivalence relations had only small differences in response accuracy between A and X trials. Blocking in these 6 participants, if considered to have occurred at all, was weak at best. Nevertheless, in 4 of 10 participants prior equivalence training with one stimulus element of a compound blocked the second, redundant stimulus element from entering into equivalence relations.

Otto, Torgrud, and Holborn (1999) suggested that blocking was the likely mechanism producing instruction-induced insensitivity to schedules of reinforcement, rather than "pliance" (Hayes, Brownstein, Zettle, Rosenfarb, & Korn, 1986, p. 253), that is, the effects of social consequences on following instructions. Participants earned points by pressing computer keys to move a cursor through a matrix on a multiple fixed-ratio 18/differential-reinforcement-of-low-rate 6-s (FR 18/DRL 6-s) schedule that alternated every 2 min. Instructions to "Go fast" or "Go slow" alternated every 1 min, thus first coinciding and then conflicting with the underlying reinforcement schedules throughout the experiment. Increasing the magnitude of reinforcement on the FR/DRL schedules and increasing social consequences for gaining points did not increase schedule-sensitive responding, supporting predictions based on the blocking hypothesis, that "participants may not have discriminated the inaccuracy of the (Go fast/Go slow) instructions" (p. 666) when it occurred. A second experiment showed that after instructional control had been established, participants who then experienced schedule contingencies without instructions developed schedule-sensitive responding, and instructional control could not be re-established. This study departed from the typical blocking paradigm in several respects. Phase one preconditioning to follow instructions was assumed. More importantly, phase two compounding of instructions with schedule-discriminative stimuli combined stimuli that controlled disparate response rates on one-half of occasions and congruent response rates on the other half of occasions. In the blocking paradigm, the separate elements of compound stimuli have always been congruent in terms of the contingency in which they participate. Although blocking may be the mechanism of instructed insensitivity to schedules of reinforcement, Otto et al.'s research may be more important in suggesting the analysis of instructional control in terms of basic principles of stimulus control, such as blocking.

Operant research is often conducted using individual-organism experimental designs, as opposed to the more common between-groups design. Since behavior occurs at the level of the individual, individual-organism research may be more appropriate for this subject matter, in particular (Barlow & Hersen, 1984; Johnston & Pennypacker, 1993). Orderly functional relationships that may be observed at the individual level are often obscured by averaged data at the group level (for both between-groups and within-groups designs). Inter-subject variability confounds effects of independent variables in between-groups research, but is eliminated in single-organism research by having participants serve as their own controls. Weak results may be produced in between-groups research, although individual participants may be greatly affected by the manipulations; their influence on the group mean may be attenuated by opposite or no effects in other group participants (e.g., Martin & Levey, 1991). Increasing group size may produce statistically significant results, but it remains that inferences may be made only about the population from which the sample was drawn, which are not generalizable to the level of the individual (Johnston & Pennypacker, 1993, p. 188). Also, more information about behavior is gained by repeated measurement within the individual over the course of experimentation, rather than by only one or very few measurements, as occurs in usual between-groups design. Single organism research focuses on obtaining a precise picture of the functional relationship between a given variable and behavior over time, which if replicated in other individuals increases the generality of experimental findings (Barlow & Hersen; Johnston & Pennypacker).

Some evidence for blocking has been shown with humans in a stimulus equivalence paradigm (Rehfeldt et al., 1998), but not yet in discriminated operant procedures such as those used with non-human participants (e.g., Seraganian & vom Saal, 1969; Williams, 1996). Therefore, the primary purpose of my proposed research was to demonstrate blocking of operant behavior in human participants by replicating basic blocking procedures used successfully with animals. Procedures suggested, by past research with humans, to reduce or eliminate potential influences from competing variables, were implemented, including: (a) presenting stimuli from only one sensory modality and from one physical source (see Kimmel & Bevill, 1991; Martin & Levey); (b) employing discrimination training between antecedent stimuli during which responding was reinforced (S^D) and was not reinforced (S^Δ); (c) minimal verbal or instructional control over participant responding (recall criticism of research of Arcediano et al., 1997, p. 9; and possible blocking by instructions in Otto et al.'s [1999] research); (d) minimizing obtrusive procedures at the transition between experimental phases that might have alerted participants to stimulus changes (see Arcediano et al.; Lyczak & Tighe, 1975); (e) including only participants who demonstrate discriminative control over responding by the end of their first discrimination training phase (see Martin & Levey); and (f) including control group participants who experience discrimination training equivalent to that of experimental participants (see Williams, 1996). Basic blocking procedures used with animals have involved between-subjects comparisons, between an experimental blocking group and a control group of subjects. These comparisons were made in this experiment also, but with a superimposed single-case research design, to observe the development of stimulus control in individuals over the course of experimental manipulations, to eliminate inter-subject variability as a confound (see Martin & Levey, 1991), and to discern whether individual participants exhibit the blocking effect.

A four-phase A-B-C-D design, replicated across participants, was used. Three phases (A, B, and D) consisted of discrimination training between two different antecedent stimuli, with responses reinforced (with points exchangeable for monetary prizes) in the presence of the putative S^D and responses not reinforced in the presence of the putative S^Δ. The discriminative stimuli in phases one (A) and four (D) consisted of single elements, whereas the discriminative stimuli in phase two (B) each consisted of two single elements, forming compound stimuli. Two groups of participants, the experimental blocking group and the control group, differed only in the stimuli presented in phase one; discriminative stimuli used for control group participants were irrelevant to the remainder of the experiment. After phase one, all procedures and stimuli for both groups were identical.

Each compound stimulus employed in phase two was composed of one stimulus novel to both groups of participants, and a second stimulus novel to control group participants but familiar to blocking group participants. The latter familiar stimuli were those involved in phase one discrimination training for blocking group participants, one as the S^D and the other as the S^Δ. The third experimental phase (C) tested responding during extinction to the novel S^D and S^Δ stimulus elements (i.e., novel in phase two). Blocking would be demonstrated by non-differential responding during test presentations of the (former) S^D and S^Δ stimulus elements alone. If the novel stimulus elements were conditioned, and not blocked, in phase two, then differential responding would continue to be observed during phase three test presentations, with more responding to the element added to the S^D and less responding to the element added to the S^Δ. Control group participants were expected to demonstrate stimulus control by differential responding (continuing from phase two) to the test stimuli.

During phase four, the novel stimuli added in phase two and tested in phase three were presented again, but with their roles reversed: the S^D in phase two became the S^Δ in phase four, and the S^Δ in phase two became the S^D in phase four. Further evidence for blocking in experimental group participants would consist of more rapid development of discriminated responding between the S^D and the S^Δ than in control group participants, since blocked stimuli are in effect still neutral (or unconditioned) for the experimental group. Conversely, control group participants were expected to develop discriminated responding more slowly than experimental group participants, since control group participants would have been conditioned to these stimuli in phase two in opposing S^D and S^Δ roles, resulting in slower acquisition of control over responding.

Experiment 1

Method

Participants. Twenty-four participants were recruited from an undergraduate introductory psychology course, and received course credit for their participation. There were 14 males (mean age 22 years, range 17 – 40) and 10 females (mean age 21 years, range 17 – 27). They were randomly assigned to either the experimental or control group. One participant in the blocking group and six participants in the control group failed to meet the discrimination criterion (described below). Their data were excluded from analysis (leaving $n = 11$ for the blocking group, and $n = 6$ for the control group). All participants signed a statement of informed consent prior to the experiment, and were told that they could withdraw from the experiment at any time (see Appendix A). Participants were tested individually, to prevent interference in key pressing behavior by neighbouring participants. (Interference was considered likely due to the identical sequence of S^D and S^Δ presentations across participants, corresponding to expected distinct periods of responding and not responding, respectively, which if visually or aurally discriminated by fellow participants would diminish experimental control over individual behavior.) The experimenter left the room after giving initial verbal instructions, and stayed in an adjacent room.

Apparatus. Experimental sessions were conducted in a 2.9-m x 2.5-m room, containing a storage cabinet, 0.6 m x 0.6 m x 1.8 m, two 1.1-m x 0.8-m tables placed side-by-side, and three chairs. A single IBM-compatible Pentium 133 personal computer, equipped with a 3½-in floppy drive, 15-in color monitor, keyboard, and two-button mouse was placed on the tables. The computer program controlled all stimulus presentations, reinforcement schedules, and data collection.

Design. A four-phase A-B-C-D design, replicated across individuals who were also assigned to one of two groups, was used (see Table 1). Participants in each group received differential treatment in phase one only; phases two to four were identical for each group. Phases one to three paralleled Kamin's (1968, 1969) three-phase blocking procedure. The phase four addition tested for blocking in a "retardation of acquisition" procedure (see Droungas & LoLordo, 1995). That is, the two novel single stimulus elements that were conditioned in phase two as components of the compound S^{D}_{AC} and S^{Δ}_{BD} (i.e., elements S^{D}_{C} and S^{Δ}_{D}), were trained in phase four in reversed roles, as S^{Δ}_{C} and S^{D}_{D}, respectively. During phase one, discrimination training in the control group employed stimuli that were not used in, and therefore were irrelevant to, the remainder of the experiment (i.e., S^{D}_{X} and S^{Δ}_{Y}), This control procedure permitted blocking and control group participants to experience an equivalent duration of practice in the operant task and in discrimination training. All phases were presented in immediate succession, without interruption, within a single session.

Table 1

Design for Experiment 1

Group	Phase 1	Phase 2	Test	Phase 4
Blocking	16 S^{D}_{A}, 16 S^{Δ}_{B}	16 S^{D}_{AC}, 16 S^{Δ}_{BD}	3 S_{C}, 3 S_{D}	16 S^{D}_{D}, 16 S^{Δ}_{C}
Control	16 S^{D}_{X}, 16 S^{Δ}_{Y}	16 S^{D}_{AC}, 16 S^{Δ}_{BD}	3 S_{C}, 3 S_{D}	16 S^{D}_{D}, 16 S^{Δ}_{C}

Note. Numerals indicate the number of presentations of each stimulus. S^{D}_{A} and S^{Δ}_{B} were red and green rectangles; S^{D}_{X} and S^{Δ}_{Y} were black and white rectangles; and S_{C} and S_{D} were blue and yellow rectangles. Colors of S^{D} and S^{Δ} were counterbalanced across participants.

Procedure. Participants sat in front of the computer keyboard and monitor. The experimenter provided initial instructions orally. The participant was requested to follow the instructions on the computer screen asking for input of personal data (false name, assigned number, age, and gender). Further instructions appeared on the computer screen as follows:

> Your task is to press the SHIFT key (either one is fine), in order to earn points. Earn as many points as you can, by pressing the SHIFT key frequently. Try your best to press the SHIFT key only when you can earn points. This depends on the colored rectangles.
>
> Win small cash prizes! Right after you finish this experiment, you can draw for small cash prizes. Each draw costs 30 points. There will be 50 tickets to draw from: 1 for \$20.00, 2 for \$10.00, 3 for \$5.00, 4 for \$2.00, 10 for \$1.00, and 30 for \$0.25.
>
> Press the ENTER key when you are ready to begin the experiment.

For easy reference during the actual experiment, a hard-copy instruction sheet beside the participant's computer terminal reiterated instructions.

One point was earned on the first key press after a variable interval had elapsed (VI reinforcement schedule) during S^D presentations, while no points could be earned during S^Δ presentations (extinction schedule). Earned points were accepted by pressing the space bar in response to an underlined blinking message that appeared on the screen, "Press the SPACE bar to accept 1 point." Continued pressing of the shift key before pressing the space bar resulted in the following message appearing on screen, "Press the Space bar before continuing!" Pressing the space bar advanced the point counter by one point and eliminated the message from the screen. The point counter appeared in the upper left corner of the computer screen, and indicated current total points throughout the experiment. Upon completion of the experiment, points were exchanged for draws for small cash prizes. The expected value of a single draw was \$1.61.

Stimulus elements in all phases were colored, 3.3-cm x 8.4-cm rectangles. When a stimulus consisted of a single rectangle, as in phases one, three (test phase), and four, it appeared on the computer screen centred in the top half of the screen, with the longer dimension placed horizontally. Phase-two compound stimuli consisted of two rectangles of the same size, which appeared on screen at the same time, with both rectangles placed horizontally and in parallel. Two cm of background separated the rectangles, which were centred on the top half of the screen. The rectangle that was already conditioned in phase one for experimental participants held the top position on the computer screen (the same position as in phase one), and the novel rectangle held the lower position on the computer screen. The pair of rectangles were placed 2 cm apart intentionally because of evidence that adjoining visual stimulus elements may interfere with the blocking effect (separating originally adjacent stimulus squares by 12 cm increased the statistical significance of the blocking effect in Martin & Levey, 1991). Stimulus colors were counterbalanced, so that half of participants in each group were conditioned with one color as S^D and the second color as S^Δ, while the other half of participants had stimuli of the same colors but in reversed roles, as the S^Δ and the S^D, respectively, to control for any effect of color.

Discrimination training in each of phases one, two, and four consisted of sixteen 20-s presentations of each of the S^D and the S^Δ, for a total of thirty-two 20-s intervals and a 640-s duration per phase. To prevent control over responding by the passage of time, which might develop if the S^D and the S^Δ were alternated strictly every 20 s (i.e., resumption or cessation of key-pressing might be controlled only by consequences that alternated every 20 s, rather than by the stimuli present during those consequences), the order of stimulus presentations was reversed after every four presentations (i.e., S^D, S^Δ,

S^D, S^Δ, then S^Δ, S^D, S^Δ, S^D, repeated four times).

The VI reinforcement schedule increased systematically and in an identical sequence across phases one and two of discrimination training, beginning with a VI 2-s (range 1 – 3 s), then a VI 3-s (range 2 – 4 s), a VI 5-s (range 4 – 6 s), a VI 8-s (range 6 – 10 s), a VI 12-s (range 10 – 14 s), and ending with a VI 17-s (range 14 – 20 s) reinforcement schedule. Each integer value within the ranges of VI reinforcement schedules was equally represented (a rectangular frequency distribution) in randomized blocks of all integers. Increasing the VI schedule and maintaining the reinforcer value caused a drop in reinforcer density as participants progressed through these phases. Any given 20-s stimulus presentation contained only one VI schedule. The number of intervals of each VI schedule in phases one and two, in sequence, was two presentations of VI 2-s, VI 3-s, and VI 5-s, followed by three presentations each of VI 8-s and VI 12-s, and finally four presentations of VI 17-s. The purpose of increasing the VI schedule was to increase resistance to extinction in preparation for the test phase, during which test stimuli were presented in extinction. Key pressing in phase-four S^D intervals was reinforced consistently on a VI 8-s schedule; it was expected that by this point in the experiment all participants would maintain responding to stimulus presentations.

Phase one (single-stimulus conditioning). During this phase, all participants were presented for the first time with a single rectangle during which key pressing was reinforced (the $S^D{}_A$) and a single rectangle during which key pressing was not reinforced (the $S^\Delta{}_B$). A red rectangle and a green rectangle were phase-one stimuli for blocking group participants, and a black rectangle and a white rectangle were phase-one stimuli for control group participants. Stimulus colors were counterbalanced; half of participants in each group were conditioned with one color as S^D and the second color as S^Δ; colors were reversed for the other half of participants.

Phase two (compound-stimulus conditioning). Compound stimuli for blocking group participants consisted of one rectangle previously conditioned in phase one, plus one rectangle of a new color. That is, the phase-one $S^D{}_A$ and $S^\Delta{}_B$ were incorporated into the phase-two $S^D{}_{AC}$ and $S^\Delta{}_{BD}$, respectively. In contrast, for control group participants both stimulus elements of the compound stimuli were novel or unfamiliar. The phase-two compound stimuli for both groups were a red rectangle with a blue rectangle, and a green rectangle with a yellow rectangle. Stimulus colors were counterbalanced in correspondence with phase one conditions; half of participants in each group were conditioned with one color as S^D and the second color as S^Δ; colors were reversed for the other half of participants.

Phase three (test for blocking). The test phase for all participants consisted of three presentations each of the novel (second) stimuli that were added in phase two (i.e., blue rectangles and yellow rectangles). Presentation of the S_C (formerly an element of the compound $S^D{}_{AC}$) was followed by presentation of the S_D (formerly an element of the compound $S^\Delta{}_{BD}$) three times, with each test interval separated from the next by two intervals (one $S^D{}_{AC}$ and one $S^\Delta{}_{BD}$ interval) of continuing discrimination training. Key pressing during the compound $S^D{}_{AC}$ continued to be reinforced on the VI 17-s schedule, but was on extinction during the compound $S^\Delta{}_{BD}$. The test stimuli were presented for 20-s periods in extinction, The purpose of continuing phase-two discrimination training amongst the stimulus control tests was to prevent significant loss of discriminated responding over the three test trials, and also prior to the phase four stimulus reversal.

Phase four (stimulus reversal; retardation of acquisition test). Rectangles that were presented as S^D elements in phase two, were now presented as S^Δ s, and vice versa. Phase-four stimuli for both groups were a blue rectangle and a yellow rectangle.

Questionnaire. At the conclusion of the experiment, participants were given a short pen-and-paper questionnaire to complete (see Appendix B). Six rectangles, one of each of the six colors used in the experiment, were presented on a single page. Experimental and control group participants were given the same questionnaire, although only four different colors of rectangles were used for experimental group participants. Their responses to the black rectangles and white rectangles, to which they had not been exposed, served as a control for responses to the other colors. Participants were asked to indicate whether or not they had earned points by key pressing during the presentation of each rectangle. They were also asked to write down any other comments that they might have about how points were earned, or about the experiment in general.

Dependent variables. The computer recorded the number of shift-key presses per 20-s stimulus interval. A "discrimination ratio" (Williams, 1996, pp. 72-73) was calculated; it represents the proportion of shift key presses occurring during the S^D over the total number of shift key presses during both the S^D and S^Δ presentations, and is a measure of the degree of discriminated responding attained between the S^D and the S^Δ. A discrimination ratio of 1.00 indicates complete stimulus control with all of the responses occurring in the presence of the S^D, and a ratio of 0.50 indicates no differential stimulus control, with an equivalent amount of responding in the S^D and the S^Δ (vom Saal & Jenkins, 1970). A discrimination ratio was calculated for each phase, combining the last four presentations of the S^D and S^Δ for phases one, two, and four (i.e., in the last 160 s or

25% of these phases). A discrimination ratio also was calculated for the first interval of the test stimuli in phase three. Participants were eliminated from further analysis, if the discrimination ratio in either phase one or phase two did not reach or surpass a criterion value of 0.70.

A suppression ratio (SR; Kamin, 1968, 1969) was calculated for the first test in phase three, using the formula SR = B/(A + B), where B is the number of key presses during the S^{Δ}_{D} 20-s test stimulus, and A is the number of key presses during the preceding compound S^{D}_{AC} 20-s interval. Note that during the interval preceding the test stimulus responding was always reinforced, and may be referred to as the baseline rate of responding. A ratio of 0.00 indicates total suppression of key pressing during the test interval. A ratio of 0.50 indicates no change in response rate, and ratios greater than 0.50 indicate an increasing response rate during the test interval.

Results

Visual inspection of graphs: Responses per 20-s stimulus interval were graphed for each participant over the duration of the experiment for visual inspection of the data. Responding of participants in the blocking group was categorized as one of high blocking, moderate blocking, or low blocking, depending on performance during the first test intervals of the S^D and the S^{Δ} in phase three. Figure 1 shows responding across all phases for 3 (out of 11) blocking group participants, of whom one blocked to a high degree (top), one to a moderate degree (middle), and one showed no evidence of blocking (bottom).

Participant B4. Participant B4 did not show appreciable differential responding in phase one until interval nine, after which responses during the S^{Δ} were eliminated and

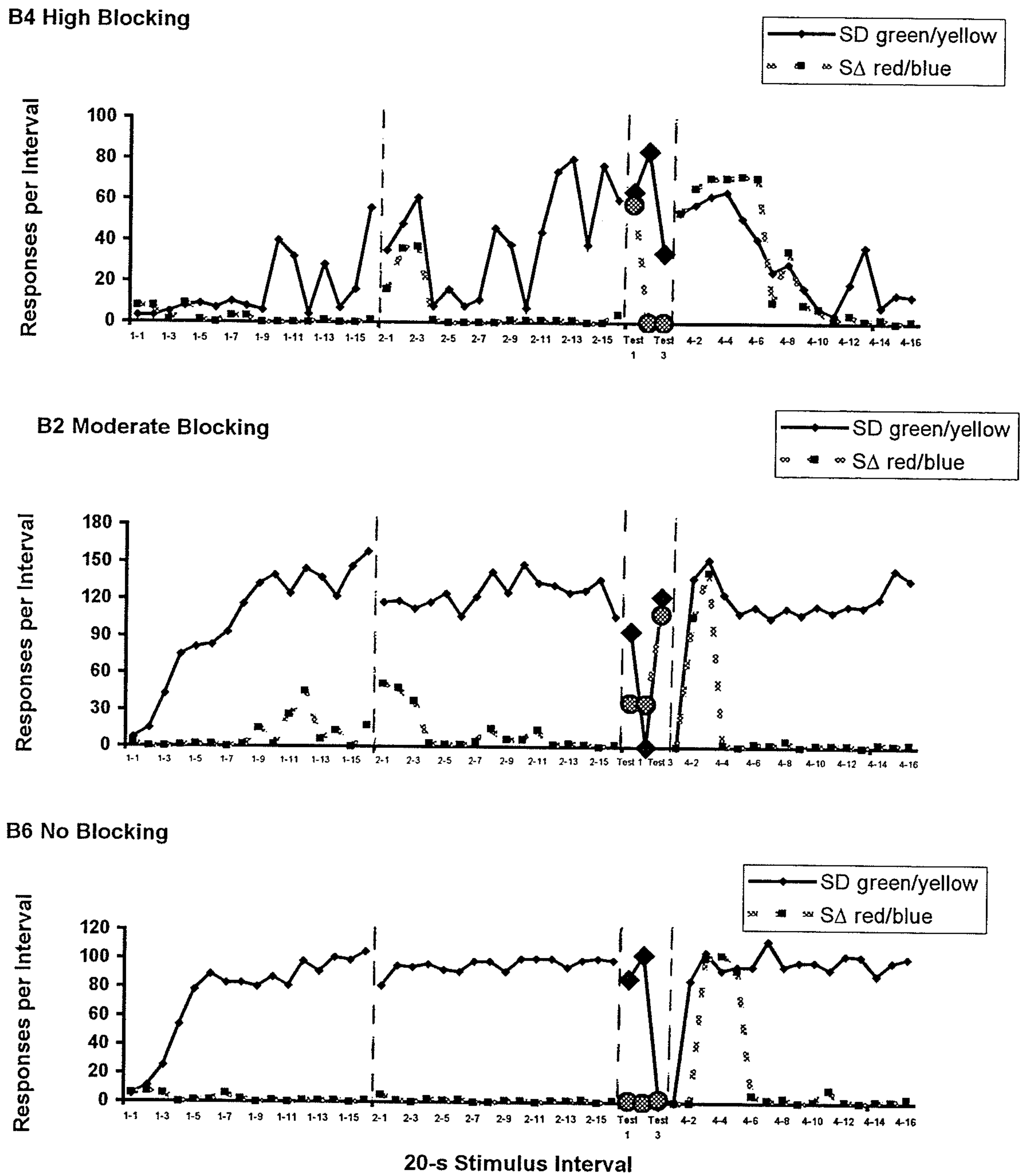


Figure 1. Number of key-presses in each consecutive 20-s stimulus interval for blocking group participants B4, B2, and B6. Large shaded symbols mark responses during test intervals in phase 3; diamonds for (former) S^D stimuli and circles for (former) S^Δ stimuli. The legend identifies stimulus colors of phase 1 (first color), phase 2 (both colors), test phase (second color), and phase 4 (second color, but in "reversed" S^D and S^Δ role).

responses during the S^D rose. However, the response rate during the S^D fluctuated considerably for the remainder of phase one, but always remained greater than the response rate during the S^Δ. By the end of phase one participant B4 had learned to discriminate between the S^D and the S^Δ, with high response rates in the presence of the S^D and negligible response rates in the presence of the S^Δ.

The introduction of compound stimuli in phase two caused a clear disruption in previous responding, with decreased differentiation of response rates during the early S^D and S^Δ intervals. The response rate fell on the first compound S^D presentation and rose on the first compound S^Δ presentation. Rates remained close together first rising and then falling in tandem, until interval eight, at which point the response rate in the presence of the S^Δ was minimal and the response rate in the presence of the S^D rose substantially. The response rate during the S^Δ remained at a consistently low level for the remainder of phase two, while the response rate during the S^D continued to fluctuate, but with a generally increasing trend. By the end of phase two participant B4 discriminated between S^D and S^Δ, to a greater degree than in the previous phase one.

Response rates in the presence of single stimuli introduced in phase three are critical to the assessment of blocking, as they reflect effects of prior conditioning. One critical comparison to be made is between the response rate during the first test of the (former) S^D element and the response rate during first test of the (former) S^Δ element. If no prior conditioning has taken place (i.e., if blocking has occurred), then there should be little difference in responding between these stimuli. If conditioning has taken place (i.e., if blocking did not occur), then response rates should continue at high levels during the (former) S^D and at low levels during the (former) S^Δ. Participant B4 exhibits a high degree of blocking on the first test interval by this criterion, as the response rates during the (former) S^D and S^Δ are essentially equivalent.

A second comparison that may indicate blocking is that between response rates during the first test interval of the single (former) S^Δ and during the compound S^Δ at the end of phase. Blocking has occurred to the extent that the response rate rises on the first test of the (former) S^Δ stimulus element, relative to the low rate obtained in phase two. This difference was large in participant B4, who also had equivalent response rates on the first test presentations of the S^D and S^Δ elements, and is therefore designated a "high blocker."

Response rates during tests two and three were likely contaminated by extinction, and by interspersed discrimination training intervals, during which participants may have been alerted to the separate elements of the compound stimuli. For these reasons, and since most blocking studies draw their conclusions from responding on the first test trial, responding during tests two and three will not be considered.

In phase 4, participant B4 responds at similar, high rates from the first to the sixth interval. Differential responding between the S^D and the S^Δ in phase four (conditioned in reversed roles as elements of compound S^Δ and S^D, respectively, in phase two) requires longer exposure to the contingencies than in phases one or two. Participant B4 does not show a higher response rate during the S^D until interval 12, and a minimal response rate during the S^Δ until interval 11. Discrimination required only 9 intervals in phase one, and 8 intervals in phase two. Discrimination takes a different form than in previous phases, as well. At the beginning of phase four response rates during both the S^D and S^Δ are at high levels, similar in magnitude to the maximal rates of phases one and two; in contrast, response rates are low during both S^{Δ} and S^{D} at the beginning of phase one, and response rates are intermediate during both S^{Δ} and S^{D} at the beginning of phase two. In phase four, participant B4 responds at high rates during both stimuli, although higher during the S^{Δ} (former S^{D}), until together the response rates begin a gradual decrease that is clearly evident by interval 7. Participant B4 shows discriminated responding only in the last five intervals.

Participant B2. In phase one, response rate during the S^{D} increases steadily, reaching relative stability at interval nine. The response rate during the S^{Δ}, which had been negligible until this point, also began to rise and fluctuate, although at much lower levels. Discrimination between the S^{D} and the S^{Δ} was evident by the end of phase one, with high response rates in the presence of the S^{D} and low response rates in the presence of the S^{Δ}.

The introduction of compound stimuli in phase two caused a decrease in differential responding during the first three S^{D} and S^{Δ} intervals for participant B2; response rates during both intervals went to intermediate levels. At interval 4, the response rate fell to low levels during the S^{Δ} but remained high with a gradual rise in rate during the S^{D}, but not to previous phase one levels. Stable and differential response rates were present for the remainder of phase two.

Participant B2 showed a moderate difference between response rates during the (former) S^{D} and S^{Δ} elements on the critical first test presentation in phase three. The difference between response rates during the S^{D} and the S^{Δ} was about half as large in the immediately preceding phase two, showing reduced stimulus control over responding (i.e., some blocking). The response rate during the test presentation of the (former) S^{Δ}

element was moderately elevated compared with the negligible response rate during the compound S^{Δ} stimulus in phase two, indicating that a degree of conditioning had occurred.

In phase four, response rates during the S^D and the S^{Δ} are nearly identical for the first three intervals. Differential responding occurs during interval four, for participant B2, at approximately the same time as in phases one and two. Differential responding was achieved by the abrupt decrease in response rate to zero during the fourth S^{Δ} interval. Response rates remained stable at high levels in the presence of the S^D and at zero in the presence of the S^{Δ} for the remainder of phase four.

Participant B6. In phase one, the response rate during the S^D steadily increases to nearly the maximal level by the sixth interval, and remains high and relatively stable for the rest of the phase (with an increasing trend after interval 11). The low response rate during the S^{Δ} decreases to zero by the fourth interval, and remains stable and very low for the rest of phase one. Participant B6 developed consistent discrimination between the S^D and the S^{Δ} by the third interval, and stable response rates from interval six onwards. Small disruptions in response rates occurred during the first intervals of the compound S^D and S^{Δ}; a small decrease in rate during the S^D, and a slight increase in rate during the S^{Δ}, indicated that the stimulus change was "noticed." Thereafter in phase two, the response rates during both the compound S^D and S^{Δ} return to their previous stable and highly differential levels.

Participant B6 demonstrated a complete lack of blocking on the first test presentation of the (former) S^D and S^{Δ} elements in phase three. The difference between response rates was virtually the same as in the immediately preceding phase two, indicating that the single components of the compound controlled responding as much as the compound stimuli had. The response rate during the (former) S^{Δ} element remained at zero, again showing complete conditioning to the single S^{Δ} element.

In phase four, participant B6 displays a high response rate during the S^D from interval two onwards. A high response rate also is evident during the S^{Δ} in intervals three to five, after which it drops to a negligible level where it stays for the rest of phase four. Differential responding was achieved by the abrupt decrease in response rate to zero during the sixth S^{Δ} interval, compared with differential responding by interval three in phase one, and from the first interval onward in phase two. Response rates remained stable at high levels in the presence of the S^D and at zero in the presence of the S^{Δ} for the remainder of phase four, indicating discriminated responding.

Appendix C shows graphed data for the remaining blocking group participants. Altogether, a high degree of blocking was demonstrated in 5 participants, a moderate degree of blocking was demonstrated in 3 participants, and little to no blocking was demonstrated in 3 participants; 8 of 11 blocking group participants showed at least a moderate blocking effect.

Figure 2 shows graphs of data for three of the control group participants, displaying a complete failure to condition (top and middle), and successful conditioning (bottom).

Participant C2. Response rates for participant C2 very gradually began increasing during the S^D while remaining low during the S^{Δ}, with discrimination between the two being evident by interval four and for the remainder of phase one. The introduction of compound stimuli in phase two produced a small rise in response rate during the S^{Δ}, with less differentiation between the S^D and the S^{Δ}; the response rate increased during the first

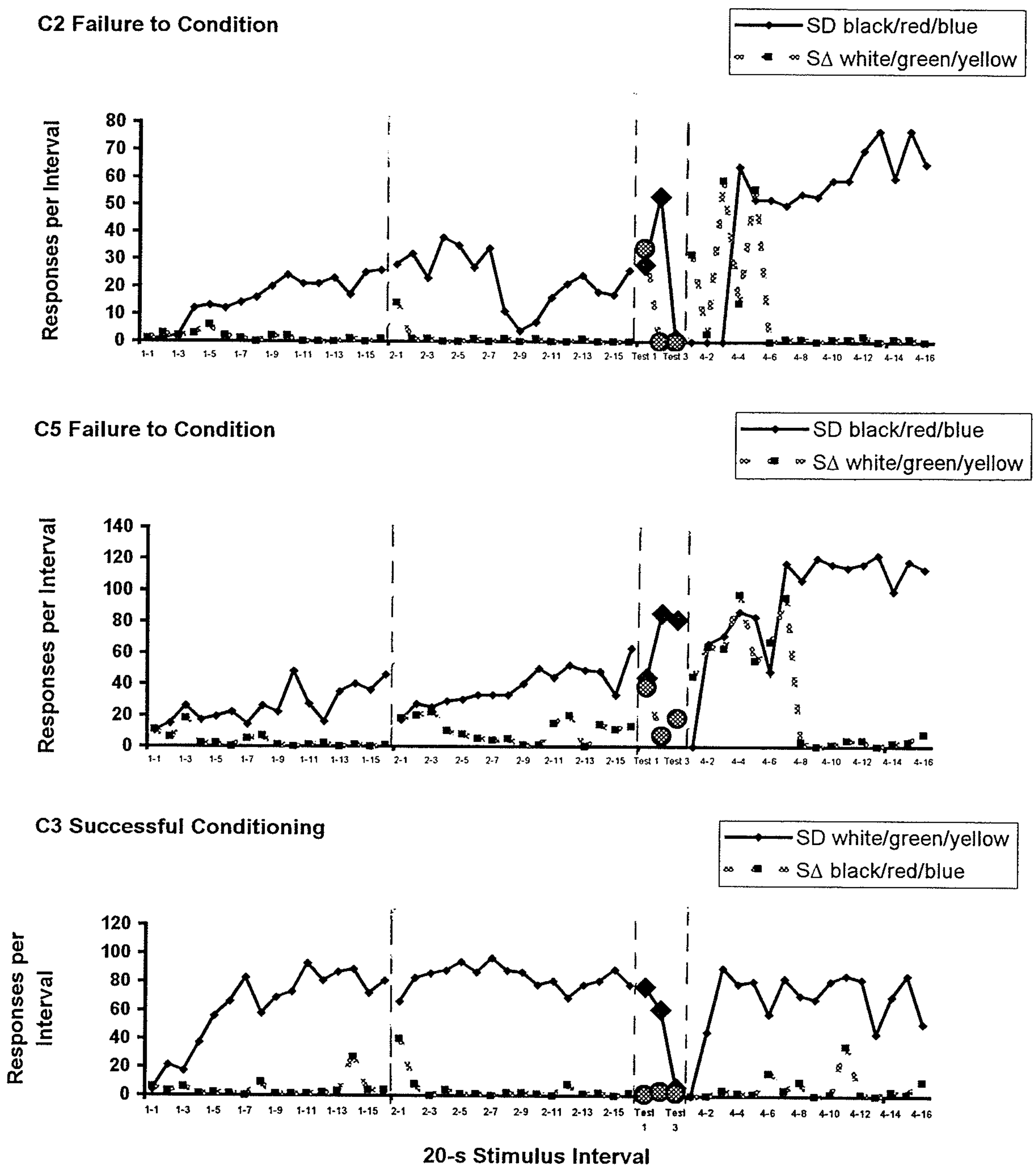


Figure 2. Number of key-presses in each consecutive 20-s stimulus interval for control group participants C1, C5, and C3. Large shaded symbols mark responses during test intervals in phase 3; diamonds for (former) S^D and circles for the (former) S^Δ. The legend identifies stimulus colors of phase 1 (first color), phase 2 (second and third color), test phase (third color), and phase 4 (third color, but in "reversed" S^D and S^Δ role).

S^{Δ} interval of phase two, but did not change during the first S^{D} interval. The response rate returned to zero during the second compound S^{Δ} interval, where it remained for the rest of phase two. Responding during compound S^{D} intervals meanwhile remained high, until interval eight when the response rate fell dramatically only to recover by interval 11. Response rate in the presence of the S^{D} then gradually increased and reached a level similar to that obtained in phase one, with corresponding evidence of discriminative control.

On the critical first test of phase three, participant C2 responded equally during both (former) S^{D} and S^{Δ} elements, indicating blocking. On the comparison between response rates during the compound S^{Δ} at the end of phase two and during the first test of the single (former) S^{Δ} element, participant C2 also showed blocking by a marked increase in response rate during the latter stimulus from zero responding.

Participant C2 begins phase four by responding more during the S^{Δ} than the S^{D}, evidence of some conditioning (and not complete blocking) in the previous phase two. The response rate during the S^{D} remains at zero until interval four, when it rises dramatically and remains at a high level for the rest of phase four. The response rate during the S^{Δ} fluctuates for several intervals, until it falls to zero at interval six, where it remains for the rest of phase four. From interval six onwards, participant C2 differentiates more between the S^{D} and the S^{Δ} during the second half of phase four than an any previous point in the experiment. Differential responding occurred at interval six, compared to interval four in phase one, and interval one in phase two, showing retarded acquisition of discrimination.

Participant C5. Participant C5 began phase one with low and equal response rates during the first interval. Thereafter response rates were higher during the S^D than during the S^Δ. By interval four rates diverge more between S^D and S^Δ, and by interval nine the rate during the S^Δ is at zero, while the rate during the S^D continues on a gradually increasing, yet variable, course to the end of phase one. The introduction of compound stimuli in phase two caused a decrease in differential responding during the first three S^D and S^Δ presentations. Response rates are intermediate and nearly identical during these three intervals for both the compound S^D and S^Δ. Thereafter the response rate falls during the compound S^Δ and rises during the compound S^D, with discrimination between stimuli evident through to the end of phase two.

Participant C5 showed no difference between response rates during the first test of (former) S^D and S^Δ elements in phase three, indicating a failure to condition. Since control group participants are not preconditioned to the other element of the compound stimuli, this failure to condition is not construed as blocking, as it is in blocking group participants. The difference in response rates between the first test of the single (former) S^Δ element and last compound S^Δ in phase two also indicated blocking, with an increased rate in the presence of the single element.

In phase four, participant C5 responded at high, and relatively non-differential, rates during both S^D and S^Δ stimulus presentations until the eighth interval, at which point the number of responses during the S^Δ decreased to negligible levels where they stayed for the remainder of phase four. The response rate during the S^D meanwhile stabilized at high levels for the remainder of phase four. Discriminated responding required eight intervals of each stimulus in phase four, compared with four intervals in phase one and two. This indicates that conditioning to single stimulus elements had occurred in their previous, reversed S^D and S^Δ roles.

Participant C3. In phase one, discrimination is evidenced between S^D and S^Δ stimulus presentations by interval two. Response rates during the S^D rise quickly and reach near maximal levels by interval seven, while response rates during the S^Δ remain at low levels, with two somewhat higher intervals, for the rest of phase one. In phase two a smaller difference between the numbers of responses during S^D versus S^Δ presentations is shown in the first interval, and response rates are at intermediate levels during both. Response rates return to their previous highly differentiated levels on the second compound interval, and remain there for the remainder of phase two.

The first test presentation in phase three produced evidence for successful conditioning for participant C3. This participant continued to discriminate on the single stimulus elements as on the compound stimuli in phase two. In phase four, participant C3 did not respond to either stimulus in the first interval. Responding during the S^Δ remained at minimal levels with four, single-interval rises in response rate during phase four. Responding during the S^D was maximal by the third interval, and generally remained high over the remainder of phase four. Differential responding between S^D and S^Δ presentations was present from interval two onwards, as in phase one; phase two showed differential responding from the start. Unlike the previous two control participants, C3 did not display a high response rate during the S^Δ at the beginning of phase four. Discriminative stimulus reversal in phase four did not impair acquisition of discrimination in this control group participant, even though performance on the test in phase three showed that conditioning to stimulus elements was successful.

Appendix D shows graphed data for the remaining three control group participants.

High response rates during the (former) S^{Δ} on the extinction test, overlapping with performance on the (former) S^{D} test, indicates that little conditioning occurred to separate elements of the compound stimulus in these three control group participants. Altogether, a five of six control group participants showed a failure to condition, which in blocking group participants was construed as blocking. Only one control group participant (i.e., C3) showed evidence of conditioning to the separate elements on the first test in phase three.

Discrimination. Differential responding developed over phases one and two in 17 of 24 participants. Data for each participant who discriminated are shown in Table 2. For each of phases two and three, the number of responses during the last four 20-s S^{D} intervals, and the discrimination ratio calculated for these four intervals combined, is given. There were no significant differences between the experimental and control group discrimination ratios in either phase one ($M = 0.92$, $SD = 0.09$ versus $M = 0.90$, $SD = 0.10$, respectively, $F(1,15) = 0.28$, $p = 0.61$) or phase two ($M = 0.96$, $SD = 0.05$ versus $M = 0.93$, $SD = 0.07$, respectively, $F(1,15) = 0.88$, $p = 0.36$). Participants in both groups developed equivalent discrimination between S^{D} and S^{Δ}, a requirement for demonstration of the blocking effect. Use of irrelevant stimuli for control group participants in phase one did not impair discrimination between compound S^{D} and S^{Δ} in phase two. For phase three, the number of responses during the first 20-s test interval of the (former) S^{Δ} stimulus, the discrimination ratio calculated for the first test intervals of the (former) S^{D} and S^{Δ} elements, and the suppression ratio for first test interval of the (former) S^{Δ} stimulus relative to the preceding compound S^{D} baseline are shown in corresponding columns.

Table 2

Results of Experiment 1

Partici-pant #	Phase 1 13	14	15	16	DR4	Phase 2 13	14	15	16	DR4	Test Phase (3) 1	DR	SR
						Blocking Group (A-AC)							
B1 'R'	5	7	2	2	0.76	8	2	3	2	0.94	3	0.60	0.46
B2	137	122	146	158	0.94	125	127	136	106	0.99	94	0.72	0.23
B3 'R'	1	1	2	1	1.00	1	1	2	1	0.83	1	0.50	0.43
B4	28	7	16	56	0.98	80	38	77	60	0.98	64	0.52	0.50
B5 'R'	4	4	2	3	0.93	3	2	2	3	0.91	3	0.60	0.46
B6	91	101	99	105	0.99	94	99	100	99	0.99	86	0.99	0.01
B7 'R'	5	4	2	3	0.93	5	5	4	4	0.90	5	0.50	0.54
B8	1	3	3	1	0.73	1	1	1	2	1.00	1	0.50	0.43
B9	97	77	85	94	0.90	130	120	127	130	0.98	121	0.90	0.10
B10 'R'	2	1	2	1	1.00	2	1	1	2	1.00	1	0.33	0.61
B11	48	45	49	64	0.99	71	71	76	76	0.99	58	0.94	0.05
Mean	*38*	*34*	*37*	*44*	*0.92*	*47*	*42*	*48*	*44*	*0.96*	*50*	*0.65*	*0.35*
						Control Group (X-AC)							
C1 'R'	2	3	3	4	0.71	3	4	4	3	0.88	5	0.56	0.52
C2 'R'	23	17	25	26	0.98	24	18	17	26	0.99	28	0.45	0.63
C3	87	89	72	81	0.90	78	81	89	78	0.98	77	0.99	0.01
C4	0	2	2	2	0.86	3	1	2	1	1.00	1	0.50	0.43
C5 'R'	35	40	36	46	0.99	49	48	33	63	0.84	44	0.54	0.44
C6	63	5	84	7	0.94	81	113	74	76	0.87	90	0.51	0.50
Mean	*35*	*26*	*37*	*28*	*0.90*	*40*	*44*	*36*	*41*	*0.93*	*41*	*0.59*	*0.42*

Note. The number of responses are shown for the last 4 S^D intervals in both phases one and two, and for the first test interval in phase 3. 'R' designates participants who experienced a red S^D and a green S^Δ in phase one. DR4 is the discrimination ratio for the last 4 S^D intervals combined, for phases one and two. DR is the discrimination ratio for the first test interval for the (former) S^D and S^Δ elements. SR is the suppression ratio for the first test interval of the (former) novel S^Δ element.

Suppression ratio. The critical test for blocking is the suppression ratio as calculated for the first test stimulus presentation in extinction in phase three. Although blocking is expected for both unfamiliar stimuli added in phase two, the suppression ratio presented here is calculated for the novel (former) S^{Δ} stimulus component, in whose presence no reinforcers previously were available, relative to the response rate during the immediately preceding compound S^{D} baseline rate. Control group participants ($M = 0.42$, $SD = 0.21$) had a higher suppression ratio than blocking group participants ($M = 0.35$, $SD = 0.21$). However, the difference between groups was not statistically significant, $F(1,15) = 0.48$, $p = 0.50$.

Response rates varied widely in Experiment 1. "Low responders" were defined as those participants whose responses were recorded in single digits ($M = 2.2$ responses per 20-s interval, $SD = 1.2$; $n = 8$), whereas "high responders" were defined as participants whose responses were recorded in double or triple digits (M = 65.3 responses per 20-s interval, SD = 30.0; $n = 9$). The difference in response rates between high and low responders was statistically significant, $F(1,15) = 34.91$, $p < 0.001$. The gender of the participant was not a factor influencing response rates, $F(1,15) = 0.90$, $p = 0.36$. Suppression ratios were lower for high responders ($M = 0.27$, $SD = 0.24$) than for low responders ($M = 0.48$, $SD = 0.07$), indicating that high responders had conditioned more to the S^{Δ} element than had low responders. This difference was statistically significant, $F(1,15) = 5.54$, $p = 0.03$. The blocking group itself consisted of six low responders and five high responders. Suppression ratios differences within this group alone were statistically significant ($M = 0.18$, $SD = 0.20$ for high responders versus $M = 0.35$, $SD = 0.21$ for low responders), $F(1,9) = 12.92$, $p = 0.01$. Response rates were less varied in the control group, which also had fewer participants; therefore no statistical test was calculated.

Phase 4 test for retardation of acquisition of discrimination. Discrimination ratios were calculated for each participant for each consecutive pair of S^D and S^Δ intervals in phase 4 (up to a total of 16 pairs of intervals). The critical interval for each individual was that interval during which the discrimination ratio reached the criterion value of 0.70 (i.e., the criterion previously used to identify adequate discrimination), and for which the criterion value was sustained over the following interval. Participants in the blocking group took somewhat longer than participants in the control group to attain the criterion discrimination ratio ($M = 7.82$, $SD = 4.87$ versus $M = 6.50$, $SD = 3.02$, respectively), a difference in direction opposite to that expected, but consistent with suppression ratio results. Differences between groups in the critical interval were not statistically significant, $F(1,15) = 0.36, p = 0.56$.

Questionnaire results. All but one of 11 blocking group participants and all 6 control group participants correctly responded whether or not they had earned points for the colored rectangles that had acted as the S^D and the S^Δ, respectively, in phases one and two. One participant correctly responded to the S^D rectangle, but made no response to the S^Δ rectangle. Ten of 11 blocking group participants and 5 of 6 control group participants correctly responded to the blue rectangles and yellow rectangles by stating that earning points depended on whether or not that rectangle appeared alone or in combination with another rectangle. The remaining one blocking participant and one control participant said that they earned points in the presence of one and not in the presence of the other, which was only partially correct, since this was true in one of phases two and four, but not in the other phase. The critical responses with respect to blocking were those to the blue rectangles and yellow rectangles. They indicate that 15 of 17 participants were aware, at least immediately after completing the experiment, of the contingencies (i.e., earning points or not by key pressing) associated with the novel stimuli (i.e., the 'to-be-blocked' stimuli for the blocking group). It is likely that the continued discrimination training intervals interspersed among the test intervals in phase three would have alerted participants to stimulus differences between reinforced and extinguished intervals, and provided the opportunity to become conditioned to the separate stimulus elements. As a consequence, these post-experimental verbal reports cannot provide satisfactory evidence that conditioning occurred during discrimination training between compound stimuli in phase two, that is, that blocking did not occur.

Blocking group participants responded to the black rectangles and white rectangles correctly in 9 of 11 cases, by saying that these colors had not appeared in the experiment. One individual was partially correct in answering only that no points had been obtained in their presence, and one individual did not respond. Four participants (3 in the blocking group and 1 in the control group) who experienced a green S^D and a red S^Δ correctly had noticed the association between the color red, "stop", and not being able to earn points, and between the color green, "go", and being able to earn points. There were no comments on the reversal of the usual contingency from participants who experienced a red S^D and a green S^Δ. Two participants noticed that points could be earned after increasing time intervals, and that continuous key pressing was not required. Five of the 7 participants who were eliminated from data analysis due to poor discrimination had distinctive responses: one participant responded that he couldn't remember; another confessed to having "had no idea what was going on"; two said they couldn't earn points during any of the colors of rectangles, which corresponded with their intra-experimental behavior – they had not pressed the shift key even once; and another said that the instructions for earning points should have been more detailed.

Discussion

Failure to condition was found in most participants (8 of 11 blocking group participants and 5 of 6 control group participants) to some degree, when evaluated by visual inspection of graphed data for individuals, corresponding with a lack of a statistical significance in a between-subjects comparison of suppression ratios. These findings are not consistent with the findings of Kamin (1968, 1969) in rats, or with the findings of Arcediano et al. (1997) in humans, who found more suppression (i.e., more conditioning) in control group subjects and less suppression (i.e., less conditioning, or blocking) in blocking group participants.

Since the term, "blocking", refers to the lack of conditioning of a stimulus presented contiguously with a preconditioned stimulus (Kamin, 1968, 1969), and since this manipulation was absent in control group participants, then the effect seen in control group participants in my experiment cannot unequivocally be said to be the blocking phenomenon. Since participants in both groups failed to condition to stimulus elements of a compound, it is impossible to conclude that the effect observed in blocking group participants was due solely to the experimental manipulation of stimulus preconditioning in phase one.

An unexpected but important finding was that individuals who pressed the shift key at high rates and those that pressed the shift key at low rates had systematically different suppression ratios. High responders appeared to suppress more and low responders suppressed less, regardless of group manipulation. High responders had conditioned to the stimuli more than low responders during discrimination training phases. This may be explained as a result of increased contact with the contingencies at higher rates of responding. Every time a reinforcer was earned by key pressing, the stimulus present gained additional strength over key-pressing behavior. Similarly, every time key pressing did not earn points in the presence of a stimulus, that stimulus gained strength in controlling the cessation or reduction of key pressing behavior. These events occurred much more frequently for high responders than for low responders, resulting in much more experience with the contingencies of reinforcement, that is, many more opportunities to learn, for high responders than for low responders. Low responders had very small differences in number of responses between S^D and the S^Δ intervals. Low responders achieved equally high discrimination ratios as high responders, however the low number of responses during S^D intervals caused doubt about the strength of conditioning achieved in discrimination training.

A number of participants failed to discriminate adequately between the S^D and the S^Δ in phases one or two. Seven of 24 participants did not meet the 0.70 discrimination ratio criterion. Two of these seven participants failed to discriminate adequately in phase two after meeting the criterion in phase one. Two participants failed to press the shift key even once during the entire experiment, despite initial oral instructions from the experimenter, and written instructions to do so given by computer and on a hard-copy instruction sheet beside the computer terminal.

The finding that most participants, regardless of group manipulation, failed to condition to separate stimulus elements of a compound stimulus, the lack of significant differences in the suppression ratio between groups, and the wide inter-individual variation in response rate and in discrimination between S^D and S^Δ, prompted a second experiment with greater control over participants' responding.

Experiment 2

A number of procedural changes were made in Experiment 2, to increase experimental control over participant responding. Changes in stimulus control measures included revised verbal instructions, modelling, highlighted keys, and experimenter presence during training. A likely contaminant of the phase four test for acquisition of discrimination, that is, continued discrimination training between compounds $S^D{}_{AC}$ and $S^\Delta{}_{BD}$ interspersed among test trials, was deleted. If blocking had occurred during phase two compound training, then it (blocking) would now not be disrupted by compound stimuli correlated with reinforced responding, alternating with single stimuli in extinction. Third, phase one preconditioning of single stimuli was eliminated for control participants, to see if this would affect conditioning to the separate components of the compound stimuli presented in phase two. This control group was Kamin's (1968, 1969) primary comparison group, and had resulted in a considerable blocking effect between subjects.

Method

Participants. Twenty-six undergraduate introductory psychology students served as participants. There were 4 males (mean age 21 years, range 17 – 26) and 22 females (mean age 22 years, range 17 – 42). They were randomly assigned to either the experimental or control group ($n = 13$ for each group). Two participants in the blocking group and 2 participants in the control group failed to meet the discrimination criterion, and their data were excluded from further analysis (leaving $n = 11$ per group). The experimenter remained in the same room as participants during the experiment, but was not in their line of sight. Experimenter presence during training was an attempt to strengthen the social contingencies over behavior in correspondence with experimental instructions.

Apparatus. The apparatus and setting were identical to that described for Experiment 1.

Design. Phase one was eliminated for all control group participants only (see Table 3). These participants began the experiment with phase-two discrimination training between the compounds, S^{D}_{AC} and S^{Δ}_{BD}. The purpose of deleting phase one conditioning was an attempt to obtain non-equivalent, or differential, responding to the S^{D}_{C} and S^{Δ}_{D} stimulus elements in the test phase. Otherwise the research design was as described previously.

Table 3

Design for Experiment 2

Group	Phase 1	Phase 2	Test	Phase 4
Blocking	16 S^{D}_{A}, 16 S^{Δ}_{B}	16 S^{D}_{AC}, 16 S^{Δ}_{BD}	3 S_C, 3 S_D	16 S^{D}_{D}, 16 S^{Δ}_{C}
Control	---	16 S^{D}_{AC}, 16 S^{Δ}_{BD}	3 S_C, 3 S_D	16 S^{D}_{D}, 16 S^{Δ}_{C}

Note. Numerals indicate the number of presentations of each stimulus. S^{D}_{A} and S^{Δ}_{B} were red and green rectangles; and S_C and S_D were blue and yellow rectangles. Colors of S^{D} and S^{Δ} were counterbalanced across participants.

Procedure. Instructions, modelling, and visual highlights were added. Each shift key was marked with three 'happy-face' stickers to increase its visibility. The experimenter also (a) pointed out the marked shift keys on the keyboard; (b) demonstrated the required response of pressing a shift key repeatedly; (c) explicitly stated that points would be earned depending on the particular colors of the rectangles that appeared on the screen; (d) explicitly informed participants that points would be exchanged for draws on cash prizes after completion of the experiment, while holding the canister of tickets, and (e) remained in the room with the participant during the experiment.

Phase three (test for blocking). The test phase consisted of three presentations each of the novel (second) stimuli that were added in phase two (i.e., blue rectangles and yellow rectangles). Presentation of the S_C (formerly an element of the compound $S^D{}_{AC}$) was followed immediately by presentation of the S_D (formerly an element of the compound $S^\Delta{}_{BD}$), and this sequence was repeated twice for a total of three test intervals for each stimulus. Discrimination training intervals with the $S^D{}_{AC}$ and the $S^\Delta{}_{BD}$ did not separate successive test intervals. Phase three now consisted only of three alternating test trials for each novel stimulus added in phase two. All other aspects of the procedure were identical to those described previously for Experiment 1, including completion of the questionnaire after the experiment.

Results

Visual inspection of graphs: Figure 3 shows graphs of response rates for two selected high blocking group participants across the four phases of the experiment.

Participant B6. Participant B6 (top) begins phase one with high and undifferentiated responding until interval eight, when the response rate during the S^Δ

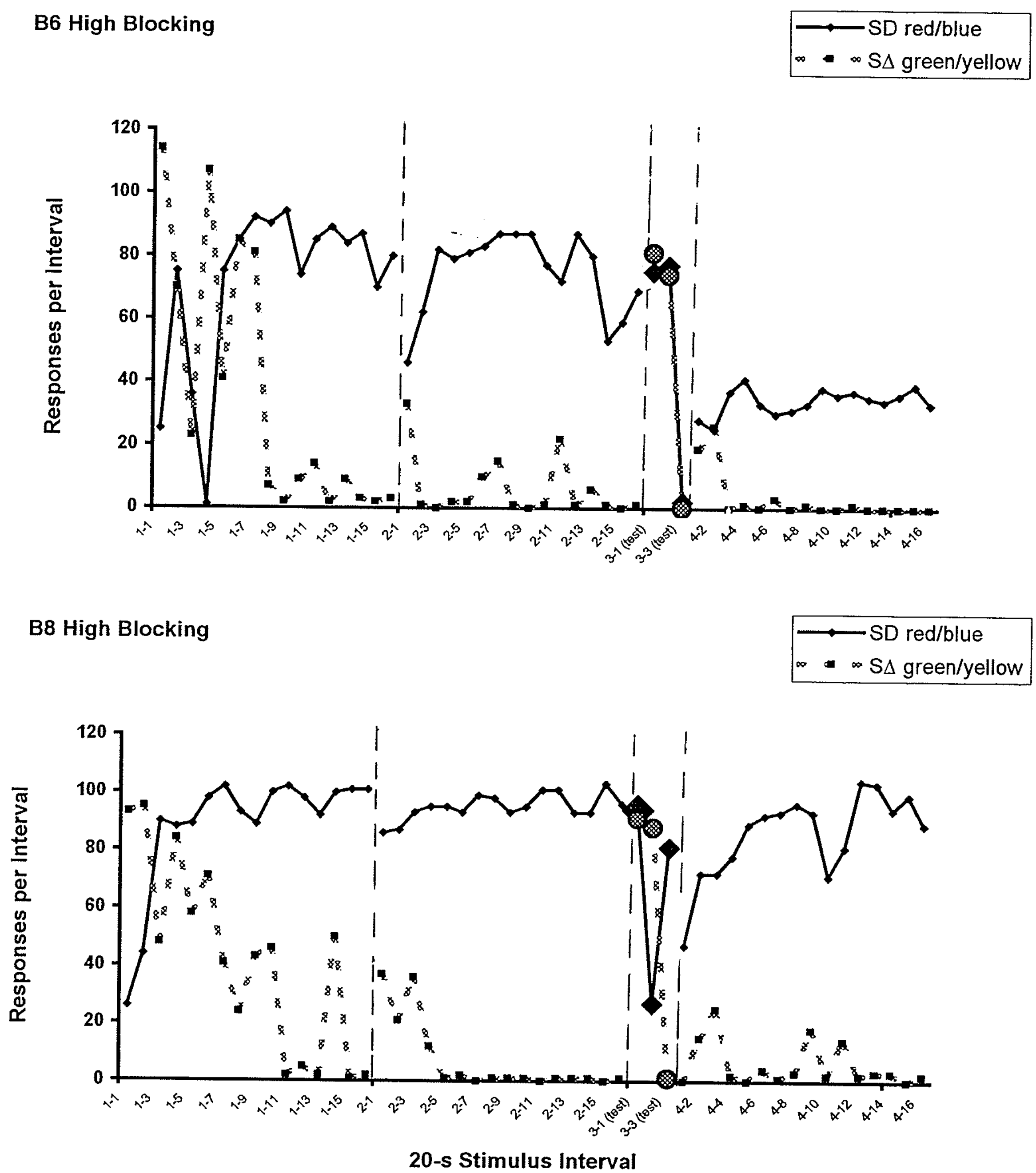


Figure 3. Number of key-presses in each consecutive 20-s stimulus interval for blocking group participants B6 and B8. Large shaded symbols mark responses during test intervals (phase 3); diamonds for (former) S^D stimuli and circles for (former) S^Δ stimuli. The legend identifies stimulus colors of phase 1 (first color), phase 2 (both colors), test phase (second color), and phase 4 (second color, but in "reversed" S^D and S^Δ role).

stimulus drops while the response rate during the S^D stimulus is maintained, with a slightly decreasing rate over the phase. The remainder of phase one shows discrimination in responding between S^D and S^Δ stimuli. The first compound S^D and S^Δ stimulus presentations in phase two produce considerably less differential responding, but for only that interval. With the second compound S^D stimulus the response rate begins to climb back up to reach its previous maximum level in the third compound S^D presentation. Meanwhile, the response rate during the compound S^Δ stimulus returns to a negligible level by interval two, and continues at a low rate, with some variability, to the end of the phase. Phase two also ends with consistent discrimination in responding between the compound S^D and S^Δ stimulus presentations. Blocking is indicated by performance on the first test in phase three. (As in Experiment 1, only performance on the first test interval for each stimulus will be considered.) First, the response rates during the (former) S^D and S^Δ elements are the same (non-differential), and second, the response rate during the (former) S^Δ stimulus is not suppressed, even though responding was suppressed during the compound S^Δ stimulus in phase two. Phase four shows clear discrimination between reversed S^D and S^Δ elements at interval three, compared to interval seven in phase one. Acquisition of discrimination in phase four was not retarded in this participant, consistent with evidence of blocking on the first test in phase three.

Participant B8. Participant B8 also begins phase one with high and indiscriminate responding, then begins to differentiate between S^D and S^Δ elements during interval five at which time the response rate drops during the S^Δ element while continuing on at a relatively stable, high response rate during the S^D. Although responding fluctuates during S^Δ intervals, phase one ends with discriminated responding between S^D and S^Δ elements.

Phase two begins with a slight drop in the compound S^D response rate and an increase in the compound S^Δ response rate. After four intervals the response rate drops to a zero level during the S^Δ intervals right to the end of phase two. The response rate during the compound S^D continues at a stable rate, much higher than the compound S^Δ rate. The first phase three test shows a high degree of blocking as the response rates for the (former) S^D and S^Δ overlap (i.e., there is no discrimination). The response rate during the (former) S^Δ element is also much higher than the response rate during the compound S^Δ in phase two. Discrimination between the reversed S^D and S^Δ elements in phase four begins on the first interval, much sooner than the fifth interval of phase one, supporting the finding of blocking, or lack of prior conditioning to these stimuli.

Figure 4 shows graphed response rate data for moderate blocking (participant B7) and no blocking (participant B1) in two more blocking group participants.

Participant B7. Participant B7 begins discriminating between S^D and S^Δ stimuli on the second interval of phase one, as the response rate during the S^Δ drops and remains low, with a few fluctuations, to the end of phase one. Response rates during the S^D rise and remain consistently higher than during the S^Δ. Phase two compound stimuli produce slight deviations in responding on the first interval of each compound stimulus, decreasing differential responding for the first interval only. S^D response rates rise again on the next interval and remain high and relatively stable. S^Δ response rates also return to previous levels (zero) on the next interval and remain low, with one exception. Blocking is evidenced in phase three by response rates being non-differential on the first test presentation of the (former) S^D and S^Δ elements, and by a high response rate during the single S^Δ element relative to the zero response rate during the compound S^Δ of phase two.

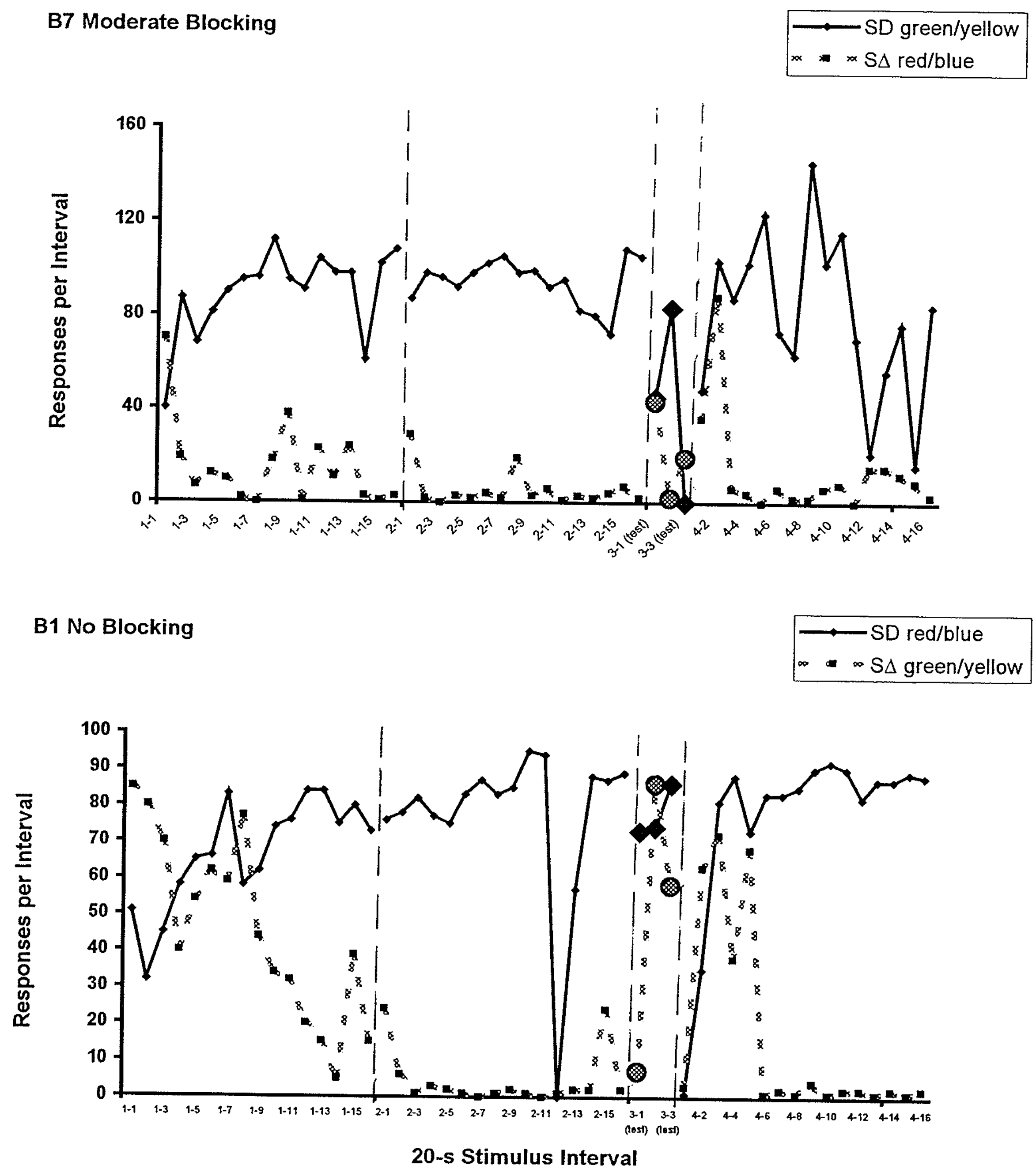


Figure 4. Number of key-presses in each consecutive 20-s stimulus interval for blocking group participants B7 and B1. Large shaded symbols mark responses during test intervals (phase 3); diamonds for (former) S^D stimuli and circles for (former) S^Δ stimuli. The legend identifies stimulus colors of phase 1 (first color), phase 2 (both colors), test phase (second color), and phase 4 (second color, but in "reversed" S^D and S^Δ role).

Discrimination between reversed S^D and S^Δ in phase four takes place at interval three, compared with interval two in phase one.

Participant B1. It takes participant more than half of phase one before discrimination between S^D and S^Δ occurs, at interval 9. At this point the response rate during the S^Δ falls, so that responding becomes differential. With the introduction of the compound S^D and S^Δ in phase two, the response rate during the S^Δ rises slightly for the first interval only, while the response rate during the S^D is not affected, rising gradually before plummeting to zero during interval 13, and then recovering prior to the end of phase two. Meanwhile, response rate during the compound S^Δ returned to low levels, with one higher rate of response occurring before the end of phase two. Highly differential responding between the former S^D and S^Δ elements occurred on the first test in phase three, and the S^Δ response rate rose only slightly and remained similar to the response rate during the compound S^Δ. These two features are indicative of conditioning having occurred, and thus no blocking. Differential responding in phase four occurs during interval 7, taking a little less time than in phase one. Therefore acquisition of discrimination was not retarded in phase four, although performance on the first phase three test showed that conditioning had occurred to the stimulus elements in reverse S^D and S^Δ roles.

Of 11 blocking group participants, 6 gave evidence of a high degree of blocking, 4 showed moderate blocking, and only one participant showed no blocking. Graphs showing data for the remaining blocking group participants are found in Appendix E.

Figure 5 shows graphed data for two control group participants, both of whom failed to condition to separate elements of the compound stimuli. Control group

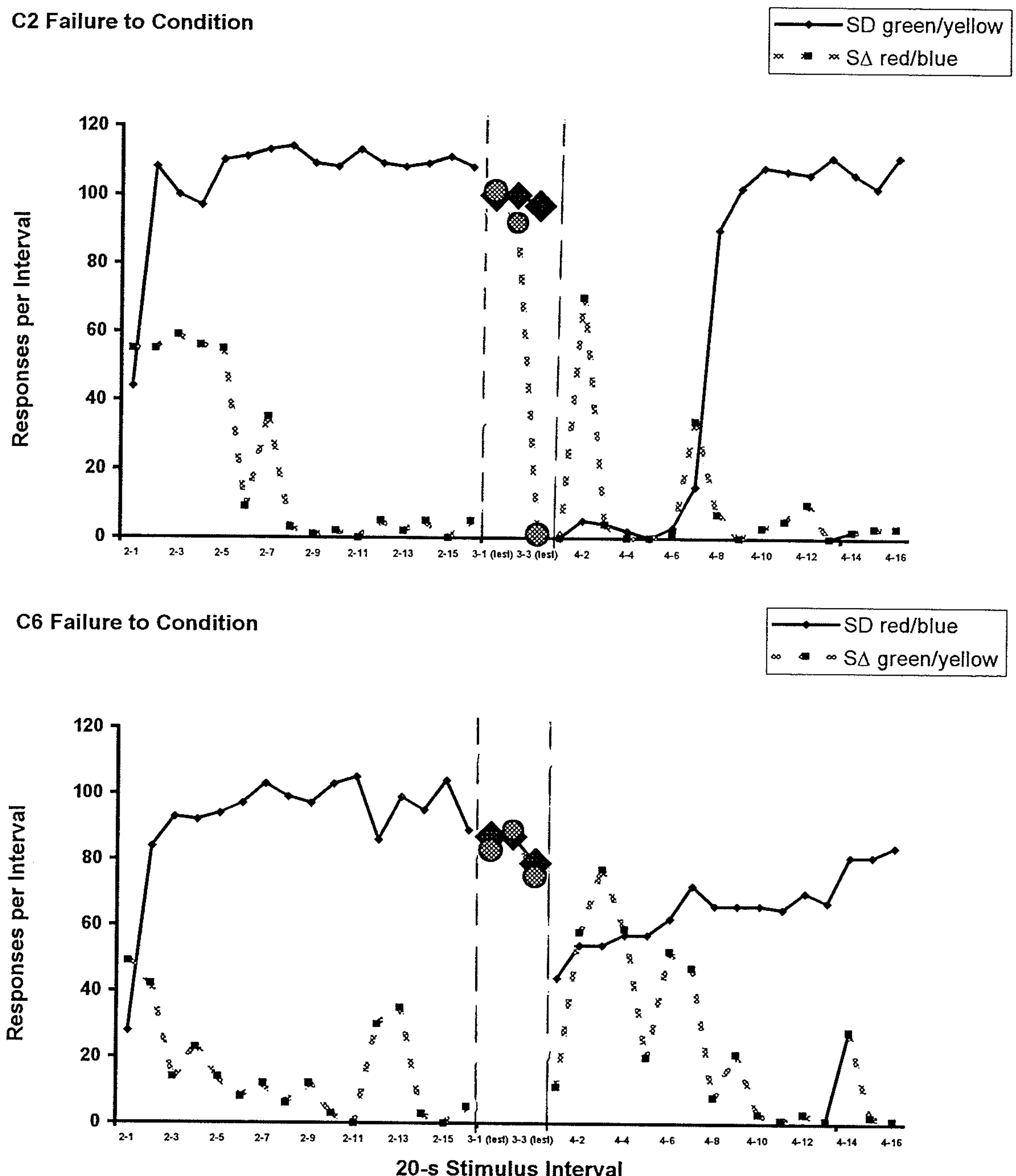


Figure 5. Number of key-presses in each consecutive 20-s stimulus interval for control group participants C2 and C6. Large shaded symbols mark responses during test intervals (phase 3); diamonds for (former) S^D stimuli and circles for the (former) S^Δ stimuli. The legend identifies stimulus colors of phase 2 (second and third color), test phase (third color), and phase 4 (third color, but in "reversed" S^D and S^Δ role).

participants began this experiment with phase two compound conditioning.

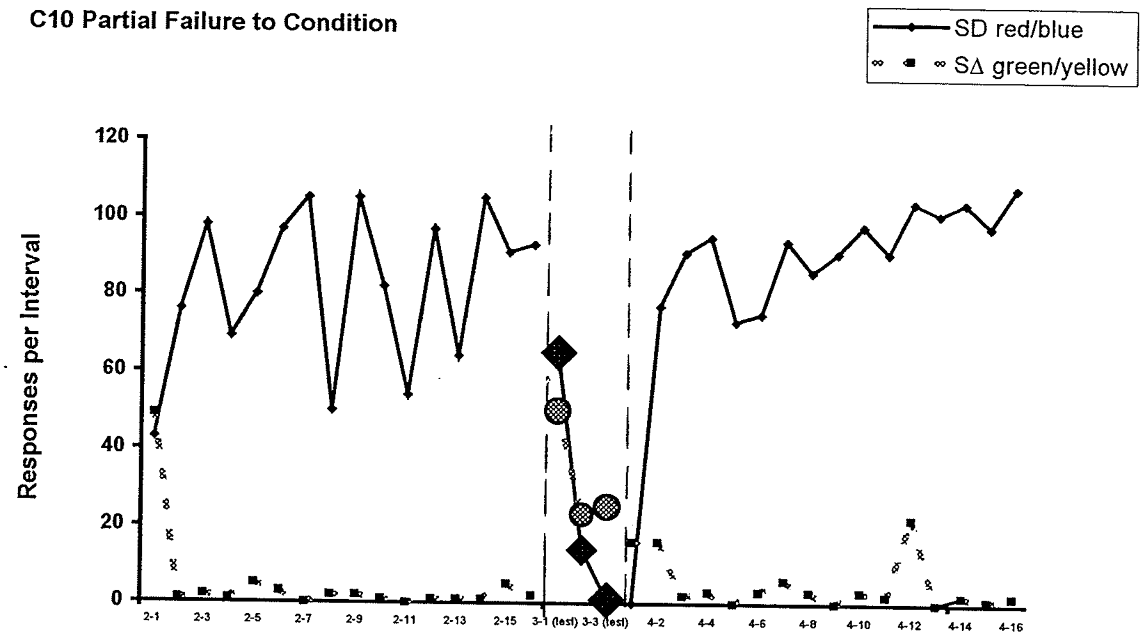
Participant C2. Participant C2 begins discriminating between compound S^D and S^Δ in interval two of phase two, with markedly increased responding during the S^D, which remains stable at this high level. Responding during the S^Δ is stable over intervals one to five, and then falls to near zero levels over three intervals, remaining at or near zero for the rest of the phase. On the first test of the (former) S^D and S^Δ elements response rates become the same (i.e., non-differential), with responding during the single S^Δ element greatly increased compared to previous responding during the compound S^Δ. Participant C2 thus has failed to condition to separate elements of the compound during phase two, even without the blocking group treatment of preconditioning to the other compound elements (phase one). Discrimination between reversed S^D and S^Δ in phase four occurs first in interval eight, taking considerably longer than in phase two. This relative delay in conditioning counters the evidence of phase three tests that showed that no conditioning occurred in phase two.

Participant C6. This participant begins to respond at higher rates during the compound S^D and at somewhat lower rates during the compound S^Δ in interval two. Discrimination is evident over the remainder of phase two. Response rates during the first test of the (former) S^D and S^Δ elements overlap, and the rate during the single S^Δ element is far higher than the low level present during the compound S^Δ of phase two. Thus, participant C6 has failed to condition to the separate elements of the compound stimulus. Acquisition of discrimination between reversed single S^D and S^Δ in phase four is retarded relative to phase two, taking five intervals rather than two intervals, respectively. As for participant C2, this retardation shows that some conditioning to these separate stimulus elements likely did occur, despite evidence to the contrary in phase three.

Figure 6 shows graphed data for two control group participants, of whom one conditions moderately to single stimulus elements (C10), and one who conditions to separate elements of the compound stimuli nearly completely.

Participant C10. Participant C10 starts phase two with similar response rates during compound S^D and S^Δ, with differential responding occurring immediately in the second intervals. Responding during the S^Δ drops to zero, and remains near zero for the remainder of the phase. Responding during the S^D rises to near the phase maximum by the third interval, and fluctuates around this high level for the remainder of the phase. Response rates during both (former) S^D and S^Δ elements on the first test of phase three are close, but not overlapping. The rate during the (former) S^Δ is considerably higher than the rate during the compound S^Δ in phase two. Both the decrease in discrimination between (former) S^D and S^Δ elements and the increased responding during the (former) S^Δ element show that stimulus elements did not condition as well as expected for a control participant. The response rate during the reversed S^D (former S^Δ element) is zero on the first interval of phase four, less than the rate during the reversed S^Δ (former S^D element). By the second interval the S^D response rate has risen to a high level similar to S^D rates in phase two, while the S^Δ response rate decreases to zero on the third interval. Discrimination is evident and consistent from interval two onwards, just as in phase two for this participant. There is no retardation of acquisition of discrimination in evidence, although phase three test performance indicates some conditioning occurred.

Participant C9. This participant begins to respond at higher rates during the compound S^D during interval two (see Figure 6, bottom). Rates rise gradually in the



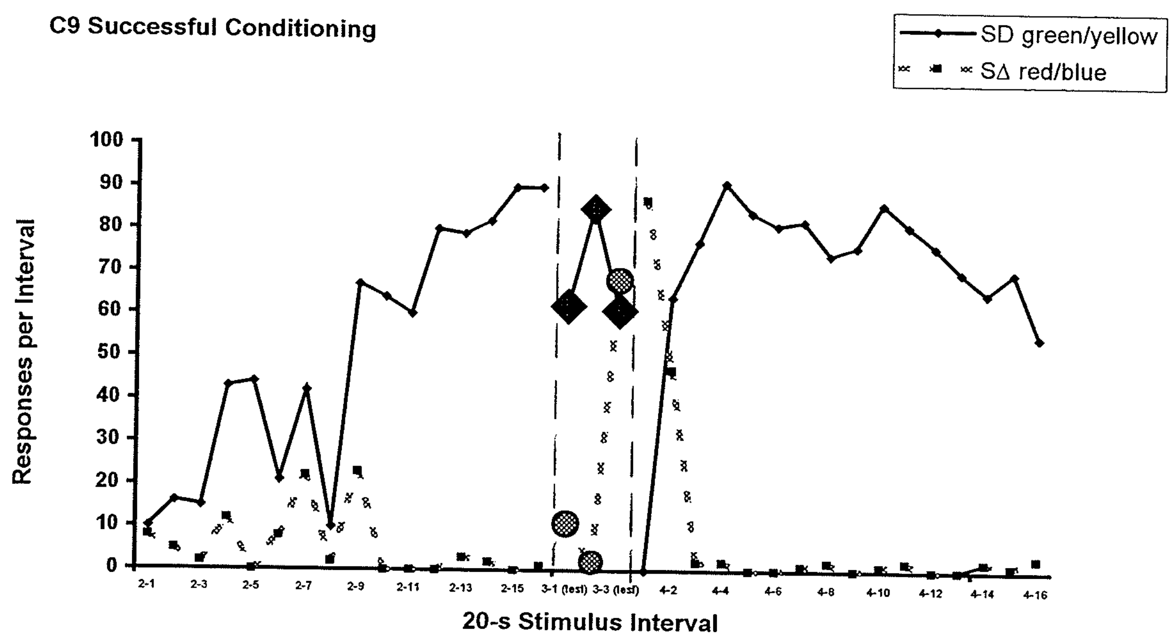


Figure 6. Number of key-presses in each consecutive 20-s stimulus interval for control group participants C10 and C9. Large shaded symbols mark responses during test intervals (phase 3); diamonds for (former) S^D stimuli and circles for the (former) S^Δ stimuli. The legend identifies stimulus colors of phase 2 (second and third color), test phase (third color), and phase 4 (third color, but in "reversed" S^D and S^Δ role).

presence of the compound S^D, with fluctuations, over the phase as corresponding response rates during the compound S^Δ decrease and stabilize at, or near zero levels. A substantial difference in response rates is achieved by interval nine. The first test of phase three produced a modest reduction in differential responding, with a slightly increased rate during the (former) S^Δ element and a somewhat larger decreased rate during the (former) S^D element. However, a large discrepancy in response rates remained, and only a small difference obtained between rates during the single S^Δ element and during the compound S^Δ of phase two. Therefore, it appears that conditioning to the S^D and S^Δ elements has occurred. Substantial discriminated responding in phase four occurs by interval two, with near zero rates during the S^Δ and high rates during the S^D; much sooner than the nine interval required for this degree of discrimination in phase two. Phase four acquisition does not seem to be retarded, relative to phase two, despite evidence provided in phase three, that conditioning occurred to these stimulus elements in reversed roles.

Of 11 control group participants, performance on the first test of phase three showed that 5 participants failed to condition to the separate stimulus elements of the compound stimulus, 2 participants showed some evidence of conditioning, and 4 participants demonstrated conditioning by continued differential responding between (former) S^D and S^Δ elements. Graphed data for the remaining control group participants can be found in Appendix F.

Discrimination. A mean discrimination ratio of 0.88 (SD = 0.09) was obtained for responding in the presence of the S^D in blocking group participants during the last four S^D and S^Δ stimulus presentations of phase one (see Table 4). Control group participants did not experience phase one. The mean discrimination ratio for the last four intervals of

Table 4

Results of Experiment 2

Participant	*Phase 1* 13	14	15	16	DR4	*Phase 2* 13	14	15	16	DR4	*Test Phase (3)* 1	DR	SR
						Blocking Group (A-AC)							
B1	84	75	80	73	0.81	57	88	87	89	0.92	73	0.61	0.07
B2	100	110	106	94	0.78	107	114	102	114	0.95	107	0.55	0.48
B3	93	83	73	83	0.88	94	17	95	109	0.77	81	0.48	0.56
B4	54	54	54	63	0.71	67	72	76	70	0.99	65	0.49	0.49
B5	74	61	77	77	0.97	80	76	81	85	0.97	91	0.73	0.42
B6	84	87	70	80	0.95	80	53	59	69	0.97	75	0.50	0.57
B7	98	61	102	108	0.92	80	72	108	105	0.96	45	0.67	0.31
B8	92	100	101	101	0.88	93	93	103	96	0.99	94	0.53	0.48
B9	96	96	96	92	0.99	89	76	89	91	0.99	39	0.46	0.26
B10	68	47	81	42	0.81	45	32	27	60	0.98	24	0.45	0.39
B11	96	68	65	69	0.98	78	78	85	85	0.99	90	0.53	0.51
Mean	*85*	*77*	*82*	*80*	*0.88*	*79*	*70*	*83*	*88*	*0.95*	*71*	*0.56*	*0.41*
						Control Group (0-AC)							
C1						49	58	55	54	0.98	67	0.57	0.52
C2						108	109	111	108	0.97	100	0.60	0.48
C3						93	88	69	20	0.98	6	0.98	0.00
C4						84	85	83	63	0.98	50	0.59	0.01
C5						83	40	67	63	0.91	66	0.55	0.37
C6						99	95	104	89	0.90	87	0.51	0.46
C7						5	5	4	6	1.00	2	0.84	0.17
C8						103	101	115	109	0.99	68	0.42	0.43
C9						79	82	90	90	0.98	62	0.72	0.11
C10						64	105	91	93	0.98	65	0.45	0.34
C11						54	55	49	53	0.80	55	0.63	0.53
Mean						*75*	*75*	*76*	*74*	*0.95*	*57*	*0.62*	*0.31*

Note. The number of responses are shown for the last 4 S^D intervals in both phases one and two, and in the first test interval of phase three. DR4 is the discrimination ratio for the last 4 S^D intervals combined, for phases one and two. DR is the discrimination ratio for the first test interval of the (former) S^D and S^Δ elements. SR is the suppression ratio for the first test interval of the (former) novel S^Δ stimulus element.

phase two was 0.95 (SD = 0.06) for both the blocking group and the control group. Between-subjects differences were not statistically significant, $F(1,20) = 0.00, p = 0.97$, indicating that all participants, regardless of group treatment, were reaching a high degree of discrimination between the S^D and S^Δ.

Suppression ratio. The suppression ratio is calculated for the novel S^Δ stimulus component, in whose presence no reinforcers previously were available, relative to the response rate during the immediately preceding compound S^D baseline rate. Blocking group participants ($M = 0.41$, $SD = 0.15$) had a higher suppression ratio than control group participants ($M = 0.31$, $SD = 0.20$), indicating less conditioning to the tested stimulus in blocking group participants. However, the difference between groups was not statistically significant, $F(1,20) = 1.81, p = 0.19$. A reduced range of suppression ratios within the blocking group, from a low of 0.26 to a high of 0.57, $n = 10$, resulted with the removal of one outlier in the blocking group (i.e., the suppression ratio of 0.07 for participant B1, see Table 4). Removal of this single value produced a mean suppression ratio of 0.44 ($SD = 0.10$), and differences between groups that approached statistical significance, $F(1,19) = 3.671, p = 0.071$.

Phase 4 test for retardation of acquisition of discrimination. Discrimination ratios were calculated for individual participants as described above for Experiment 1. Although the control group participants ($M = 6.82$, $SD = 4.38$) took, on average, two more intervals, in the expected direction, than blocking group participants ($M = 4.82$, $SD = 2.71$) to reach the criterion level of discrimination (i.e., a discrimination ratio of 0.70), these differences were not statistically significant, $F(1,15) = 1.66, p = 0.21$. Control group participants needed longer exposure to the contingencies than blocking group participants to acquire discriminated responding in phase four. This supports the suppression ratio results of this experiment, both providing evidence of greater conditioning of S^D and S^Δ elements in control group participants.

Questionnaire results. All 11 blocking group participants and 10 of 11 control group participants correctly responded that they had earned points or not for the colored rectangles that had acted as elements of the compound S^D and the S^Δ, respectively, in phase two. One participant incorrectly stated that no points were available in the presence of the S^D element. Seven of 11 blocking group participants and 8 of 11 control group participants correctly responded to the blue rectangles and yellow rectangles by stating that earning points depended on whether or not that rectangle appeared alone or in combination with another rectangle. Three of 4 remaining blocking participants and one control participant said they earned points in the presence of the phase four S^D and not in the presence of the phase four S^Δ, neglecting to comment on the reversed roles of these rectangles during the compound phase. One blocking group participant and two control group participants said they had earned points during both blue and yellow rectangles. The critical responses to the blue rectangles and yellow rectangles indicate that 15 of 22 participants were aware, at least immediately after completing the experiment, of the contingency (earning points or not by key pressing) associated with the novel stimulus (i.e., the 'to-be-blocked' stimulus for the blocking group). A somewhat smaller proportion, although still the majority, of participants in Experiment 2 described the conditionality of these stimuli, possibly reflecting a higher degree of blocking (i.e., a lower degree of conditioning in phase two).

Ten of 11 blocking group participants and 8 of 11 control group participants responded to the black rectangles and white rectangles correctly, by saying that these colors had not appeared in the experiment. Three individuals were partially correct in answering only that no points had been obtained in their presence. One individual said that points could be earned if white appeared with blue (which never occurred). Two participants, both in the blocking group, mentioned the common association between the color red and "stop", and between the color green and "go"; one of these participants noted that the association coincided with being able to earn points, but the other participant correctly noted that they were opposed to the experimental contingencies that she experienced.

Discussion

A reduced degree of conditioning was found in most participants (10 of 11 blocking group participants and 7 of 11 control group participants) in Experiment 2, when evaluated by visual inspection of graphed data for individuals. Almost all blocking group participants exhibited this effect, however, so did over half of control group participants. As in Experiment 1, (where 8 of 11 blocking group participants showed little conditioning, but also 5 of 6 control group participants) it cannot be concluded that preconditioning of one stimulus element produced lack of conditioning to the second element, that is, that blocking occurred. Control group participants, who were not exposed to preconditioning of one stimulus element (the experimental variable), exhibited the same phenomenon.

It may be that blocking group participants actually do fail to respond in similar fashion to the (former) S^{Δ} element as to the previous S^{Δ} compound, due to the blocking effect of preconditioning with the other element. Control group participants may fail to condition to stimulus elements of a compound for some other reason. One such reason has been identified as configural learning, as opposed to elemental learning (Martin & Levey, 1991; Williams, Sagness, & McPhee, 1994). When Martin and Levey separated adjacent colored squares of a compound stimulus by 12 cm, this change in procedure produced a statistically significant finding of blocking in humans in eyelid conditioning. When compound stimulus elements are separable, it may facilitate responding to the separate elements (p. 245). Williams et al. began a series of experiments with the aim of demonstrating blocking in humans, but were not successful on repeated attempts. Their explanation was that participants were "using a configural strategy", and that the "outcome was attributed to the integral stimulus rather than to either of the separable predictive cues" (p. 695). Their solution was to prepare participants with tasks that encouraged "elemental" strategies, as opposed to "configural" strategies. A question to consider might be whether the typical preconditioning of single stimulus elements in phase one of the blocking procedure is not an elemental strategy? If this were so, then the blocking effect would be countered by increased conditioning to separate elements. Control group participants conditioned to irrelevant single stimuli in phase one should then demonstrate increased conditioning to stimulus elements during compound presentations. Control group participants without prior single element training in phase one would learn configurally, and would not condition to single stimulus elements during compound conditioning. These predictions are the opposite of the results obtained in our Experiments 1 and 2, in which control group participants showed better conditioning of separate stimulus elements when they had no prior elemental (i.e., phase one) training. Further exploration of elemental versus configural learning using our procedure might include, for example, separating the rectangular stimuli in the current procedure by more than the current 2 cm, into the range of 12 cm used by Martin and Levey.

Suppression ratio differences between groups were not statistically significant, but there was a trend toward reduced conditioning to separate stimulus elements in the blocking group, with a mean suppression ratio of 0.41 in the blocking group versus 0.31 in the control group. These differences were not nearly as great as those reported by Kamin (1968, 1969) in rats, whose blocking group median suppression rate was 0.45 versus the control group suppression rate of 0.05. Blocking group participants in my experiment did not block as much as Kamin's rats (0.41 to 0.45, respectively), and control group participants in this experiment did not condition as much as Kamin's rats (0.31 to 0.05, respectively). However, the suppression ratios in my experiment were similar to those of Arcediano et al. (1997) in humans, with blocking group ratios of 0.41 and 0.39, respectively and control group ratios of 0.31 and 0.27, respectively. Arcediano et al.'s suppression ratio differences were statistically significant with a total of 30 participants, somewhat more than the 22 participants in my study. Participants in the Arcediano et al. study also responded with reduced variability ($SE = 0.02$ for the blocking group and $SE = 0.04$ for the control group) when compared with my values ($SE = 0.04$ for the blocking group and $SE = 0.06$ for the control group). Statistically significant findings could be obtained with the current procedure either if a few more participants were added or if variability in responding were reduced, or both.

Response rates were less varied across participants in Experiment 2 than in Experiment 1. This was likely a function of the increased control features that were instituted, particularly the experimenter's demonstration of repetitive key pressing before the participant began the experiment. Other factors may have been experimenter presence in the room during the experiment, showing the participant the container of tickets for cash prizes, highlighting the keys that participants were required to press, or a combination of all these features. A benefit of the more sizeable response rates was increased confidence in participants' discrimination between S^D and S^Δ intervals. Only 1 participant out of 22 in Experiment 2 (as opposed to 8 of a total of 17 in Experiment 1) could be classified as a low (single-digit) responder; all others were high responders. Participants' high response rates may have worked against the blocking effect, since high responders in Experiment 1 conditioned more to separate elements of compound stimuli than low responders, thus producing a lower suppression ratios than would have been obtained with low responders. In fact, although Experiment 2 was composed almost entirely of high responders, there also was a shift toward decreased conditioning to separate elements of compound conditioning in blocking group participants.

General Discussion

An apparent blocking effect was observed in individual participants, when response rates were graphed across experimental phases. However, prior conditioning with a single stimulus was called into question as the only manipulation or factor leading to a failure to condition, since a failure to condition also was observed in many control participants. Between-subjects comparisons yielded no statistically significant differences in either experiment; however, a much larger effect in the expected direction was observed in Experiment 2.

More substantial blocking might be achieved with enhanced aversive control procedures, as in Arcediano et al. (1997), who threatened a Martian invasion if responding occurred during the S^{Δ}. This consequence for responding during S^{Δ} presentations likely motivated participants to pay more attention to the contingencies than would have the mere inability to gain points, as occurred in this experiment. Aversive consequences during the S^{Δ} probably increased participants' discrimination between S^{D} and S^{Δ}, and thereby increasing the probability of demonstrating the blocking effect (see Martin & Levey, 1991). A possibility with the current procedure is programming a response cost during the S^{Δ}, for example, a total loss of points, with the aim of complete elimination of responding during the S^{Δ}. Such a contingency might also have the advantage of engaging undergraduate student participants in the task to a greater degree.

Reducing the variability within- and between-subjects likely would have increased the significance of the blocking effect in Experiment 2. Martin and Levey (1991) were able to demonstrate blocking in human eyelid conditioning when using a within-subjects design, but not when using a between-subjects design. A single-case research design that presented both blocking and control procedures within individuals would reduce both between-subjects and within-subjects variability, while allowing only large effects to be observed. For example, a single-case research design might begin with the traditional first three phases of the blocking group procedure. A fourth phase that presented two unfamiliar, compound stimuli, one as S^{D} and the other as S^{Δ}, each consisting of two novel stimulus elements, if followed by a second test phase ("phase five") which presented single, phase-four S^{D} and S^{Δ} elements in extinction, would constitute the control procedure. The control sequence of phases and blocking sequence of phases could be counterbalanced among individual participants, to control for order of presentation.

A feature of the current experiments that may have reduced the amount of blocking observed in blocking group participants is the change in the reinforcement schedule when moving from the last interval of phase one to the first interval of phase two (from VI 17-s back to VI 2-s reinforcement). Kamin (1968, 1969) cautioned against changing experimental procedures other than those critical to blocking (i.e., from a single stimulus to a compound stimulus), which was likely to disrupt the blocking effect. Lyczak and Tighe (1975) demonstrated blocking in young children only when disruptive occurrences at the transition between experimental phases were eliminated, minimizing participants' attention to phase changes. Follow-up research with the current design but without discriminable schedule changes at phase transitions should be done to determine if the blocking effect can be observed.

Additional modifications of the current procedure that may enhance findings of blocking in human participants are pretraining of the required responses, before institution of the three phases of the blocking procedure, and increased training to single stimulus elements in phase one. Although human studies of blocking have usually been done within single experimental sessions (e.g., Arcediano et al., 1997; Martin & Levey, 1991), animal studies usually have required multiple training sessions. For example, Williams (1998) used rats and gave them 6 single stimulus training sessions followed by 5 phase two compound stimulus training sessions. Each session consisted of 30 stimulus presentations. Vom Saal and Jenkins (1970) used pigeons and gave them 15 daily phase one sessions followed by 11 daily phase two session, with 40 trials each of the CS+ and CS- per session. Longer duration of training before testing assures that steady state response levels had been reached before new manipulations were added, so that changes in responding could more definitively be attributed to the new manipulations (e.g., compound training added to single stimulus training before stable response rates were attained could confound results and conclusions). Some previous studies also followed Kamin (1968), who presented blocking group rats with 16 single stimulus trials (phase one) but only 4 compound stimulus trials (phase two). Arcediano et al., for example, presented college students with 16 single stimulus trials, but only 4 compound stimulus trials. The influence of duration of training prior to, and during blocking phases, as well as the ratio of single stimulus presentations to compound stimulus presentations, requires further investigation.

Regarding the important topic of interspecies generality of experimental findings, in particular the generality of the blocking effect which is demonstrated so readily in non-human animals, but which seems evasive in humans, Sidman has some pertinent words of caution: "Differences are not difficult to find" (1960, p. 55). Experimental results that differ between humans and other animals, however, may have more to do with experimental procedures and their relevance to the particular species than with the phenomenon being studied. Thus the challenge that still remains is to systematically unravel the controlling variables of which blocking behavior is a function, in humans.

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Appendices

Appendix A

Statement of Informed Consent

I (print name of participant): ______________________________, agree to participate in the experiment under the direction of Anna Bergen, to be conducted in room P222, Duff Roblin building, in the psychology department at the University of Manitoba. I understand that the time to complete the experiment (with questionnaire) will be about 20 minutes.

I understand that the purpose of this study is to examine the conditions necessary for learning. I also understand that in order for the researchers to examine this topic I will be asked to watch the computer monitor, and to press keys on the keyboard as directed by instructions given on the computer screen.

I understand that there are no known risks involved in my participation in this study. I understand that every effort will be made to keep my data confidential. My responses will be identified only by a code number and not by my name. I understand that I may talk individually with the experimenter, Anna Bergen (233-7181 at home), or with her research advisor, Dr. Stephen Holborn (office 474-8245), about the experiment if I so desire.

I understand that I may withdraw my consent and discontinue participation at any time without receiving any negative consequences. I have been given the opportunity to ask questions concerning the procedure, and any questions have been answered to my satisfaction.

This study has been reviewed by the Psychology/Sociology Research Ethics Board (PSREB). Any questions about my rights as a research participant or the conduct of this research may be directed to the Psychology Department Head, Dr. Gerry Sande (474-9360), or the chairperson of the PSREB, Dr. Bruce Tefft (474-7599). I understand that I will receive a copy of this consent form.

I have read and understood the above.

Participant's signature______________________________ Date____________

I have explained the research procedure in which the participant has agreed to participate, and have given him/her a copy of this informed consent form.

Experimenter's signature ______________________________ Date____________

Appendix B

Participant's Post-Experimental Report

Date: ______________________ Participant Code: __________________________

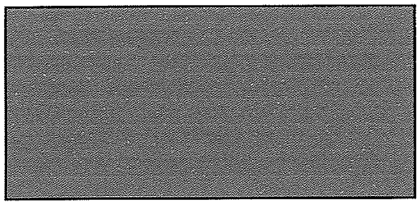
You have now successfully completed the experiment. Good work! Now, there are a few questions we would like you to answer. Please do your best when answering. Look at the rectangles on the next page and indicate whether or not you earned points when you pressed the shift key when this rectangle was present. If you cannot remember, just make your best guess.

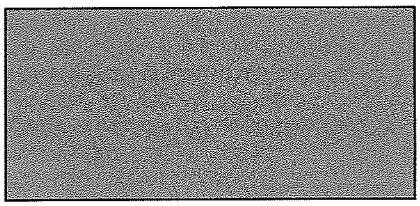
Write down any impressions you have about how the points are related to the particular rectangle color, in the "Comments" area beside each rectangle. Please also write down anything else about the rectangles or what you did.

Thank you for your participation!

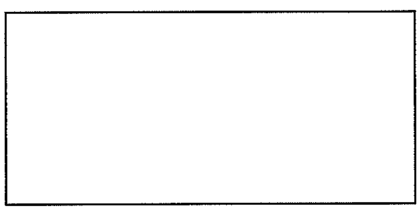
Anna Bergen

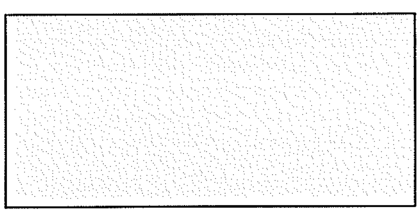
Participant's Post-Experimental Report

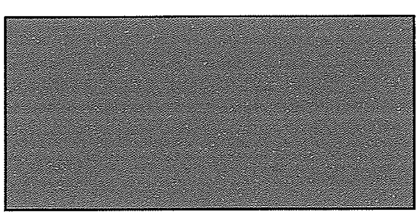
1.  Yes ☐ No ☐ Comments:

2.  Yes ☐ No ☐ Comments:

3.  Yes ☐ No ☐ Comments:

4.  Yes ☐ No ☐ Comments:

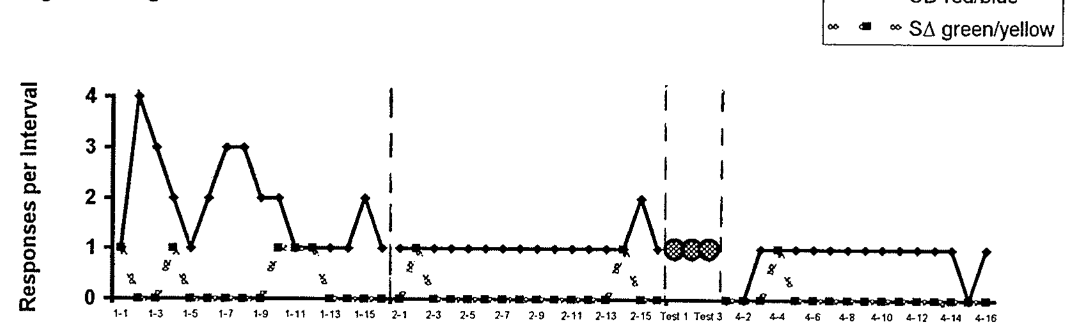
5.  Yes ☐ No ☐ Comments:

6.  Yes ☐ No ☐ Comments:

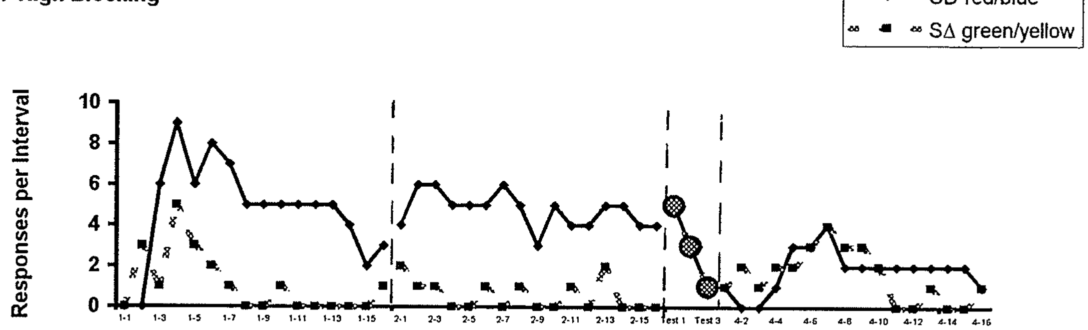
Appendix C

Experiment 1, Blocking Group Participants

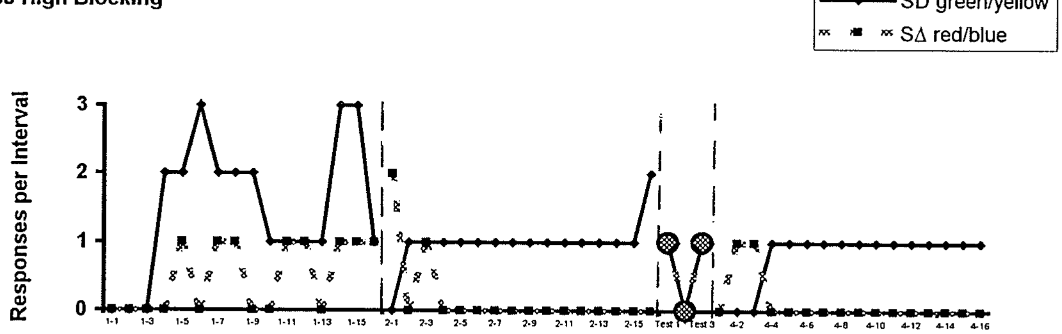
B3 High Blocking



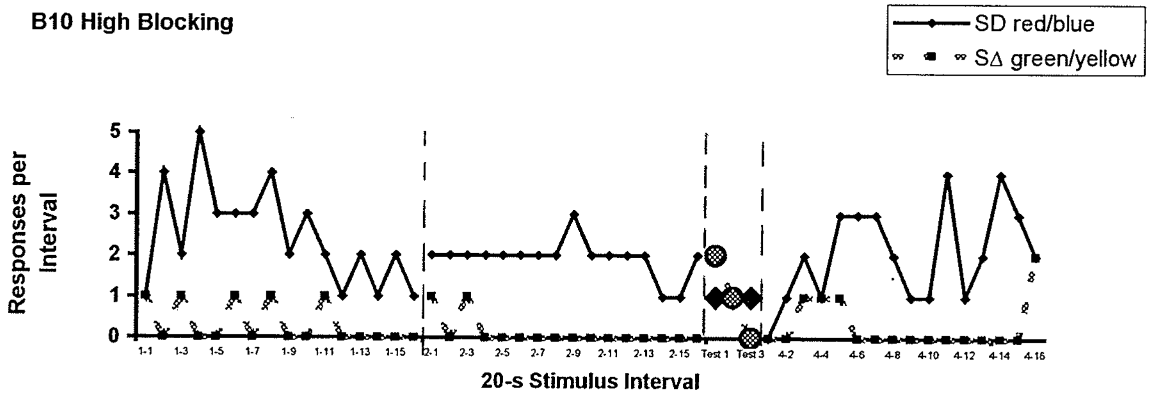
B7 High Blocking



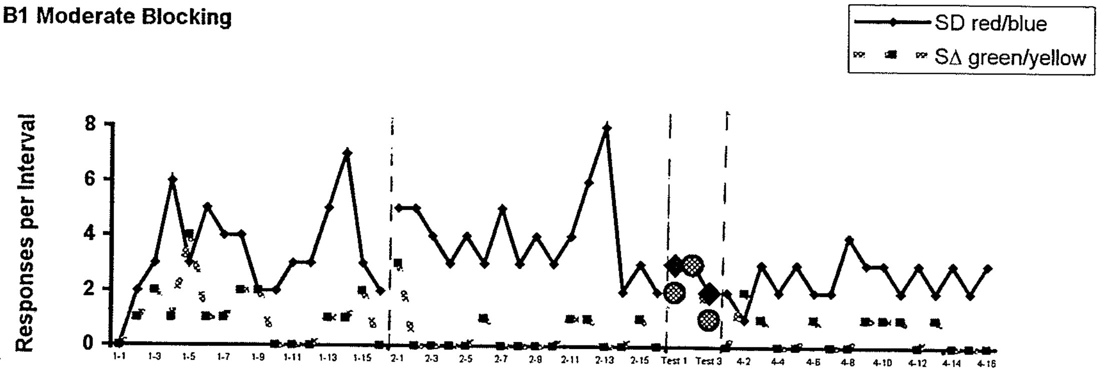
B8 High Blocking



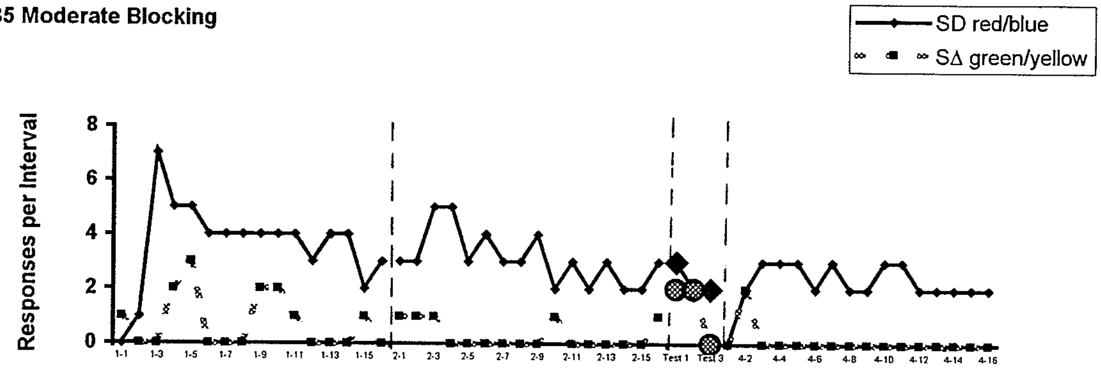
B10 High Blocking



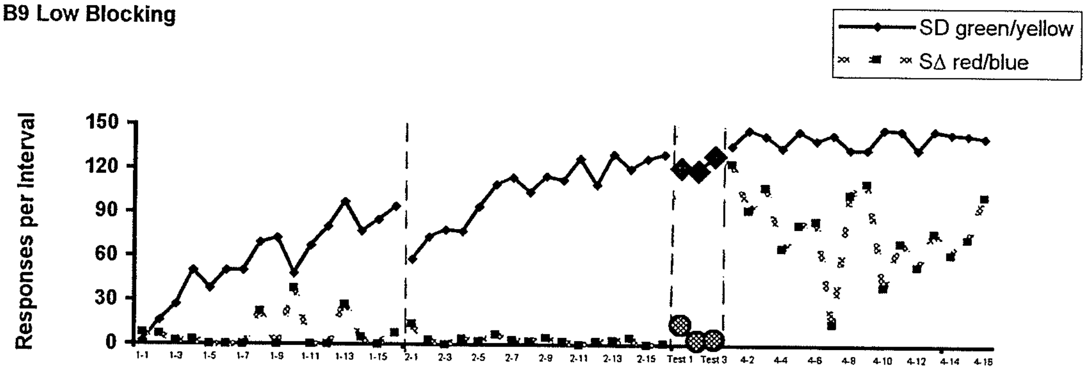
B1 Moderate Blocking



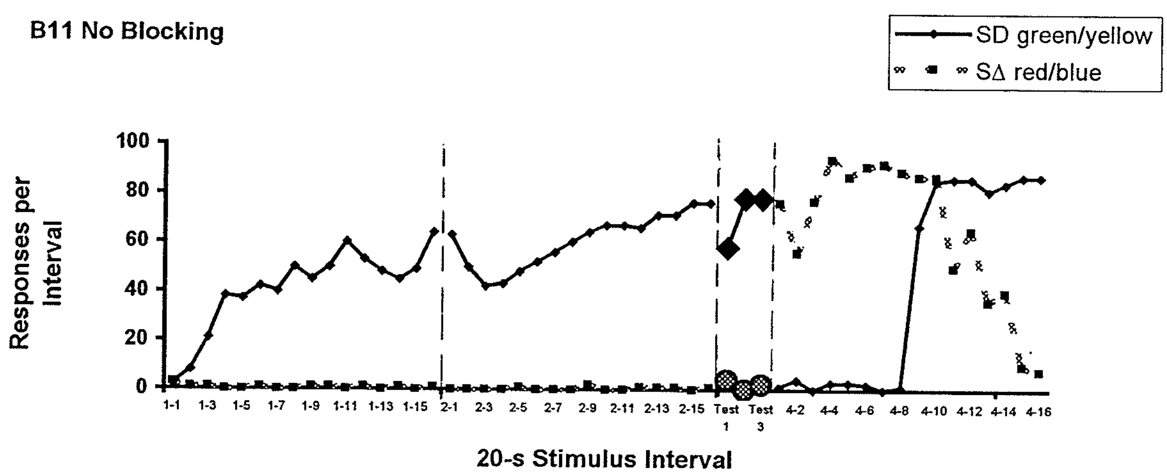
B5 Moderate Blocking



B9 Low Blocking

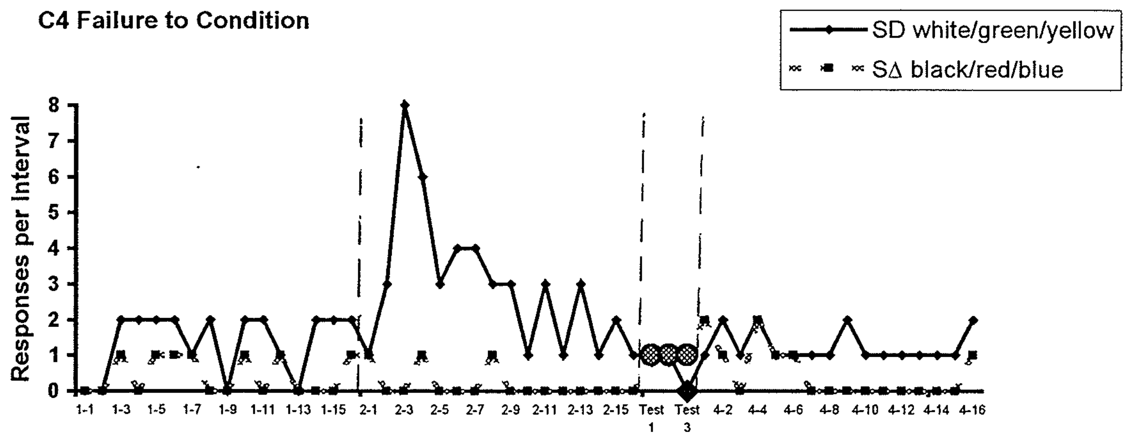


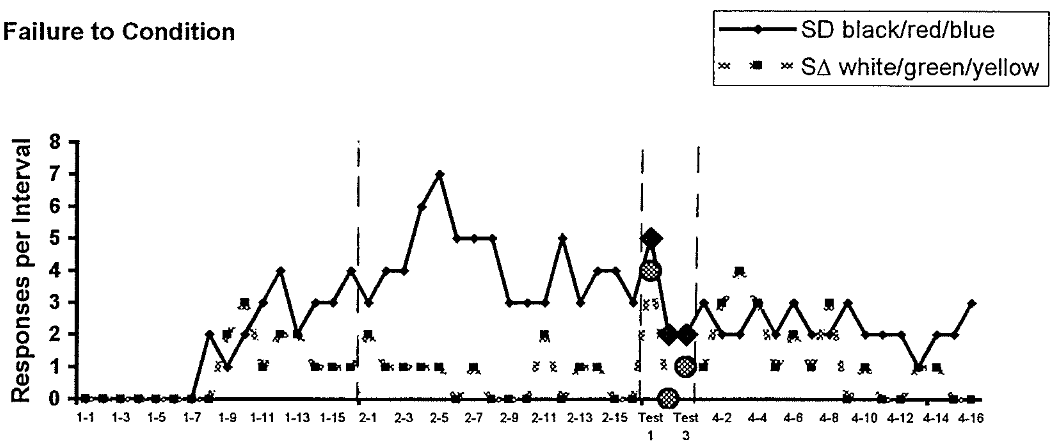
B11 No Blocking

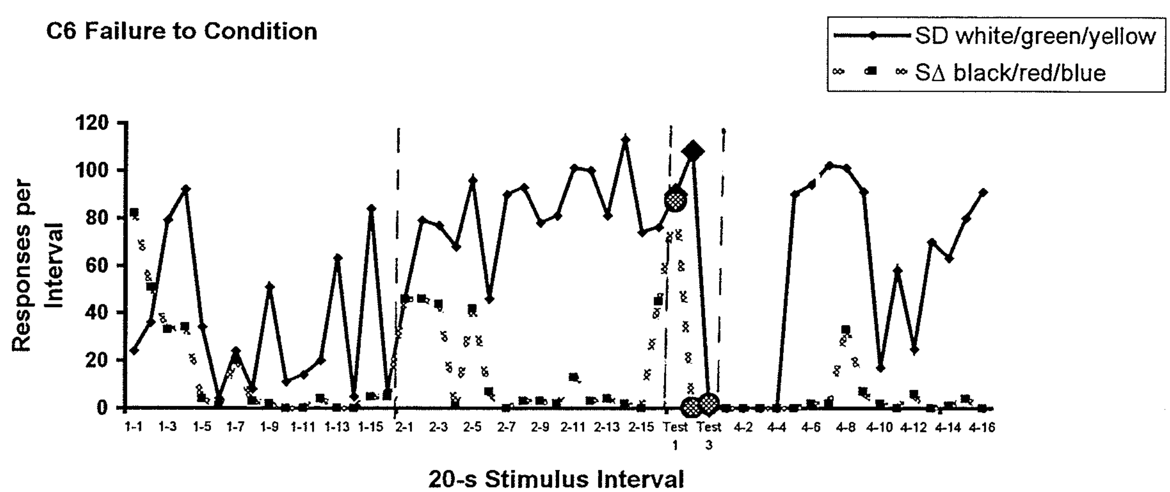


Appendix D

Experiment 1, Control Group Participants



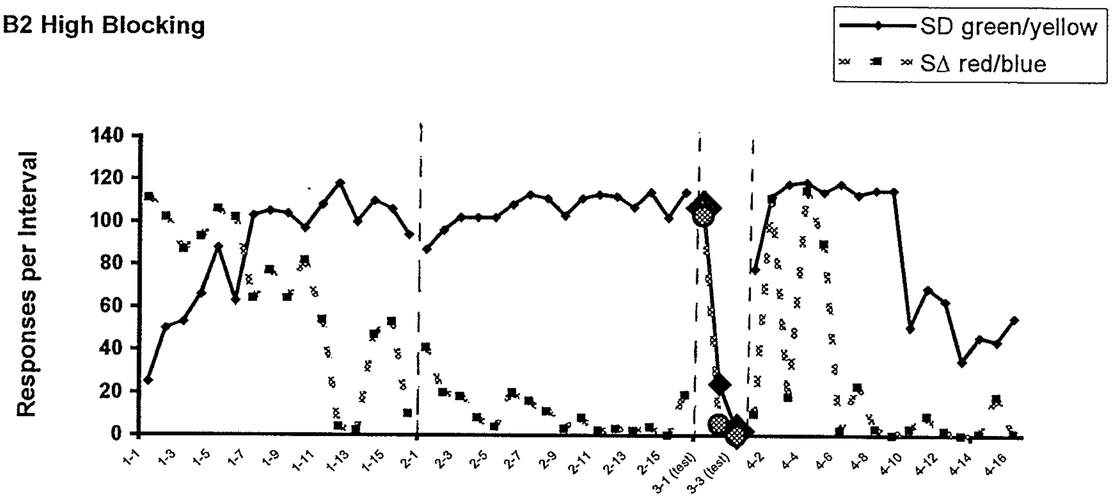




Appendix E

Experiment 2, Blocking Group Participants

B2 High Blocking



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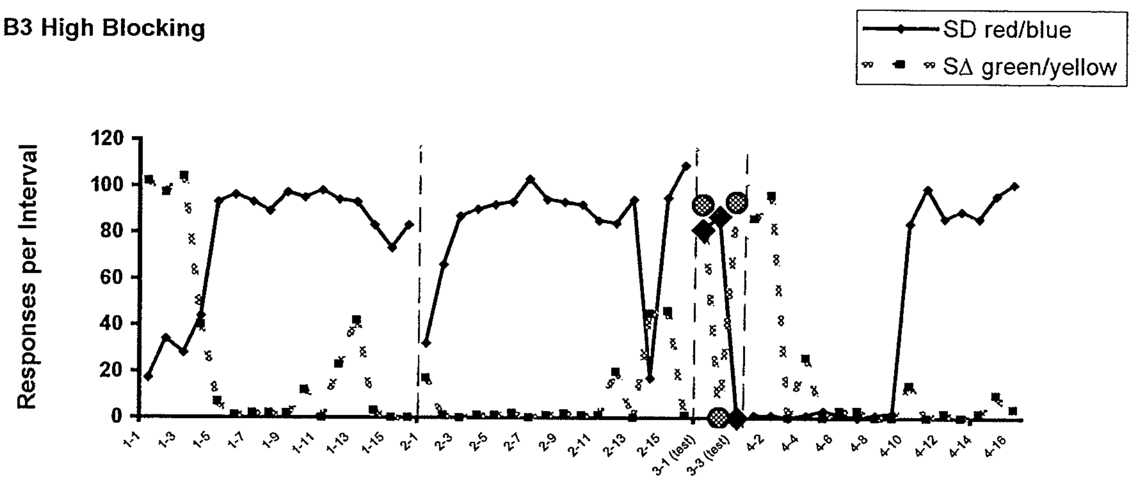

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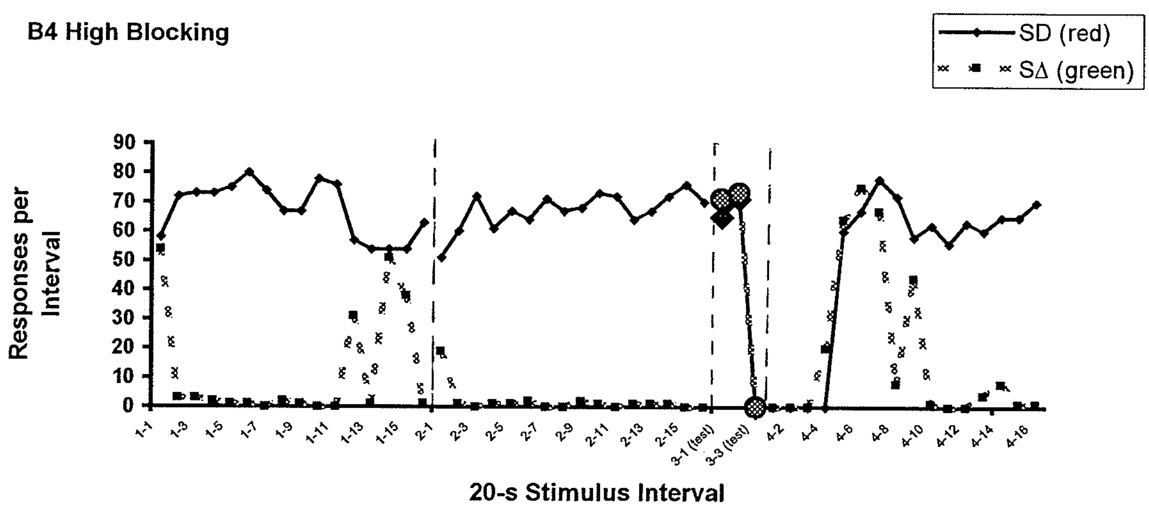
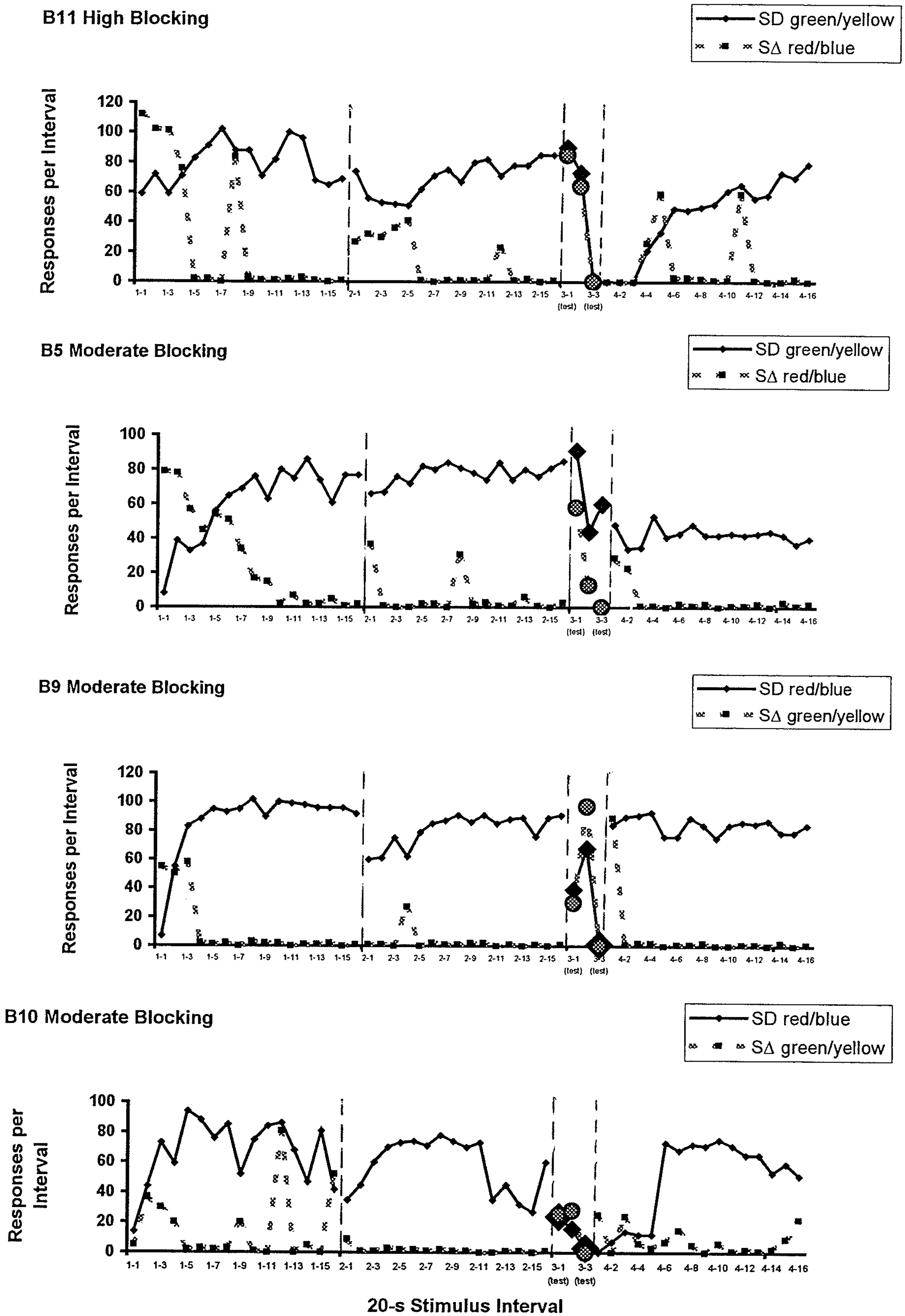
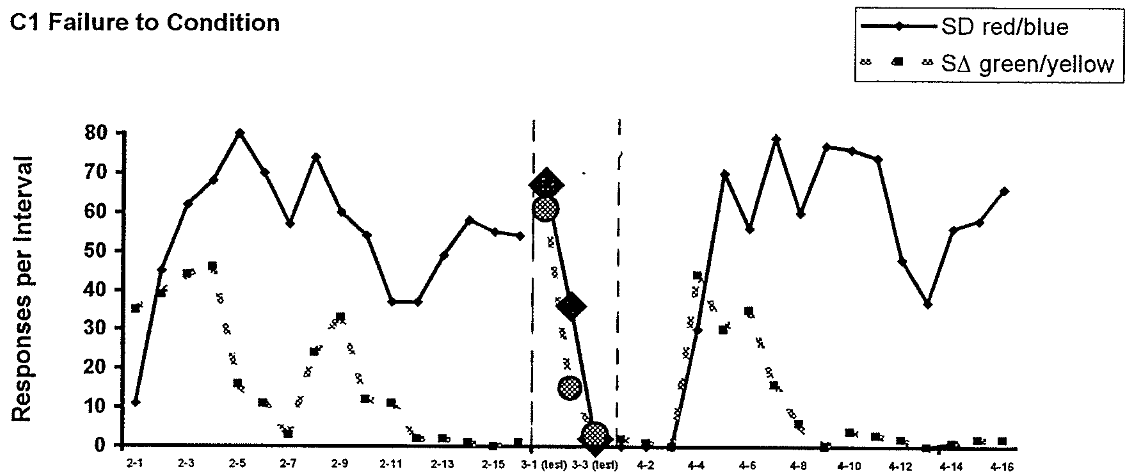



B11 High Blocking
SD green/yellow
SΔ red/blue
Responses per Interval
120
100
80
60
40
20
0
1-1 1-3 1-5 1-7 1-9 1-11 1-13 1-15 2-1 2-3 2-5 2-7 2-9 2-11 2-13 2-15 3-1 (test) 3-3 (test) 4-2 4-4 4-6 4-8 4-10 4-12 4-14 4-16
B5 Moderate Blocking
SD green/yellow
SΔ red/blue
Responses per Interval
100
80
60
40
20
0
B9 Moderate Blocking
SD red/blue
SΔ green/yellow
Responses per Interval
120
100
80
60
40
20
0
B10 Moderate Blocking
SD red/blue
SΔ green/yellow
Responses per Interval
100
80
60
40
20
0
20-s Stimulus Interval

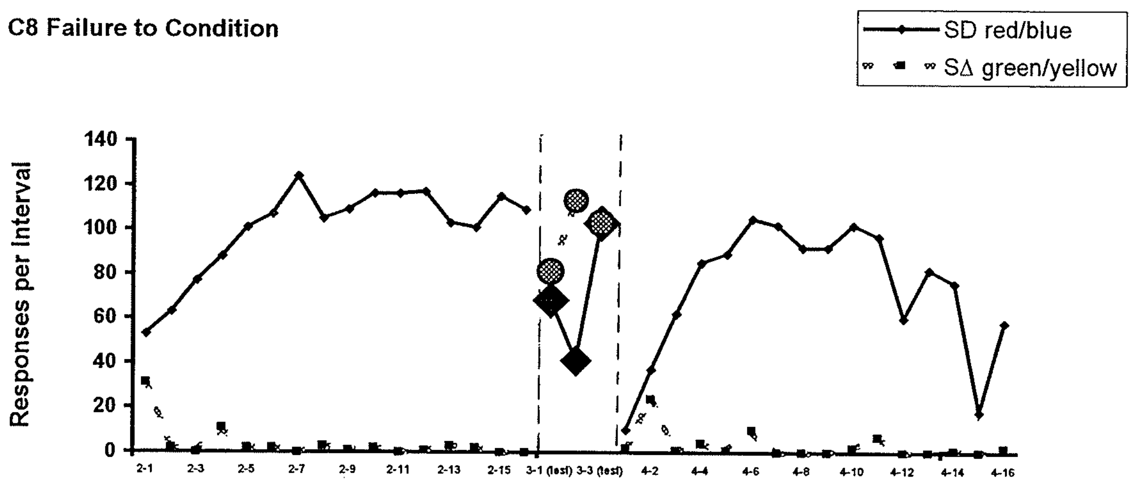
Appendix F

Experiment 2, Control Group Participants

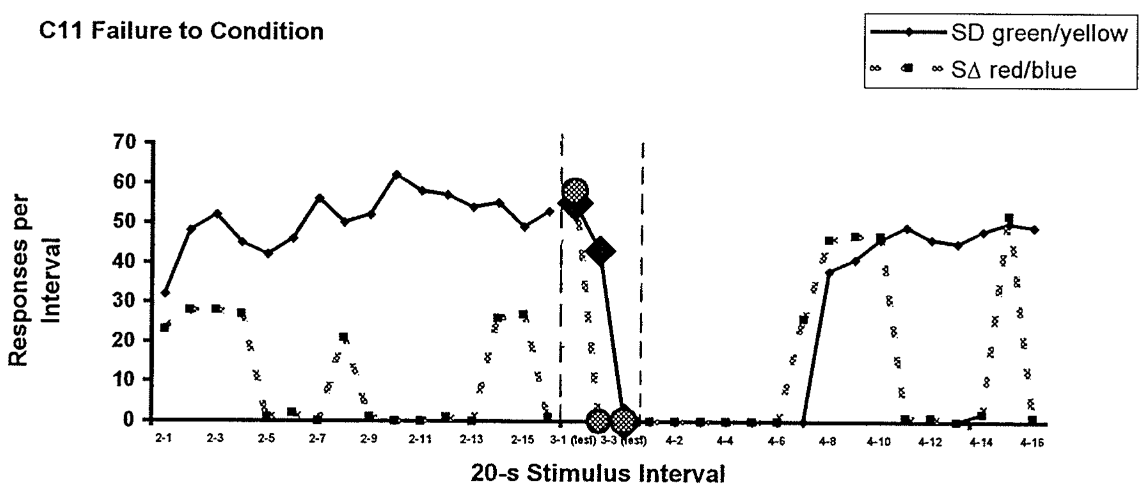
C1 Failure to Condition



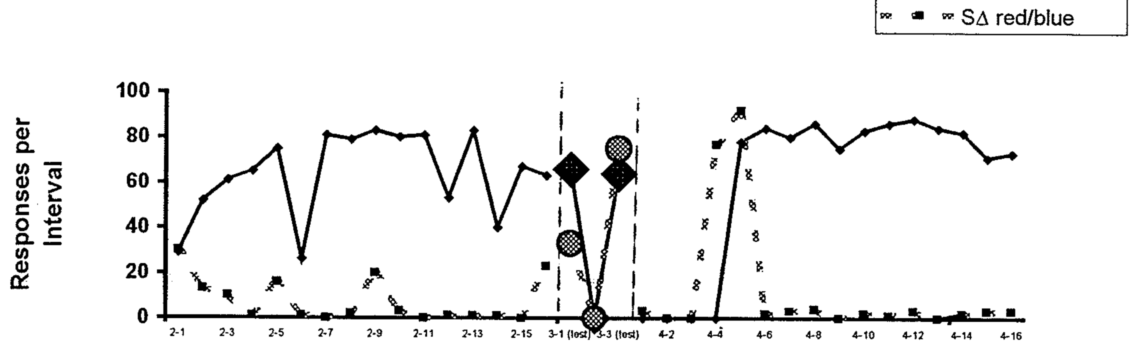
C8 Failure to Condition



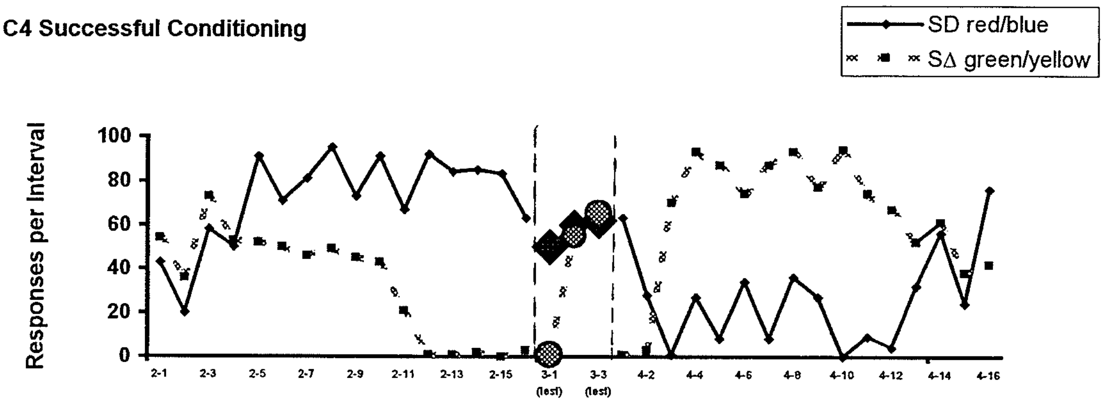
C11 Failure to Condition



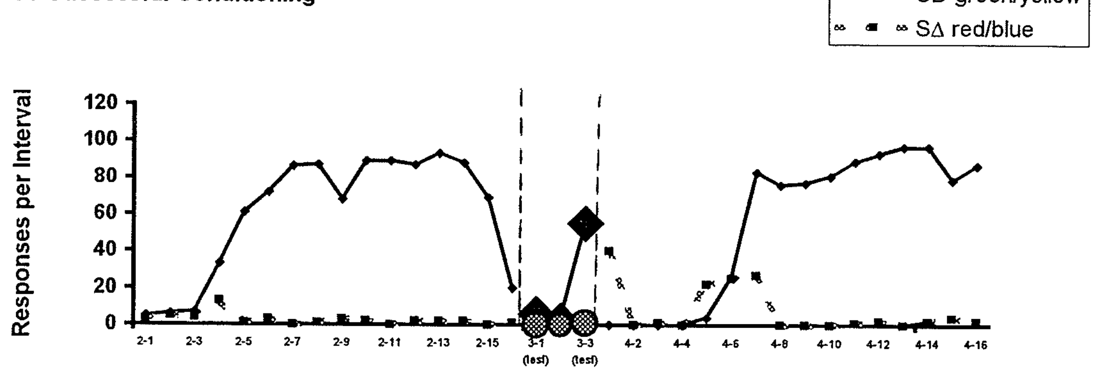
C5 Moderate Conditioning



C4 Successful Conditioning



C3 Successful Conditioning



C7 Successful Conditioning