Experimental Analysis of Blocking in Human Operant Behaviour

by

Anna E. Bergen

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Department of Psychology

University of Manitoba

Winnipeg, Manitoba

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Abstract

The blocking effect is the reduced stimulus control achieved by an unfamiliar (target) stimulus, “X”, when it is paired during conditioning with a stimulus, “A”, that already has acquired control. Blocking has been relatively difficult to accomplish with nonverbal behavior in human participants, compared with either nonverbal behaviour in animals or verbal behaviour in humans. Thus my primary research purpose was to produce blocking in the nonverbal, operant behaviour of human participants. My secondary research purpose was to achieve blocking of verbal behaviour. My third research purpose was to evaluate the relationship between verbal and nonverbal results. Four experiments were conducted with introductory psychology students pressing keys in response to coloured stimuli on a computer monitor. In Experiments 1A and 1B, the blocking procedure was applied only to the negative discriminative stimulus (S^{-}) which was paired with a response-cost contingency. Stimulus colours employed as the preconditioned and target stimuli were counterbalanced between Experiments 1A and 1B. Statistically significant results were obtained in the first case, but not in the second. Overshadowing likely occurred in both experiments, adding to blocking effects in Experiment 1A and subtracting from blocking effects in Experiment 1B. In Experiments 2A and 2B, overshadowing was better controlled and the blocking procedure was applied to both positive (S^{+}) and negative (S^{-}) stimuli. The key finding was blocking in Experiment 2B, with a large, statistically significant difference in response rates during the positive target stimulus. The success of blocking in Experiment 2B likely was a consequence of the powerful point-loss contingency employed with the negative stimulus, which greatly reduced the probability of generalized high-rate responding. It appears to be the first

demonstration of blocking of a positive stimulus in an operant procedure employing human participants; it supports the continuity of learning principles across species. Verbal response measures in both Experiments 2A and 2B also suggested that blocking occurred. In Experiment 2A however, nonverbal measures failed to show blocking, suggesting that in humans verbal measures may be more sensitive to blocking manipulations than are nonverbal measures.

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Blocking refers to the decrease in conditioned responding to an antecedent stimulus when it is presented together with a second antecedent stimulus that already has acquired control over responding; and when these stimuli are presented contingently with a reinforced response in operant conditioning, or with an unconditioned stimulus (US) in Pavlovian conditioning. Had the stimulus been presented on its own (or together with another novel stimulus) and contingently with a reinforced response or with a US, it would have developed stimulus control. Kamin (1968) first observed this phenomenon in a Pavlovian procedure. He named it the “blocking effect” (p. 14), because it is as if the preconditioned stimulus interferes with (i.e., blocks) conditioning of the new stimulus with which it is paired.

The blocking effect typically is demonstrated in a three-phase procedure, consisting of two acquisition (i.e., conditioning or training) phases followed by a final test phase (Kamin, 1968, 1969a). The first acquisition phase, also known as Phase 1 (or the preconditioning phase), involves conditioning of a single novel stimulus (designated stimulus, “A”, the blocking stimulus), by pairing it repeatedly with either a reinforced response or a US. The second acquisition phase, also known as Phase 2 (or the compound conditioning phase), involves conditioning of a compound stimulus (designated “AX”), which consists of the preconditioned stimulus A plus a novel target stimulus "X” (the to-be-blocked stimulus). It is the response to the target stimulus X that will demonstrate whether or not blocking has occurred. The final test phase, also known as Phase 3, involves individual presentations of each component stimulus, A and X, in extinction (i.e., not contingently with either the reinforced response or the US), while observing the behaviour of experimental subjects.

In the experimental blocking procedure, Phases 2 and 3 are identical for all subjects in both blocking and control groups. The only experimental difference between groups is Phase 1 treatment, in which the blocking group is preconditioned with stimulus A but the control group is not. As a result, control group subjects, unlike blocking group subjects, first are introduced to both stimuli of the compound, A and X, as neutral (or novel) stimuli in Phase 2. When A and X are tested separately in the final phase, control group subjects typically demonstrate conditioning to both stimuli. Blocking is observed if blocking group subjects demonstrate conditioning to stimulus A (the preconditioned stimulus) but reliably less conditioning than control group subjects to stimulus X (the target stimulus).

To illustrate, Kamin (1968) used rats in a conditioned suppression procedure (Annau & Kamin, 1961; Estes & Skinner, 1941), in which the effects of Pavlovian aversive conditioning phases and the test phase were evaluated by their impact on a stable baseline of operant bar pressing for food. Phase 1 preconditioning involved pairing of stimulus A (i.e., a light) with an aversive US (i.e., an electric shock) for 16 trials. The shock itself temporarily disrupted the rats' ongoing bar pressing; after repeated pairing of the light with shock, presentation of the light on its own disrupted bar pressing. Through repeated pairing with the shock, the light had acquired status as a conditioned stimulus (CS). The Phase 2 conditioning procedure involved pairing of a compound stimulus, consisting of the light (blocking stimulus A) along with a tone (target stimulus X), with the electric-shock US for 8 trials. Finally, in Phase 3 the light and the tone were presented individually and in extinction (i.e., without the shock US). The primary dependent measure for the conditioned suppression procedure was the change in rate of underlying operant bar pressing when the target stimulus X (the tone) was presented in Phase 3. Control group rats showed conditioning (i.e., the rate of operant bar pressing decreased, or was suppressed) to both the light and the tone. Blocking group rats demonstrated conditioning to the light (the preconditioned stimulus A) but much less so for the tone (target stimulus X). That is, acquisition of CS status by the tone appeared to have been blocked by prior conditioning of the light. This effect occurred despite the fact that both groups received an equal number of acquisition trials with the tone target stimulus in Phase 2.

Kamin's (1968) blocking effect was deemed important for several reasons, including the challenge it presented to temporal contiguity as a sufficient condition for learning. It now appeared that learning was dependent not only on contiguity, but also on the conditioning histories of other stimuli present during conditioning (i.e., blocking was conceptualized as a phenomenon of stimulus competition or stimulus selection). As a direct result, theories to accommodate the new findings developed (e.g., Rescorla & Wagner, 1972) and research on blocking with non-human animals flourished (Williams, 1999).

The generality of learning principles across species also has been challenged due to the difficulties that have been encountered in demonstrating blocking in humans. These difficulties have supported the contention that fundamental differences exist between human and non-human animal learning in general, and between verbal and nonverbal learning in particular (Arcediano, Matute, & Miller, 1997). While the continuity of *biological* principles across species is accepted, some researchers have argued that *behavioural* principles discovered in animals do not necessarily apply to humans (e.g., Brewer, 1974). Others (myself included) suggest that before concluding that learning principles do not generalize to humans, important variables controlling human behaviour remain to be identified (e.g., Perone, Galizio, & Baron, 1988).

For a closer examination of some of the difficulties encountered in studies of blocking in humans, please see the review of relevant Pavlovian blocking studies in Appendix A. One potentially important variable identified in this research is whether the preconditioned and target stimuli that form the Phase 2 compound stimulus are in the same sensory modality. Despite Kamin's (1968) positive finding using a visual stimulus (light) and an auditory stimulus (tone) with rats as subjects, several subsequent researchers employing human participants were unable to demonstrate blocking with a visual and auditory compound stimulus (e.g., Davey & Singh, 1988; Lovibond, Siddle, & Bond, 1988). In contrast, other researchers using human participants were able to demonstrate blocking when the compound stimulus was composed of two visual stimuli (e.g., Hinchy, Lovibond, & Ter-Horst, 1995; Pellón and Garcia Montaño, 1990). Finally, Kimmel & Bevill (1991) were unable to demonstrate blocking with a mixed-modality compound stimulus but were successful when they changed to visual stimulus elements only.

The spatial configuration (arrangement in space) of the elements of a visual compound stimulus also may interfere with the blocking effect (e.g., Martin & Levey, 1991; Pellón & Garcia Montaño, 1990). When visual compounds were presented with little or no spatial separation between elements, blocking was not demonstrated. Only when these researchers increased the spatial separation between the same two stimulus elements, was blocking observed. In the former case, conditioning of the compound as an integral whole, or as a configuration, was suspected to have prevented conditioning of the separate stimulus elements.

The blocking effect was reported in human participants more recently by Arcediano, Matute, et al. (1997) and Arcediano, Escobar, and Matute (2001). They selected a “nonverbal behavioural response” (Arcediano, Escobar, et al., 2001; p. 197) as opposed to a verbal response (e.g., human causal judgment in Dickinson, Shanks, & Evenden, 1984) or a physiological measure (e.g., electrodermal conditioning in Davey & Singh, 1988). Participants pressed keys at a computer keyboard in response to the experimental stimuli which were presented on a computer screen. Similarly to Kamin’s (1968) procedure, these researchers superimposed an aversive Pavlovian conditioning procedure on a baseline of operant responding, and measured their results in terms of suppression of the underlying operant responding. In their first study (Arcediano, Matute, et al., 1997), the control group experienced an “explicitly unpaired” procedure (p. 192), which potentially resulted in super-conditioning of the target stimulus (Droungas & LoLordo, 1995; see Appendix A) and an “apparent blocking effect” (Arcediano, Escobar, et al., 2001; p. 355). Due to this control procedure, the researchers subsequently considered this earlier demonstration of blocking as ambiguous.

In their subsequent series of experiments, Arcediano, Escobar, et al. (2001) instituted several procedural changes. First, the explicitly unpaired control group (Arcediano, Matute, et al., 1997) was replaced with a control group that experienced a Phase 1 training phase identical to that of the blocking group, but with an irrelevant stimulus (recommended as the most appropriate control group by Hinchy et al., 1995; see

Appendix A). Second, whereas in their earlier study they had utilized both auditory and visual stimuli (high- and low-frequency tones and blue- and yellow-coloured computer screens, respectively), Arcediano, Escobar, et al. (2001) restricted their stimulus elements to the visual modality (i.e., coloured light panels) to increase the sensitivity of their preparation to the blocking phenomenon. Participants played a computer video game in which they pressed the space bar to enable the escape of an inmate from a jail cell; they gained one point for every successful escape. Superimposed discrimination training paired conditioned stimuli (CS+s) with the aversive US event, the closing of the jail cell exit, unless the participant stopped key pressing. CSs that were not associated with the aversive US (i.e., CS−s) were added to the procedure as "distractor" (Arcediano, Matute, et al., 1997; p. 193) or "filler" (Arcediano, Escobar, et al., 2001; p. 358) stimuli. A filler CS− contrasted with the CS+ because it (by definition) was not paired with the aversive US and thus was less likely to elicit suppression. Filler stimuli were expected to prevent excess generalization of the suppression response conditioned to the CS+ (i.e., the preconditioned stimulus A). All CSs, both CS+ and CS−, were 6-s presentations of colours displayed randomly in one of two light panels located on the walls of the jail cell. A statistically significant finding of blocking was reported in the first experiment of their series (Arcediano, Escobar, et al., 2001).

In their second experiment, Arcediano, Escobar, et al. (2001) replicated both the blocking effect found in their first experiment and also "recovery from blocking" previously shown with rats (e.g., Blaisdell, Gunther, & Miller, 1999, p. 63; see Miller & Matzel's [1988] comparator hypothesis, which explains blocking as a performance failure rather than as a learning, or acquisition, failure). Additional changes were made to increase further the experimental sensitivity to blocking. To reduce generalized suppression to stimuli other than the CS+, both the number of filler CS− trials was increased and the number of CS+ trials was decreased. To prevent configural conditioning of the compound stimulus, light panels were moved to different heights and separate walls of the jail cell. To increase participants' ability to discriminate between CS+ and CS− stimuli, a punisher was applied if they stopped space-bar pressing during CS− presentations (i.e., the punisher was closing the jail exit). Instructions were altered by making them more explicit, informing participants about both the light panels and the punisher.

Blocking also has been demonstrated in animal operant procedures. Seraganian and vom Saal (1969) trained rats to bar-press for food on a variable-interval (VI) reinforcement schedule. In Phase 1, the blocking-group rats only were presented with 3-min periods of a noise stimulus that was paired with extinction (i.e., no food reinforcer was available). The control-group rats experienced a continuous VI reinforcement schedule with no stimulus presentations. In Phase 2, both groups received 3-min periods of a compound noise-light stimulus paired with extinction. Finally, blocking was measured by comparing rats' response rates during presentations of the light stimulus with their response rates immediately prior to stimulus presentations. A statistically significant difference was obtained between groups, with control-group rats suppressing their responding during the light stimulus to a much greater extent than blocking-group rats (suppression ratios of 0.19 vs. 0.08, respectively).

Williams (1996) performed an experiment similar to that of Seraganian and vom Saal (1969), except that stimulus presentations were correlated with food reinforcement for lever-pressing rather than with extinction. Williams gave his control-group rats analogous conditioning experience in Phase 1 by using an alternate stimulus (a clicker vs. a noise for the blocking group). In Phase 2, both groups were trained with a noise plus a houselight. When responding to the houselight was tested, the difference between groups again was statistically significant. Control-group rats demonstrated more stimulus control than did blocking-group rats (61 responses vs. 29 responses, respectively).

Vom Saal and Jenkins (1970) employed discrimination training between two stimuli with pigeons pecking keys for food. In Phase 1, blocking-group pigeons learned to discriminate between a red key paired with food and a green key not paired with food. Control-group pigeons had no Phase 1 training. In Phase 2, the red key was compounded with a tone and the green key was compounded with a noise. Both groups learned to discriminate between the red-key-plus-tone stimulus, paired with food, and the green-key-plus-noise stimulus, presented in extinction. When both groups were tested with the tone stimulus (which had been paired with a reinforcer during Phase 2), the control group responded at a statistically significantly higher rate than did the blocking group (discrimination ratios of 0.77 vs. 0.57, respectively).

Operant blocking procedures also have been employed with human participants, but with less success. Card-sorting tasks were used with undergraduate students (Trabasso & Bower, 1968/1975) and with primary school children (Lyczak, 1976; Lyczak & Tighe, 1975). Trabasso and Bower reported that overshadowing confounded their results. Lyczak and Tighe demonstrated blocking only when they minimized obtrusive procedures between phases (i.e., instructions and observable manipulations by the experimenter; described below as the “transitional trial” effect, Kamin, 1968, p. 16).

Lyczak showed blocking, but only when he used a response latency dependent measure rather than the number of errors made. Blocking was described as a “low-probability event” in humans as opposed to animals (Lyczak & Tighe, p. 121).

A somewhat more convincing demonstration of blocking was reported more recently by Rehfeldt, Dixon, Hayes, and Steel (1998) in a stimulus equivalence paradigm. Undergraduate students were trained on matching tasks for point reinforcers. In Phase 1 only single stimuli were matched. In Phase 2 one of the three stimuli was paired with a second, target stimulus during matching training. Five of the ten participants were successful in demonstrating equivalence among the three original stimuli. Of these five participants, four also demonstrated blocking by decreased response accuracy to the target stimulus.

A number of researchers have examined the blocking effect in teaching reading, or word-naming skills to children with moderate mental retardation (e.g., Didden, Prinsen, & Sigafoos, 2000; Singh & Solman, 1990). They found that naming words occurred more quickly when they were trained without accompanying picture prompts. However, differences in group treatment preclude the conclusion that blocking of word naming by the accompanying picture is the responsible manipulation (e.g., rehearsal training procedure occurring primarily in the word-only condition).

As summarized above, in much of the blocking research with human participants to date blocking has either been very difficult to produce or results have been ambiguous (e.g., Davey & Singh, 1988; Martin & Levey, 1991). Experimental effects typically have been small, not easily replicable, or questionable on methodological grounds (e.g., Arcediano, Matute, et al., 1997; Pellón & Garcia Montaño, 1990). Exceptions are noted in two areas of research: human causal learning (also known as human contingency judgment; see a review and analysis by Dickinson, 2001) and studies of selective attention in persons with symptoms of mental disorders (e.g., Serra, Jones, Toone, & Gray, 2001, in chronic schizophrenics). In both of these areas of research, participants are required to generate rules about stimulus associations during Phase 1 and 2 training and they receive immediate verbal feedback about the accuracy of their predictions during training. Again in both areas of research, the dependent measure of the test phase consists of participants' predictions about the added stimulus in Phase 2. For example, in human causal learning, the preconditioned and target stimuli were stocks on the stock market and the associated event was an increase in value of the stock (Chapman & Robbins, 1990). In studies of selective attention, the stimuli were colored shapes on a computer screen and the associated event was the appearance of another colored shape. Experimental procedures in both cases involve explicit generation of rules and test responses in both cases are predictions based on the rules generated. That is, they explicitly require participants to be aware of the contingencies and to actively think about them – they are cognitive (or verbal) responses.

Recently, blocking appears to have been demonstrated in human participants using nonverbal response measures in a study using electro-dermal conditioning (Hinchy et al., 1995) and with an aversive conditioned suppression procedure (Arcediano, Escobar et al., 2001). In both of these studies Pavlovian conditioning procedures were employed, whereby the Phase 1 single stimulus (CS+) and the Phase 2 compound stimulus were paired with a US, and as a consequence acquired status as CS+s that elicited conditioned responding. The primary purpose in my research was to systematically replicate the blocking effect in the nonverbal behaviour of human participants using an operant procedure. The second purpose in my research was to measure verbal, post-experimental (questionnaire) responses, to assess for blocking. The third purpose was to evaluate the relationship between verbal and nonverbal dependent measures. The Phase 1 preconditioned stimulus was paired, not with a US as in Pavlovian conditioning, but with consequences for responses made during that stimulus presentation. As a result, the stimulus acquired status as a discriminative stimulus (S^+ or S^-) that controlled the type of response emitted during its presence. Verbal responses were obtained via a post-experimental questionnaire.

My first experiment shared a number of features with the experiments reported by Arcediano, Escobar, et al. (2001). First, antecedent stimuli were in the visual modality only, to reduce differences in stimulus salience and response variability both within and across individuals, that may be produced by including stimuli from different sensory modalities (e.g., visual and auditory; Martin & Levey). Second, discrimination training between an S^+ and S^- (or a CS+ and CS− in Arcediano, Escobar, et al., 2001) was required during acquisition phases, to reduce stimulus generalization. Third, a punisher, in terms of point loss for responding, also was instituted as a consequence for key-pressing during the S^-, both for the single preconditioned S^- in Phase 1 and for the compound S^- in Phase 2. The purpose of instituting punishment was to strengthen the contingencies, and thereby to improve discrimination between the positive (S^+) and negative (S^-) stimuli (see Arcediano, Escobar, et al., 2001; p. 360), and again to reduce stimulus generalization during the test phase. Fourth, inclusion criteria were used to eliminate data of participants who did not demonstrate discrimination between S^+ and S^-, since demonstration of blocking requires reliable discrimination (Martin & Levey, 1991; see Appendix A).

A fifth feature that my first experiment shared with the experiments of Arcediano, Escobar, et al. (2001) was that the control group was as recommended by Hinchy et al. (1995). That is, control group participants experienced discrimination training in Phase 1 equivalent to that of experimental participants, to rule out such differences as the cause of blocking. During Phase 1 training, the control group was presented with alternate stimuli (i.e., colours) that were irrelevant to the remainder of the study. As an additional control procedure, a novel stimulus was employed during the test phase, to determine the extent of stimulus generalization (Davey & Singh, 1988; Hinchy et al., 1995). In addition, the novel stimulus was tested prior to the target stimulus, in the hope that it would bear the major brunt of the transitional trial effect (i.e., merely transitioning from a compound to a single stimulus likely will disrupt response rates; Kamin, 1968), thereby allowing responding to the target stimulus to be influenced primarily by the blocking manipulation.

A sixth feature of Arcediano, Escobar, et al.'s (2001) research that was emulated in my research was the presentation of discriminative stimuli within the matrix of a computer video game. This design may have disguised the stimulus manipulations and thus promoted blocking. Demonstration of associative phenomena such as blocking may require a masking or distracting task in humans, as has the phenomenon of latent inhibition in humans (e.g., Lubow & Gewirtz, 1995). By superimposing the blocking manipulation on an underlying operant, "baseline" discrimination task, the procedure for my first experiment was thought to be somewhat analogous to that of Arcediano, Escobar, et al. (2001). The baseline discrimination task consisted of one pair of single stimuli (i.e., one discrimination between an S^+ and an S^-). Discrete intervals of a second pair of stimuli (i.e., both an S^+ and an S^-) then were interspersed among the presentations of the baseline discriminative stimuli. The focal stimulus to which the blocking manipulation was applied was the S^- in this second, superimposed discrimination. This focal S^- was preconditioned in Phase 1 and compounded with a novel stimulus (the target stimulus) during Phase 2 conditioning, and in both phases responding was punished by point loss. The purpose of the second S^+ was to act as a filler, or distracter stimulus (described previously) to reduce the probability of generalized suppression to any stimulus upon testing.

In order to minimize any disruptive effects of the transition from Phase 1 to Phase 2 (see Lyczak & Tighe, 1975) on blocking, differences in procedures at the transition between phases that existed in my earlier study (Bergen, 2002), other than the necessary compounding of the preconditioned stimulus with novel stimuli, were eliminated (Hinchy et al., 1995; Kamin, 1968, 1969). In Bergen (2002), Phase 1 ended with a VI 17-s reinforcement schedule for the S^+ but Phase 2 began with a VI 2-s schedule for the S^+. This change in reinforcement schedules at the transition from Phase 1 to Phase 2 was eliminated, as it could disrupt response rates on the transitional trial to Phase 2, thus precluding blocking. The same reinforcement schedule attained during S^+ intervals by the end of Phase 1, a variable-ratio schedule (VR10), was continued on into Phase 2. During the VR10 schedule, every 10^{th} response, on average, was reinforced by point gain.

Verbal instructions were kept to a minimum, in the attempt to approximate the same conditions as with nonverbal animals. In this experiment, participants were asked to earn as many points as possible and were told that they would need to figure out how to do this during different segments of the experiment; at various times they would need to press the shift key either “frequently and steadily”, or “very infrequently”, or not at all. They were not told explicitly that the availability of points was associated with stimuli on the computer screen. Participants also were asked to complete a brief questionnaire (see Appendix D) after the experiment, to obtain information about their level of awareness of the stimuli and contingencies.

The experimental hypothesis was that, due to preconditioning of stimulus A (Phase 1), blocking group participants would be hindered from conditioning to the novel target stimulus, X, which was compounded with stimulus A in Phase 2 training. Control group participants would suppress responding to the target stimulus on testing, as they would have conditioned to the target and because responding during target stimulus presentations was punished during training. Blocking group participants were not expected to condition (at all or as well) to the target stimulus and therefore would not suppress responding to the same degree on the test trial. As a result, there would be a statistically significantly higher response rate to the target stimulus in the blocking group than in the control group.

In my earlier research (Bergen, 2002), after participants had experienced acquisition phases with either positive reinforcement or extinction contingencies (i.e., no punishment), they tended to respond to all new stimuli at high response rates (i.e., stimulus generalization) without further training. Extrapolating that finding to my current experiment led to the expectation that participants in both groups would have a relatively high response rate to the novel stimulus on testing, since neither group previously would have been exposed to this stimulus. The difference in response rates between the novel and the target stimulus was therefore expected to be much greater in control group participants than in blocking group participants, for whom both the target and the novel stimulus would appear to be novel on testing. Such a result would constitute a finding of blocking. An additional hypothesis, regarding the verbal responses obtained on the post-experimental questionnaire, was that awareness of the contingencies associated with the target stimulus also would be less in the blocking group than in the control group (i.e., due to blocking). The experiment was conducted in two parts, Experiments 1A and 1B, with Experiment 1B being a replication of Experiment 1A, but with a reversal of colours for the preconditioned and target stimuli.

Experiment 1A

Method

Participants

Thirty-one participants were recruited from an undergraduate introductory psychology course at the University of Manitoba. They received course credit for participation. 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 C for a copy of the consent form). Participants were allocated alternately to the blocking and control groups.

Inclusion criteria. Statistical analysis included data from all participants whose performance met two inclusion criteria: (a) an overall positive point total in the experiment, and (b) a discrimination ratio of 0.80 or greater in the last half of the second training phase. The purpose of both of these criteria was to exclude data from a minority of participants whose responding, for whatever reason, did not come under control of experimental instructions and contingencies. The discrimination ratio (Williams, 1996, pp. 72-73) was calculated for each participant by dividing the number of key presses occurring during the "positive" discriminative stimulus (S^{+}_{A}), by the total number of key presses during both the positive and "negative" discriminative stimuli (S^{+}_{A} and S^{-}_{B}, respectively). The last four Phase 2 presentations of the baseline positive and negative stimuli were used to calculate this ratio; by this point in the experiment response rates generally were stable (note discrimination ratios of 0.96 and 0.97 in the blocking and control groups, reported in Results below). A participant's data were included in the statistical analysis only if 80% or more of their key presses occurred during the positive stimulus (i.e., a discrimination ratio of 0.80 or greater).

Data for a total of three participants were excluded from the analysis. Data were lost for one participant due to a computer malfunction. Data for two control group participants were excluded, as they did not meet the inclusion criteria: one for failing to attain a positive point total, and the other for failing to attain the minimum discrimination ratio 0. 0.80. This left the data for 28 participants, consisting of 7 males (mean age 20 years, range 18 – 24) and 21 females (mean age 20 years, range 18 – 23). There were 4 males and 11 females in the blocking group (n = 15), and 3 males and 10 females in the control group (n = 13).

Apparatus and Setting

Experimental sessions were conducted in two small rooms (approximately 3 m by 2.5 m), the first containing a storage cabinet, a table, and three chairs; and the second containing two four-drawer filing cabinets, a table, two chairs and one reclining chair. An

IBM-compatible Pentium 133 personal computer, equipped with a 3½-in floppy drive, 15-in colour monitor, keyboard, and two-button mouse, was placed on the table in each room. The experiment itself was conducted in the first room. The computer program was created by a fellow graduate student, J. Slivinski (2008) for his dissertation research and was modified for my blocking experiments. The entire (non-verbal) experimental procedure including all stimulus presentations, reinforcement schedules, and data collection were administered via the computer program. The questionnaire was administered on the computer terminal in the second room immediately following the conclusion of the experiment for each individual participant.

Procedure and Instructions

Experiment. Participants sat in front of the computer keyboard and monitor. They were tested individually, to prevent interference in key pressing behaviour from neighbouring participants. Interference from neighbouring participants was considered likely due to an identical sequence of S^+ and S^- presentations, which were expected to be associated with distinct patterns of responding; if response patterns were visually or aurally discriminated by fellow participants, experimental control over individual behaviour could be diminished.

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 or initials, assigned participant number, and true age and gender). Further instructions appeared on the computer screen as follows:

> Your goal is to earn as many points as possible, by pressing either SHIFT key. Aim for 200 points or more. Your total points earned will appear in the upper left

hand corner of the screen.

You also will need to press the SHIFT key to figure out the best way to earn points during different segments of the experiment.

For example, sometimes you will earn the most points if you press the SHIFT key frequently and steadily. Other times you will earn points only if you press the SHIFT key very infrequently. On some occasions you will not be able to earn points at all (you can stop pressing on these particular occasions).

Your task is to figure this out and to earn as many points as you can.

Please press the ENTER key to continue.

The following instructions were presented after the test phase (Phase 3):

You now have finished the experiment.

There is a brief questionnaire for you to complete in the next room.

Thanks for participating in this experiment!

For easy reference during the experiment, a hard-copy of these instructions was placed beside the computer keyboard. The experimenter left the room after giving initial verbal instructions, and stayed in the adjacent room during the experiment.

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 the number of points earned 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.

Questionnaire. At the conclusion of the experiment, participants were escorted to the adjacent room where they were asked to answer a short questionnaire presented via computer (see Appendix D). Participants in both groups were administered the same questionnaire. All colours (in rectangular form) that had been presented during the experiment were presented on the questionnaire. Participants were asked to indicate whether or not (Yes/No) they had earned points by key pressing for each individual colour. They also were asked to describe how they earned points.

Design

The experimental design is described in Table 1. Three phases include two acquisition or conditioning phases and a final test phase. The experiment was replicated across individual participants who were assigned to one of two groups, either the experimental (blocking) group or the control group. Group experience differed only in Phase 1; Phases 2 and 3 were identical for all participants in both groups. For the control group participants, discrimination training in Phase 1 employed a stimulus that was different from that used for the blocking group participants (i.e., the $S^{-}_{CONTROL}$ in Table 1). This stimulus was not used in, and therefore was irrelevant to, the remainder of the experiment. This control procedure permitted blocking and control group participants to experience equivalent durations of discrimination training in Phase 1. All phases were presented in immediate succession, without interruption, and within a single session.

Table 1

Design for Experiments 1A and 1B

Group	Phase 1	Phase 2	Test Phase
A. Both groups, baseline discrimination:			
	16 S^{+}_{A}, 16 S^{-}_{B}	11 S^{+}_{A}, 11 S^{-}_{B}	
B. Both groups, filler stimulus:			
	3 S^{+}_{FILLER}	3 S^{+}_{FILLER}	
C. Stimuli involved directly in blocking manipulation:			
Blocking group:	3 S^{-}_{PRE}	2 $S^{-}_{PRE+TARGET}$	
Control group:	3 $S^{-}_{CONTROL}$	2 $S^{-}_{PRE+TARGET}$	
D. Both groups, test phase:			S_{NOVEL}, S^{-}_{B}, S^{+}_{A}, S_{TARGET}

Note. Single-element stimuli are represented by the symbols S^{+}_{A} (red), S^{-}_{B} (green), S^{+}_{FILLER} (maroon), S^{-}_{PRE} (fuchsia in Experiment 1A and silver in Experiment 1B), and $S^{-}_{CONTROL}$ (teal). The compound stimulus presented in Phase 2 only is represented by the symbol, $S^{-}_{PRE+TARGET}$ (fuchsia-plus-silver). Single stimuli presented once only in the test phase are represented by the symbols S_{NOVEL} (aqua), S^{-}_{B}, S^{+}_{A}, and S_{TARGET} (silver in Experiment 1A and fuchsia in Experiment 1B). Numeral prefixes indicate the number of presentations of each stimulus. Superscripts ($^{+}$ and $^{-}$) indicate whether the stimulus acted as a “positive” or “negative” discriminative stimulus, respectively. Test stimuli (S_{NOVEL} and S_{TARGET}) have no superscripts since they were presented in extinction.

Stimulus elements. Stimuli were coloured, 3.3-cm x 8.4-cm rectangles presented on the computer monitor. When a stimulus consisted of a single rectangle, it was located in the center of the top half of the screen, with the longer dimension lying horizontally. In the case of a compound stimulus (i.e., in Phase 2), two rectangles appeared on screen at the same time. If one of the component stimuli had been previously conditioned (i.e., in Phase 1), then it occupied the upper position. The second component rectangle was placed 2 cm apart from the first rectangle, below and parallel to the top rectangle. The pair of rectangles were placed 2 cm apart intentionally because of evidence that adjoining visual stimulus elements may interfere with the blocking effect, possibly by configural conditioning (e.g., Martin & Levey, 1991).

Discrimination training. All phases consisted of a series of presentations of stimuli, each with its own associated schedule of reinforcement. Each stimulus was presented for a 15-s interval, whether it was a single stimulus element or a compound stimulus. The underlying or "baseline" discrimination was between a positive stimulus (i.e., red S^{+}_{A}) and a negative stimulus (i.e., green S^{-}_{B}), and each stimulus was presented 16 times in Phase 1 and 11 times in Phase 2 (see Table 1). To prevent control over responding by the passage of time rather than stimulus colour, which might develop if the sequence of S^{+} and S^{-} intervals was not varied, the order was reversed after every two presentations of each stimulus. The sequence of baseline stimulus presentations in each phase was: S^{+}, S^{-}, S^{+}, S^{-}, then S^{-}, S^{+}, S^{-}, S^{+}; all repeated until the prescribed number of presentations of each stimulus was reached.

A second pair of stimuli (i.e., both an S^{+} and an S^{-}), presented less frequently, was interspersed among intervals of the baseline stimuli. Table 2 shows the exact sequence of stimulus presentations for Experiment 1A. The baseline discrimination was presented alone for the first 12 intervals (i.e., six presentations of each of the baseline positive, red S^{+}_{A}, and negative, green S^{-}_{B}). Thereafter, the positive, maroon filler stimulus (S^{+}_{FILLER}), was presented and repeated after every eight intervals of the baseline stimuli for a total of six presentations to the end of Phase 2. The negative, fuchsia-coloured rectangle (S^{-}_{PRE}) in the case of the blocking group (or the teal-coloured rectangle [$S^{-}_{CONTROL}$] for the control group) was presented three times in Phase 1 and in compound with the target another two times in Phase 2, evenly interspersed between presentations of the filler stimulus (see Table 2). The stimulus compound was identical for both groups of participants, consisting of a fuchsia and a silver rectangle, the critical preconditioned and novel target stimulus elements, respectively, of the compound stimulus of the blocking paradigm ($S^{-}_{PRE+TARGET}$ in Table 1).

Table 2

Sequence of Stimulus Presentations for Experiment 1A

Phase 1					
1	Red S+	Green S-	Red S+	Green S-	
2	Green S-	Red S+	Green S-	Red S+	
3	Red S+	Green S-	Red S+	Green S-	Maroon S+
4	Green S-	Red S+	Green S-	Red S+	Fuchsia S-
5	Red S+	Green S-	Red S+	Green S-	Maroon S+
6	Green S-	Red S+	Green S-	Red S+	Fuchsia S-
7	Red S+	Green S-	Red S+	Green S-	Maroon S+
8	Green S-	Red S+	Green S-	Red S+	Fuchsia S-
Phase 2					
1	Red S+	Green S-	Red S+	Green S-	Maroon S+
2	Green S-	Red S+	Green S-	Red S+	Fuchsia-Silver S-
3	Red S+	Green S-	Red S+	Green S-	Maroon S+
4	Green S-	Red S+	Green S-	Red S+	Fuchsia-Silver S-
5	Red S+	Green S-	Red S+	Green S-	Maroon S+
Phase 3 (test phase)					
1	Green S-	Red S+	Aqua Novel Stimulus		
2	Green S-	Red S+	Silver Target Stimulus		

Note. The red S+ and the green S- comprise the underlying, baseline discrimination. The maroon S+ was added to act as a “filler” or “distractor” stimulus, to reduce stimulus generalization. The fuchsia S- functioned as the stimulus preconditioned in Phase 1 and it was compounded in Phase 2 with the target stimulus, a silver rectangle. The presentation sequence begins at the top left and continues across each row proceeding to subsequent rows. In Experiment 1B the fuchsia and silver stimuli reverse roles.

Contingencies. Two response repertoires were required of participants: a high response rate and a low response rate. Positive discriminative stimuli (i.e., the baseline red S^{+}_{A} and the filler maroon S^{+}_{FILLER}) were programmed to train high response rates. During presentations of the baseline positive discriminative stimulus, the red S^{+}_{A}, one point could be earned by the participant on progressively increasing fixed ratio (FR) schedules. In the initial two presentations, 2 key presses earned one point (FR2). In subsequent presentations of the red rectangle, 3, 4, 6, and then 8 key presses were required to earn one point. By the end of Phase 1, an average of 10 key presses earned a single point on a variable-ratio (VR10) schedule. To distinguish the maroon S^{+}_{FILLER} stimulus from the red S^{+}_{A} stimulus, the point consequences were made to differ. During presentations of the maroon, filler S^{+}_{FILLER} stimulus, two points could be earned on an abbreviated, progressively increasing FR schedule, requiring first 6, then 8, and finally 10 key presses to earn two points on a variable-ratio (VR10) schedule. In Phase 2, VR10 was continued for all presentations of both the red S^{+}_{A} and the maroon S^{+}_{FILLER}. The purpose of increasing the response requirements of the FR schedules was to eventually enable control by the VR10 schedule. A variable ratio schedule at the increased response requirement was expected to increase resistance to extinction in preparation for the test phase, during which test stimuli were presented in extinction.

Negative discriminative stimuli (i.e., the baseline green S^{-}_{B} and either the fuchsia S^{-}_{PRE} [in blocking group participants] or the teal $S^{-}_{CONTROL}$ [in control group participants]; and the Phase 2 compound stimulus, $S^{-}_{PRE+TARGET}$) were programmed to train low response rates. During presentations of the baseline negative discriminative stimulus, a green S^{-}_{B}, five points could be earned by the participant for “differential reinforcement of low-rate” responding (DRL). To earn five points, a key press was required after at least 8 s of not responding (i.e., not key pressing) at all (DRL8s). This schedule was maintained for the green S^{-}_{B} throughout both Phases 1 and 2. The remaining three stimuli are those critical to the demonstration of blocking in my research design: (a) the preconditioned stimulus, the fuchsia S^{-}_{PRE} (for blocking group participants in Phase 1), (b) the control teal $S^{-}_{CONTROL}$ (for control group participants in Phase 1), and (c) the Phase 2 compound stimulus, the fuchsia-plus-silver $S^{-}_{PRE+TARGET}$ (for both groups in Phase 2). Rather than punish key pressing immediately during the S^{-}_{PRE}, $S^{-}_{CONTROL}$, and $S^{-}_{PRE+TARGET}$, participants lost 20 points after 4 key presses and on every 4th key press thereafter (FR4). This slight delay in punishing consequences was expected to increase participants’ attention to the stimulus then on the screen, and thus their discrimination among stimuli. More immediate point loss consequences (e.g., FR1) had the undesirable possibility of being associated with the immediately preceding stimulus, thus creating ambiguity (decreasing discrimination).

Phase 1 (preconditioning). During this phase, all participants were presented with the baseline discrimination between two differently-coloured single rectangles: a red rectangle (the S^{+}_{A}) to generate high-rate responding and a green rectangle (the S^{-}_{B}) to generate low-rate responding. Two additional stimuli were presented in between presentations of the baseline stimuli: the maroon rectangle (the filler S^{+}_{FILLER}) to generate high-rate responding, and either a fuchsia rectangle (the preconditioned S^{-}_{PRE} for blocking group participants) or a teal rectangle (the control $S^{+}_{CONTROL}$ for blocking group participants), both programmed to generate low-rate responding. The independent variable consists of the difference between groups in Phase 1: the experimental (blocking) group is conditioned to a (negative) stimulus that is to be compounded with a second stimulus in Phase 2. In contrast, the control group is conditioned to a different (negative) stimulus, in order to equate experience in discrimination training between groups, but the particular stimuli (i.e., colours of the rectangles) presented in the control group were otherwise irrelevant to the remainder of the experiment.

Phase 2 (compound-stimulus conditioning). A compound stimulus, a fuchsia-plus-silver $S^{\Delta}_{PRE+TARGET}$, was presented for the first time to all participants in Phase 2, replacing the single negative stimulus of Phase 1. Although Phase 1 differed between groups, from the onset of Phase 2 both groups of participants experienced identical stimuli and contingencies. For blocking group participants, one component of the compound stimulus, the fuchsia rectangle, had already been conditioned in Phase 1, but the silver rectangle was a new, unfamiliar, or novel stimulus. In contrast, for control group participants, *both* components of the compound stimulus were novel. The baseline discrimination, between the red S^{+}_{A} and the green S^{-}_{B} continued unchanged from Phase 1 into Phase 2. Similarly, the maroon filler S^{+}_{FILLER} continued to be presented in Phase 2 unchanged.

Phase 3 (test phase). The test phase for all participants was identical and consisted of the following sequence of stimulus presentations: first an aqua-coloured novel stimulus (S_{NOVEL}) followed by the green S_{B}, then the red S_{A}, and finally by the target stimulus, the silver S_{TARGET}. All test stimuli were presented only once for 15 s in extinction (thus superscripts and numerals are removed; see Table 1).

*Dependent variables.*The primary comparison between blocking and control groups was the difference in responding to the target stimulus (silver S_{TARGET}) during testing. The control group was expected to have a reliably lower mean response to the silver target stimulus than the blocking group. Test responses were reported in terms of relative response rates: for each individual participant, the number of key press responses during the silver S_{TARGET} was divided by the mean number of key presses made during the baseline red S^{+}_{A} (high rate responding) in the last four presentations of Phase 2 (i.e., by which time stable response levels were achieved; note again the discrimination ratios of 0.96 and 0.97 in the blocking and control groups, reported in Results below). Relative response rates, rather than the absolute response rates, were used to generate group means, in order to reduce the effect of variable response levels across participants.

The second comparison made between blocking and control groups was the difference in responding to the novel test stimulus (aqua S_{NOVEL}) in terms of relative response rates (as described for the S_{TARGET} stimulus above). Since participants in neither group had been conditioned with the novel aqua colour, no difference in responding was expected between groups and response levels were expected to be high. Generalization of responding to neutral stimuli also could be gauged with this test.

The third comparison between groups was in terms of the magnitude of the within-group difference in response rates between the S_{NOVEL} and S_{TARGET} (the S_{NOVEL} – S_{TARGET} difference). If blocking occurred, then the blocking group was expected to have little difference in response rates between the silver S_{TARGET} and the aqua S_{NOVEL} stimuli, as neither stimulus would have been conditioned. The control group, on the other hand, was expected to have a reliably greater difference in response rates to the S_{NOVEL} and the S_{TARGET}, with high rates to the neutral S_{NOVEL} and low response rates to the S_{TARGET} that had been associated with point loss. All results are reported in terms of relative, rather than absolute, response rates.

Results

To determine if there were any group differences that might override or confound the effect of the blocking manipulation, groups were compared in terms of mean response rates and mean discrimination ratios. Other between-group comparisons made to demonstrate group equivalency were point totals attained during the experiment, age, and gender. The results of these comparisons will be reported first, to be followed by the results of the test of the target stimulus (i.e., the effect of the blocking manipulation).

Analysis of mean response rates, in terms of the number of key-press responses per 15 s averaged over the last four 15-s presentations of the red S^+_A (immediately preceding the test phase), indicated no differences between the blocking and control groups (*M* = 52.0 responses per 15 s, *SD* = 17.3 and *M* = 53.8 responses per 15 s, *SD* = 15.6, respectively; $F[1, 26] = 0.09$, $p = .77$). Analysis of discrimination ratios (i.e., the proportion of total responses to both S^+_A and S^-_B occurring during the S^+_A), calculated using response rates during the last four presentations of the baseline red S^+_A and green S^-_B prior to the test phase, indicated no differences between groups (*M* = 0.96, *SD* = 0.03 for the blocking group and *M* = 0.97, *SD* = 0.01 for the control group, $F[1, 26] = 0.69$, $p = .42$). In other words, for the blocking group 97% of total responses including both S^+_A and S^-_B presentations occurred during the S^+_A intervals (i.e., during which responding was reinforced); for the control group 96% of all responses occurred during the S^+_A intervals. This was a good indication that participants in both groups were discriminating between the S^+ and the S^- reliably and equivalently.

Participants earned similar point totals regardless of group assignment (*M* = 300.6

points, *SD* = 85.3 for the blocking group versus *M* = 293.0 points, *SD* = 76.6 for the control group, $F[1, 26] = 0.06$, $p = .81$), suggesting that participants' responding was equivalent across both groups. Groups also did not differ in terms of age (*M* = 20.0 years, *SD* = 1.7 for the blocking group versus *M* = 19.6 years, *SD* = 1.6 for the control group, $F[1, 26] = 0.37$, $p = .55$) and gender composition ($F[1, 26] = 0.04$, $p = .84$). Thus, any observed differences between groups in responding to the target stimulus in the test phase are more likely to be due to Phase 1 preconditioning in the blocking group and lack thereof in the control group.

Experimental Results

To quantify the size of the difference between the blocking and control groups, in this and subsequent experiments, the Hedges's *g* statistic is reported for statistically significant results only (Coe, Effect Size Calculator). Hedges's *g* is a standardized mean difference measure of effect size; that is, it measures the size of the difference between group means in terms of standard deviation units or Z-scores, thus describing the amount of overlap between the two groups (Coe, 2002). Hedges's *g* is similar to Cohen's *d* statistic, but corrects for overestimation of population effect size of the latter (Coe, Effect Size Calculator; Rosnow & Rosenthal, 2003).

Results of the tests of the silver target stimulus and the aqua novel stimulus are shown for each group in Figure 1. The dark columns on the left side for each group show the response rates during the test of the target stimulus, in relative terms. That is, response rates during test presentations are expressed as a proportion of the mean stable response rates attained during the last four presentations of the red S^{+}_{A} (period of high-rate responding) prior to the test phase. A lower response rate was expected for control group participants, who should have been well-conditioned to the silver target stimulus. Blocking group participants were expected to respond at the higher rate, as conditioning of the silver target stimulus should have been blocked by the presence of the preconditioned stimulus. It can be seen that the blocking group (left side of the chart) responded at a much higher rate than did the control group, as expected (M = 0.55, SD = 0.33 for the blocking group versus M = 0.13, SD = 0.15 for the control group, F[1, 26] = 17.87, p = .00, g = 1.55). This difference was statistically significant and in the expected direction, suggesting that blocking took place.

The white columns on the right side for each group in Figure 1 show the response rates during the test of the novel aqua stimulus, in relative terms (as described above). It was expected that groups would respond similarly to the irrelevant, neutral stimulus, as neither group had been exposed to an aqua rectangle prior to testing. Blocking group participants responded at a similar high level during both the target and novel tests, as was expected; however, contrary to expectations, control group participants did not respond at a high level during the novel stimulus test. It can be seen in Figure 1 that the control group again responded at a much lower rate than the blocking group (M = 0.62, SD = 0.45 for the blocking group versus M = 0.28, SD = 0.34 for the control group, F[1, 26] = 4.9, p = .04, g = 0.82). This difference was statistically significant, but it was not expected.

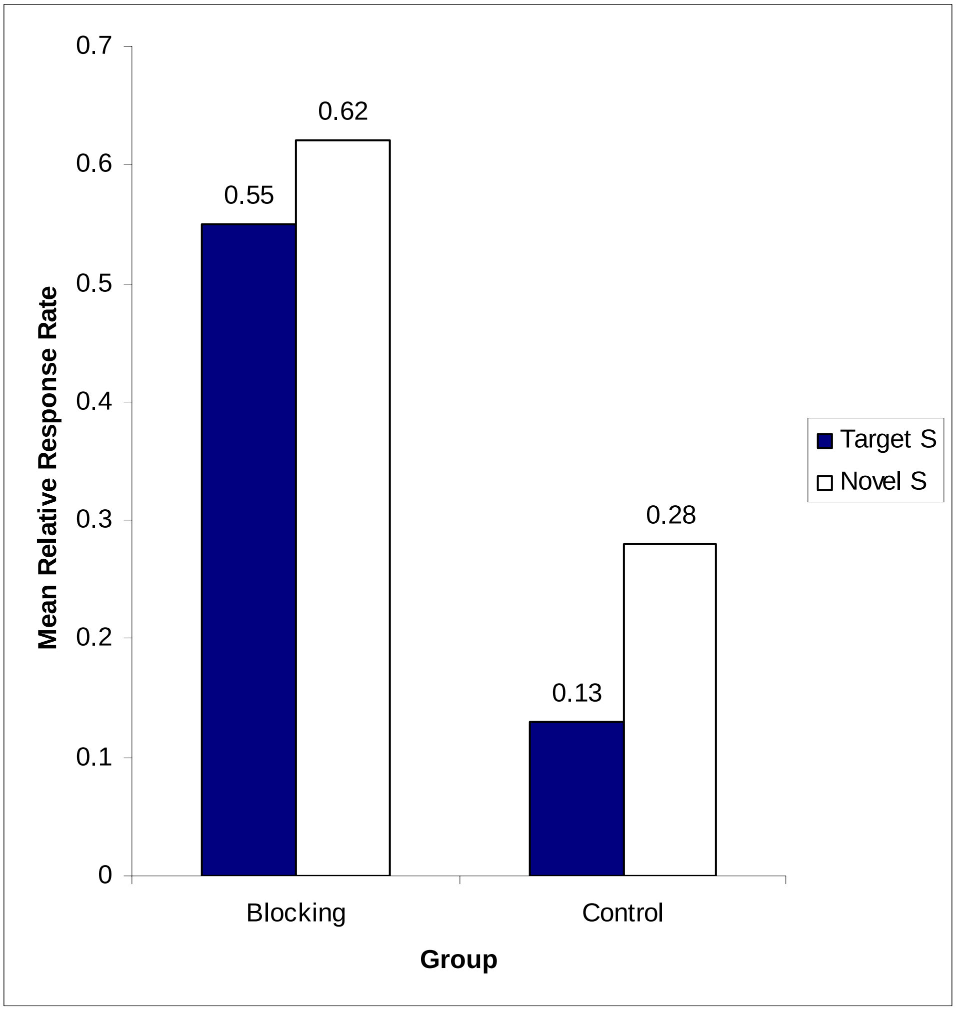

Figure 1. Results of Experiment 1A: Mean relative response rates (as a proportion of baseline response rates to the S^+_A) during tests of the silver target stimulus and the novel aqua stimulus, in blocking and control groups.

The third comparison between groups was in terms of the magnitude of the within-group difference in response rates between the aqua S_{NOVEL} and the silver S_{TARGET}. Response rates are calculated in relative terms (as described above). The blocking group was expected to show little difference in response rates between these two stimuli, as neither would have been conditioned if blocking had occurred. The control group was expected to show a larger difference in response rates between the novel and target stimuli, with a high rate to the neutral novel stimulus but a low response rate to the silver target, during which responding had been punished with point loss. The difference in responding between target and novel stimuli can be observed in Figure 1 as the difference between the darker (target stimulus) and lighter (novel stimulus) bars. It can be seen that differences between response rates during the tests of the target and novel stimuli were greater for the control group than for the blocking group, as expected (M = 0.06, SD = 0.52 for the blocking group versus M = 0.15, SD = 0.33 for the control group, F[1, 26] = 0.27, p = .61). The lack of a statistically reliable effect appeared to be due largely to the lower than expected response rate of control participants to the novel stimulus.

Questionnaire Results

Baseline and filler stimuli. All participants in both groups correctly indicated that points were available during the baseline red S^{+}_{A} (i.e., 100% for both groups). Most participants, although somewhat fewer in each group, also correctly indicated that points were available during the baseline green S^{-}_{B} (i.e., 80%, or 12 of 15 in the blocking group, and 77%, or 10 of 13 in the control group; points were available on a DRL schedule). Finally, most participants in both groups also correctly indicated that points were available during the maroon filler S^{+}_{FILLER} (i.e., 73%, or 10 of 13 in the blocking group, and 100% of the control group).

Preconditioned, novel, and target stimuli. All participants in both groups (i.e., 100%) correctly indicated that they lost points if they key-pressed during the fuchsia, preconditioned stimulus. For the novel, aqua stimulus, approximately one-third fewer participants in the blocking group correctly indicated that points were not available than did participants in the control group (i.e., 60%, or 9 of 15 in the blocking group, versus 92%, or 12 of 13 in the control group). Finally, fewer blocking group participants correctly associated the silver target stimulus with point loss than did participants in the control group (i.e., 60% or 9 of 15 in the blocking group, versus 92%, or 12 of 13 in the control group).

Discussion

In conclusion, there were several interesting findings in Experiment 1A. Most importantly, statistically reliable differences in response rates to the silver target stimulus (X) suggested that blocking of the target stimulus had occurred. The blocking group responded at a statistically significantly higher rate than the control group to the previously negative, target stimulus, suggesting that participants in the blocking group had not been conditioned, or had been blocked, to this stimulus. Also, the blocking group responded similarly to both the target stimulus (silver) and the novel stimulus (aqua), again suggesting that the target stimulus was no more conditioned during the experiment than a completely novel stimulus. This finding also is consistent with a finding of blocking. The control group demonstrated a greater difference in response rates between the target and the novel stimulus, as expected, but this difference was not statistically significant.

An unexpected finding was that blocking and control groups did not respond similarly to an irrelevant, novel (aqua) stimulus. The control group responded at a rate less than half that of the blocking group. A likely explanation for this response difference to the novel stimulus is stimulus generalization of *suppressed responding* to new stimuli, evident in the control group but not in the blocking group. Although both the blocking group and control group participants experienced an equal number of total presentations of the point loss contingency, they differed in the *number of different stimuli* associated with this contingency. Although both the blocking group and control group participants received equal time with the point loss contingency, the control group experienced the point loss contingency with more different stimuli (i.e., three differently-coloured rectangles: the single teal stimulus in Phase 1 and the fuchsia-plus-silver compound stimulus of Phase 2) than did the blocking group (i.e., two differently-coloured stimuli: the single fuchsia stimulus in Phase 1 and the fuchsia-plus-silver compound stimulus of Phase 2). When all participants were confronted, in Phase 2, with a new, compound negative stimulus, control group participants saw two new colours, but blocking group participants saw only one new colour, and the associated point-loss contingency, for them, was suggested already by the preconditioned stimulus of Phase 1. Thus, the compound stimulus presentation, at the onset of Phase 2, is likely to have made a greater impact on the control group than on the blocking group. These factors may well be responsible for the greater caution exercised by control group participants in key-pressing during novel stimulus presentations.

Questionnaire responses, obtained immediately after completion of the experiment, indicated that the majority of participants in both groups were aware of whether or not points could be earned for each stimulus colour. However, regarding the silver target stimulus, more control group participants than blocking group participants were aware of the associated contingency, consistent with the experimental findings suggesting that conditioning to the target was blocked in the blocking group. A second difference of similar magnitude was found in questionnaire responses to the novel stimulus. More control group participants, than blocking group participants, correctly identified that points were not available during the novel stimulus, although neither group had previous experience with this stimulus. This questionnaire result is consistent with the generalized suppression of responding seen in control group participants during the test of the novel stimulus, and may be a result of the same causal factors.

Experiment 1B

My purpose in conducting Experiment 1B was simply to replicate the blocking effect demonstrated in Experiment 1A, while counterbalancing the two colours used for the preconditioned stimulus (A) and the target stimulus (X) in Experiment 1A. If the blocking effect were demonstrated again, with the colours of the preconditioned and target stimuli reversed, this would show that the particular colours of the stimuli were equivalent in terms of conditioning and did not interact with or confound the effects of the blocking procedure. Whereas in Experiment 1A the preconditioned stimulus was fuchsia and the target stimulus was silver, in Experiment 1B the preconditioned stimulus was silver and the target stimulus was fuchsia.

Hypotheses are restated here with one modification, in accordance with the findings of Experiment 1A. Once again it was hypothesized that blocking would occur:

that the blocking group would respond at reliably higher rates to the target stimulus than would the control group, demonstrating a relative lack of conditioning to the target stimulus in the blocking group. The blocking group was expected to respond at similar rates to both the target and novel test stimuli. A greater difference in response rates between the target and novel test stimuli was expected in the control group than in the blocking group. In view of reduced responding to the novel test stimulus by the control group in Experiment 1A, it was expected that the blocking group also would respond at a reliably higher rate than the control group to the novel (test) stimulus.

With respect to questionnaire results, it was expected that the findings of Experiment 1A would be replicated. That is, most participants in both groups would correctly identify positive and negative contingencies, but that reliably fewer blocking group participants than control group participants would respond correctly to the target stimulus.

Method

Participants and Apparatus

Twenty-three participants were recruited, as described previously for Experiment 1A. They were allocated alternately to the blocking and control groups. Data for a total of 3 participants were excluded: One participant became confused and exited the experiment before it was finished. Data for two participants were excluded for not meeting the inclusion criteria (described above for Experiment 1A): one blocking group participant for failing to attain a positive point total, and one control group participant for failing to attain a discrimination ratio at or above 0.80. This left the data for 20 participants, consisting of 10 males (mean age 20 years, range 18 – 24) and 10 females (mean age 27 years, range 18 – 47). There were 5 males and 5 females in each group, experimental (*n* = 10) and control (*n* = 10). The apparatus and setting were identical to those described for Experiment 1A above.

Design and Procedure

The experimental design is shown in Table 1, and is identical to that described for Experiment 1A with one exception: the colours used for the preconditioned (S^{-}_{PRE}) and target (S^{-}_{TARGET}) stimuli in Experiment 1A were reversed (counterbalanced). In Experiment 1B the silver-coloured rectangle acted as the Phase 1, preconditioned stimulus (S^{-}_{PRE}) in blocking group participants, and the fuchsia-coloured rectangle acted as the novel, target stimulus added in Phase 2 to compose the silver-plus-fuchsia compound ($S^{-}_{PRE+TARGET}$). In Phase 2, the compound stimulus ($S^{-}_{PRE+TARGET}$) consisted of the same colours as used in Experiment 1A, but upper and lower positions on the computer screen were reversed, with the silver (preconditioned stimulus) now in the upper position and the fuchsia (novel target stimulus added in Phase 2) now in the lower position.

The primary comparison between blocking and control groups was the difference in responding to the fuchsia target stimulus (S_{TARGET}) during testing, as opposed to the silver target stimulus in Experiment 1A. As for Experiment 1A, two additional between-group comparisons were response rates to a novel aqua stimulus (S_{NOVEL}), and within-group response rate differences between the target and novel test stimuli. Except for changes in the colours of the preconditioned and target stimuli, the procedure and materials, including the inclusion criteria, stimulus colours, instructions, and questionnaire, were identical to that implemented in Experiment 1A.

Results

Once again the results of comparisons made to demonstrate group equivalency will be reported first, followed by results of the test of the blocking manipulation. As for Experiment 1A above, no statistically significant differences were found between groups with respect to (a) mean response rates in the last half of Phase 2 (M = 60.9, SD = 10.5 for the blocking group versus M = 58.3, SD = 18.6 for the control group, F[1, 18] = 0.15, p = .70); (b) mean discrimination ratios in the last half of Phase 2 (M = 0.97, SD = 0.02 for the blocking group and M = 0.96, SD = 0.02 for the control group, F[1, 18] = 0.13, p = .73); (c) point totals (M = 180, SD = 118 for the blocking group versus M = 224, SD = 123 for the control group, F[1, 18] = 0.65, p = .43); (d) age (M = 25.6, SD = 11.1 for the blocking group versus M = 21.1, SD = 3.0 for the control group, F[1, 18] = 1.52, p = .23); and (e) gender composition (five females and five males in each group). Thus, results for the test of the target stimulus are more likely to be due to the blocking manipulation rather than to other between-group differences.

Experimental Results

Results of the tests of the fuchsia target stimulus and the aqua novel stimulus are shown for each group in Figure 2. The dark columns on the left side for each group represent the response rates to the test of the fuchsia target stimulus for each group. Response rates for both the target and novel stimuli are expressed in relative terms, that is, as a proportion of the mean (high) response rates achieved by individual participants during the last four S^{+}_{A} intervals in Phase 2. The control group was expected to respond at a lower rate, as participants should have conditioned to the target during Phase 2 conditioning. Blocking group participants were expected not to have conditioned to the target stimulus in Phase 2, and thus were expected to respond at higher rates on testing. It can be seen that the blocking and control groups responded identically to the target stimulus (thus no F-test was undertaken), in contrast with expectations and with the results of Experiment 1A. The blocking group result indicates that these participants had conditioned to the fuchsia target stimulus despite the blocking manipulation.

The white columns on the right side for each group in Figure 2 represent the relative response rates during the novel aqua stimulus. In light of the findings of Experiment 1A, it was expected that the blocking group would respond at much higher rates to the novel test stimulus than would the control group, possibly as a result of more experience with the point loss contingency in the control group (same number of presentations but associated with more stimuli). Blocking group participants responded at the expected higher level and, once again, control group participants responded at a much lower level, for a statistically significant difference ($M = 0.73$, $SD = 0.54$ for the blocking group versus $M = 0.18$, $SD = 0.47$ for the control group, $F[1, 18] = 5.91$, $p = .03$, $g = 1.04$). The Experiment 1B result for this test replicated the same results in Experiment 1A.

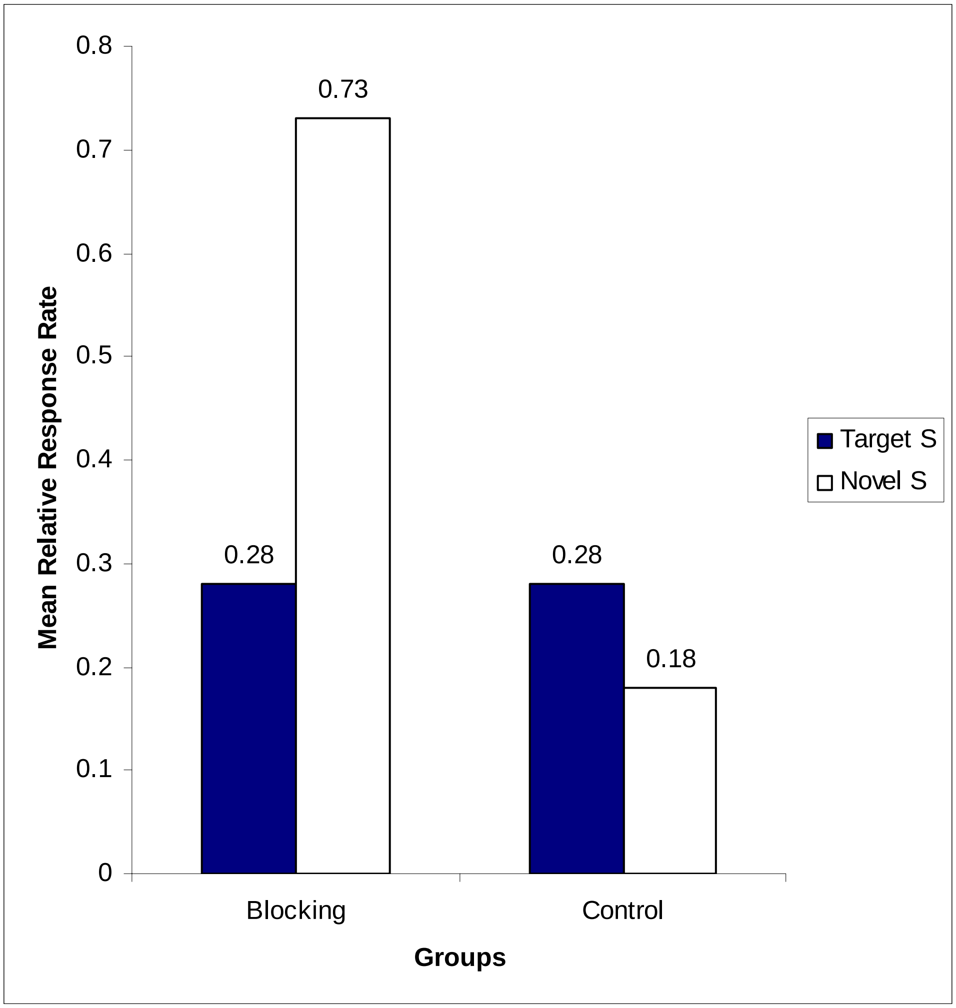

Figure 2. Results of Experiment 1B: Mean relative response rates (as a proportion of baseline response rates to the S^{+}_{A}) during tests of the fuchsia target stimulus and the novel aqua stimulus, in blocking and control groups.

The third comparison between groups was in terms of the magnitude of the within-group difference in relative response rates between the aqua S_{NOVEL} and the fuchsia S_{TARGET}. The blocking group was expected to show little difference in responding to these two stimuli, as neither would have been conditioned, if blocking were successful. The control group, on the other hand, was expected to show a larger difference in responding between the novel and target stimuli, with reliably lower rates to the target stimulus during which responding had been punished with point loss. In contrast with expectations, the blocking group showed a reliably greater difference in response rates to the two test stimuli than did the control group ($M = 0.45$, $SD = 0.53$ for the blocking group versus $M = 0.10$, $SD = 0.26$ for the control group, $F[1, 18] = 8.79$, $p = .01$). This result appears to be due to the unexpectedly low response rates of both the blocking group to the target stimulus and the control group to the novel stimulus.

Questionnaire Results

Baseline and filler stimuli. All participants in both groups correctly indicated that points were available during the baseline red S^{+}_{A} (i.e., 100% for both groups). Most participants, although somewhat fewer in each group, also correctly indicated that points were available during the baseline green S^{-}_{B} (i.e., 80%, or 8 of 10 in the blocking group, and 90%, or 9 of 10 in the control group; points were available on a DRL schedule). Finally, most participants in both groups also correctly indicated that points were available during the maroon filler S^{+}_{FILLER} (i.e., 100%, or 10 of 10 in the blocking group, and 90%, or 9 of 10 in the control group).

Preconditioned, novel, and target stimuli. Most participants in both groups (i.e., 70%, or 7 of 10 in the blocking group, and 90%, or 9 of 10 in the control group) correctly indicated that they lost points if they key-pressed during the silver, preconditioned stimulus. For the novel, aqua stimulus, the results replicated findings of Experiment 1A: approximately one-third fewer participants in the blocking group correctly indicated that points were not available than did participants in the control group (i.e., 60%, or 6 of 10 in the blocking group, versus 90%, or 9 of 10 in the control group). Finally, somewhat fewer blocking group participants correctly associated the fuchsia target stimulus with point loss than did participants in the control group (i.e., 80% or 8 of 10 in the blocking group, versus 90%, or 9 of 10 in the control group).

Discussion

In conclusion, the main finding of Experiment 1B was counter to expectations. In sharp contrast to the results of Experiment 1A where a finding of blocking was supported, in Experiment 1B blocking and control groups responded identically to the target stimulus. Identical response rates on testing the target stimulus, indicate that participants of both groups, regardless of differences in procedure, were equally conditioned to the target stimulus. Unlike Experiment 1A, the blocking group also responded far less to the target stimulus than to the novel stimulus, again inconsistent with a blocking effect. In fact, in this experiment the blocking group demonstrated a reliably greater within-group difference in response rates between the target and novel stimuli than did the control group, contrary to expectations. These measures indicate that, unlike in Experiment 1A, blocking did not occur in Experiment 1B.

Since the only difference in procedures between Experiments 1A and 1B was that the colours of the preconditioned and target stimuli were reversed, it appears to be the case that the effects of stimulus colour interfered with the effects of the blocking procedure. Overshadowing of one colour by another likely occurred. Overshadowing occurs when one of two stimuli, which are conditioned simultaneously, elicits a stronger conditioned response than the other stimulus. The stimulus that elicits the stronger conditioned response is considered to be more *salient* (e.g., more intense; Mackintosh, 1976). The target stimulus in Experiment 1A was the silver rectangle, whereas the target stimulus in Experiment 1B was the fuchsia stimulus. The relative intensity of the fuchsia colour may have overshadowed the more subdued silver colour during Phase 2 compound conditioning. Blocking-group participants appear to have conditioned to the fuchsia target stimulus in Experiment 1B, despite the fact that conditioning to the silver target in Experiment 1A was prevented. Such an explanation also calls into question the finding of blocking in Experiment 1A: the silver target may have been overshadowed, rather than, or as well as, being blocked, by the preconditioned fuchsia stimulus.

With respect to the novel test stimulus, the blocking group again responded at a reliably higher rate than did the control group, despite the fact that neither group had been exposed to the stimulus prior to the test phase. Counterbalancing of colours of the preconditioned and target stimuli did not affect this finding, which replicated the result found in Experiment 1A. The same conditions that suggested a generalization of suppressed responding to novel stimuli in Experiment 1A pertain to Experiment 1B, that is, different experiences with the response cost contingency. Whereas both groups had the identical number of presentations of stimuli associated with the response-cost contingency, there were more such stimuli in the control group (i.e., three) than in the blocking group (i.e., two). Also, at the onset of Phase 2, control group participants were confronted with a compound stimulus of which both component stimuli were new. The same compound stimulus had one already familiar component stimulus for the blocking group, and only one new component stimulus. These experimental differences for control group participants may have sensitized them to novel stimuli, resulting in generalized response suppression.

Questionnaire responses once again indicated that the majority of participants in both groups were aware of whether or not points could be earned for each stimulus colour. Regarding verbal (i.e., questionnaire) responses to the target stimulus, only somewhat fewer blocking group participants than control group participants reported awareness of the associated contingency (i.e., 80% versus 90%, respectively). This group difference is in the direction expected for blocking, but is far less supportive of blocking than in Experiment 1A. A finding replicated from Experiment 1A was that a greater proportion of control group participants verbally reported that points were not available for the novel stimulus, despite the fact that neither group had previous experience with this stimulus. This finding is consistent with the finding that the control group demonstrated generalized suppression of key-pressing during the novel stimulus. Both the verbal (i.e., questionnaire) and the key-pressing results for the novel stimulus likely are due to the same experimental differences between groups, as described above.

Experiment 2A

My primary purpose in Experiment 2 was to increase experimental control, through simplifying stimulus presentations and improving instructions. Specifically, the number of different colours employed was decreased, to reduce the likelihood of confounding the blocking effect with any unintentional, inadvertent effect of stimulus colour (as occurred in Experiments 1A and 1B). Therefore, the baseline stimuli of

Experiments 1A and 1B were used as the focal stimuli for blocking in Experiment 2A. Unlike Experiments 1A and 1B, no second set of stimuli or filler stimuli were superimposed or added to the experiment, other than those required for the blocking manipulation. Phase 1 for Experiment 2A consisted, therefore, only of a single positive stimulus (S^+) and a single negative stimulus (S^-).

Also unlike in Experiments 1A and 1B, after Phase 1 conditioning, *both* single stimuli (i.e., S^+ and S^-) were compounded with a different novel stimulus in Phase 2. This enabled the effects of preconditioning to be observed on both the S^+ and S^- target stimuli, rather than only on the S^- target stimulus, as was the case for Experiments 1A and 1B. This procedure also was an extension of my earlier research (Bergen, 2002; see Appendix B). However, Experiment 2A differed in several ways from the earlier experiments in: (a) the use of a response-cost contingency (i.e., point loss; described previously for Experiment 1A) during the S^- intervals, rather than merely extinction; (b) elimination of reinforcement schedule changes at the transition from Phase 1 to Phase 2 (described previously for Experiment 1A); and provision of more explicit instructions.

Note that instructions may interfere with the phenomenon being investigated, if responding comes under control of the instructions rather than under control of the experimental contingencies (e.g., Kaufman, Baron, & Kopp, 1966). For this reason instructions in Experiments 1A and 1B were kept to a minimum. For example, participants were not informed that point availability was associated with the colour of the rectangle on the computer screen, or that different response rates also were associated with the colour of the rectangle on the screen. They also were not informed of the point-loss contingency. Despite this argument in favour of minimizing instructions, in

Experiment 2A instructions were made more complete and explicit by informing participants about the colour stimuli and their association with point availability, by specifically informing them of the point-loss contingency, and also by informing participants about response rate requirements. Skinner (1966) maintained that "[v]erbal instructions may be defended when the resulting behaviour is not the primary object of interest" (p. 23); in my experiment the acquisition of discrimination and of stable response rates, and the earning of points, were not the primary focus (although they were required for blocking to occur and to be observed). Also, Williams, Sagness, and McPhee (1994; see their Experiment 5) found that the addition of "category" instructions (p. 704), which explicitly identified stimulus categories as positive, neutral, or negative, produced statistically significant blocking effects in a preparation that otherwise, repeatedly, had not done so. The instructional changes, therefore, were made to increase experimental control without jeopardizing the behaviour of interest.

Other changes implemented in Experiment 2A included the addition of a pre-training phase and an inter-trial interval (ITI), both employed by Arcediano, Escobar, et al. (2001), who reported blocking in human participants. A pre-training phase was added for the purpose of reducing the time required to learn the discrimination (between S^+ and S^- target stimuli) and to strengthen the discrimination by making it explicit (through preliminary practice and instructions, as above), and thereby to increase the likelihood of finding a blocking effect. Although free operant research does not usually include ITIs, they may promote conditioning and reduce stimulus generalization, when responding during the ITIs is permitted, but not reinforced (Hachiya & Ito, 1991; Saunders & Williams, 1998).

In addition, the single test presentation of the target stimulus, as in Experiments 1A and 1B, was replaced in Experiment 2A with three test presentations of each of the S^+ and S^- stimuli. In a study of blocking in human eyelid conditioning, Martin & Levey (1991) found that differences between blocking and control conditions on the first test trials alone were not statistically significant, although they were in the direction that suggested blocking. These researchers demonstrated blocking when all test trials (10 to 20) were combined. In my experiment, therefore, the relative response rates of both the first test trials and the combined total of three test trials were analysed for blocking, to observe whether or not the Martin and Levey finding was replicated.

To maximize response rate differences between S^+ and S^- stimuli between groups, stimulus presentations during the test phase only were reduced from 15 s to 5 s; the largest difference in response rates between groups was expected to fall at the beginning of test intervals, since testing involved extinction and since human participants are known to stop responding quickly in extinction (Spence, 1966). Therefore, the shorter 5-s test presentation might capture the greatest difference in response rates between the two target stimuli, before participants detect the shift to extinction and begin to reduce their response rates.

The experimental hypothesis was that both the S^+ and the S^- target stimuli would be conditioned successfully in the control group (i.e., high response rates during the positive S^+ target, but low response rates during the negative S^- target), but not in the blocking group. As a result, the difference in response rates between the positive target stimulus and the negative target stimulus on testing would be greater in the control group than in the blocking group. The smaller the difference in response rates between the positive and negative target stimuli in the blocking group, the greater the degree of blocking that will have occurred. These differences were hypothesized to occur on both the first test trials of the positive and negative target stimuli, and also on the combined totals of all three test trials of each target stimulus. Regarding questionnaire responses, based on findings in Experiments 1A and 1B, it was hypothesized that most participants in each group would report the contingencies associated with each stimulus correctly. Also, reliably more participants in the control group than in the blocking group were expected to give accurate (and contrasting) reports about the differentiated contingencies associated with the positive and negative target stimuli.

Method

Participants and Apparatus

Sixty-nine participants were recruited, as described previously for Experiment 1A. They were assigned randomly to either the blocking group or the control group (in blocks of four; each group consisted of two sub-groups with colours of the preconditioned and target stimuli counterbalanced). Data for a total of 23 participants were excluded from the analysis, using the inclusion criteria previously described for Experiment 1A. This left the data for 46 participants, consisting of 20 males (mean age 24 years, range 18 – 37) and 26 females (mean age 24 years, range 18 – 47). There were 10 males and 12 females in the blocking group ($n = 22$), and 10 males and 14 females in the control group ($n = 24$). The apparatus and setting were identical to those described previously for Experiment 1A.

The number of participants excluded in this experiment, though based on the identical exclusion criteria described previously for Experiment 1A, represents a considerable increase from the numbers in Experiments 1A and 1B, in each of which only 3 participants' data were eliminated. Twenty-two of these 23 participants did not meet the criterion of obtaining a positive point total, with point totals ranging from 0 to -1758 and with a median of -116 points (note that points were lost in increments of 20 points for every 4 responses on the shift key). This occurred despite the fact that it was made very clear, via explicit instructions (see below) and practice during the pre-training phase, that the objective was for participants to earn maximum points and to stop responding when points could be lost. The remaining participant whose data was excluded had a zero response rate in Phase 2, and thus did not meet the discrimination ratio inclusion criterion. Fourteen of the eliminated participants were from the control group and 9 were from the blocking group; 16 were female and 7 were male.

These 23 participants may not have read the instructions sufficiently, may not have understood them, or perhaps were not motivated to follow them. However, such interpretations appear less likely upon reviewing their data. The mean discrimination ratio across the last four pairs of positive and negative stimuli prior to the test phase, for all 23 eliminated participants, was 0.79, suggesting that most participants responded reliably more during the positive stimulus than during the negative stimulus, as instructed (discrimination ratios were 0.81 and 0.77 for the blocking and control group participants, respectively). Looking further, it was noted, however, that the eliminated participants responded at a reliably lower rate than the experimental sample, with a mean relative response rate (during the last four positive stimulus intervals prior to testing) of 34 for all eliminated participants (and 38 and 32 for the blocking and control group participants, respectively). The mean relative response rate of the experimental sample (during the last four positive stimulus intervals prior to testing) was 66 (and 65 and 67 for the blocking and control groups, respectively). This response-rate difference between eliminated and included participants (34 versus 66, respectively) suggests that the eliminated participants may have suffered more from generalized suppression of responding during the experiment. Although the excluded participants obtained a negative point total at the end of the experiment, they also had earned points by responding during positive intervals, but not at a rapid enough rate to overcome their point losses.

A difference between the designs of Experiments 1A and 1B on the one hand and the design of Experiment 2A on the other, suggests a possible explanation for the greater number of eliminated participants, their negative total points, and their reduced response rates, in Experiment 2A. Experiment 2A included 25 presentations of a negative stimulus associated with a 20-point loss upon responding (17 in Phase 1 and 8 in Phase 2). In comparison, Experiments 1A and 1B included only 5 stimulus presentations during which 20 points could be lost upon responding (3 in Phase 1 and 2 in Phase 2). The five-fold increased risk of point loss in Experiment 2A likely explains both the actual increase in negative point totals as well as the suppressed response rates that prevented some participants from earning enough points to counteract their losses.

Procedure and Instructions

The procedures for the experiment remained as described previously for Experiment 1A. The questionnaire was modified due to the change in the stimulus colours (see Appendix E). The number of instructions during this experiment was increased in order to implement a “pre-training” or practice phase before Phase 1. Pre-training consisted of four sets of instructions with key-pressing practice intervals after each set of instructions. In contrast to Experiments 1A and 1B, participants were: (a) advised explicitly to observe stimulus colours and associated point consequences; (b) given guidelines as to response rates to maximize points earned (e.g., three times per second rather than "frequently" in Experiments 1A and 1B); and (c) given a rule to respond to new colours until they could make a determination whether or not to key-press. Instructions for Experiment 2A follow:

First Instructions:

> Welcome to the experiment, "Keewatin."
>
> What follows is a simple game in which you try to earn as many points as possible.
>
> Press the SHIFT key (either one will work) about 3 times a second or more to earn lots of points.
>
> Try this on the next screen.
>
> Please press the ENTER key and begin pressing the SHIFT key.

These instructions were followed by a 15-s interval during which the positive, single stimulus (S^{+}_{A}) was presented and during which one point was available after every three key presses (FR3 schedule).

Second Instructions:

> Did you see your point total in the upper left hand corner of the screen?
>
> Did you notice the colour of the rectangle on the screen?
>
> Try this again. Press ENTER and press the SHIFT key at least 3 times per second

to earn points.

The same positive, single stimulus was presented again with points available on an FR3 schedule.

Third Instructions:

Sometimes you will lose 20 points if you press the SHIFT key.

You don't want to do this too often, or you will lose all the points you have earned.

The colour of the rectangle on the following screen is associated with point loss.

Try pressing SHIFT on the following screen and see what happens. Then STOP pressing while that colour is on screen.

Press ENTER and try it now.

These instructions were followed by a 15-s interval during which the negative, single stimulus (S^{-}_{B}) was presented and during which 20 points were lost from their running total, after every four key presses (FR4 schedule). It was possible to obtain negative point totals.

Fourth Instructions:

As you can see, whether you earn or lose points depends on the colour of the rectangle on the screen.

To get a high point total by the end of the game, press SHIFT when you can earn points, but STOP pressing SHIFT when you know you will lose points.

Try it on the next two screens –

Press SHIFT and earn points on the first screen;

Don't press any keys on the second screen or you will lose points.

Press ENTER to continue.

These instructions were followed by a single presentation of the positive, single stimulus (S^{+}_{A}) and then by a single presentation of the negative, single stimulus (S^{-}_{B}), both with their associated schedule of reinforcement.

The following instructions introduced Phase 1 of the experiment proper:

If you see other colours of rectangles besides the two you have seen so far, you should find out if you can earn points.

Try pressing the SHIFT key for new colours to check them out.

Keep pressing the SHIFT key **until you get a response**

If you gain points, keep pressing.

But if you lose points, STOP pressing.

Please press ENTER to begin.

The following instructions were presented after the test phase (Phase 3):

You have finished the experiment.

There is a short questionnaire for you in the next room.

Thanks for participating!

Due to the simplicity of the experiment, and the addition of more explicit instructions during a new pre-training phase, the hard copy instructions were thought to be superfluous. Therefore, unlike in Experiments 1A and 1B above, no hard copy of the instructions were made available to participants, thus eliminating this possible source of distraction during the on-screen experiment.

Design

The experimental design is described in Table 3. Three phases were replicated across individual participants who also were randomly assigned to either the blocking or the control group. As previously, only the first phase varied between blocking and control group participants; all other phases were identical across all participants. During Phase 1, discrimination training in the control group employed a pair of stimuli (one positive S^{+}_{E} and one negative S^{-}_{F}) that were not used in, and therefore were irrelevant to, the remainder of the experiment. This control procedure permitted blocking and control group participants to experience an equivalent duration of discrimination training in Phase 1. All phases were presented in immediate succession, without interruption, and within a single session. Stimulus descriptions and locations on the computer screen were as described previously for Experiment 1A.

Table 3

Design for Experiments 2A and 2B

Group	Phase 1	Phase 2	Test
Blocking group:	16 S^{+}_{A}, 16 S^{-}_{B}	8 S^{+}_{AX}, 8 S^{-}_{BY}	3 S_{X}, 3 S_{Y}
Control group:	16 S^{+}_{E}, 16 S^{-}_{F}	8 S^{+}_{AX}, 8 S^{-}_{BY}	3 S_{X}, 3 S_{Y}

Note. S^{+}_{A}, S^{-}_{B}, S^{+}_{E}, and S^{-}_{F} represent different single-element discriminative stimuli which were conditioned in Phase 1. S^{+}_{AX} and S^{-}_{BY} represent different compound discriminative stimuli conditioned in Phase 2, with responses reinforced with points during the first stimulus and with responses consequated with point loss for the latter stimulus. S^{+}_{X} and S^{-}_{Y} represent the single-element target stimuli presented in extinction in the test phase. Numerals indicate the number of presentations of each stimulus during the specified phase.

Discrimination training. Discrimination training proceeded as described previously for Experiment lA, with the following changes. First, the “baseline” discrimination as employed in Experiments 1A and 1B, between a positive stimulus (e.g., red S^{+}_{A}) and a negative stimulus (e.g., green S^{-}_{B}), was the only discrimination present and therefore the discrimination of interest. Second, each of the positive (red S^{+}_{A}) and negative (green S^{-}_{B}) single stimuli preconditioned in Phase 1 was compounded with a second stimulus of a different colour during Phase 2. These two compounds were the positive, red-plus-blue S^{+}_{AX} and the negative, green-plus-yellow S^{-}_{BY}. Third, colours were counterbalanced within groups, so that red acted as the S^{+}_{A} in half of blocking group participants and as S^{-}_{B} in the other half of participants. In like manner, Phase 1 single stimulus colours for the control group procedure (i.e., black and white) were counterbalanced, and compound stimulus colours were counterbalanced within both groups of participants.

In addition, each presentation of a discriminative stimulus throughout the experiment was followed by an inter-trial interval (ITI), which consisted of 2 s during which a black screen was presented without any stimulus display. There were no consequences for key pressing during the ITI: no points were available nor could points be lost.

Contingencies. Once again both high and low response rate repertoires were required of participants. The positive discriminative stimuli included two single stimuli presented in Phase 1 (i.e., the S^{+}_{A} for the blocking group and the S^{+}_{E} for the control group), and a compound stimulus presented in Phase 2 (i.e., S^{+}_{AX} for both groups). Reinforcement schedules associated with these stimuli were chosen to produce high response rates. One point could be earned by the participant on a progressively increasing FR schedule and finally on a variable-ratio (VR) schedule. Initially 3 key presses were required to earn one point (FR3), followed by 4 key presses (FR4). In subsequent presentations on VR schedules, 7, 8, and 9 key presses were required to earn one point. By the end of Phase 1, an average of 10 key presses earned a single point on a variable-ratio (VR10) schedule. This last reinforcement schedule continued for all presentations of the positive, compound discriminative stimulus (S^{+}_{AX}) in Phase 2. The purpose of increasing the response requirements of the FR schedules, as well as the earlier change to a VR schedule, was to increase resistance to extinction in preparation for the test phase, during which test stimuli were presented three times in extinction.

The negative discriminative stimuli included two single stimuli presented in Phase 1 (e.g., the green S^{-}_{B} or white S^{-}_{F}, for the blocking and control group, respectively) and a compound stimulus presented in Phase 2 (e.g., the green-plus-yellow S^{-}_{BY} for both groups). These stimuli were programmed to produce low response rates by programming a response cost: participants lost 20 points on every fourth key press (FR4 schedule).

Phase 1 (preconditioning). During this phase, all participants were presented with the discrimination between two differently-coloured single rectangles (either red or green): the S^{+}_{A} to generate high-rate responding and the S^{-}_{B} to generate low-rate responding. The control group was conditioned to a different pair of stimuli (black and white) in Phase 1 only, in order to equate experience in discrimination training across groups, but with stimuli that were otherwise irrelevant to the remainder of the experiment. The sequence of stimulus presentations was as follows: S^{+}_{A}, S^{-}_{B}, S^{+}_{A}, S^{-}_{B}, then S^{-}_{B}, S^{+}_{A}, S^{-}_{B}, S^{+}_{A} for the blocking group; and S^{+}_{E}, S^{-}_{F}, S^{+}_{E}, S^{-}_{F}, then S^{-}_{F}, S^{+}_{E}, S^{-}_{F},

S^{+}_{E} for the control group (replicated three times for each group).

Phase 2 (compound-stimulus conditioning). At the onset of Phase 2 the compound stimuli, the S^{+}_{AX} and the S^{-}_{BY}, appeared for the first time for all participants, replacing the single stimuli of Phase 1. Compounds consisted of red-plus-blue and green-plus-yellow pairs of rectangles, each presented to half of participants (in both groups) as the S^{+}_{AX} and to the other half of participants as the S^{-}_{BY}. Although Phase 1 differed between groups, in Phase 2 both groups of participants experienced identical stimuli and contingencies. For blocking group participants, one component of each compound stimulus had already been conditioned in Phase 1, but the added stimuli were new, unfamiliar, or novel. In contrast, for control group participants, *both* components of the compound stimuli were novel. The sequence of stimulus presentations for both groups was S^{+}_{AX}, S^{-}_{BY}, S^{+}_{AX}, S^{-}_{BY}, then S^{-}_{BY}, S^{+}_{AX}, S^{-}_{BY}, S^{+}_{AX} ; all replicated once.

Phase 3 (test phase). The test phase also was identical for all participants and consisted of three presentations of each of the target stimuli. The target stimuli were the novel stimulus elements that were compounded with the preconditioned stimuli in Phase 2 (i.e., the S^{+}_{X} and the S^{-}_{Y}; blue and yellow counterbalanced within groups). They were presented in extinction (thus superscripts are removed) in the following sequence: S_X, S_Y, S_X, S_Y, S_X, and S_Y. Order of presentation was not counterbalanced; Martin and Levey (1991) found that counterbalancing the serial order of tests of the target stimuli did not affect statistical significance of results. Unlike in Experiments 1A and 1B, all test stimuli were presented for 5 s rather than for 15 s, in an attempt to maximize response differences between positive and negative target stimuli by reducing exposure to extinction.

*Dependent variables.*Groups were compared in terms of their response rates to each of the two target stimuli, the positive target (the S_X) and the negative target (the S_Y), over all three tests combined and also on the first tests alone. In comparison to the blocking group, the control group was expected to have a reliably higher response rate to the positive target (the S_X) and a reliably lower response rate to the negative target (the S_Y). As described previously for Experiments 1A and 1B, test responses were reported in terms of relative response rates. That is, for each individual participant, the total number of key press responses on the first tests and also on the combined total of all three tests of each target stimulus (i.e., both S_X and S_Y), was divided by the mean number of key presses made during the baseline S^+_{AX} (mean high response rate) in the last four presentations of Phase 2 (i.e., stable response levels). Relative response rates, rather than absolute response rates, were used to generate group means, in order to reduce the effect of variable response levels across participants.

In addition, the magnitude of the within-group response-rate difference between the positive and negative target stimuli (i.e., $S_X – S_Y$) was compared between groups on both the first tests of each target stimulus, and on all three tests combined. The control group was expected to have a greater S_X minus S_Y difference than was the blocking group. (This comparison is analogous to the comparison between groups of S_{NOVEL} minus S_{TARGET} difference, employed as a dependent measure in Experiments 1A and 1B). If blocking had occurred, then the blocking group was expected to have reliably smaller difference in response rates between the S_X and the S_Y, as neither stimulus would have been conditioned (i.e., both would remain novel) and thus response rates would be similar to both. All results were reported in terms of relative, rather than absolute, response rates.

The final dependent measure consisted of verbal responses on the post-experimental questionnaire. Responses to the positive (S_X) and negative (S_Y) target stimuli were established as either (a) the "same"; when participants gave the same response to both target stimuli: usually "no", that points were not available during presentations of either stimulus, but occasionally "yes", that points were available during presentations of both stimuli; or as (b) "different"; when participants gave different responses to the target stimuli: a "yes", that points could be earned during one target stimulus, but a "no" to the other target stimulus. Different responses to the target stimuli were considered to be accurate and a reflection of conditioning, and same responses were considered to be a reflection of lack of conditioning (i.e., blocking). Since control group participants, unlike blocking group participants, were expected to be conditioned to the target stimuli, they also were expected to give accurate, that is, different responses. Blocking group participants were expected to give same responses.

Results

Once again groups initially were compared for possible differences that may have confounded the effect of the blocking manipulation. As for Experiments 1A and 2A, no statistically significant differences were found between groups with respect to (a) mean response rates in the last half of Phase 2 (M = 65.0, SD = 7.6 for the blocking group versus M = 67.5, SD = 8.9 for the control group, F[1, 44] = 1.00, p = .32); (b) mean discrimination ratios in the last half of Phase 2 (M = 1.00, SD = 0.00 for both the blocking group and the control group); (c) point totals (M = 102, SD = 43 for the blocking group versus M = 100, SD = 51 for the control group, F[1, 44] = 0.01, p = .94); (d) age (M = 23.2 years, SD = 2.8 for the blocking group versus M = 24.1, SD = 7.2 for the control group, *F*[1, 44] = 0.30, *p* = .58); and (e) gender composition (*F*[1, 44] = 0.06, *p* = .80). Therefore, results for the test of the target stimuli are more likely to be due to the blocking manipulation than to other between-group differences.

Experimental Results for All Three Tests Combined

Results of the tests to detect the blocking effect over all three tests of the target stimuli are shown in Figure 3. The dark columns on the left side for each group show the relative response rates for all three tests of the positive target stimulus (S_X) combined. (Relative response rates are the absolute response rates over the mean stable response rates attained during the last four presentations of the S^+_{AX} [period of high-rate responding] prior to the test phase.) A high response rate was expected for control group participants, who should have been well-conditioned to the positive target stimulus, during which points were available in Phase 2 conditioning. Although conditioning to the positive target stimulus in Phase 2 was expected to be blocked in blocking group participants, they also were expected to respond at a high rate to blocked stimuli due to generalization of high-rate responding to novel stimuli (see Appendix B). As can be seen in Figure 3, both groups responded at relatively high rates with the control group performing at somewhat higher response rates. The difference between groups was not statistically significant (*M* = 0.58, *SD* = 0.39 for the blocking group versus *M* = 0.71, *SD* = 0.39 for the control group, *F*[1, 44] = 1.30, *p* = .26).

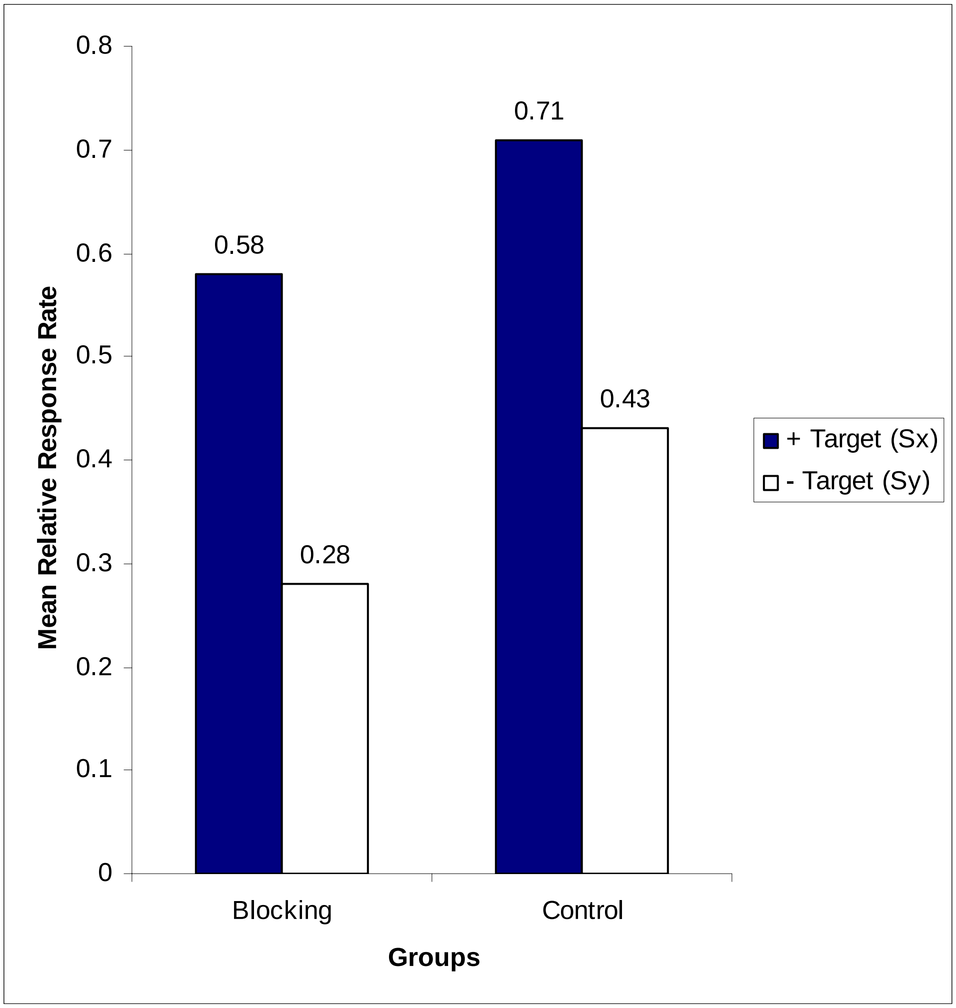

Figure 3. Results of Experiment 2A: Mean relative response rates (as a proportion of baseline response rates to the S^{+}_{AX}) over all three tests combined, for the positive (S_X) and negative (S_Y) target stimuli (blue and yellow, counterbalanced) in blocking and control groups.

The white columns on the right side of Figure 3 show the relative response rates for all three tests of the negative target stimulus (S_Y) combined for each group. A low response rate was expected for control group participants, who should have been well-conditioned to the negative target stimulus, during which participants lost 20 points if they responded. In contrast, due to blocked conditioning and also stimulus generalization (i.e., the tendency to respond at high rates to novel stimuli), blocking group participants were expected to respond at a higher rate. As can be seen in Figure 3, the blocking group showed greater suppression of responding than the control group, in contrast with expectations, although the difference also was not statistically significant ($M = 0.28$, $SD = 0.38$ for the blocking group versus $M = 0.43$, $SD = 0.41$ for the control group, $F[1, 44] = 1.74$, $p = .19$).

The difference between the dark and white columns in Figure 3 represents the magnitude of the within-group difference in relative response rates between the positive S_X and the negative S_Y for each group (combined for all three tests of each stimulus). The blocking group was expected to show little difference in responding to these two stimuli due to lack of conditioning (i.e., due to blocking). The control group, on the other hand, was expected to show a larger difference in responding between the positive and negative stimuli, as conditioning should have occurred in Phase 2. However, group differences on this measure were negligible ($M = 0.30$, $SD = 0.38$ for the blocking group versus $M = 0.28$, $SD = 0.64$ for the control group, $F[1, 44] = 0.22$, $p = .88$). The blocking group shows more discrimination between positive and negative target stimuli than expected, and the control group shows less discrimination than expected.

Experimental Results of First Tests Only

In terms of the relative response rates during the first test of the positive target stimulus (S_X), the difference between groups was not statistically significant ($M = 0.16$, $SD = 0.14$ for the blocking versus group $M = 0.21$, $SD = 0.14$ for the control group, $F[1, 44] = 1.10$, $p = .30$).

In terms of the relative response rates during the first test of the negative target stimulus (S_Y), both groups responded at a lower rate than during the positive target stimulus (S_X), but again, there were no statistically significant differences ($M = 0.11$, $SD = 0.17$ for the blocking group versus $M = 0.13$, $SD = 0.15$ for the control group, $F[1, 44] = 0.20$, $p = .66$).

Finally, the magnitude of the within-group response rate-difference between the positive S_X and the negative S_Y on the first tests were greater for the control group than for the blocking group, and thus not in favour of a blocking interpretation. Group differences, however, were not statistically significant ($M = 0.06$, $SD = 0.14$ for the blocking group versus $M = 0.08$, $SD = 0.23$ for the control group, $F[1, 44] = 0.14$, $p = .71$).

Questionnaire Results

Preconditioned stimuli. Most participants in the blocking group (i.e., 95%, or 21 of 22) correctly indicated whether or not points were available for the Phase 1 S^+_A and S^-_B (i.e., the green and red stimuli). Most participants in the control group (i.e., 92%, or 22 of 24) also correctly indicated whether or not points were available for their Phase 1 S^+_E and S^-_F (i.e., the black and white stimuli).

Target stimuli. The critical stimuli for blocking were the two target stimuli, the yellow or blue S^{+}_{X} and S^{-}_{Y}, conditioned as part of the Phase 2 compounds (i.e., S^{+}_{AX} and S^{-}_{BY}). Participants in the control group were expected to have conditioned to both elements of the compounds, and therefore should be able to correctly describe the contingencies: during the S^{+}_{AX} they were able to earn points, but during the S^{-}_{BY} they lost points. They were expected to give *different* responses for the two target stimuli. More control group participants (i.e., 67%, or 16 of 24) responded in the expected direction. In contrast, participants in the blocking group were expected to give the *same* response to both yellow and blue target stimuli, both of which would appear to be novel, if blocking were successful. More blocking group participants (i.e., 73%, or 16 of 22) indicated that points were not available during both target stimuli (i.e., gave the same response to both positive and negative targets). Chi-square analysis showed that the difference between groups was statistically significant ($\chi^2[1, N = 46] = 10.56$, $p = .00$).

Discussion

Contrary to expectations, there were no group differences between groups in response rates on testing of the positive target stimulus (S_X), the negative target stimulus (S_Y), or of the magnitude of response rate differences between the positive and negative targets ($S_X - S_Y$). Blocking was not demonstrated in this experiment by any of the three response rate measures, either on the first test, or on the combination of all three tests, of each target stimulus.

The verbal dependent measure, in direct contrast, provided evidence of blocking. It suggests the possibility that a degree of blocking occurred despite an absence of supportive evidence in the response-rate measures. Verbal (written) responses on the post-experimental questionnaire to the two target stimuli were compared and characterized as either the same (i.e., that points either were available, or were not available, during both target stimuli) or as different (i.e., that points were available during one target stimulus, but were not available during the other). The control group, which should have conditioned to both positive and negative target stimuli, yielded a reliably greater proportion of different responses (i.e., $S_X \neq S_F$) than same responses, as expected. Although two-thirds (i.e., 67%) of control group participants gave accurate questionnaire responses about the target stimulus contingencies, it should be noted that a much greater proportion of participants (i.e., 92%) were able to give accurate questionnaire responses about the preconditioned stimulus contingencies. Thus it appears that control group participants were not as certain in reporting the contingencies of the target stimuli as they were in reporting the contingencies of the preconditioned stimuli.

The blocking group gave questionnaire responses consistent with blocking and contrasting with the responses of the control group. They were expected to have reduced conditioning to both the positive and negative target stimuli, and indicated this on the questionnaire by giving a reliably greater proportion of same (i.e., 73%; $S_X = S_Y$) rather than different responses. As with the control group, more blocking group participants (i.e., 95%) gave accurate (i.e., different) responses for the contingencies of the preconditioned stimuli. That most blocking group participants (i.e., 37%) did not give accurate (i.e., different) responses about the contingencies of the target stimuli is a demonstration of blocking on this cognitive measure. As with the control group, blocking group participants were not as certain in reporting the contingencies of the target stimuli as they were in reporting the contingencies of the preconditioned stimuli.

In conclusion, results were mixed, with three dependent measures based on key-pressing during all three test presentations of each target stimulus, indicating that blocking did not take place. A fourth dependent measure, a derived measure based on post-experimental verbal responses, suggested that some degree of blocking did occur.

Experiment 2B

My first purpose in conducting Experiment 2B was to attempt to demonstrate the blocking effect in both the nonverbal and verbal measures, by making a number of changes in the experimental procedure that might promote blocking. The same research design was employed but with an alteration in colours of the preconditioned stimuli, since Experiments 1A and 1B demonstrated that stimulus colours can override the effects of the experimental blocking manipulation. While all the same colours were used as in Experiment 2A, they were reassigned to different functions. In Experiment 2A, Phase 1 stimulus colours for the S+ and S– were red and green, two colours which likely had associations for participants prior to experimental conditioning (i.e., red means 'stop' and green means 'go'). To avoid any potential impact of these prior associations during the pre-conditioning phase, blue replaced red as a stimulus colour in Phase 1 in Experiment 2B. The blue and green preconditioned stimuli were counterbalanced across blocking group participants (black and white were used for Phase 1 stimuli in the control group). Compound stimuli in Phase 2 were the same as in Experiment 2A but with a reversal of location of the component stimuli on the computer screen. For the blue-red compound stimulus in Experiment 2B, the blue rectangle occupied the upper position on screen, and the red rectangle occupied the lower position.

Instructions received a minor revision (described below) to remove a potential obstacle to blocking. Because the control group suppressed responding to the negative target stimulus less than the blocking group in Experiment 2A, both the ITI duration and the FR response-cost schedule also were adjusted (described below) so that point loss with key-pressing was more immediate once the new, negative stimulus color was on screen. The goal was to strengthen the association of the point-loss contingency with the negative stimulus, and, as a result, to improve the discrimination between the positive and negative target stimuli, and thus to reduce responding to the negative target in particular. The design and procedures for the experiment remained as described previously for Experiment 2A.

Given these changes to the experiment, my experimental hypotheses again were that both the positive (S_X) and negative (S_Y) target stimuli would be conditioned successfully in the control group (i.e., high response rates during the positive target, but low response rates during the negative target), but reliably less so in the blocking group. This would result in a greater within-group difference in response rates between the positive and negative target stimuli in the control group than in the blocking group. Analyses of both the first tests of the target stimuli and the combined totals of all three tests were expected to reveal blocking. Regarding the post-experimental questionnaire, it was hypothesized that the control group would have reliably more different (i.e., $S_X \neq S_Y$) verbal responses than the blocking group, and that the blocking group would have reliably more same (i.e., $S_X = S_Y$) verbal responses than the control group, replicating the effects in Experiment 2A and supporting the blocking effect.

Method

Participants and Apparatus

Thirty-five participants were recruited as described previously for Experiment 1A.

Participants were assigned randomly to either the blocking group or to the control group (in blocks of four; each group consisted of two sub-groups with colours of the preconditioned and target stimuli counterbalanced). Data for a total of 8 participants (23% of original sample) were excluded from the analysis, using the inclusion criteria described previously for Experiments 1A, 1B, and 2A. Fewer participants' data were excluded than in Experiment 2A (23 participants, or 33% of original sample), although the experiments were very similar. Only two participants did not attain a positive point total (vs. 22 in Experiment 2A) and 6 did not meet the discrimination ratio inclusion criterion (vs. 1 in Experiment 2A). As in Experiment 2A, the mean relative response rate for eliminated participants was much lower than that of the experimental sample (i.e., 7 for eliminated participants [zero rate for 7 of 8 participants] and 66 for participants that met inclusion criteria).

A possible explanation for the difference in the number and proportion of participants' data eliminated is idiosyncratic factors, such as individual conditioning histories and reactions to the point-loss contingency. It appears likely that the response rates of the eliminated participants generally were suppressed due to the point-loss contingency, as in Experiment 2A. All 8 eliminated participants were from the control group. Recall that control group participants were likely to be more affected by the point-loss contingency than were blocking group participants, due to a difference in the number of different stimulus colours associated with this punishing contingency (three colours for the control group [the preconditioned white stimulus and the green-plus-blue compound stimulus] and only two colours for the blocking group [green or blue preconditioned and the green-plus-blue compound stimulus]; see discussion about generalization of response suppression in Experiment 1A).

This left the data for 27 participants, consisting of 8 males (mean age 19 years, range 18 – 23) and 19 females (mean age 20 years, range 17 – 33). There were 5 males and 12 females in the blocking group (n = 17), and 3 males and 7 females in the control group (n = 10). The apparatus and setting were identical to those described previously for Experiment 1A.

Procedure and Instructions

The procedures for the experiment remained as described previously for Experiment 2A. Stimulus colours were changed and the questionnaire was modified to match this change (see Appendix F). The pre-training phase of Experiment 2A was retained with minor rewording of the instructions (see Appendix G): as for Experiment 2A, but unlike for Experiments 1A and 1B, participants were advised explicitly regarding the importance of the stimulus colours and the recommended response rates. Instructions for Experiment 2A also recommended a strategy when novel stimuli were encountered, that is, participants were advised to “Try pressing the SHIFT key for new colours to check them out … until you get a response. If you gain points, keep pressing. But if you lose points, STOP pressing.” In contrast, instructions for Experiment 2B were mute regarding novel stimuli; the rule for responding to new colours simply was omitted, to reduce the possibility of drawing attention (and awareness) explicitly to stimulus changes at the onset of both Phase 2 and the test phase. Drawing participants’ attention to stimulus changes on transitional trials could result in failure to block (e.g., Kamin, 1968; Appendix A for discussion regarding transitional trials).

Design

The experimental design is described in Table 3, and is identical to that for Experiment 2A. Discrimination training proceeded as for Experiment 2A, with the following changes. The single, positive stimulus (S^{+}_{A}) was blue in this experiment rather than red as in Experiment 2A. The single, negative stimulus (S^{-}_{B}) remained green. In other words, the initial discrimination was between blue and green, rather than between red and green. The compound stimuli in Phase 2 were the blue-plus-red positive stimulus (S^{+}_{AX}) and the green-plus-yellow negative stimulus (S^{-}_{BY}). The target stimuli tested in the final phase were the red S_X and the yellow S_Y (the red stimulus was no longer in the context of red versus green, thus would be less likely to draw forth “stop” versus “go” responses). As for Experiment 2A, colours were counterbalanced within groups (e.g., blue and green each acted as the S^{+}_{A} in half of blocking group participants and as S^{-}_{B} in the other half of participants). The black S^{+}_{E} (positive stimulus) and white S^{-}_{F} (negative stimulus), single discriminative stimuli used in the control group during Phase 1, were not counterbalanced, since they were irrelevant to the remainder of the experiment.

Contingencies remained as described previously for Experiment 2A, with the exception of the schedule for the negative stimuli. As before, participants lost 20 points for pressing the shift key during both the Phase 1 S^{-}_{B} and the Phase 2 compound S^{-}_{BD}. However, the schedule was reduced from FR4 to FR2, in an attempt to strengthen the association between point loss and responding during the S^{-}_{B} and S^{-}_{BD}, and thereby to discourage continued responding which would result in excessive point loss and subsequent elimination of the participants’ data from analysis (recall that the data of 22 of 69 participants in Experiment 2A were eliminated due to a negative point total). In addition, the duration of the ITI was extended from 2 s, as in Experiment 2A, to 4 s during which a black screen was presented without any stimulus display. The purpose of extending the ITI was to maintain discrimination between the S^+s and the S^-s, specifically by more clearly separating these stimuli and thus preventing inadvertent continued responding beyond the end of the S^+ interval from being punished at the onset of the S– interval. With these exceptions, the phases of the experiment proceeded as described above for Experiment 2A. The dependent variables were as described previously for Experiment 2A.

Results

Once more, groups were compared for possible differences that may have confounded the effect of the blocking manipulation. No statistically significant differences were found between groups with respect to both mean discrimination ratios in the last half of Phase 2 (M = 1.00, SD = 0.00 for both the blocking group and the control group) and gender composition (F[1, 25] = 0.00, p = .98). However, statistically significant differences were found for three other comparisons: (a) mean response rates in the last half of Phase 2 (M = 70.5, SD = 12.0 for the blocking group versus M = 58.1, SD = 12.3 for the control group, F[1, 25] = 6.60, p = .02); (b) point totals (M = 178, SD = 44 for the blocking group versus M = 94, SD = 55 for the control group, F[1, 25] = 18.47, p = .00); and (c) age (M = 18.4 years, SD = 0.7 for the blocking group versus M = 22.0, SD = 5.8 for the control group, F[1, 25] = 6.49, p = .02). Covariate analyses were conducted with each of these factors, that is, with mean response rates, point totals, and age, as covariates (see Appendix H). As the conclusions drawn were not altered by the results of these analyses, the uncorrected F tests are reported, which parallel those conducted for the prior three experiments.

Experimental Results for All Three Tests Combined

Results of the tests to detect the blocking effect are shown in Figure 4. The dark columns on the left side for each group show the relative response rates for all three tests of the positive target stimulus (S_X) combined. (Relative response rates are the absolute response rates over the mean stable response rates attained during the last four presentations of the S^+_{AX} [period of high-rate responding] prior to the test phase.) A high response rate was expected for control group participants, who should have been well-conditioned to the positive target stimulus, during which points were available in Phase 2 conditioning. Although conditioning to the positive target stimulus in Phase 2 was expected to be blocked in blocking group participants, they also were expected to respond at a relatively high rate due to stimulus generalization (Appendix B). As can be seen in Figure 4, both groups responded at higher rates during the test of the positive target stimulus (S_X) than during the test of the negative target stimulus (S_Y), but with the control group performing at a reliably higher response rate (M = 0.94, SD = 0.17 for the control group and M = 0.53, SD = 0.39 for the blocking group, $F[1, 25] = 9.22$, $p = .01$, $g = 1.47$).

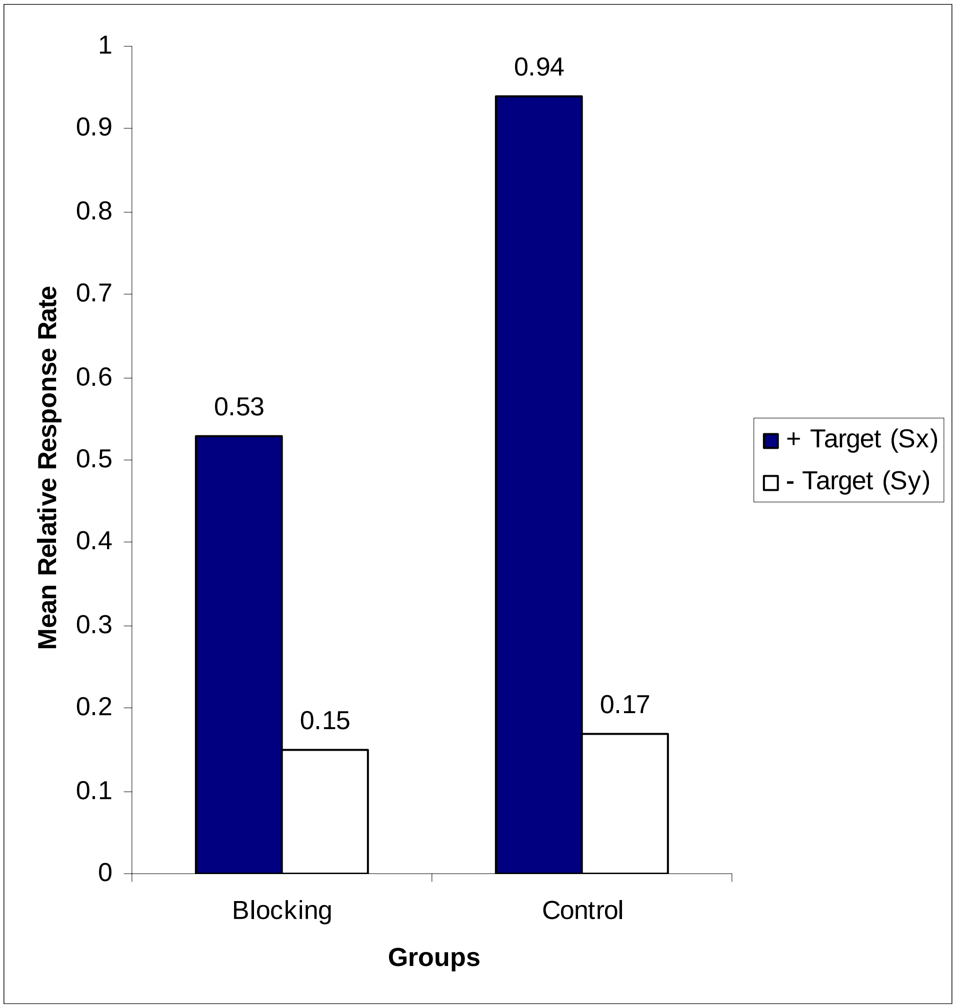

Figure 4. Results of Experiment 2B: Mean relative response rates (as a proportion of baseline response rates to the S^{+}_{AX}) over all three tests combined, for the positive (S_X) and negative (S_Y) target stimuli (yellow and red, counterbalanced) in blocking and control groups.

The white columns in Figure 4, on the right side for each group, show the relative response rates for all three tests of the negative target stimulus (S_Y) combined for each group. A low response rate was expected for control group participants, who should have been well-conditioned to the negative target stimulus, during which participants lost 20 points if they responded. In contrast, due to blocked conditioning and stimulus generalization of high response rates to novel (i.e., blocked) stimuli, blocking group participants were expected to respond at a higher rate. As can be seen in Figure 4, both groups performed similarly and at a low rate during the negative target stimulus (M = 0.15, SD = 0.28 for the blocking group versus M = 0.17, SD = 0.33 for the control group, $F[1, 25] = 0.03$, $p = .86$).

The difference between the dark and white columns in Figure 4 represents the magnitude of the within-group difference in relative response rates between the positive S_X and the negative S_Y for each group. The blocking group was expected to show little difference in responding to these two stimuli due to lack of conditioning (i.e., blocking). The control group, on the other hand, was expected to show a larger difference in responding between the positive and negative stimuli, as conditioning should have occurred in Phase 2. As expected, the S_X minus S_Y difference was much greater in the control group than in the blocking group (M = 0.39, SD = 0.36 for the blocking group and M = 0.77, SD = 0.38 for the control group, $F[1, 25] = 6.67$, $p = .02$, $g = 1.00$).

Experimental Results of First Tests Only

In terms of the relative response rates during the first test of the positive target stimulus (S_X), groups were not statistically, significantly different (M = 0.16, SD = 0.15 for the blocking group versus M = 0.21, SD = 0.11 for the control group, $F[1, 25] = 0.98$,

p = .33).

In terms of the relative response rates during the first test of the negative target stimulus (S_Y), both groups again responded at a lower rate than during the positive target stimulus (S_X), but again, there were no statistically significant differences (M = 0.02, SD = 0.09 for the blocking group versus M = 0.05, SD = 0.12 for the control group, $F[1, 25]$ = 0.35, p = .56).

Finally, the between-groups difference in magnitude of the within-group response rate-difference between the positive S_X and the negative S_Y on the first tests was small (0.03) and not statistically significant (M = 0.14, SD = 0.14 for the blocking group versus M = 0.17, SD = 0.11 for the control group, $F[1, 25]$ = 0.30, p = .59).

Questionnaire Results

Preconditioned stimuli. All participants in the blocking group (i.e., 100%, or 17 of 17) correctly indicated whether or not points were available for the Phase S^+_A and S^-_B (i.e., the green and blue stimuli). Similarly, all participants in the control group (i.e., 100%, or 10 of 10) also correctly indicated whether or not points were available for their Phase 1 S^+_E and S^-_F (black and white, respectively).

Target stimuli. The two target stimuli were the yellow or red S^+_X and S^-_Y, which were conditioned as part of the Phase 2 compounds (i.e., S^+_{AX} and S^-_{BY}). Participants in the control group were expected to have conditioned to both elements of the compounds, and therefore should have been able to correctly identify the contingencies. They were expected to give *different* responses for the two target stimuli (i.e., that one stimulus was associated with available points but that the other was not). More control group participants (i.e., 60%, or 6 of 10) correctly indicated whether or not points were available for the target stimulus as expected, and gave different answers for the S^{+}_{X} and S^{-}_{Y} targets. In contrast, participants in the blocking group were expected to give the *same* response to both yellow and red target stimuli, which would appear to be novel if blocking was successful. More blocking group participants (i.e., 82%, or 14 of 17) responded in line with expectations (i.e., they answered that points were not available for both targets). Chi-square analysis showed that the difference between groups was statistically significant ($\chi^2[1, N = 27] = 6.25, p = .01$).

Discussion

Recall that in Experiment 2A evidence for blocking was found only on the verbal (questionnaire) measure. However, in marked contrast in Experiment 2B, compelling evidence of blocking was evident in both verbal and nonverbal (response-rate) measures. The findings supportive of blocking were the following: the significantly greater response rates during testing of the positive target stimulus (S_X) in the control group than in the blocking group, and the significantly greater within-group response-rate difference between the positive and negative targets ($S_X – S_Y$) in the control group than in the blocking group. Both these results were found only when all three test trials of each target stimulus were combined, and were not found when looking at the first test trials only.

There were no reliable differences between groups in terms of the response rates during the tests of the negative target stimulus (S_Y). In fact, response rates were found to be identical in both groups when the three test trials combined were analysed. Relative to Experiment 2A, response rates during the negative target stimulus were reduced for both the blocking and control groups. This suggests that changes to the experimental procedure in Experiment 2B (e.g., the decrease in the reinforcement schedule from FR4 to FR2 for a 20-point loss, or the increase in the ITI, from 2 s to 4 s) were successful in increasing discrimination of the negative stimulus in both groups, despite the blocking procedure. In contrast, relative to Experiment 2A, conditioning of the positive stimulus (S_X) was much improved only in the control group. The larger difference in response rates, between positive and negative target stimuli, in the control group versus the blocking group, therefore is driven completely by the difference in responding (and conditioning) to the positive target stimulus. It appears that blocking of conditioning in this experiment occurred primarily, if not exclusively, to the positive target stimulus.

The between-group difference in the verbal response measure (i.e., same versus different responses to positive and negative target stimuli on the questionnaire) was statistically significant in Experiment 2B, replicating the finding of Experiment 2A. As in Experiment 2A, more control group participants gave accurate (i.e., different) responses for contingencies associated with the positive and negative stimuli. More blocking participants gave same responses for the contingencies. These results support the finding of blocking in this experiment, and are congruent with the results of the nonverbal measures.

As in Experiment 2A, the proportion of control group participants accurately reporting contingencies associated with target stimuli was much lower for the target stimuli (at 60%), than was the proportion for the preconditioned stimuli (at 100% for the black and white stimuli). Meanwhile, only 20% blocking group participants gave accurate responses for the target stimulus (i.e., 80% of participants demonstrated blocking by their verbal reports), while 100% of blocking group participants gave accurate responses for the preconditioned stimuli. Replicating the verbal results of

Experiment 2A, participants in both blocking and control groups were less certain about the contingencies associated with the target stimuli, presented in compound in Phase 2, than they were about the contingencies of the single stimuli conditioned in Phase 1. Possible explanations include that the contingency associated with a single stimulus is less ambiguous than a contingency associated with compound stimulus; the greater number of conditioning trials with the single stimuli than with the compound stimuli (i.e., 16 vs. 8, respectively) also may have influenced the degree of certainty about contingencies.

In conclusion, three dependent measures suggest that, in this experiment, the blocking group was blocked from conditioning, more so to the positive target stimulus than the negative stimulus; whereas the control group was successfully conditioned to both. These measures are the response rate difference to the positive (i.e., S_X) target stimulus; the magnitude of the within-group response rate difference to target stimuli (i.e., $S_X – S_Y$ difference); and the group difference in verbal responses to the positive and negative target stimuli on the questionnaire. The statistically significant difference in the verbal response measure also replicated the results of Experiment 2A.

General Discussion

The primary purpose in the sequence of four experiments that I conducted was to demonstrate blocking in the nonverbal behaviour of human participants using an operant procedure. Contradictory results were found between the first two experiments, which were identical in methodology other than a reversal of colours for the preconditioned and target stimuli. In the context of the disappointing results of Experiment 1B, the highly reliable findings of Experiment 1A were taken to indicate that overshadowing occurred in both experiments; in the direction of blocking in Experiment 1A, and in the direction opposite to blocking in Experiment 1B. In an attempt to minimize overshadowing, different stimulus colours were used in Experiments 2A and 2B. Further, the colours employed as the preconditioned and target stimuli were counterbalanced within both experiments, to control the effects of inadvertent overshadowing. Despite these attempts, no blocking in the non-verbal measure was apparent in the results of Experiment 2A. Further changes were made to increase discriminability of the negative stimulus (i.e., increased ITI, reduced FR point-loss schedule), colours again were altered, and instructions were altered to eliminate advice on how to respond to novel stimuli. Finally, a substantial blocking effect was found in Experiment 2B. Unlike previous demonstrations of blocking in human participants (e.g., Hinchy et al., 1995; Arcediano, Escobar, et al., 2001), the blocking effect in Experiment 2B was observed in responding to a positive target stimulus, and not in responding to a negative target stimulus. Blocking of the negative target stimulus presumably was prevented by the highly punishing (point-loss) contingency, as demonstrated by essentially equivalent, very low response rates in both blocking and control groups.

Right from the outset, other investigators have noted the problem of equating physical characteristics of preconditioned and target stimuli. Kamin (1968) demonstrated blocking using a light as the preconditioned stimulus and a noise as the target stimulus. He also found blocking when he reversed the stimuli, so that the noise was preconditioned and the light became the target stimulus. He suggested that a "symmetrical blocking effect" (p. 14) would require that the two stimuli used would need to be equivalent in terms of ability to evoke similar response rates upon conditioning.

Kamin (1969b) reported that keeping the intensity of the preconditioned stimulus (A) constant, but varying the intensity of the target stimulus (X), resulted in varying degrees of blocking that were directly related to the difference in intensities of the two stimuli. My Experiments 1A and 1B findings contrasted, suggesting that the fuchsia and silver stimuli that were employed (in reverse roles in 1B) were not equivalent in terms of intensity and therefore effective conditioning. Not only was blocking not symmetrical, in Experiment 1B the fuchsia as target stimulus completely overwhelmed the silver stimulus, in terms of control over responding, despite the advantage of preconditioning for the latter.

Overshadowing and blocking are related phenomena of stimulus competition (Kamin, 1969b; Mackintosh, 1976). Conditioning of the target stimulus is hindered in both cases: in blocking due to prior conditioning of the blocking stimulus, and in overshadowing due to the greater salience, intensity, or strength of the overshadowing stimulus (Mackintosh). Furthermore, just as in blocking, “the degree of overshadowing increases both with an increase in the intensity of the overshadowing element of a compound CS, and with a decrease in the intensity of the overshadowed element” (Mackintosh, p. 191). Either overshadowing or blocking could produce the results of Experiment 1A, but only overshadowing the results of Experiment 1B. In both experiments, therefore, it is more likely that the more intense (i.e., salient) fuchsia colour overshadowed the less intense silver colour. When the more intense, overshadowing colour (fuchsia) also fills the role of the preconditioned stimulus in the blocking procedure, as in Experiment 1A, the conditions for both blocking and overshadowing prevail. When the more intense, overshadowing colour occupies the role of the target stimulus in the blocking procedure, as in Experiment 1B, the conditions for blocking and overshadowing are in opposition. In the case of Experiment 1B, the experimental blocking manipulation likely was overwhelmed by an overshadowing effect in the reverse direction.

In order to demonstrate a "symmetrical blocking effect" (Kamin, 1968; p. 14) and to avoid overshadowing, Kamin recommended that the compound stimulus elements be equivalent in salience, in other words, in their ability to be conditioned at similar rates. Miller and Matute (1996) reported that stimuli with inherent biological significance, such as "food, sex, electric shock," and other stimuli of high intensity (e.g., a loud noise; p. 378), be avoided in blocking experiments due to their ability to resist blocking. They recommend that generally both the preconditioned and the target stimulus should be of moderate intensity. The target stimulus, in particular, is required to be of low salience. In my Experiments 1A and 1B, the fuchsia-coloured rectangle was more salient or intense a stimulus than the more subtly-coloured silver rectangle. Thus, in Experiment 1B, the silver preconditioned stimulus was easily overshadowed by the fuchsia target stimulus, illustrating resistance to blocking by the more intense stimulus, as suggested by Miller and Matute.

My secondary purpose in conducting these four experiments was to measure verbal, post-experimental (questionnaire) responses, and my third purpose was to evaluate the relationship between the results of the verbal and nonverbal dependent measures. Results of Experiments 1A and 1B suggested a positive correspondence between nonverbal and verbal results. Verbal responses in Experiment 1A showed more differentiation between groups than in Experiment 1B, paralleling the results of the response-rate measures for each experiment. For Experiments 2A and 2B, the results of the verbal response measure on the post-experimental questionnaire suggested that blocking was present in both cases, even though the nonverbal response-rate measures supported blocking only in Experiment 2B. The presence of positive results in both nonverbal and verbal measures in Experiment 2B strengthened the claim that blocking had been demonstrated. However, the discordance between the results of the nonverbal and verbal measures for Experiment 2A implies that these measures may not be equally sensitive to the blocking effect; that is to say, the verbal measure may be more sensitive to blocking than is the nonverbal measure.

Other researchers also have questioned participants about experimental contingencies immediately following blocking experiments (e.g., Hinchy et al., 1995; Martin & Levey, 1991). Congruence between verbal (or cognitive) post-experimental self-reports and nonverbal, conditioned responses was found by Hinchy et al., with both verbal and nonverbal measures suggesting blocking. Martin and Levey, however, were unable to find blocking in their post-experimental questionnaire results, despite findings of blocking in their eyelid conditioning experiment. The lack of blocking in their verbal self-reports may have been due to the relatively larger number of test trials in their study, that is 10 trials for each stimulus, all under extinction (vs. only 2 and 3 trials of each stimulus, in Hinchy et al. and in my Experiments 2A and 2B, respectively). The relatively large number of extinction trials may have eliminated stimulus control and thereby any differential verbal behavior associated with the two stimuli. Regarding the importance of awareness of the contingency for blocking in human participants to occur, Martin and Levey concluded that awareness is not necessary, at least within a “simple animal paradigm" (p. 251). No studies were located in which blocking was found in a self-report measure but not in the nonverbal behavioural measure (as occurred in my Experiment 2A).

Kirsch, Lynn, Vigorito, and Miller (2004) discuss cognitive and conditioning theories, two rival explanations of the processes involved in conditioning, whether classical or operant. The cognitive theory posits that cognition (and awareness), in the form of an expectancy of, or a belief in, a future event or outcome (i.e., that involving delivery of the US in classical conditioning or of the consequence in operant conditioning), plays a dominant role in producing nonverbal conditioned responses. Some cognitive theorists believe that for conditioned responses to occur, it is necessary for the individuals to be aware of the contingencies operating. In contrast, the older, conditioning theory posits that (nonverbal) conditioned behaviours are "automatic" and "mechanistic" (p. 370), and do not require the individual to be cognizant of the contingencies in play. Whereas the role of cognition, or awareness, is causal in cognitive theory, in conditioning theory it is described as an epiphenomena (p. 385), and plays no causal role. In my Experiment 2A, verbal and nonverbal responses did not correspond for blocking group participants: they showed blocking on a cognitive level (i.e., per self-reports on questionnaires), but no blocking was demonstrated on a nonverbal level. In this case, the verbal reports (awareness of contingencies) produced by blocking-group participants did not appear to have influenced their nonverbal responding, calling into question the cognitive theory of conditioned behaviour. (Verbal and nonverbal results for control group participants, on the other hand, were congruent and demonstrated successful conditioning.) Further research is required to determine the nature of the relationship between verbal and nonverbal behaviour, and to determine whether awareness plays a causal role in the production of conditioned, nonverbal behaviour.

Results of tests of the novel stimulus in Experiments 1A and 1B did not match expectations of consistently high-rate responding in both groups. In Experiment 1A, despite the fact that participants in neither group had previous exposure to the novel stimulus, only blocking group participants generalized their high-rate responding (from the positive stimuli) to the novel stimulus, as expected; control group participants, surprisingly, did not. This pattern was replicated in Experiment 1B. A potential explanation involves the punishment (i.e., point loss) contingency. Both groups of participants experienced an equal number of conditioning intervals with the point-loss contingency. However, two experimental differences between groups might have increased the impact of the point-loss contingency for the control group. The first difference is that control group participants experienced the punishment contingency with three different stimulus colours (i.e., the Phase 1 control stimulus, the blocking stimulus, and the target stimulus), whereas blocking group participants experienced it with only two different stimulus colours (i.e., the preconditioned [blocking] stimulus and the target stimulus). The second difference between groups that might have emphasized the point-loss contingency for control participants in Experiments 1A and 1B is that both elements of the compound stimulus were novel for them; in contrast, for the blocking group one stimulus element already was known to occasion point loss. As a result, participants in the control group may have been more likely than those in the blocking group to suspect the point-loss contingency with novel stimuli in general. Control group participants may have generated a rule to be more cautious in responding during novel stimuli. Whatever the reason, control group participants did generalize their low-rate responding (emitted during previous point-loss intervals) to the novel colour stimulus in the test phase.

Verbal (questionnaire) responses to the novel stimulus, in Experiments 1A and 1B, also were influenced by the punishment contingency to a greater degree in the control group than in the blocking group. That is, verbal and nonverbal responses were congruent within groups with respect to the novel stimulus, but with reliably more control group participants reporting that points were not available.

Another effect of the punishing point-loss contingency may have been to prevent blocking of the negative target stimulus in Experiment 2B. The point-loss contingency was utilized in these experiments for the purposes of improving discrimination between the positive and negative stimuli, particularly between the positive and negative target stimuli in the control group, and specifically to reduce the generalization of high-rate responding to any novel stimulus (e.g., a blocked stimulus) during the test phase. High response rates are commonly exhibited in human participants presumably due to their conditioning history in their natural environments (e.g., Torgrud, Holborn, & Zak, 2006; Weiner, 1970). Although these goals were achieved, the point-loss contingency in my experiment appears to have been so intense that the negative target stimulus was resistant to blocking: in Experiment 2B the negative target stimulus was unexpectedly conditioned in the both blocking and control groups.

The high degree of stimulus control exerted by the negative target stimulus in Experiment 2B, appears to have improved discrimination between positive and negative stimuli. In the control group, very high response rates occurred during testing of the positive target stimulus and very low response rates occurred during testing of the negative target. Blocking group participants also demonstrated the same very low response rates during testing of the negative target stimulus (i.e., blocking was resisted due to the strong point-loss contingency). The positive target stimulus however, lacked similar salience. Blocking group participants responded at a much lower response rate to the positive target stimulus than did control group participants, demonstrating the blocking effect. In essence, the generalized inhibition of responding (in contrast to the usual high-rate responding of humans) permitted the blocking effect to emerge in the only case where participants safely could respond – when S^+ was present.

Blocking was found in my final experiment (2B), not on the first test trials, but only when the results of all three tests periods were combined. This pattern also was found by Martin and Levey (1991) and by Kimmel and Bevill (1991). Martin and Levey, in an eyelid conditioning procedure with human participants, observed a decrement in responding from the last compound training trial to the first test trial, which they speculated might be a "novelty effect" (Martin & Levey, p. 252; see also Kamin's "transitional trial" effect, 1968. p. 16) due to the change in stimulus presentations. Kimmell and Bevill (1991) scheduled four test trials in their blocking study in electrodermal conditioning with human participants. They observed no blocking on the first test trials of the target and preconditioned stimuli. However, they found that a "delayed blocking effect" (p. 132) was clearly established on the second and subsequent pairs of test trials. Kimmell and Bevill speculated that at least one extinction trial was required for the blocking effect to be evidenced, therefore also, in effect, identifying responding on the transitional test trial as unique. If the novelty effect is responsible for obscuring blocking on the first, or transitional test trials, then a higher than typical degree of blocking may be required for blocking to be observed on the first test trial. Martin and Levey advise, and I concur, that “decrements in responding due to blocking have to be disentangled from the effects of a change in the stimulus schedule” (p. 252).

In my Experiment 2B the finding of blocking in the nonverbal behaviour of human participants replicated results of other, relatively recent research with human participants. Blocking of nonverbal behaviour in human participants was reported previously by Arcediano, Escobar, et al. (2001) in a similar, computerized key-pressing experiment (in a conditioned suppression procedure) and by Hinchy et al. (1995) in electrodermal conditioning. The blocking effect found here is the first, to my knowledge, involving a discriminative stimulus for operant behaviour in human participants. It also is the first in which the blocking effect is shown with a discriminative stimulus for reinforced responding, rather than with an aversive discriminative stimulus. Additionally, verbal, post-experimental questionnaire responses also showed blocking. When blocking of nonverbal behaviour was demonstrated (as in Experiment 2B), participants’ verbal responses were congruent with their nonverbal behaviour, replicating the findings of Hinchy and his colleagues, and suggesting that cognitive and nonverbal behavioural processes can be complimentary. Finally, my blocking research also replicates and confirms previous reports that blocking is challenging to demonstrate with a nonverbal response. Blocking of nonverbal behaviours in human participants does not yet appear to be as “robust and easily reproducible” as it has in animals (Kamin, 1969b; p.52)

My replication of blocking with human participants supports the continuity principle, that is, the contention that learning principles discovered in non-human animals are generalizable to humans (e.g., Perone et al., 1988). My findings do not provide support for the theory that fundamental differences in learning exist between humans and other animals. Confirmation of blocking also supports the contention that contiguity or contingency alone are not sufficient conditions for learning, but that conditioning of a given stimulus also depends on the conditioning histories of other stimuli present (note that Miller & Matzel [1988] theorize that blocking is not a failure to learn but instead a failure to give expression to that learning under particular circumstances). Regarding the variables previously hypothesized to be important in demonstrating the blocking effect in humans, evidence from my research indicates that distractor stimuli (or filler stimuli; e.g., Arcediano, Escobar, et al., 2001), may not be required. Masking of the onset of the compound stimulus phase by intermixing Phase 1 and Phase 2 trials within a single-phase experimental procedure (e.g., Hinchy et al., 1995) also may not be required. As Kamin (1968) and Miller and Matute (1996) recommend, my findings also emphasize that stimuli employed in blocking need to be equivalent in intensity (i.e., salience). In common with other studies that have shown blocking with human participants, I employed stimuli from only one sensory modality (i.e., visual) and instructions that were explicit about discrimination performance and the variety of contingencies (e.g., Experiment 5 in Williams et al., 1994). Finally, my findings indicate that the blocking effect may not be evident on the first test trials, but may require multiple test trials, replicating the findings of Kimmel and Bevill (1991).

There are a number of limitations to my research, including the following. It proved to be difficult to determine which of the available colours would be equivalent in terms of intensity or salience, so that neither the preconditioned stimulus nor the target stimulus would overshadow the other, and thus confound the results. Colours that were different in terms of darkness or brightness were frequently similar in terms of hue; both brightness and hue were thought to affect blocking results. The punishment (i.e., point loss) contingency, while effective in improving discrimination of target stimuli in the control group, apparently was too intense to allow blocking of the negative target stimulus in the blocking group; that is, the negative target discriminative stimulus became resistant to blocking. Since previous demonstrations of blocking of nonverbal behaviours in human participants have involved aversive contingencies (e.g., Arcediano, Escobar, et al., 2001; Hinchy et al., 1995), my preparation likely would produce blocking, if a smaller point loss were to be employed.

Future investigations of blocking within an operant procedure in human participants should seek to show blocking of discriminative stimuli for both reinforced and unreinforced (or punished) responding, particularly as the blocking effect in Pavlovian studies is generally found in a conditioned suppression procedure (i.e., with an aversive conditioned stimulus). Colour stimuli have been employed in recent studies demonstrating blocking in humans (e.g., Arcediano, Escobar, et al., 2001; Martin & Levey, 1991); future research could extend the blocking effect to include a variety of visual (e.g., shapes) and non-visual (e.g., auditory) stimuli, as in animals. Recently, researchers have shown the finding of "recovery from blocking" in human participants employing Pavlovian conditioning procedures (e.g., Arcediano, Escobar et al., 2001), supporting Miller and Matzel's (1988) suggestion that blocking is a performance deficit rather than an acquisition (i.e., conditioning) deficit. Recovery from blocking with human participants using operant procedures would extend these findings. Blocking sometimes has been found on the first test trials (e.g., Arcediano, Escobar et al., 2001) and at other times has been found only when analyzing multiple test trials (e.g., Martin & Levey, 1991; my present Experiment 2B). Identifying the variables responsible for these differences and disentangling the effects of blocking from the effects of the initial test trial as a transitional trial (or a novelty effect; see Martin and Levey), also would strengthen any conclusions regarding findings of blocking.

In conclusion, in my research I was successful in demonstrating blocking of both verbal and nonverbal behaviours in an operant procedure with human participants, thus replicating other recent findings of blocking with humans, and extending the finding of blocking to operant behaviour. As previously stated by Kimmel and Bevill (1991), these results “leave little doubt that blocking can occur under certain conditions… in humans. It is not yet clear, however, what these conditions are” (p. 137); only time and future research will tell.

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Appendix A

Review of Pavlovian Blocking Studies with Human Participants

Multiple variables have been manipulated in attempts to produce blocking in humans, as described in this review of six Pavlovian studies of blocking in either eyelid conditioning (Martin & Levey, 1991) or electro-dermal conditioning (i.e., Davey & Singh, 1988; Hinchy, Lovibond, & Ter-Horst, 1995; Kimmel & Bevill, 1991; Lovibond, Siddle, & Bond, 1988; and Pellón and Garcia Montaño, 1990). Factors implicated as affecting the demonstration of blocking include: (a) the sensory modality of each component stimulus of the Phase 2 compound; (b) the strength of conditioning of the first component stimulus in Phase 1; (c) the spatial configuration and degree of separation of visual stimuli, in the control group in particular, impacting configural versus elemental conditioning; (d) the particular control condition or group chosen; (e) transitional trial effects; and (f) others.

Sensory Modality of Component Stimuli

The use of bi-sensory rather than uni-sensory compounds may affect blocking results. Kamin (1968) employed a bi-sensory compound, consisting of an auditory stimulus (tone) and a visual stimulus (light) with rats as subjects. In human studies, tones have been compounded with geometric drawings (e.g., triangles and squares; see Davey & Singh, 1988) or with light (see Kimmel & Bevill, 1991), and white noise has been compounded with pictures (e.g., of flowers or mushrooms; see Lovibond et al., 1988). Whether the auditory stimulus was the Phase 1 preconditioned, or the Phase 2 novel stimulus, Davey and Singh did not find blocking. However, when both stimuli were presented in the visual modality, Kimmel and Bevill were able to observe blocking (see their Experiment 3). Martin and Levey suggested that presenting stimuli in two different sensory modalities could introduce differential salience of the stimuli along some dimension (i.e., salience being the magnitude of the difference between the stimulus and background stimulation; Dinsmoor, 1995, p. 254) as well as increased response variability, both potentially confounding the observed results.

Seraganian (1974) compared the effect of bi-sensory versus uni-sensory compounds in blocking of operant behaviour, using pigeons pecking for food. The between-modality (bi-sensory) groups were trained with white noise (auditory) and coloured keys (visual) as stimuli, whereas the within-modality (uni-sensory) groups were trained with a tilted white line appearing on variously coloured keys (i.e., lines and colours both visual stimuli). Variable salience of stimuli from different modalities was recognized as a potential confound, since development of stimulus control of these stimuli was found to occur at different rates. Therefore, rather than training pigeons with a fixed number of Phase 1 acquisition trials, Seraganian trained them until they met a specified discrimination criterion. (The criterion was that four of five responses occur in the presence of the S^{+} rather than in the presence of the S^{-} for three consecutive daily sessions; this translates into a discrimination ratio of 0.80.) Blocking was demonstrated in both between- and within-modality groups, although differences were statistically greater in the within-modality condition. Seraganian suggested that other combinations of bi-sensory stimulus elements may preclude blocking depending on various stimulus qualities (i.e., stimulus salience; e.g., diffuse vs. localized, intensity), as well as on increased response variability, and therefore greater statistical variance (as suggested by Martin & Levey, 1991).

Strength of Phase 1 Preconditioning

The degree of conditioning attained by the preconditioned stimulus in Phase 1 is a factor influencing the demonstration of blocking. Kamin (1968) showed that the blocking effect was reduced when the number of preconditioning (i.e., Phase 1) trials were reduced (e.g., from 16 to 4) and Martin and Levey (1991) showed that the blocking effect was reduced when participants did not discriminate well by the end of Phase 1. As already mentioned, Seraganian (1974) continued his Phase 1 training with pigeons until a discrimination criterion had been met. An alternative procedure to assure that participants have been conditioned is to employ a fixed number of conditioning trials but then to eliminate the data from those participants who subsequently do not meet the discrimination criterion. In the group of studies reviewed here, from 10% to 32% of total participants trained were excluded due to poor conditioning (poor discrimination; i.e., 6 of 58 in Davey & Singh, 1988; 57 of 229 in Lovibond et al., 1988; 45 of 143 in Martin & Levey, 1991; and 14 of 44 in Hinchy et al, 1995). A minority of these participants were excluded due to equipment failure. Martin and Levey, having excluded 45 participants due to poor conditioning, went further by dividing the remaining participants into those who discriminated well in Phase 1 (mean difference of 8.22 responses between CS+ and CS−) and those who discriminated poorly (mean difference of 0.83 responses between CS+ and CS−). On the first test trial to the novel stimuli added in Phase 2 (i.e., the target stimuli), the poor discriminators did not respond differentially, but the good discriminators did so. Martin and Levey concluded “that blocking does occur, provided the precondition of efficient discrimination is met” (p. 249).

Spatial Configuration of Component Stimuli

Effects of spatial configuration (arrangement in space) of component stimuli within the compound were investigated by Martin and Levey (1991) and Pellón and Garcia Montaño (1990). In Experiment 1 of Martin and Levey, compound stimuli consisted of two 12 cm x 12 cm coloured squares (red, green, blue, or yellow) immediately adjacent to each other on a horizontal panel of four squares (i.e., in either positions 1 and 2, or 3 and 4). Suspecting *configural* or *integral* (i.e., the compound as a whole) rather than *elemental* conditioning (i.e., the separate component stimuli) of the compound stimulus in Phase 2, the two coloured squares were separated in Experiment 4 so that they occupied alternate positions on the same horizontal panel, 12 cm apart (i.e., either positions 1 and 3, or 2 and 4). With only this difference between Experiments 1 and 4, the statistical significance of results increased. Thus, spatial separation of individual components of the Phase 2 compound stimulus translated into larger differences in test responding between blocking and control conditions, via increased conditioning to individual stimulus components in the *control* condition. Were configural conditioning to occur in the control group and blocking to occur in blocking group, then the target stimulus on testing would be perceived as a novel stimulus for both groups. As a result, test trials would reveal no differences between groups even though blocking had occurred.

Similarly, Pellón and Garcia Montaño (1990) tested for blocking between groups which varied only in spatial arrangement of the compound stimulus. Stimuli were either a red circle and a green triangle, “a pair of brackets separated by an 8° visual angle”, or “a pair of brackets separated by a visual angle of 2°” (p. 417), in three different blocking and control groups. Blocking was found in the groups trained with the red circle and green triangle and in the groups trained with the brackets separated by an 8° visual angle, but not in the groups trained with the brackets separated by a 2° visual angle. Assuming elemental conditioning of the red circle and the green triangle and the brackets with an 8° angle, and configural conditioning of the brackets with the smaller 2° angle, then the results support the hypothesis that configural conditioning of compound stimuli, in control group participants, precludes a finding of blocking.

Control Conditions and/or Groups

Various control groups have been employed in blocking designs. Table A1 presents control conditions and groups that have been employed in human blocking studies. Kamin (1968) employed a control group without any stimulus conditioning in Phase 1, but with Phases 2 and 3 identical to that of the blocking group. Pellón and Garcia Montaño (1990) used the same control group subsequently to demonstrate blocking with human participants. Results of these studies now are questioned because the control group experienced fewer exposures to the US (i.e., none during Phase 1) than did the blocking group, confounding their experimental results (Hinchy et al., 1995).

Table A1

Blocking Control Groups and Conditions

Group	Phase 1	Phase 2	Test Phase
Blocking Group	A+	AB+	B−
CONTROL GROUPS			
Kamin Control	−	AB+	B−
Single Stimulus	−	B+	B−
Novel Control	A+	AB+	C−
Unpaired Control	D−	DE+	E−
Blocking Control	F+	AB+	B−

Notes. A, B, C, D, and D represent different stimuli. A represents the preconditioned stimulus; B is the novel, to-be-blocked, target stimulus added in Phase 2; C is a novel stimulus introduced during the test phase; D is presented alone and unpaired in Phase 1, but paired with a novel stimulus, E, and the unconditioned stimulus (US) in Phase 2; and F is an irrelevant stimulus conditioned in the blocking control group during Phase 1 only. Symbols + and − indicate whether stimuli were paired or not, respectively, with the US.

A single-stimulus control group (see Table A1) was employed by Pellón and Garcia Montaño (1990) in addition to the Kamin control group, for the purpose of ruling out the possibility of overshadowing of the target stimulus in the Kamin control group. Overshadowing is the development of relatively less stimulus control during conditioning of a given stimulus when it is paired with a more salient (e.g., more intense, more biologically significant) stimulus. Response differences between the single-stimulus group and the control group indicate that the stimulus element in the control group was not fully conditioned as a component of the Phase 2 compound, possibly due to overshadowing, potentially minimizing detection of blocking (any differences between blocking and (Kamin) control groups on the test would be less than had no overshadowing occurred).

Davey and Singh (1988) used a novel control group (see Table A1), with Phases 1 and 2 identical to the blocking group, but tested with an entirely new stimulus. If the target stimulus added to the preconditioned stimulus in Phase 2 truly was blocked, then responding to it in the test phase should be the same as to an entirely novel stimulus.

Another type of control is the “unpaired” (Davey & Singh, 1988, p. 19) or “super-conditioned” (Lovibond et al., 1988, p. 382) control group (see Table A1), or the within-subjects design with an unreinforced (i.e., CS−) stimulus condition (attributed to Rescorla, 1981; in Davey & Singh, 1988, Experiments 2 and 3; Kimmel & Bevill, 1991, Experiment 3; Martin & Levey, 1991, within-subjects designs). What these control groups (or conditions) have in common is a CS not paired with the US, although both the CS and US are presented, independently, in Phase 1 (i.e., the CS acquires an inhibitory conditioning history). In Phase 2, this inhibitory control stimulus is compounded with a novel stimulus and *paired with the US* (i.e., it becomes a CS+ in compound). During compound conditioning, the novel stimulus likely will be conditioned to a greater degree (i.e., super-conditioned) than if the compound had consisted of two novel stimuli. As a consequence, the difference between groups (or between conditions in a within-subjects design) potentially is inflated by super-conditioning, which may be misattributed to blocking. Therefore, results of studies using such control groups (i.e., Kimmel & Bevill; Martin & Levey; Arcediano, Matute, et al, 1997) also are suspect (Hinchy et al., 1995).

The final control group was illustrated in Hinchy et al. (1995), and is identified in Table A1 as the blocking control group. This control group has equivalent conditioning experience as the blocking group, and is without the detracting features described above for the Kamin and super-conditioning (unpaired) control groups. Hinchy et al. successfully demonstrated blocking in a Pavlovian electro-dermal conditioning procedure using a shock US. CSs were visual stimuli, 6-cm square coloured blocks presented on a computer monitor, and separated by 3 cm when presented in compound. Blocking and control groups were trained identically except for one difference; the Phase 2 compound for the control group consisted of two novel stimuli, but for the blocking group consisted of one novel stimulus and one preconditioned stimulus.

Manipulations to Reduce Transitional Trial Effects

Kamin (1968) had observed disrupted, or fluctuating, response rates in the majority of rats on the first compound trial of Phase 2 (i.e., the transitional trial). Response rates on subsequent compound trials stabilized and returned to previous Phase 1 levels, as though the added stimulus element was no longer “noticed” (1968, p. 16). Disrupted response rates also were observed on the reverse transition, from compound to single stimulus training, suggesting that it was change itself that disrupted responding and not specifically the addition of a new stimulus. Kamin found that the magnitude of blocking observed varied inversely with the degree of disruption exhibited on the transitional trial. For instance, when the intensity of the US was increased from a 1-mA shock in Phase 1 to a 4-mA shock in Phase 2, then blocking was prevented. But if the shock US was held constant at either level, blocking occurred. Kamin named this the "transitional trial effect" (1968, p. 16). Hinchy et al. (1995), in their demonstration of blocking with human participants, introduced a new procedure to mask the transition between acquisition Phases 1 and 2. They intermixed Phase 1 single-element and Phase 2 compound-element acquisition trials in a single training phase. In addition, they also included multiple CS+s and CS−s (i.e., "fillers"), both compound and single-element, to reduce participants' skills at discriminating changes between training and testing phases. They attributed their statistically significant blocking effect largely to the integrated training phase.

Other Factors Affecting Blocking

Researchers have identified other potentially important factors related to blocking. Kimmel and Bevill (1991) attributed their statistically significant blocking effects (i.e., Experiment 3) to a change from a between-subjects to a within-subjects comparison. Pellón and Garcia Montaño (1990) ascribed their success, relative to Davey and Singh (1988) and Lovibond et al. (1988), to the greater number of acquisition trials in total and particularly in Phase 1 relative to Phase 2 (e.g., 16:10 vs. 6:6 and 6:4, respectively); to analysis of the first test trial only; and to their use of an absolute rather than relative measure of skin conductance. There may be factors other than those reviewed above that influence whether blocking occurs, or whether it will be detected. As Dinsmoor has stated, “Perhaps no single factor can account for all of the data obtained in experiments on blocking and overshadowing (1995, p. 259).

Appendix B

Review of Findings in M.A. Research (Bergen, 2002)

In my previous blocking research (Master's thesis; Bergen, 2002) with undergraduate psychology students, participants were required to press a shift key to earn points and to discriminate between stimulus conditions in an operant procedure in which points were (S^+) and were not (S^-) available. Stimuli were rectangles of different colours presented on a computer screen. In Phase 1, a single rectangle of one colour (e.g., red) acted as the S^+ and alternated with a single rectangle of another colour (e.g., green), which acted as the S^-. The control group received Phase 1 training in which the S^+ and S^- rectangles were of different colours than those for the blocking group (i.e., the control recommended by Hinchy et al., 1995). In Phase 2, there were two compound stimuli, the S^+ compound and the S^- compound, each of which consisted of two rectangles separated by 2 cm of space. Each compound consisted of the stimulus that had been preconditioned (in the blocking group only) plus an additional neutral target stimulus. Phases 2 and 3 were identical for blocking and control groups. Groups were compared during the test phase (Phase 3) in terms of differences between their response rates to the S^+ and S^- target stimuli – the neutral stimulus elements that had been added in Phase 2.

Two experiments were reported (Bergen, 2002). In Experiment 1 the blocking group showed higher response rates during the S^+ target test than did the control group, demonstrating better conditioning in the blocking group, in opposition to the expected results. In Experiment 2 however, the control group achieved higher response rates during the S^+ target test than did the blocking group, which indicated that control group participants were more strongly conditioned to the target stimuli, as expected for blocking. Results for neither experiment were statistically significant. However, experimental control improved in Experiment 2 in that response rates were less varied across participants and discrimination between the target S^+ and S^- stimuli on test trials was greater in control group participants (i.e., target stimuli were better conditioned) than in blocking group participants (i.e., suggesting a degree of blocking).

Possible explanations for the absence of a finding of blocking in these two experiments (Bergen, 2002) include configural conditioning of the compound in Phase 2 for the control group; transitional trial effects at the onset of Phase 2 and Phase 3; and stimulus generalization. Configural conditioning of the compound stimuli during Phase 2, for the control group only, would result in deficient conditioning of the separate target S^+ and S^- stimulus elements in direct contrast to expected and required results for the control group (Williams, Sagness, & McPhee, 1994). Configural conditioning would produce individual target stimuli that appeared to be novel to control group participants; blocking would produce individual target stimuli that appeared to be novel to blocking group participants; as a result participants in both groups would discriminate little between the target S^+ and S^- stimuli on testing, and response rates would be similar. Due to the blocking in the blocking group and to configural learning in the control group, no between group differences would be demonstrated and blocking would remain undetected.

A second possible explanation for the lack of experimental effect may be that blocking did not occur in Phase 2, but instead target stimuli were “noticed” at the onset of Phase 2 by blocking group participants, who therefore were conditioned. Kamin (1968) found that transitional trials caused disruption of previously stable responding.

Transitional trials occur in two places in the three-phase blocking procedure: at the transition from Phase 1 to Phase 2 (change from single stimuli to compound stimuli) and at the transition from Phase 2 to Phase 3 (change from compound stimuli to single stimuli). Kamin found that the greater the number of procedural differences at these transition points, the greater was the disruption in response rates and the smaller was the resulting blocking effect. My earlier experiments (Bergen, 2002) had a change in experimental procedure at the onset of Phase 2 beyond the required compounding of stimuli; this was the change from a variable interval 17-s (VI 17-s) to VI 2-s reinforcement schedule during S+ presentations. This change in addition to the change from single to compound stimuli may have been enough to cause participants to notice the new target stimuli, thereby increasing the likelihood that the target stimulus would be conditioned rather than blocked (Kamin, 1968; Lovibond et al., 1988). Similarly, the change from compound stimulus to single stimulus at the transition from Phase 2 to Phase 3 is accompanied by a change from reinforcement to extinction. This could increase disrupted responding in the first test in particular, making interpretation of test results more ambiguous (see also Martin & Levey, 1991).

A third possible explanation for lack of experimental effect in my earlier research (Bergen, 2002) is *stimulus generalization*. It was noted that most participants in both groups responded at higher rates at the onset of Phases 2, 3, and 4 than at the onset of the experiment (i.e., at onset of Phase 1). This could be due to stimulus generalization, or "the spread of the effects of reinforcement during one stimulus to other stimuli differing from the original along one or more dimensions" (Saunders & Williams, 1998; p. 208). In other words, once participants had learned that points were available when a red rectangle was presented on the computer screen, they were more likely to press the response key when they saw a rectangle of any colour on the computer screen. If responding during test presentations was affected by stimulus generalization rather than by stimulus control (effects of conditioning in prior phases), then response rates to test stimuli would be less differentiated between groups, with little demonstrable experimental effect.

My more recent research includes other changes from my Master's research (Bergen, 2002) included the shortening of stimulus presentations from 20 s to 15 s, as this enabled a shortening of the experimental procedure and still allowed discrimination among stimuli. (A further reduction to 10-s stimulus presentations resulted in lower and more variable discrimination ratios among participants.) For Experiment 1A and 1B, the number of presentations of the stimuli critical to the blocking procedure was reduced from 16 of each of the S^+ and S^- in both Phases 1 and 2 to only 3 presentations of each of the S^+ and S^- in Phase 1 and 3 S^+ and 2 S^- presentations in Phase 2. (The critical stimuli were embedded in the baseline discrimination of 16 presentations each of both S^+ and S^- in Phase 1 and 11 each of both S^+ and S^- in Phase 2.) The reduced number of critical stimulus presentations was based on previous research of Pavlovian blocking in human participants (e.g., 6 total acquisition trials in Hinchy, Lovibond, & Ter-Horst, 1995; 4 Phase 1 and 2 Phase 2 trials in Lovibond et al., 1988). The number of acquisition trials was reduced "in order to shorten the experiment and reduce the opportunity for habituation to the shock" (or other punishing consequence) "or a general decline in arousal prior to the test phase" (Lovibond et al., p. 387).

A final change involved the test phase (Phase 3). Three test presentations of each target stimulus (both S^+ and S^-) were made in my earlier research (Bergen, 2002). Previous research of Pavlovian blocking with human participants has used multiple test presentations of the target stimulus (e.g., 3 in Davey & Singh, 1988; 4 in Kimmel & Bevill, 1991). Martin and Levey (1991) also found a blocking effect when comparing groups' response decrement over multiple test trials, but failed to find statistically significant blocking on the first test trial. Because humans extinguish responding rapidly during extinction, Martin and Levey considered it as "crucially important to any convincingly argued view of blocking that it should be seen to occur on the first trial of the extinction test series" (p. 248). Arcediano, Escobar, et al. (2001) and others (e.g., Pellón & Garcia Montaño, 1990) presented their target stimulus only once in the test phase. In my current experiment the target and novel stimuli each were presented only once during the test phase. The baseline discrimination continued, with one presentation of each of the red S^+ and the green S^- after the novel stimulus test, to stabilize response rates after the potentially disrupting effect of the first test.

Appendix C

Consent Form

Research Project Title: Experimental Analysis of Blocking in Human Operant Behaviour

Researcher: Ms. Anna Bergen, M.A., Graduate Student, Dept. of Psychology

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

The purpose of this study is to examine the conditions necessary for learning. To examine this topic, you will be asked to watch a computer monitor for instructions and to press the shift key and the space bar on the keyboard as instructed. No known risks are involved. The computer will record demographic information (age and sex) and responses. Responses will be identified by a code number rather than by name, to keep data confidential. Only the principal researcher will have access to the raw data. The time required to complete the experiment and questionnaire will be about 45 minutes, for 2 course credits. A brief summary of the results will be posted in Duff Roblin on the second floor bulletin board outside the main entrance to the large lecture hall, room P230, after completion of the experiment.

You should feel free to ask for clarification or new information throughout your participation. You may talk individually with the experimenter, Anna Bergen (xxx-yyyy at home), or with her research advisor, Dr. Stephen Holborn (office xxx-yyyy), about the experiment, if you so desire. You may withdraw your consent and discontinue participation at any time without prejudice or consequence.

This research has been approved by the Psychology/Sociology Research Ethics Board (PSREB). If you have any concerns or complaints about this project you may contact any of the above-named persons or the Human Ethics Secretariat at 474-7122, or email margaret_bowman@umanitoba.ca.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and that you have agreed to participate. In no way does this waive your legal rights nor release the researchers or involved institutions from their legal and professional responsibilities.

Participant's signature: ______________________________ Date _________________

Experimenter's signature: ____________________________ Date _________________

Appendix D

Post-Experimental Questionnaire (Experiments 1A and 1B)

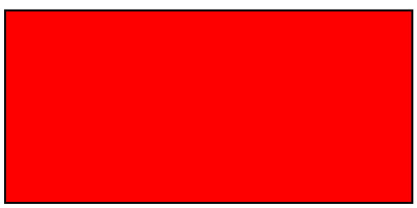
Date: ______________________ Participant Number: __________________________

Please answer the following questions:

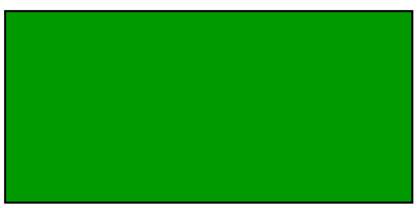
1. Did you make up any guidelines for yourself about pressing the shift key?

   ____

2. Look at the rectangles below and beside each one indicate whether or not you earned points by pressing the shift key when this colour of rectangle was on screen. (Use your best guess if you cannot remember exactly.)



(red) Yes ☐ No ☐
Comments:

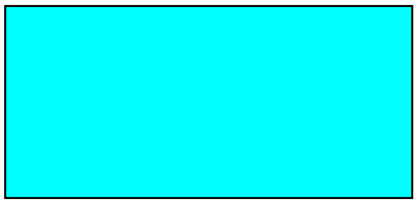


(green) Yes ☐ No ☐
Comments:

(maroon) Yes ☐ No ☐
Comments:

(fuchsia) Yes ☐ No ☐
Comments:

(silver) Yes ☐ No ☐
Comments:



(aqua) Yes ☐ No ☐
Comments:

3. How did you decide when to press the shift key, and when not to press the shift key?

____

4. What did you learn during the experiment? Explain briefly.

____

5. Please write down any comments you have about this experiment.

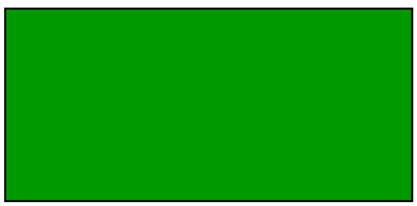
____

Appendix E

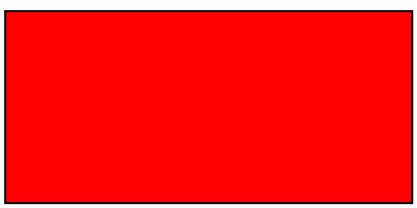
Post-Experimental Questionnaire (Experiment 2A)

Date: ______________________ Participant Number: __________________________

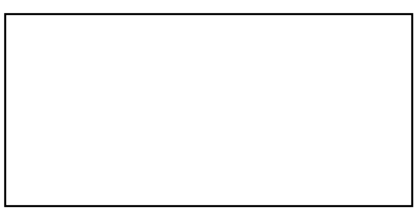
1. Place an X in either the 'YES' or 'NO' box beside each rectangle below to indicate whether you earned points, or not, when this colour was on the screen. Guess if you can't remember exactly.



(green) Yes ☐ No ☐
Comments:

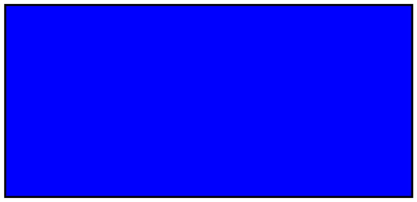


(red) Yes ☐ No ☐
Comments:

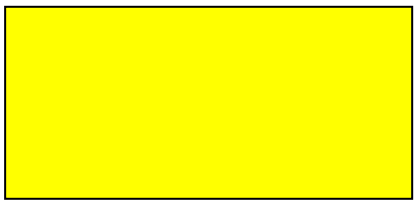


(white) Yes ☐ No ☐
Comments:

(black) Yes ☐ No ☐
Comments:



(blue) Yes □ No □
Comments:



(yellow) Yes □ No □
Comments:

2. How did you decide when to press the shift key, and when not to press the shift key?

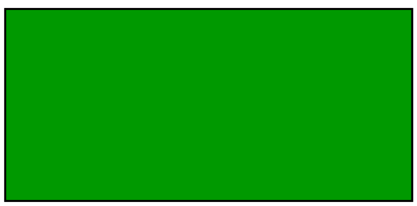
3. What was this experiment about?

Appendix F

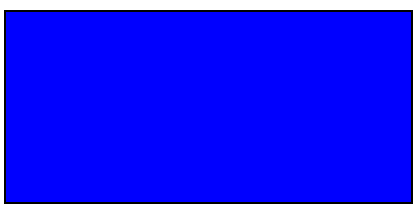
Post-Experimental Questionnaire (Experiment 2B)

Date: ______________________ Participant Number: __________________________

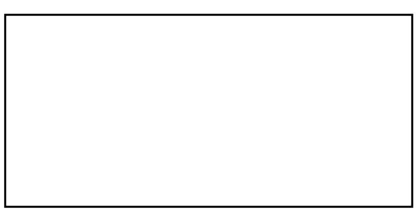
1. Place an X in either the ‘YES’ or ‘NO’ box beside each rectangle below to indicate whether you earned points, or not, when this colour was on the screen. Guess if you can’t remember exactly.



(green) Yes ☐ No ☐
Comments:

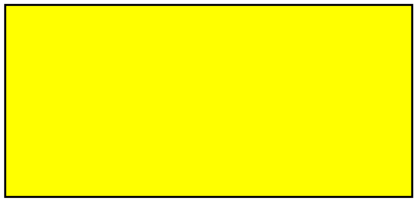


(blue) Yes ☐ No ☐
Comments:

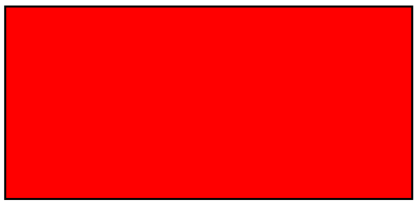


(white) Yes ☐ No ☐
Comments:

(black) Yes ☐ No ☐
Comments:



(yellow) Yes ☐ No ☐
Comments:



(red) Yes ☐ No ☐
Comments:

2. What was this experiment about?

Include any other comments you have (optional).

Appendix G

Experiment 2B Instructions

First Instructions:

> Welcome to the experiment, "Keewatin."
>
> Please try to earn as many points as you can.
>
> To earn points, press the SHIFT key (either one) about 3 times a second.
>
> Please practice pressing the SHIFT key, at 3 presses/second, on the next screen.
>
> Please press ENTER to proceed.

These instructions were followed by a 15-s interval during which the positive, single stimulus ($S+_A$) was presented and during which one point was available after every three key presses (FR3 schedule).

Second Instructions:

> You just saw a coloured rectangle on the previous computer screen. Whenever this colour of rectangle is on screen, if you press the SHIFT key, you will earn points.
>
> The point counter is in the upper left hand corner of the screen. It keeps track of the points you have earned.
>
> The next screen has the same colour of rectangle. Practice earning points again by pressing SHIFT about 3 times a second.
>
> Press ENTER and earn points.

The same positive, single stimulus was presented again with points available on an FR3 schedule.

Third Instructions:

> By now you have earned a few points. Good!
>
> Not all colours of rectangles are associated with earning points. Sometimes you will lose 20 points by pressing the SHIFT key.
>
> The colour of the rectangle on the following screen is associated with point loss.
>
> Press the SHIFT key during the following screen for a demonstration.
>
> Then STOP pressing SHIFT when you see that you lose points. You don't want to lose all the points you have earned.
>
> Press ENTER and try it now.

These instructions were followed by a 15-s interval during which the negative, single stimulus (S^{Δ}_{B}) was presented and during which 20 points were lost after every two key presses (FR2 schedule). This is a slight change from the previous experiment, in which points were lost after four key presses (FR4). In this experiment, point loss was a more immediate consequence after beginning to key press.

Fourth Instructions:

> As you can see, earning or losing points depends on the colour of the rectangle on the screen.
>
> To get a high point total, press SHIFT when you can earn points, but do NOT press SHIFT when you know you will lose points.
>
> Practice this again on the next two screens –
>
> > Press SHIFT to earn points on the first screen;

Do NOT press SHIFT on the second screen or you will lose points.

Press ENTER to continue.

These instructions were followed by a single presentation of the positive, single stimulus ($S+_A$) and then by a single presentation of the negative, single stimulus (S^{Δ}_B), both with their associated schedule of reinforcement.

The following instructions introduced Phase 1 of the experiment proper:

You have enough information and practice now to begin the experiment.

Try to earn as many points as possible. To achieve a high point total, press the SHIFT key when you can earn points but stop pressing the SHIFT key when you lose points.

Please press ENTER to begin.

The following instructions were presented after the test phase (Phase 3):

You have finished the experiment.

There is a short questionnaire for you in the next room.

Thanks for participating!

Appendix H

Covariate Analyses for Differences Between Groups

Discrimination ratios and gender were found to be equivalent between groups in Experiment 2B, suggesting that the groups did not differ systematically in ways other than the experimental manipulation. However, differences between groups were found in mean response rates; point totals; and age (see Table H1). Covariate analyses conducted with response rates, point totals, and age as covariates did not alter conclusions regarding significant results (i.e., positive target response rates and the positive-negative response-rate [i.e., $S_X - S_Y$] differences) and non-significant results (i.e., negative target response rates).

Table H1

Covariate Analyses for Experiment 2B

Analysis	Initial *p*	Covariate *p*
Response rate as covariate:		
Positive target:	.01	.01
Negative target:	.86	.91
Difference:	.02	.02
Points earned as covariate:		
Positive target:	.01	.01
Negative target:	.86	.82
Difference:	.02	.05
Age as covariate:		
Positive target:	.01	.02
Negative target:	.86	.92
Difference:	.02	.05

Note. All tests refer to relative response-rate differences between groups, for all three tests combined. The positive and negative tests refer to the S_X and S_Y target stimuli, respectively. The difference test refers to the ($S_X – S_Y$) response rate difference, for all three pairs of tests combined.