THE EFFECTS OF NUMBER OF SAMPLE STIMULI AND NUMBER OF CHOICES IN A DETECTION TASK ON MEASURES OF DISCRIMINABILITY

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Six pigeons were trained on a conditional discrimination task involving the discrimination of various intensities of yellow light. The research asked whether stimulus–response discriminability measures between any pair of stimuli would remain constant when a third or fourth sample and reinforced response were added. The numbers of different sample stimuli presented and different responses reinforced were two (Part 1), three (Parts 2 and 4), and four (Part 3). Across conditions within parts, the ratios of reinforcers obtainable for correct responses were varied over at least five levels. In Part 5, the numbers of sample stimuli and reinforced responses were varied among two, three, and four, and the reinforcer ratio between consecutive remaining samples was constant at 2:1. It was found that once a particular response had been reinforced, subjects continued to emit that response when the conditional stimulus for that response was no longer presented. Data analysis using a generalization-based detection model indicated that this model was able to describe the data effectively. Four findings were in accord with the theory. First, estimates of stimulus–response discriminability usually decreased as the arranged physical disparity between the sample stimuli decreased. Second, stimulus–response discriminability measures were independent of response–reinforcer discriminability measures, preserving parameter invariance between these measures. Third, stimulus–response discriminability measures for constant pairs of conditional stimuli did not change systematically as conditional stimulus–response alternatives were added. Fourth, log stimulus–response discriminability values between physically adjacent conditional stimuli summed to values that were not significantly different from estimates of the discriminability values for conditional stimuli that were spaced further apart.

Key words: conditional discrimination, stimulus–response discriminability, response–reinforcer discriminability, key peck, pigeons

Over the last 20 years, a considerable amount of empirical research has been reported on the interaction of stimulus and reinforcer control in conditional discriminations. This includes work using signal-detection and matching-to-sample paradigms. This research has been driven by, and has informed, a series of quantitative behavioral models designed to describe such performances. As described extensively by Davison and Nevin (1999), these models were initially an attempt to develop the signal-detection models of Green and Swets (1974) using a well-supported quantitative model of behavior allocation in choice situations (the generalized matching law; Baum, 1974). The initial model using generalized matching was suggested by Davison and Tustin (1978). Although some good support for this model was forthcoming (Davison & McCarthy, 1988), it failed in two areas: First, it could not convincingly—that is, with constant parameters—deal with conditional discrimination situations in which "errors" were occasionally reinforced (Davison & McCarthy, 1980; Nevin, Jenkins, Whittaker, & Yarensky, 1982). Second, it could not be logically generalized to more complex conditional discriminations in which the number of conditional stimuli, or the number of choices, exceeded two. Davison and Jenkins (1985) offered a revised model, using an alternative formulation to generalized matching, but this model also was unable to be applied to conditional discriminations with more than two conditional stimuli and responses.

Davison (1991) and Alsop (1991) introduced a new model for conditional discriminations that could be generalized to both the reinforcement-for-"errors" situation and to many-stimulus and many-response situations.

Conventional 2-stimulus 2-response conditional-discrimination matrix

	B_1	B_2
S_1	R_{11}	R_{11}/d_r
S_2	R_{11}/d_s	$R_{11}/d_s/d_r$

3-stimulus 3-response conditional-discrimination matrix

	B_1	B_2	B_3
S_1	R_{11}	R_{11}/d_{r12}	R_{11}/d_{r13}
S_2	R_{11}/d_{s12}	$R_{11}/d_{s12}/d_{r12}$	$R_{11}/d_{s12}/d_{r13}$
S_3	R_{11}/d_{s13}	$R_{11}/d_{s13}/d_{r12}$	$R_{11}/d_{s13}/d_{r13}$

Fig. 1. The operation of the Davison (1991) and Alsop (1991) model in the 2 × 2 and 3 × 3 conditional discrimination procedures. Only the effects of a reinforcer delivered for a B_1 response following S_1 presentation are shown. Reinforcers delivered in any of the cells will generalize according to the same logic, and the generalized effects in each cell will be additive.

The model analyzes the two (or more) three-term contingencies (stimulus–response–reinforcer) that occur in conditional discriminations. It assumes that subjects may occasionally make errors in detecting the relation between responses emitted and reinforcers obtained, as shown by Jones and Davison (1998), such that they behave as if a different response had been reinforced. The ability of the subject to discriminate pairs (i, j) of response–reinforcer contingencies is measured by a parameter d_{rij}, termed *response–reinforcer discriminability*. If response–reinforcer discriminability is sufficient, there will be differential reinforcement with respect to the conditional stimuli that will allow the subject to discriminate the relation between the conditional stimuli and associated responses—to discriminate the stimuli. But, as above, the subject may not discriminate the stimulus–behavior relations perfectly and may behave as if the stimulus presented was a different stimulus. The ability of the subject to discriminate pairs (i, j) of stimulus–response relations is

measured by a parameter d_{sij}, termed *stimulus–response discriminability*. Thus, the model assumes that imposed changes in response–reinforcer relations will affect d_r but will not affect d_s, and that imposed changes in stimulus–response relations will affect d_s but will not affect d_r. The model and its implications are more fully discussed by Davison and Nevin (1999).

The operation of the model for both the standard (two stimuli and two responses) conditional discrimination paradigm and a nonstandard (three stimuli and three responses) paradigm is shown in Figure 1. When a reinforcer, R, is delivered for Response 1 after presentation of Stimulus 1 (R_{11}), its effect generalizes to other stimulus–response combinations depending on the degree to which the stimulus–response relations are discriminable (d_s) and the degree to which the response–reinforcer relations are discriminable (d_r). Of course, when there are three stimuli and three responses, three d_s parameters $(d_{s12}, d_{s13}, \text{and } d_{s23})$ and three d_r pa-

rameters (d_{r12}, d_{r13}, and d_{r23}) are required. The logical operation of the model shown in Figure 1 applies to reinforcers delivered in any stimulus–response cell of the matrices, and the generalized effects are additive within each cell. The ratio of responses emitted between any pair of cells is predicted by the ratio of direct and generalized reinforcers between the cells. Thus, for Cells 11 and 12, with B_1 reinforced in S_1, B_2 reinforced in S_2, and B_3 reinforced in S_3, the effective reinforcer rates in the six cells are

Cell 11: $R_{11} + \dfrac{R_{22}}{d_{s12}d_{r12}} + \dfrac{R_{33}}{d_{s13}d_{r13}},$

Cell 12: $\dfrac{R_{11}}{d_{r12}} + \dfrac{R_{22}}{d_{s12}} + \dfrac{R_{33}}{d_{s13}d_{r23}},$

Cell 13: $\dfrac{R_{11}}{d_{r13}} + \dfrac{R_{22}}{d_{s12}d_{r23}} + \dfrac{R_{33}}{d_{s13}},$

Cell 21: $\dfrac{R_{11}}{d_{s12}} + \dfrac{R_{22}}{d_{r12}} + \dfrac{R_{33}}{d_{s23}d_{r13}},$

Cell 22: $\dfrac{R_{11}}{d_{s12}d_{r12}} + R_{22} + \dfrac{R_{33}}{d_{s23}d_{r23}},$

Cell 23: $\dfrac{R_{11}}{d_{s12}d_{r13}} + \dfrac{R_{22}}{d_{r23}} + \dfrac{R_{33}}{d_{s23}},$

Cell 31: $\dfrac{R_{11}}{d_{13}} + \dfrac{R_{22}}{d_{s12}d_{r12}} + \dfrac{R_{33}}{d_{r13}},$

Cell 32: $\dfrac{R_{11}}{d_{s13}d_{r13}} + \dfrac{R_{22}}{d_{s23}} + \dfrac{R_{33}}{d_{r23}},$ and

Cell 33: $\dfrac{R_{11}}{d_{s13}d_{r13}} + \dfrac{R_{22}}{d_{s23}d_{r23}} + R_{33}.$

Thus, for example, the ratio of effective reinforcers between Cells 22 and 23 is

$$\frac{B_{22}}{B_{23}} = c\,\frac{\dfrac{R_{11}}{d_{s12}d_{r12}} + R_{22} + \dfrac{R_{33}}{d_{s23}d_{r23}}}{\dfrac{R_{11}}{d_{s12}d_{r13}} + \dfrac{R_{22}}{d_{r23}} + \dfrac{R_{33}}{d_{s23}}}.$$

The parameter c, termed *response bias* (Baum, 1974), is added for completeness to describe any inherent bias towards emitting B_2 over B_3. Equivalent equations can readily be derived for any pairwise ratio of responses within rows of the matrices in Figure 1, and further equations using the same logic can be derived for matrices of any size. However, beyond 3×3 matrices, the number of discriminability parameters that are required quickly becomes large, requiring many conditions of data collection to provide an adequate ratio of data to free parameters. The effectiveness of the model as applied to 2×2 matrices has been reviewed by Godfrey and Davison (1998) and by Davison and Nevin (1999).

The present experiment was an explicit test of the Davison (1991) model as a function of the number of different stimulus–response pairs that could be reinforced. It asked whether stimulus–response and response–reinforcer discriminability parameters remained constant, as required by the model, when stimulus–response–reinforcer alternatives were added and subtracted from the matrix. It also asked whether stimulus–response discriminability parameter values were ordinally related to physical stimulus disparities, as found by Alsop and Davison (1991) for two-stimulus conditional discriminations, when further different stimuli were added to the discrimination.

Subjects were asked to discriminate between two (Part 1), three (Parts 2 and 4), or four (Part 3) sample stimuli differing in intensity. Across each experimental part (except Part 4; see Table 1), the ratio of reinforcers between responses was varied over at least five levels while each of the stimuli was presented equally frequently. A fifth experimental part was arranged in which the number of sample stimuli presented was increased or decreased by one in each consecutive condition while the reinforcer ratio between pairs of stimuli was kept constant, allowing the effects of adding and removing a sample stimulus on detection performance to be investigated.

METHOD

Subjects

Six adult homing pigeons, numbered 61 to 66, were maintained at 85% ±15 g of their ad-lib body weights by postsession feeding of mixed grain. Water and grit were freely available in the home cages at all times.

Apparatus

The lightproof and sound-attenuating experimental chamber was 340 mm high, 310
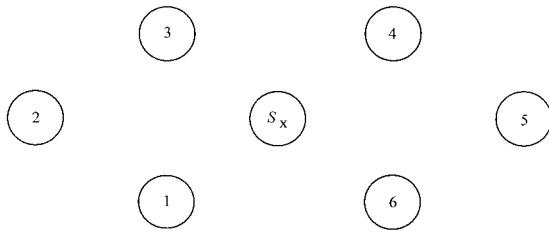
Fig. 2.   A diagrammatic representation of the arrangement of keys in the experimental chamber (not drawn to scale). The key labeled S_x is where the sample stimulus (one of six different light intensities, S_1 to S_6) could be presented (but only S_2 to S_5 were used in the present experiment). The keys around this key show the appropriate response (e.g., a response to Key 2 was reinforced after Stimulus 2 had been presented).

mm wide, and 340 mm deep. Seven circular plastic response keys (20 mm diameter) were arranged on one wall of the chamber, as shown in Figure 2. The center keys in a vertical direction were 250 mm above the grid floor, and the upper and lower pairs of keys were 30 mm above and below these keys. All the choice keys around the center key were 150 mm center to center. For convenience, the outer (choice) keys were numbered one to six in a clockwise order from the bottom left (Key 1) to the bottom right (Key 6) (Figure 2). All seven keys were used during this experiment. When operative, red light-emitting diodes (LEDs) illuminated the six outer keys. The center (conditional stimulus) key was yellow, and its intensity was determined by six resistors set to produce different voltages across the LED. To be recorded, pecks to each key had to exceed approximately 0.1 N. All responses on darkened keys had no scheduled consequences and were not recorded.

Situated 130 mm beneath the center key was a 45-mm square opening that provided access to a food magazine containing wheat. Food reinforcement consisted of 3-s access to wheat, during which time the keylights were extinguished and the food magazine was raised and illuminated by a yellow LED. When the reinforcement period ended, the magazine light was switched off, the magazine was lowered, and the center keylight simultaneously switched back on. The magazine and keylights were the only source of illumination.

An exhaust fan was attached to the outside of the chamber which provided ventilation and helped to mask any external noise. An IBM®-compatible personal computer situated in a room remote from the experimental chamber controlled all experimental events and recorded the data using MedState® notation software.

Procedure

No initial magazine or key-pecking training was necessary, because all subjects had extensive experimental histories. Birds 61, 63, 65, and 66 had previously served in discrete-trials signal-detection procedures (Voss, 1989; Voss, McCarthy, & Davison, 1993) and in a variety of single-key and concurrent schedules. Birds 62 and 64 had served as subjects in an experiment involving arithmetic and exponential concurrent schedules (Alsop & Elliffe, 1988). The subjects were given a number of pretraining sessions before each experimental part. Initially, pretraining involved slowly decreasing the overall reinforcer rate and varying the frequency of reinforcement between responses signaled by two highly discriminable center-key intensities. The intensity difference between these stimuli was then reduced slowly to the values shown in Part 1 (Table 1). When a new conditional stimulus was introduced (at the start of Parts 2 and 3), the available choice alternatives (keys lit red) initially were just those for correct responses following the center-key stimulus intensities. After a few sessions, the number of choice alternatives was increased to all six. Note that although all six choice responses were available in all conditions of the experiment, responses to Keys 1 and 6 were never reinforced.

There were five parts in the present experiment. The sequence of parts and conditions, and the number of training sessions conducted in each, are shown in Table 1. Conditions 7 and 22 to 26 were conditions similar to those reported here but are irrelevant to the current experiment.

In all conditions, a discrete-trials procedure was used, and the sequence of events was as follows: A trial began with the illumination of the center key by a yellow light of a particular intensity with the six choice keys initially darkened and inoperative. The intensities of the sample stimuli (only S_2 to S_5 were used) to be presented on the center key are shown

Table 1

Sequence of experimental conditions, sample stimuli used and their intensity, arranged reinforcer ratio, and the number of training sessions in each condition. Note that Conditions 7 and 22 to 26 do not appear in this table because they were designed for another similar experiment.

Part	Condition	Sample stimuli[a]	Reinforcer ratio	Number of sessions
1	1	2, 5	1:1	24
	2		1:5	61
	3		8:1	35
	4		1:2	25
	5		5:1	31
	6		1:8	32
2	8	2, 4, 5	1:1:1	34
	9		1:4:4	28
	10		4:4:1	27
	11		4:1:4	28
	12		1:1:7	29
	13		7:1:1	35
	14		1:7:1	43
3	15	2, 3, 4, 5	1:1:1:1	29
	16		1:5:5:9	28
	17		5:9:1:5	38
	18		9:5:5:1	25
	19		5:1:9:5	27
	20		5:5:9:1	32
	21		2:5:1:12	27
4	27	2, 4, 5	4:1:4	29
5	28	4, 5	2:1	32
	29	3, 4, 5	4:2:1	34
	30	2, 3, 4, 5	8:4:2:1	27
	31	2, 4, 5	4:2:1	31
	32	2, 4	2:1	22
	33	2, 3, 4	4:2:1	48
	34	2, 3	2:1	22
	35	2, 3, 5	4:2:1	24
	36	3, 5	2:1	23

[a] The nominal voltages for sample stimuli were S_2, 19.5 V; S_3, 18.5 V; S_4, 17.5 V; and S_5, 16.5 V.

in Table 1. One peck on the center key extinguished the yellow center key and resulted in all six choice keys being illuminated red. All choice keylights were of approximately the same intensity. The first response emitted on any choice key extinguished all keylights. If this peck was on the choice key at the correct location, a 3-s food reinforcer was occasionally produced. In all conditions of the experiment, a correct response following the presentation of S_n was to choice-key n, as shown in Figure 2. Responses that were correct but were not reinforced produced 3-s illumination of the magazine light alone. A single peck on the choice key at an incorrect location (i.e., an error) produced a 3-s blackout.

Food reinforcers were arranged as follows: Every 1 s throughout the whole session, a probability gate set at .025 determined whether a reinforcer would be arranged (an average arranged time between reinforcers of 40 s). A food reinforcer arranged by this procedure was allocated to the next correct response on an alternative (e.g., for the next B_2 following S_2 presentation) by randomly selecting a number from a list. This list contained two, three, or four different items in different parts of the experiment according to how many responses could be reinforced. Reinforcer ratios between alternatives were changed by varying the relative frequencies of the items in the list. Once arranged, a reinforcer remained available, and no more were arranged, until it was delivered following a correct response on the specified alternative. This is a controlled reinforcer-ratio procedure (McCarthy & Davison, 1984, 1991; Stubbs, 1976), which insured that the obtained reinforcer ratios between alternatives closely approximated the arranged ratios. The ratio of reinforcers between the sample stimuli was varied across conditions within each part of the experiment (see Table 1). The sample stimulus presented on each trial was randomly chosen, and the stimuli occurred equally frequently.

A new trial (i.e., the illumination of the center key yellow of some intensity) began either immediately after food presentation, when the magazine light extinguished, or when the blackout period ended. A noncorrection procedure was in effect throughout the experiment. That is, presentations of the sample stimuli on the center key on any given trial were independent of both the sample and the accuracy of choice on the preceding trial.

Experimental sessions were conducted 7 days per week. Each session began and ended in blackout after either 40 min had elapsed or following the delivery of 36 (Parts 1, 2, 4, and 5) or 40 (Part 3) food reinforcers, whichever event occurred first. The data collected each session were the numbers of responses to each choice key following each sample stimulus and the numbers of food reinforcers obtained from correct responses.

Experimental conditions were changed only when all subjects had satisfied the following stability criterion a total of five, not nec-

essarily consecutive, times: Following 10 sessions, the mean accuracy levels (proportion correct) were calculated across blocks of five sessions, starting with Sessions 10 to 14. The criterion required that mean accuracy over the last set of five sessions did not differ from the mean over the previous nonoverlapping set of five sessions by more than .05. The minimum number of sessions per condition was thus 19. Typically, once a subject had reached its individual criterion, it continued to show stable performance. The mean number of training sessions, averaged across the 30 experimental conditions, was 32.3 (Table 1).

In Part 1, two different sample stimuli, S_2 (nominally 19.5 V) and S_5 (nominally 16.5 V) were presented on the center key. A third sample stimulus was added in Part 2 (S_4, nominally 17.5 V) and a fourth in Part 3 (S_3, nominally 18.5 V). Part 4 was a replication of Condition 11 of Part 2 but is reported separately because of the effects that adding Stimulus 3, and reinforcing Response 3, in Part 3 had on the emission of Response 3. Part 5 involved adding or removing one sample stimulus across successive conditions while the reinforcer ratio between samples was held constant (see Table 1). The intensity of the light emitted by the LED does not change linearly with voltage, but intensities are ordinally related to voltage.

RESULTS

The data used in the following analyses were the numbers of responses to each choice alternative following each center-key stimulus, and the numbers of reinforcers obtained for correct responses, summed over the last five sessions of each condition for each subject. No data are reported for Responses 1 and 6. These responses were never reinforced, and response counts to them were typically zero. To correct for zeros in all other cells, 0.5 was added to the summed behavior for all conditions, as suggested by Hautus (1995). The raw data for each subject are shown in the Appendix. Condition 27, arranged in Part 4, was a replication of Condition 11 (Part 2), but for reasons that will become apparent in the Discussion, the data from this condition were not included in the Part 2 analyses.

For Part 1 data, relative behavior measures

$[B_{22}/(B_{22} + B_{25})$ and $B_{52}/(B_{52} + B_{55})]$ were used to fit the relative form of the appropriate equations using the Quattro-Pro Optimizer, a nonlinear iterative fitting program. Estimates of d_s and d_r were calculated such that the sum of deviations between obtained and predicted relative response rates was minimized. The results are shown in Table 2. All parameter estimates were constrained to be less than 10,000 (a log value of 4) and greater than 1, the normal range of d_s and d_r values. A systematic occurrence of estimates at either of these two limits would, of course, be important, but in only one case for Bird 62 was a parameter estimate (d_{r25}) bounded by the constraint. In general, we would expect that the present procedure would produce high d_r values (log d_r values greater than 1.5) in all conditions, because the response locations were highly discriminable. We would expect d_s values to vary from high values when stimuli were physically distant to low values (log d_s less than 0.5) when they were physically close.

The parameter estimates are shown in Table 2 along with the percentage of variance accounted for by the fit and the mean square error of the fit. Estimates of d_s and d_r were both high, indicating that the subjects were well able to discriminate both the stimulus–response and the response–reinforcer contingencies. Estimates of c, inherent bias (Davison, 1991), were not obtained in the analyses presented in Table 2 because too many bias parameters (three for the 3×3 matrix and six for the 4×4 matrix) would subsequently be required. However, a separate analysis of the Part 1 data indicated that, overall, subjects showed no systematic preference for one response over another, with logarithmic inherent bias averaging -0.10. The percentage of data variance accounted for by the fits without inherent bias was greater than 98% for each subject, and the values of the mean square errors ($M = 0.003$) were small, indicating that the model was able to describe the data well.

For Parts 2 and 3, the appropriate relative forms of the model were fitted to the data in the same way as in Part 1. For reasons discussed later, the data from Part 4 (Condition 27) were not used in this analysis of the Part 2 data. Relative behavior measures were calculated for each stimulus using the behavior

Table 2

Logarithmic estimates of stimulus–response discriminability (d_s) and response–reinforcer discriminability (d_r) between each sample and choice stimulus pair from fits to the model as appropriate for each part. %VAC is the percentage of variance accounted for by the fit, and MSE is the mean square error.

	Stimulus–response discriminability						Response–reinforcer discriminability						%VAC	MSE
	d_{s23}	d_{s24}	d_{s25}	d_{s34}	d_{s35}	d_{s45}	d_{r23}	d_{r24}	d_{r25}	d_{r34}	d_{r35}	d_{r45}		
Part 1														
61			1.88						1.52				100	0.001
62			1.17						4.00[a]				99	0.003
63			1.79						1.45				100	0.002
64			1.49						1.18				98	0.006
65			2.18						1.49				100	0.001
66			1.97						1.74				100	0.002
Part 2														
61		1.20	1.55			0.26		1.40	2.99			4.00[a]	99	0.005
62		0.95	1.73			0.22		4.00[a]	1.89			1.47	99	0.002
63		0.89	1.68			0.40		4.00[a]	1.71			1.23	97	0.007
64		1.17	1.70			0.40		1.46	2.09			1.47	99	0.003
65		1.18	1.61			0.21		4.00[a]	4.00[a]			1.52	97	0.008
66		1.39	1.61			0.22		1.51	4.00[a]			1.97	99	0.002
Part 3														
61	0.39	1.33	1.77	0.64	1.65	0.33	1.58	2.54	2.56	2.94	2.19	4.00[a]	93	0.008
62	0.48	1.20	1.35	0.67	0.84	0.38	1.30	2.14	2.37	1.59	4.00[a]	1.55	87	0.011
63	0.20	1.35	4.00[a]	0.77	2.52	0.69	2.16	1.33	2.30	1.42	1.68	1.29	92	0.010
64	0.27	1.14	1.95	0.61	1.39	0.51	4.00[a]	1.73	2.52	1.81	2.72	1.65	93	0.008
65	0.27	1.12	1.73	0.65	1.58	0.64	4.00[a]	4.00[a]	2.89	4.00[a]	1.78	1.05	91	0.011
66	0.33	1.24	2.24	0.64	1.45	0.67	4.00[a]	2.65	2.70	1.37	4.00[a]	1.71	92	0.010
Part 5														
61	1.24	1.86	3.94	1.06	1.42	0.30	2.94	2.82	2.70	2.80	2.64	2.79	84	0.023
62	1.16	1.93	1.85	0.96	1.17	0.30	1.82	1.59	1.94	1.90	1.74	1.97	74	0.037
63	0.91	1.60	2.00	0.78	1.45	0.36	1.77	1.71	1.99	1.94	1.73	2.02	80	0.031
64	2.36	1.98	2.22	1.51	1.50	0.52	2.77	3.08	3.03	3.00	3.07	2.94	77	0.034
65	0.92	1.53	2.12	0.81	1.74	0.43	1.72	1.54	1.88	1.75	1.48	1.92	70	0.043
66	1.28	2.71	3.78	0.65	1.67	0.50	1.75	1.47	1.83	1.76	1.46	1.85	63	0.051

[a] Maximum values allowed in the nonlinear regression.

ratios $B_{22}/(B_{22} + B_{24})$, $B_{22}/(B_{22} + B_{25})$, $B_{24}/(B_{24} + B_{25})$ and $B_{42}/(B_{42} + B_{44})$, $B_{42}/(B_{42} + B_{45})$, $B_{44}/(B_{44} + B_{45})$ and $B_{52}/(B_{52} + B_{54})$, $B_{52}/(B_{52} + B_{55})$, $B_{54}/(B_{54} + B_{55})$ in Part 2. The following additional relative behavior measures were used in Part 3: $B_{32}/(B_{32} + B_{33})$, $B_{32}/(B_{32} + B_{34})$, $B_{32}/(B_{32} + B_{35})$, $B_{33}/(B_{33} + B_{34})$, $B_{33}/(B_{33} + B_{35})$, $B_{34}/(B_{34} + B_{35})$, $B_{22}/(B_{22} + B_{23})$, $B_{32}/(B_{32} + B_{33})$, $B_{42}/(B_{42} + B_{43})$, $B_{52}/(B_{52} + B_{53})$, $B_{23}/(B_{23} + B_{24})$, $B_{23}/(B_{23} + B_{25})$, $B_{33}/(B_{33} + B_{34})$, $B_{33}/(B_{33} + B_{35})$, $B_{43}/(B_{43} + B_{44})$, $B_{43}/(B_{43} + B_{45})$, $B_{53}/(B_{53} + B_{54})$, and $B_{53}/(B_{53} + B_{55})$. No bounded d_s parameter estimates, and 6 of 18 bounded d_r parameter estimates, were found in Part 2. Variance accounted for was at least 97% for each subject (63 data points per subject), and mean square errors ($M =$ 0.005) between data and predictions were very small. In Part 3, of the d_s parameter estimates, one (d_{s25} for Bird 63) was bounded, and 8 of 36 d_r estimates were bounded (Table 2). The percentage of data variance accounted for by the fits to the appropriate form of the model in Part 3 were all greater than 86% (126 data points per subject), and mean square errors ($M = 0.010$) were small, but were larger than those for Parts 1 and 2.

Figure 3 shows the estimates of log d_s from Parts 1 to 3 of this experiment according to the stimulus pair appropriate for each parameter. As expected, values of d_s increased significantly with increases in physical stimulus separation. In Part 2, d_{s24} values for each subject were all smaller than d_{s25} values (significant on a sign test at $p < .05$; Ferguson,

Fig. 3. The value of stimulus–response discriminability (log d_s) as a function of the various pairs of conditional stimuli presented for each subject in Parts 1 to 3.

1973). In Part 3, a nonparametric trend test (Ferguson, 1973) indicated that stimulus–response discriminability measures increased significantly with increasing conditional stimulus differences (d_{s23}, d_{s24}, d_{s25}) ($\Sigma S = 18$, $N = 6$, $k = 3$, $p < .05$). Similarly, on a sign test, the values of d_{s35} were significantly larger than those of d_{s34} ($p < .05$). There was no significant trend in the values of d_{s25} across Parts 1, 2, and 3 as the number of alternatives was increased ($\Sigma S = 4$, $N = 6$, $k = 3$, $p > .05$), and there was no significant difference in d_{s24} values between Parts 2 and 3 ($p > .05$). However, values of d_{s45} in Part 3 were all greater than those in Part 2 ($p < .05$). Focusing on stimuli nominally 1 V apart in Part 3 (d_{s23}, d_{s34}, d_{s45}), the value of d_{s34} was significantly greater than that of d_{s23}, but neither of the other comparisons (d_{s23}, d_{s45}; d_{s34}, d_{s45}) reached significance. Also, in Part 3 alone, the mean log discriminability of stimuli 1 V apart was 0.51, those 2 V apart was 1.40, and those 3 V apart was 2.17.

In all parts, estimates of response–reinforcer discriminabilities (d_r) were large, indicating very high discriminability between the choice alternatives (Table 2). On trend tests, these estimates showed no systematic changes with increasing numbers of alternatives, and a Friedman analysis of variance across all d_r estimates from Parts 1 to 3 showed that no significant differences were present.

After completing Part 3, Condition 27, a replication of Condition 11, was arranged in which Stimulus 3 was no longer presented and Response 3 was no longer reinforced. This condition is labeled Part 4 in Table 1. However, as can be seen from the Appendix, the replication was imperfect. Compared with Condition 11, all Response 3 counts (in Stimuli 2, 4, and 5) increased ($p < .05$ on a sign test), and the mean percentage increase was 910%. On the other hand, only four of the eight counts for Responses 2, 4, and 5 increased (not significant). It is evident, therefore, that there had been an effect of reinforcing Response 3 in the presence of Stimulus 3 in Part 3 that was not lost when this response was no longer reinforced. Of course, the model can handle the generalization of reinforcer effects to nonreinforced responses. This finding, however, must modify our analysis of the data collected in Part 5.

Part 5 Analyses

In Part 5, the numbers of stimuli and reinforced responses were manipulated across conditions while the ratio of reinforcers between successive stimuli was held constant at 2:1. Given the results of the replication done in Part 4, these data needed to be analyzed in a way different from those analyzed in Parts 1 and 2. Rather than just using responses on the two, three, or four reinforced alternatives, we needed to use all four response counts in every condition, whether they arranged two, three, or four reinforced alternatives. The results of this analysis are shown in Table 2 and are plotted in Figure 4. As Table 2 shows, the fits to the model were generally good, with between 63% and 84% of the variance accounted for (216 data points), and with mean square errors averaging 0.036. The values of d_{s23}, d_{s24}, and d_{s25} ($M = 1.31$, 1.93, and 2.65, respectively) again increased with increasing physical separation. Although all individuals did not show this monotonic trend (Table 2), a nonparametric trend test showed that this increase was significant across individuals ($N = 6$, $k = 3$, $\Sigma S = 12$, $p < .05$). For 5 of the 6 subjects, d_{s35} ($M = 1.49$) was also greater than d_{s34} ($M = 0.96$), but this difference was not significant on a sign test. For stimuli nominally 1 V apart, the pattern of results was different from those found in Part 3: Estimates of log d_{s34} were significantly smaller than those of log d_{s23}, and d_{s45} values were significantly larger than d_{s34}, and smaller than d_{s23}, values (sign tests, $p < .05$). The d_s values for stimuli 2 V apart did not differ significantly from each other (sign test, $p > .05$), but were significantly greater than those from stimuli 1 V apart.

To determine whether stimulus–response and response–reinforcer measures were independent, estimates of response–reinforcer discriminability (d_r) were plotted as a function of estimates of stimulus–response discriminability (d_s) in Figure 5 for both Parts 3 and 5. Straight lines were fitted to these data by the method of least squares. For Part 3, the relation across all subjects had a small negative slope that was less than two standard deviations away from a slope of zero. For individual subjects, three of the slopes were positive and three negative, and none individually was significantly different from zero.
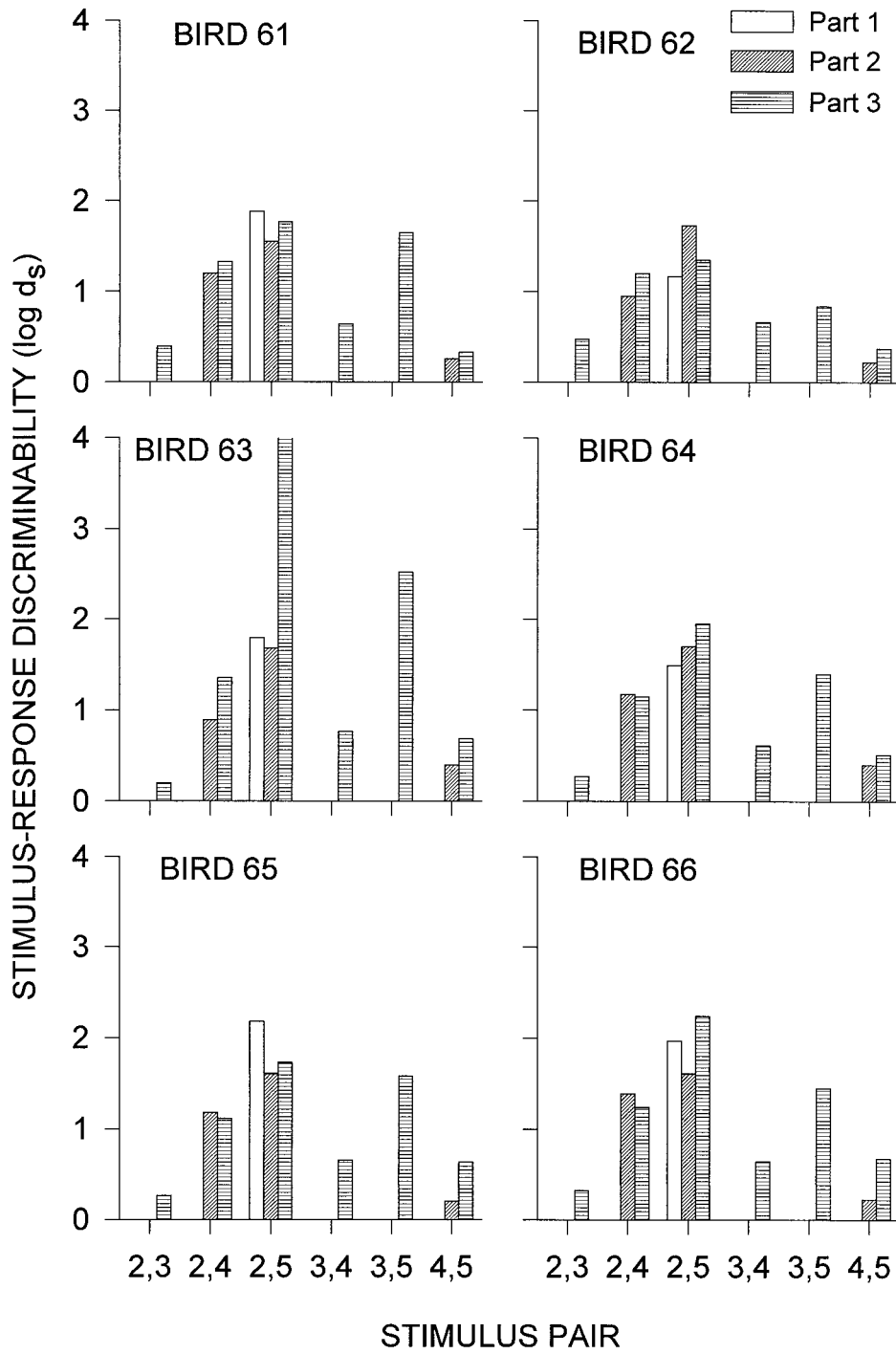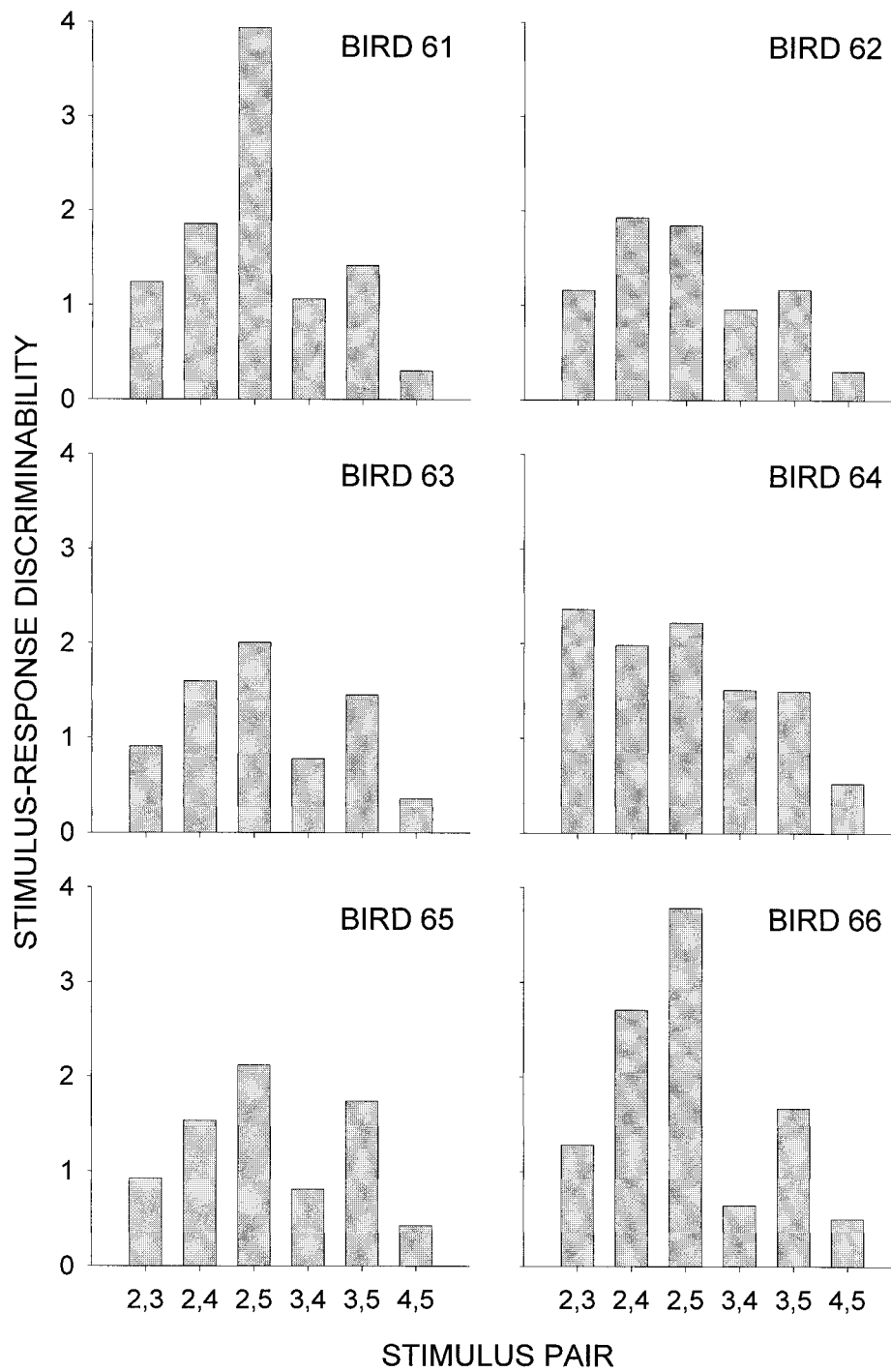
Fig. 4.   The value of stimulus–response discriminability (log d_s) as a function of the various pairs of conditional stimuli presented for each subject in Part 5.
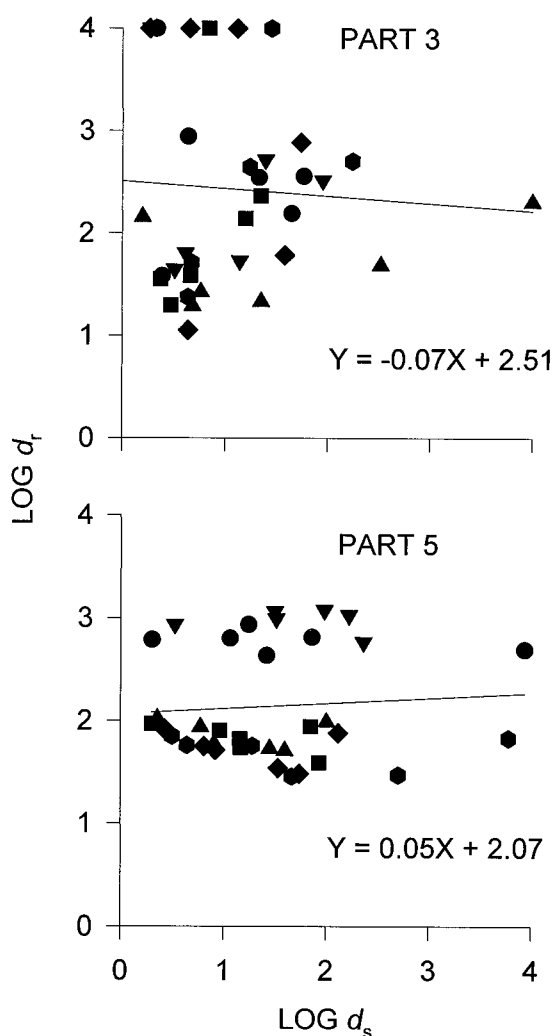
Fig. 5. Estimates of response–reinforcer discriminability (log d_r) as a function of estimates of stimulus–response discriminability (log d_s) for all subjects in Parts 3 and 5. The different symbols show estimates from different subjects.

The overall relation in Part 5 was slightly positive, but again was not more than two standard deviations from a slope of zero. Although all individual subjects showed positive slopes, none was significantly different from zero. Thus, there was no evidence of any relation between d_s and d_r values.

DISCUSSION

The extension of the standard two-stimulus two-response matching-to-sample task pro-

duced a set of conditional discrimination data that allowed the effects of increasing the number of sample and choice stimuli on detection performance to be investigated. The model as written appropriately for 2×2, 3×3, and 4×4 detection matrices (Davison, 1991) was used to analyze the data. The data collected here provide the first sufficiently extensive set to allow this aspect of the model to be assessed.

In the present experiment, stimulus–response discriminability was varied by arranging sample stimuli that differed in light intensity. No attempt to vary response–reinforcer discriminability was made, and each choice key was located at a roughly similar distance from the sample stimulus (Figure 2). Although it would have been interesting to vary the level of response–reinforcer discriminability, the number of conditions required was too large to be incorporated into the present study, and such an investigation for 2×2 stimulus–response matrices has already been reported (Godfrey & Davison, 1998). The main focus of the present experiment was to investigate whether adding further samples and responses to a 2×2 detection task affected estimates of stimulus–response or response–reinforcer discriminability. As expected, estimates of response–reinforcer discriminability were large across all choices, indicating high discriminability between the choice alternatives. Analyses showed that response–reinforcer discriminability was not affected by the addition of further samples, and estimates of d_r did not differ significantly across the experimental parts. Finally, estimates of response–reinforcer discriminability were independent of stimulus–response discriminability estimates, as shown in Figure 5. Thus, parameter invariance for d_r, and independence of d_r from d_s values, were preserved in the present study, unlike the study of Nevin, Cate, and Alsop (1993), but as reported by Godfrey and Davison (1998). Godfrey and Davison suggested that the reason Nevin et al. failed to find parameter independence might result from a failure of the present model to incorporate appropriately the large inherent biases between different-latency choice responses that occurred in Nevin et al.'s experiment. As we reported above, inherent biases were usually small in the present data, so the present results were consistent with their explanation,

although they only provide weak additional support.

Estimates of d_{s24} and d_{s25} were not affected by the addition of further samples and choices across Parts 1 to 3, but d_{s45} values were significantly larger in Part 3 than in Part 2. However, of the 30 pairwise comparisons of d_s parameter estimates among Parts 1, 2, and 3, 20 increased and 9 decreased, a result that is not significant on a sign test ($z = 0.5$). We can conclude that the model overall provided estimates of stimulus–response discriminability that were independent of the number of stimulus–response–reinforcer combinations arranged.

Another aspect of the Part 3 data was that stimulus–response discriminability measures for stimuli 1 V apart were significantly lower for Stimuli 2 and 3 than for Stimuli 3 and 4. It is likely that this finding simply represents the fact that a fixed change in voltage across the bulb did not lead to a corresponding fixed change in the discriminability of the stimuli. This is of no consequence for the present experiment, as long as stimulus disparity on some dimension (e.g., intensity, and possibly color) changes ordinally with voltage.

The Part 4 data (the replication in Condition 27 of the arrangement in Condition 11) indicated that after a stimulus–response relation had been reinforced in a condition, subjects continued to emit those responses in subsequent conditions even though the sample was no longer presented. This appears to be a result of an historical influence of the previous occasional reinforcement for emitting this response. In Part 1, at the start of the experiment, when two samples were presented, subjects rarely emitted any responses to the unreinforced choice alternatives. When a further sample was added, the subjects responded to the added choice alternative, but also now generalized between this stimulus–response alternative and the other stimuli and responses, making additional stimulus–response and response–reinforcer errors. It was, therefore, not until another sample stimulus had been explicitly added that the subjects' behavior generalized to that stimulus and its associated response. But, as shown above, the addition of further stimuli did not affect estimates of stimulus–response or response–reinforcer discriminability. As a result, in Part 5, although the number of samples and reinforced choices varied between two, three, and four, the subjects always emitted responses to the four, previously reinforced, choice alternatives.

Estimates of stimulus–response and response–reinforcer discriminability in Part 5 were therefore calculated from 4×4 fits to the Davison (1991) model, as in Part 3. The results of this analysis were shown in Table 2 and Figure 4. The model described the data well, with 63% to 84% of the variance accounted for, and an average mean square error of 0.036 (216 data points per subject). Estimates of response–reinforcer discriminability were large and not significantly different (sign test, $p > .05$) from estimates from Part 3. As expected, estimates of stimulus–response discriminability increased with increases in the arranged physical disparity of the samples. Discriminability between S_2 and S_5 was the largest, followed by discriminability between S_2 and S_4 and between S_3 and S_5. Unlike Part 3, estimates of log d_{s34} were significantly smaller than those of log d_{s23}. In addition, d_{s34} values were significantly larger than d_{s45} values and were smaller than d_{s23} values. Although d_r estimates in Parts 3 and 5 were not significantly different on sign tests, d_{s23}, d_{s24}, and d_{s34} estimates were significantly larger in Part 5 than in Part 3 (sign tests, $p < .05$). Thus, in summary, the model for more than two stimulus and response alternatives was well able to describe the data from each of Parts 3 and Part 5, but there was an indication that some measures changed between the parts.

Estimates of stimulus–response discriminability can also be examined in terms of their distance apart in log d_s psychometric space. If the present model is correct, then log d_s values should conform to a linear scale such that, for example, the estimated value for log d_{s24} would equal the summation log d_{s23} + log d_{s34}. Was this true in the analysis of the present data? First, in Parts 2 and 3 (Table 3), sums of stimulus–response discriminability estimates (e.g., d_{s23} + d_{s34}) were less than the value obtained for the single estimate (e.g., d_{s24}) in 21 of 24 cases, and this difference was significant on a binomial test ($p < .05$). However, in Part 5, only 7 of 18 sums of discriminabilities were less than the single estimates, which was not significant on a binomial test.

Table 3

Summation of points along the log d_s space and the actual value obtained from Davison (1991) model fits to Parts 2, 3, and 5. The difference between these two values is also reported.

Part	Bird	$d_{s24} + d_{s45}$	d_{s25}	Difference
2	61	1.463	1.553	−0.090
	62	1.172	1.729	−0.557
	63	1.289	1.677	−0.389
	64	1.573	1.701	−0.128
	65	1.386	1.608	−0.222
	66	1.615	1.609	0.006

Part	Bird	$d_{s23} + d_{s34}$	d_{s24}	Difference	$d_{s34} + d_{s45}$	d_{s35}	Difference	$d_{s23} + d_{s34} + d_{s45}$	d_{s25}	Difference
3	61	1.028	1.328	−0.300	0.971	1.647	−0.676	1.362	1.766	−0.405
	62	1.141	1.198	−0.057	1.042	0.841	0.201	1.518	1.349	0.169
	63	0.963	1.353	−0.390	1.451	2.519	−1.068	1.649	4.000	−2.351
	64	0.888	1.144	−0.256	1.128	1.392	−0.264	1.402	1.950	−0.548
	65	0.923	1.117	−0.194	1.295	1.582	−0.287	1.563	1.734	−0.171
	66	0.966	1.239	−0.273	1.314	1.450	−0.136	1.640	2.239	−0.599
5	61	2.303	1.858	0.445	1.364	1.419	−0.055	2.606	3.938	−1.332
	62	2.122	1.930	0.192	1.265	1.166	0.100	2.425	1.848	0.577
	63	1.687	1.596	0.091	1.137	1.450	−0.314	2.046	2.003	0.044
	64	3.874	1.982	1.892	2.035	1.499	0.537	4.399	2.222	2.177
	65	1.733	1.532	0.201	1.239	1.738	−0.499	2.160	2.117	0.043
	66	1.926	2.706	−0.780	1.146	1.665	−0.519	2.426	3.783	−1.357

On the basis of these results, support for the linear model of log d_s psychometric space is equivocal. However, large values of log d_s were often not precisely estimated, and changes in the parameter estimates (say, ±10%) did not have a great effect on the adequacy of the fit of the model to the data. It could be argued that the best estimates of the pairwise log d_s values would come from averaging their values in Parts 3 and 5, in which all estimates were available. When this was done, 8 of the 18 sums of log d_s values were greater than the single estimates of log d_s, which is not significant on a sign test. Further, when the log d_s values averaged over Parts 3 and 5 were used to predict the group data in all conditions of the present experiment (using only cells in which more than five responses on average were emitted), relative pairwise predictions accounted for 95% of relative pairwise response measures with a mean square error of 0.02 ($N = 327$). Thus, we can conclude that the linear metric of log d_s cannot be ruled out by the present data.

The data obtained in Part 5 can be used to determine whether a range effect occurred in the present experiment. The range effect is the finding that discrimination between two constant stimuli is affected by the range of stimuli available, and this has been shown in both human judgment (e.g., Parducci, 1974) and animal discrimination (e.g., Hinson & Tennison, 1988). Part 5 of the present experiment, in which the number of different light-intensity conditional stimuli was varied, should show range effects. In Conditions 28, 29, and 30, the stimuli presented were, respectively, S_4 and S_5; S_3, S_4, and S_5; and S_2, S_3, S_4, and S_5. We looked for changes in discrimination between S_4 and S_5 over these three conditions, and between S_3 and S_4 between Conditions 29 and 30. Over Conditions 28 to 30, using trend tests, there were no significant changes in log B_4 to B_5 total response ratios on the pairs of keys (e.g., B_4 and B_5), on log response ratios in just S_4 and S_5, or on point estimates of discriminability as measured by log d (Davison & Tustin, 1978). Similarly, between Conditions 29 and 30, there were no significant differences on these measures for B_3 and B_4. Conditions 34 and 35 arranged S_2 and S_3, and S_2, S_3, and S_5, respectively. Again, there were no significant changes in any of the above measures for B_2 and B_3. Thus, there were apparently no range effects at all in the present data. The reason for this is unclear, especially because Hinson and Tennison showed reliable range effects
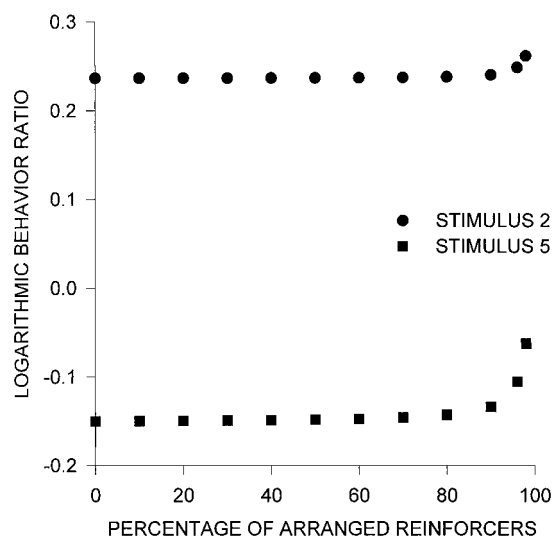
Fig. 6.   Calculated theoretical log response ratios (log $B_2|S_2/B_5|S_2$ and log $B_2|S_5/B_5|S_5$) as a function of the percentage of reinforcers arranged for R_3 and R_4. The calculations used discriminability parameters (log d_s and log d_r) averaged over all 6 subjects.

in a conditional discrimination procedure similar to that used here. However, although Hinson and Tennison used four flicker-frequency conditional stimuli, they used only two choice responses, one correct for the lower frequencies and the other correct for the higher frequencies. Perhaps the range effect depends on the mapping of more conditional stimuli onto fewer responses.

The principle of indifference from irrelevant alternatives (Luce, 1959) was supported by the present data at least at the parameter level of analysis; that is, d_s and d_r values remained constant as the number of alternatives was increased. Also, as shown above, response ratios between choices with constant reinforcer frequencies also remained constant as the number of alternatives was increased. Is this a general finding? Because the model fitted well, we can ask whether it predicts constant response ratios under all conditions. Figure 6 shows predicted response ratios for Responses 2 and 5 and Stimuli 2 and 5 as the reinforcer frequency for Responses 3 and 4 is varied from 0% through 50% to 99% of all reinforcers. It can clearly be seen that response ratios are predicted to change when most of the reinforcers come to be obtained for other choice alternatives, and that a measure of stimulus discriminability such as log d

(Davison & Tustin, 1978), which is the distance between the pairs of functions at a log reinforcer ratio of zero, would change considerably. This effect could not have been shown empirically with the present data because the variation in the percentage of reinforcers for R_3 and R_4 varied only from 0% to 50% over Parts 1 to 3, and, as Figure 6 shows, there is little change in log response ratios predicted over that range. However, the results predicted in Figure 6 are clearly amenable to further experimental testing.

In summary, Davison's (1991) model was able to account for the findings of the present study. Arranging a detection task with more than two samples and choices in the present study provided a thorough test of this model. Four findings provided support for the model. First, stimulus–response discriminability estimates reflected the physical difference between the conditional stimuli. Second, stimulus–response and response–reinforcer discriminability measures were unrelated and showed parameter independence. Third, stimulus–response discriminability parameter estimates did not change systematically as conditional stimulus–response alternatives were added. Fourth, log stimulus–response discriminability values between physically adjacent conditional stimuli summed to values that were not significantly different from estimates of the discriminability values for conditional stimuli that were spaced further apart. Finally, although this is not a formal part of the model, it was able to deal with the unusual conditions of Part 5 in which the number of sample stimuli and reinforced choices was manipulated, rather than the frequency of reinforcement, by taking into account in the analyses the apparently one-way historical effect of reinforcement for a stimulus–response alternative.

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APPENDIX

Raw data from Parts 1 to 5. Data were summed over the last five sessions from each condition for each subject. Correct and incorrect responses and the reinforcers obtained for correct responses are shown for each sample stimulus. Behavior is denoted for response j in the presence of stimulus i, B_{ij}, and reinforcers are denoted R_i.

Bird	Condi-tion	Stimulus 2					Stimulus 3				
		B_{22}	B_{23}	B_{24}	B_{25}	R_2	B_{32}	B_{33}	B_{34}	B_{35}	R_3
61	1	900	0	0	108	90	0	0	0	0	0
	2	855	0	1	14	30	0	0	0	0	0
	3	860	3	0	12	160	0	0	0	0	0
	4	889	0	0	60	60	0	0	0	0	0
	5	802	0	0	1	150	0	0	0	0	0
	6	718	3	0	75	20	0	0	0	0	0
	8	575	0	64	10	58	0	0	0	0	0
	9	589	1	45	6	18	0	0	0	0	0
	10	640	0	85	4	76	0	0	0	0	0
	11	611	0	37	26	74	0	0	0	0	0
	12	598	0	12	39	20	0	0	0	0	0
	13	601	0	46	4	134	0	0	0	0	0
	14	352	0	381	15	16	0	0	0	0	0
	15	317	187	20	9	32	191	248	82	11	35
	16	129	389	48	11	7	56	321	153	45	41
	17	194	367	1	6	36	123	426	11	12	65
	18	349	175	14	1	59	210	229	98	2	37
	19	378	127	74	12	38	140	95	338	21	8
	20	352	198	23	0	41	138	267	163	5	41
	21	178	259	30	30	17	84	268	77	72	40
	27	564	0	74	4	78	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	1	482	138	9	94
	30	352	124	4	0	90	150	245	79	9	44
	31	565	6	100	0	104	0	0	0	0	0
	32	675	3	241	1	120	0	0	0	0	0
	33	491	143	16	0	105	148	366	136	0	46
	34	734	183	4	0	120	197	704	25	0	60
	35	553	104	3	0	98	141	499	5	16	49
	36	0	0	0	0	0	21	644	6	102	120
62	1	907	1	0	27	90	0	0	0	0	0
	2	744	1	0	168	24	0	0	0	0	0
	3	948	1	0	6	160	0	0	0	0	0
	4	849	3	0	164	60	0	0	0	0	0
	5	788	0	0	31	149	0	0	0	0	0
	6	668	0	0	282	20	0	0	0	0	0
	8	565	5	69	41	47	0	0	0	0	0
	9	400	1	260	78	17	0	0	0	0	0
	10	623	2	98	17	74	0	0	0	0	0
	11	594	5	49	75	74	0	0	0	0	0
	12	421	1	101	85	15	0	0	0	0	0
	13	637	5	19	8	134	0	0	0	0	0
	14	313	1	411	50	19	0	0	0	0	0
	15	221	200	45	52	26	161	177	100	85	27
	16	83	331	61	77	5	35	269	95	149	24
	17	203	375	7	7	37	170	351	30	38	59
	18	259	293	34	3	58	160	296	115	17	34
	19	273	151	66	109	38	122	112	199	167	6
	20	176	342	104	11	34	106	285	229	16	34
	21	103	476	8	28	14	72	395	40	104	35
	27	652	18	60	93	79	0	0	0	0	0

APPENDIX

(*Extended*)

		Stimulus 4					Stimulus 5		
B_{42}	B_{43}	B_{44}	B_{45}	R_4	B_{52}	B_{53}	B_{54}	B_{55}	R_5
0	0	0	0	0	57	0	0	952	90
0	0	0	0	0	17	0	0	846	150
0	0	0	0	0	132	0	0	743	20
0	0	0	0	0	31	0	0	916	120
0	0	0	0	0	109	5	2	688	30
0	0	0	0	0	18	0	0	776	160
89	0	392	168	59	22	0	325	304	58
27	2	419	196	79	6	0	352	283	74
114	1	503	112	78	86	0	417	228	20
81	0	200	389	19	65	0	89	519	79
60	0	134	452	20	3	0	83	565	133
347	1	215	86	20	385	1	84	175	19
23	0	662	63	126	3	0	639	101	15
9	141	227	152	30	2	27	225	270	33
7	99	228	239	36	3	8	165	398	71
35	218	94	222	6	34	28	97	418	31
44	85	384	27	40	75	37	360	65	7
19	15	472	86	69	6	2	366	217	39
16	90	456	18	69	34	25	450	69	9
23	92	85	301	10	6	20	28	445	100
66	2	385	193	20	6	0	143	494	76
12	2	797	88	120	1	0	421	478	60
2	98	485	41	43	0	3	382	241	24
9	70	326	78	23	7	3	300	175	12
24	3	544	100	47	3	1	410	257	27
18	1	892	5	60	0	0	0	0	0
13	106	526	3	29	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	53	117	83	402	25
0	0	0	0	0	3	42	17	715	60
0	0	0	0	0	44	0	1	889	90
0	0	0	0	0	1	0	0	916	133
0	0	0	0	0	487	0	0	471	20
0	0	0	0	0	54	0	0	962	115
0	0	0	0	0	179	0	0	637	29
0	0	0	0	0	0	0	0	940	160
67	0	344	273	47	4	0	300	373	52
35	0	406	305	72	9	0	366	373	71
119	0	523	92	77	24	0	567	142	19
83	0	189	452	19	19	0	163	545	76
21	0	103	489	18	7	0	61	548	119
236	3	227	197	19	88	0	249	328	18
61	0	639	76	127	22	0	654	98	17
70	106	172	174	29	41	82	170	228	28
17	150	150	233	26	7	67	150	329	50
94	298	63	137	5	59	198	76	257	35
76	226	240	38	32	55	140	321	70	7
27	17	356	204	67	17	8	317	254	38
22	151	428	30	68	9	96	486	43	5
17	202	74	320	6	17	101	65	427	76
87	7	217	510	20	19	3	152	649	80

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(*Continued*)

Bird	Condi-tion	Stimulus 2					Stimulus 3				
		B_{22}	B_{23}	B_{24}	B_{25}	R_2	B_{32}	B_{33}	B_{34}	B_{35}	R_3
	28	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	422	197	32	94
	30	313	88	22	11	55	191	158	62	23	31
	31	531	10	98	20	88	0	0	0	0	0
	32	714	7	204	2	120	0	0	0	0	0
	33	315	222	17	2	71	145	296	113	3	38
	34	615	390	6	1	117	391	580	33	9	57
	35	391	265	1	8	107	142	500	11	12	45
	36	0	0	0	0	0	14	946	6	30	120
63	1	1,034	0	0	69	90	0	0	0	0	0
	2	982	0	1	39	30	0	0	0	0	0
	3	973	0	1	31	160	0	0	0	0	0
	4	816	0	0	108	60	0	0	0	0	0
	5	828	0	0	15	150	0	0	0	0	0
	6	766	2	0	183	20	0	0	0	0	0
	8	669	0	67	14	59	0	0	0	0	0
	9	672	1	28	22	20	0	0	0	0	0
	10	685	0	109	13	70	0	0	0	0	0
	11	772	0	6	27	79	0	0	0	0	0
	12	647	0	58	66	18	0	0	0	0	0
	13	608	0	24	30	140	0	0	0	0	0
	14	311	0	484	17	17	0	0	0	0	0
	15	235	183	92	19	29	173	146	191	21	31
	16	79	445	80	11	8	52	417	133	13	36
	17	104	515	12	1	27	94	487	43	9	49
	18	380	172	92	10	60	312	130	203	12	36
	19	423	98	45	6	36	236	122	193	20	9
	20	245	314	80	3	36	176	241	216	7	40
	21	223	394	20	4	18	182	402	47	9	43
	27	711	15	65	32	78	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	438	305	8	103
	30	360	167	74	8	71	254	117	216	20	33
	31	630	6	148	10	102	0	0	0	0	0
	32	775	9	187	18	120	0	0	0	0	0
	33	493	253	58	4	96	224	345	235	5	52
	34	807	248	35	2	114	490	529	68	1	57
	35	540	222	8	7	99	323	388	41	24	50
	36	0	0	0	0	0	15	883	22	48	120
64	1	752	0	0	212	90	0	0	0	0	0
	2	757	3	18	107	30	0	0	0	0	0
	3	891	0	0	56	160	0	0	0	0	0
	4	754	0	0	213	60	0	0	0	0	0
	5	773	0	0	94	150	0	0	0	0	0
	6	569	0	1	308	20	0	0	0	0	0
	8	627	2	142	21	59	0	0	0	0	0
	9	578	3	195	49	19	0	0	0	0	0
	10	525	0	233	8	80	0	0	0	0	0
	11	687	1	67	50	80	0	0	0	0	0
	12	589	1	54	82	20	0	0	0	0	0

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(*Extended*)

	Stimulus 4					Stimulus 5			
B_{42}	B_{43}	B_{44}	B_{45}	R_4	B_{52}	B_{53}	B_{54}	B_{55}	R_5
0	1	779	346	120	0	1	586	535	60
0	154	377	114	46	0	45	353	251	20
52	142	179	63	15	20	37	220	153	8
45	6	469	141	44	14	1	265	379	20
51	2	854	18	60	0	0	0	0	0
22	152	383	5	21	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	6	253	79	327	27
0	0	0	0	0	3	380	52	556	60
0	0	0	0	0	139	0	0	964	90
0	0	0	0	0	42	0	0	975	150
0	0	0	0	0	160	0	8	826	20
0	0	0	0	0	11	0	0	910	120
0	0	0	0	0	36	0	0	809	30
0	0	0	0	0	16	0	0	940	160
139	0	299	311	60	18	0	196	536	59
67	2	402	248	78	46	0	245	425	79
198	1	459	144	73	68	0	448	292	20
160	0	186	459	20	17	0	122	671	80
124	0	236	410	20	5	0	52	712	140
60	0	382	220	20	4	0	307	347	20
41	0	737	29	113	5	1	724	79	14
62	67	249	148	35	30	28	131	337	29
14	113	288	191	39	1	31	109	467	66
50	270	140	174	6	14	87	100	431	31
63	78	446	67	30	3	10	552	89	6
41	32	349	148	62	1	3	229	335	36
44	68	481	46	75	16	13	491	122	7
71	257	181	131	9	10	24	37	569	98
191	27	404	200	20	0	4	95	725	80
42	4	955	139	120	2	1	510	627	60
0	96	589	68	50	0	1	433	315	26
36	39	379	157	16	9	20	308	266	8
35	5	592	164	50	1	1	519	281	25
15	9	943	24	60	0	0	0	0	0
8	71	710	15	25	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	13	97	161	507	24
0	0	0	0	0	0	28	11	929	60
0	0	0	0	0	106	0	0	857	90
0	0	0	0	0	19	0	0	865	150
0	0	0	0	0	253	0	5	693	20
0	0	0	0	0	33	0	0	942	120
0	0	0	0	0	31	0	1	833	30
0	0	0	0	0	2	0	0	873	160
87	2	444	260	59	17	0	325	454	59
22	1	534	274	77	5	1	396	427	75
77	1	594	95	80	87	1	399	283	20
81	0	290	435	20	28	0	98	680	80
59	1	255	416	20	20	0	65	643	140

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(*Continued*)

Bird	Condition	Stimulus 2					Stimulus 3				
		B_{22}	B_{23}	B_{24}	B_{25}	R_2	B_{32}	B_{33}	B_{34}	B_{35}	R_3
	13	763	0	10	9	140	0	0	0	0	0
	14	359	0	405	21	19	0	0	0	0	0
	15	251	246	39	28	31	180	207	122	50	30
	16	130	376	102	35	9	54	333	209	45	43
	17	200	448	18	5	33	174	431	44	22	61
	18	297	303	73	4	68	186	296	186	8	41
	19	411	61	146	7	34	255	64	283	18	6
	20	218	361	81	3	31	113	314	228	7	36
	21	129	478	40	28	20	91	408	94	81	44
	27	593	4	72	31	78	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	5	589	198	12	102
	30	437	143	42	2	89	263	255	99	9	41
	31	612	12	135	5	101	0	0	0	0	0
	32	766	11	178	1	120	0	0	0	0	0
	33	544	171	70	0	108	197	450	141	1	48
	34	551	456	37	0	120	141	822	89	2	60
	35	521	284	8	3	98	218	549	26	22	54
	36	0	0	0	0	0	1	919	43	56	120
65	1	925	1	0	79	90	0	0	0	0	0
	2	964	3	0	55	30	0	0	0	0	0
	3	977	1	0	14	160	0	0	0	0	0
	4	962	2	0	139	60	0	0	0	0	0
	5	996	0	0	46	150	0	0	0	0	0
	6	807	2	0	117	20	0	0	0	0	0
	8	656	2	127	53	53	0	0	0	0	0
	9	387	9	255	174	15	0	0	0	0	0
	10	746	1	91	11	77	0	0	0	0	0
	11	785	1	23	37	78	0	0	0	0	0
	12	547	28	87	143	20	0	0	0	0	0
	13	609	2	27	22	140	0	0	0	0	0
	14	468	1	451	16	16	0	0	0	0	0
	15	254	336	54	16	35	173	291	157	43	33
	16	102	438	30	51	7	66	373	114	71	40
	17	200	417	6	23	40	142	441	17	45	79
	18	359	200	45	2	57	236	201	155	14	40
	19	438	20	134	32	29	253	22	324	29	4
	20	288	253	105	15	36	142	204	296	13	34
	21	147	414	31	46	18	87	423	48	76	40
	27	731	3	36	6	80	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	0	502	274	22	98
	30	365	153	27	8	92	218	257	63	14	45
	31	638	1	101	10	104	0	0	0	0	0
	32	802	6	146	4	120	0	0	0	0	0
	33	482	216	23	1	100	249	344	130	0	50
	34	831	396	15	3	120	490	687	57	7	60
	35	460	322	3	15	97	263	494	5	41	49
	36	0	0	0	0	0	5	898	2	63	120

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(*Extended*)

		Stimulus 4					Stimulus 5		
B_{42}	B_{43}	B_{44}	B_{45}	R_4	B_{52}	B_{53}	B_{54}	B_{55}	R_5
202	0	445	132	20	148	1	247	384	20
12	0	706	73	137	6	0	627	153	20
63	85	264	153	29	18	40	217	287	29
3	123	329	191	43	1	18	216	409	68
70	334	96	168	6	30	165	92	381	31
75	178	373	54	37	13	29	480	157	7
83	11	424	104	65	16	8	388	217	36
25	190	402	41	70	18	71	432	142	6
31	199	104	343	9	7	24	41	603	104
17	6	324	352	20	1	2	151	549	79
3	2	656	188	120	2	4	309	541	60
9	154	559	81	46	21	16	423	347	21
40	217	313	62	21	15	123	212	283	11
21	9	630	106	52	13	5	328	417	22
33	2	907	19	60	0	0	0	0	0
5	320	461	5	20	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	12	309	122	372	26
0	0	0	0	0	12	351	142	513	60
0	0	0	0	0	15	1	0	987	90
0	0	0	0	0	16	2	0	1,000	150
0	0	0	0	0	49	1	1	936	20
0	0	0	0	0	4	0	0	1,103	120
0	0	0	0	0	9	1	0	1,032	30
0	0	0	0	0	24	0	0	893	160
14	0	598	225	52	3	0	512	317	54
27	0	618	181	59	1	1	611	220	64
52	2	752	47	78	9	2	683	158	19
28	0	193	627	20	0	0	140	711	78
12	3	182	622	20	2	0	162	657	140
52	2	345	266	20	15	4	240	404	20
18	0	884	36	112	3	1	862	71	15
49	67	462	82	33	10	9	497	149	29
15	123	334	149	40	3	15	354	249	72
49	320	115	162	7	15	40	173	420	35
77	108	373	48	40	41	39	336	190	5
39	5	500	83	54	3	5	420	195	27
14	65	546	33	71	2	17	514	125	6
9	129	165	336	9	0	9	144	488	105
51	8	446	272	20	4	0	170	606	80
0	0	773	244	120	0	0	251	768	60
1	115	485	185	52	1	12	263	519	27
41	127	326	62	24	6	6	245	294	11
19	0	529	201	49	1	0	219	536	27
10	3	876	61	60	0	0	0	0	0
13	165	537	6	26	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	5	43	11	743	29
0	0	0	0	0	0	23	3	938	60

APPENDIX

(*Continued*)

Bird	Condi-tion	Stimulus 2					Stimulus 3				
		B_{22}	B_{23}	B_{24}	B_{25}	R_2	B_{32}	B_{33}	B_{34}	B_{35}	R_3
66	1	892	0	0	65	90	0	0	0	0	0
	2	844	5	0	42	30	0	0	0	0	0
	3	780	0	0	7	160	0	0	0	0	0
	4	856	5	0	49	60	0	0	0	0	0
	5	949	0	0	4	150	0	0	0	0	0
	6	690	1	0	162	20	0	0	0	0	0
	8	562	0	38	20	53	0	0	0	0	0
	9	491	0	77	44	18	0	0	0	0	0
	10	635	0	59	2	79	0	0	0	0	0
	11	608	0	16	10	80	0	0	0	0	0
	12	444	0	27	79	16	0	0	0	0	0
	13	521	1	0	1	140	0	0	0	0	0
	14	423	0	177	38	19	0	0	0	0	0
	15	264	282	4	1	36	188	304	58	5	43
	16	59	466	20	2	7	22	358	138	28	31
	17	92	460	2	0	28	83	461	10	0	50
	18	276	178	30	0	59	162	209	108	1	32
	19	383	68	128	1	36	160	54	365	5	7
	20	244	256	67	1	34	69	188	303	6	32
	21	114	286	34	21	14	67	275	60	56	34
	27	658	0	24	10	80	0	0	0	0	0
	28	0	0	0	0	0	0	0	0	0	0
	29	0	0	0	0	0	2	530	135	13	104
	30	415	91	3	2	83	308	174	23	4	42
	31	627	0	18	0	100	0	0	0	0	0
	32	733	0	28	1	120	0	0	0	0	0
	33	499	250	11	0	101	288	291	173	5	51
	34	544	274	0	0	120	292	525	0	0	60
	35	436	181	0	0	95	296	312	3	0	39
	36	0	0	0	0	0	4	800	1	11	120

APPENDIX

(*Extended*)

	Stimulus 4					Stimulus 5			
B_{42}	B_{43}	B_{44}	B_{45}	R_4	B_{52}	B_{53}	B_{54}	B_{55}	R_5
0	0	0	0	0	38	0	0	920	90
0	0	0	0	0	31	3	1	853	150
0	0	0	0	0	23	0	0	762	20
0	0	0	0	0	11	2	1	896	120
0	0	0	0	0	27	2	0	915	30
0	0	0	0	0	3	3	0	853	160
93	0	323	201	53	17	0	277	325	56
24	0	381	212	62	9	0	292	310	60
60	0	560	75	77	37	0	470	185	20
47	0	163	425	18	6	0	83	550	74
22	0	81	452	16	2	0	40	513	120
83	2	230	205	19	28	1	218	275	19
20	0	555	57	128	5	0	490	145	18
41	123	295	93	35	9	59	228	253	35
3	102	269	175	34	2	58	172	314	65
56	321	93	85	6	10	124	73	341	32
40	173	235	34	35	17	94	217	150	7
32	38	442	68	60	12	21	299	250	31
13	111	422	23	64	11	89	357	119	7
14	91	119	232	6	4	13	36	403	83
146	3	281	265	20	5	2	76	611	80
2	1	679	208	120	0	0	116	778	60
0	155	432	90	50	1	18	162	491	26
36	124	242	109	19	9	11	124	370	10
50	8	508	72	55	10	1	302	323	20
7	1	750	12	60	0	0	0	0	0
31	146	565	12	28	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	15	247	118	231	23
0	0	0	0	0	1	16	2	800	60