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RESPONSE RESTRICTION AND SUBSTITUTION WITH AUTISTIC CHILDREN

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Few studies to date have examined time reallocation in naturalistic, multiresponse human repertoires when one or more responses are restricted. For this experiment, free-operant baseline levels of six responses were measured for four autistic children. The high-probability responses were made unavailable, one at a time, such that subjects had access to five, four, three, and two responses in successive restriction conditions. A return to the six-response free-operant baseline condition completed the experiment. Results were compared to predictions made by four time-reallocation models. These results were described accurately only by the selective substitution model. Further analyses examined alternative explanations for the individual reallocation patterns obtained. An expanded selective substitution definition is proposed that may characterize orderly patterns observed in multiresponse repertoires under restriction conditions more accurately than the other existing models.

Key words: response restriction, response substitution, reinforcement, time reallocation, autistic children

Considerable research has focused on identifying the variables that contribute to an increase in the level of one response when a contingency is established between two responses. Some studies have shown that mere restriction of one response in a pair is sufficient to produce an increase in the other response, independent of any contingent relation (e.g., Allison & Timberlake, 1974; Bernstein, 1974; Dunham, 1972; Timberlake, 1979). Few studies, however, have restricted access to one response and examined the effects on two or more other responses (Dunham, 1977; Knapp, 1976; Konarski, Crowell, Johnson, & Whitman, 1982; Konarski, Johnson, Crowell, & Whitman, 1981; but see, e.g., Lyons & Cheney, 1984; Rojahn, Mulick, McCoy, & Schroeder, 1978). Bernstein and Ebbesen (1978) were among the first to point out that restriction of one response may result in differential changes in the levels of several other responses in a subject's repertoire due to preexisting relationships among the responses. In fact, in their research with adults, Bernstein and Ebbesen (1978) found that responses substituted for one another selectively. That is, when a contingency restricted access to one response, subjects did not distribute the additional available time among several remaining responses proportionate to the relative baseline probabilities of those responses, but rather spent most of their time on one other response. An important implication of this finding is that when a contingency consists of instrumental and contingent responses that are substitutable, the instrumental response may increase substantially merely because the contingent response is unavailable. Conversely, if responses are not substitutable, increases in the instrumental response should be the result of the contingency alone (Bernstein & Ebbesen, 1978).

Separating the effects of a contingency from the effects of response restriction is especially difficult when responses are temporally extended, because restricting one response (relative to its baseline level) leaves time available to be filled with any of several alternative responses (Lyons & Cheney, 1984). Several models have been developed, some of which attempt to predict which of two or more alternative responses will substitute for re-

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stricted responses. The various models propose that when a response is restricted:

1. The remaining responses will occupy the same proportion of available time as they did in baseline. This has been called the constant-ratio rule (Luce, 1959; Rachlin & Burkhard, 1978).

2. The most probable remaining alternative will increase disproportionately, and the response most sequentially dependent on the restricted response will decrease while other responses maintain their baseline levels. This has been called the most probable remaining response rule (Dunham & Grantmyre, 1982).

3. Newly available time will be redistributed equally among remaining responses. This has been called the equal redistribution rule (Lyons & Cheney, 1984).

4. Time reallocation will be unique for each individual and must be determined empirically before a contingency is established. This has been called the selective substitution rule (Bernstein & Ebbesen, 1978).

At present, little is known about the applicability of the first three models to the multiresponse repertoires of humans, or about the generality of Bernstein and Ebbesen's (1978) selective substitution findings. In many everyday situations with humans, constraints are imposed on certain classes of behavior while other classes remain unconstrained, independent of any particular reinforcement schedule requirements that may be in effect. A number of variables (e.g., response topographies, recent reinforcement histories, existing response classes, other response interrelationships) may account for response patterns following restriction of particular responses (Thompson & Lubinski, 1986). Evidence as to how these variables operate on naturalistic human repertoires would contribute not only to a better conceptualization of the reinforcing properties of contingent access in ordinary human behavior (Bernstein, 1982), but also to applications of behavior-change technology (Wahler, 1975).

Response-restriction effects in multiresponse repertoires can be examined in a number of ways. One method, as demonstrated by Bernstein and Ebbesen (1978), is to devise a contingency involving two responses and then track changes occurring not only in the instrumental response but also in other selected responses when the contingent response is restricted. Another approach is to structure an arbitrary multiresponse repertoire for the subject and then systematically remove the opportunity to engage in one or more responses without imposing a contingency (Dunham, 1977). In a recent study, Lyons and Cheney (1984) used the latter method to examine response-restriction effects with rats. They tested each of the aforementioned predictive rules and found none except Bernstein and Ebbesen's to be valid under the conditions of their experiment. That is, response substitution patterns were idiosyncratic. The present study attempted a similar analysis, using four autistic children as subjects.

In the present study, a different six-response repertoire was used for each subject. Materials enabling all responses programmed for each experimental condition were made available to the subject in a small room. An experimenter recorded the occurrence of all responses and a residual category of other responses, using a partial-interval recording method to estimate proportions of session time taken up by each response. Lyons and Cheney (1984) restricted either a low- or a high-probability response and interposed a six-response baseline condition between restriction conditions. In the present study, the highest probability programmed response was removed in successive conditions, beginning with a six-response baseline and removing access to one programmed response in each subsequent condition until only two programmed responses remained available. The final condition was a return to the six-response baseline. Results were analyzed for comparison with predictions made by the four models described above (except the sequential-dependencies component of the Dunham and Grantmyre model), and for patterns of response substitution.

METHOD

Subjects

Four children classified as autistic by a multidisciplinary assessment team and exhibiting the behavioral characteristics of autism as defined by the National Society for Autistic Children (Ritvo & Freeman, 1978) served as subjects. All of the children attended a day treatment program for autistic and autistic-like children. Selection of these subjects arose

Table 1

Subject characteristics.

Subject	Gender	Chronological age	Mental age (Instrument)
1	Male	10 years 10 months	3 years 11 months (Stanford-Binet)
2	Male	6 years 8 months	4 years 6 months (Stanford-Binet)
3	Female	7 years 2 months	18.5 mos./25.5 mos. (Bayley Mental/Motor Scales)
4	Male	6 years 0 months	14.5 months (Slosson)

from a practical need to identify activity reinforcers to use in their daily training programs and the necessity of empirically determining the relative probabilities of responses that might serve to reinforce other responses. Individual subjects are described in Table 1.

Setting

Experimental sessions were conducted in one of two small rooms, each containing two chairs and one small table or desk. One of the rooms also contained other equipment that was screened from the subject's view. Sessions were conducted once per school day and lasted approximately 10 min. Sessions began with the experimenter saying to the child, "Here are some things for you to play with." Materials for each session were arranged randomly on the table in front of the subject. No other instructions were given, and the experimenter did not interact further with the subject except as necessary to ensure the subject's safety (e.g., to remove any small object placed in the mouth, or to prohibit climbing on furniture).

Response Selection and Definitions

The children's classroom teacher and the first investigator selected six responses to serve as programmed responses for each subject. The only constraints imposed on this selection were that materials enabling all responses had to be available or potentially available in the classroom, and each response had to be either a play activity or of some adaptive value to the child (e.g., self-help, academic, or motor activities). Materials for programmed responses for each subject are listed in Table 2. Throughout the experiment a child was considered to be engaged in a programmed response if his or her head was oriented toward or he or she had physical contact with the materials for one of the programmed responses (see Bernstein & Ebbesen, 1978). A category of responses, labeled the residual category, included any behavior that occurred when the subject's head was not oriented toward, nor did he or she have contact with materials for, any of the programmed responses (see Lyons & Cheney, 1984).

Recording and Agreement

A partial-interval recording method was used to estimate the relative probability of occurrence of each response. Sessions were divided into 20 intervals, each 30 s in duration, marked by an audiotape signal that was audible only to the experimenter via an earphone. A letter code was used for each response, with the letter "O" designated for the residual category as defined above. The letter code was recorded for each response that occurred at any time during the interval, but a particular response was recorded only once regardless of how many times it recurred during an interval. A partial-interval recording method such as this is likely to yield an overestimate of actual

Table 2

Materials for programmed responses for each subject.

Subject 1	Subject 2	Subject 3	Subject 4
Calculator	Puzzle	Toy radio	Rocking chair
Number puzzle	Picture book	Puzzle	Plastic letters
Plastic letters	Writing worksheet	Picture book	Pegboard
Writing worksheet	Crayons and picture	Pegboard	Crayon and paper
Distar reading worksheet	Distar reading worksheet	Pencil and paper	Picture book
Picture book	Rocking chair	Clothespins	Toy car

response duration but is sensitive to relative changes in duration (Harrop & Daniels, 1986). This was also the most feasible method available to document several responses that potentially could occur in rapid succession, because no automated multiple-event recorder was available when the study began. At the end of each session, the percentage of intervals during which each of the programmed responses and responses in the residual category occurred was calculated and used as the estimate of the relative probability of each response. Because it was possible that more than one response could occur in any interval, the sum of percentages for all responses for any given session could (and often did) exceed 100%.

At least one interobserver agreement check per condition was conducted. An exact agreement method was used to determine agreements and disagreements (see Repp, Deitz, Boles, Deitz, & Repp, 1976). That is, both observers must have recorded exactly the same response codes for an interval to be scored an agreement; otherwise it was scored a disagreement. Because the absence of subject contact with any of the available materials was recorded as an occurrence in the residual category, there were no unscored intervals. The exact agreement method provided a conservative index of interobserver agreement. Agreement percentages were calculated by dividing the number of intervals on which there was complete agreement by the total number of intervals and multiplying by 100% (Kelly, 1977). Interobserver agreement ranged from 65% to 100%, with means of 87%, 92%, 87%, and 89% for the 4 subjects across all conditions.

Although absolute response duration has been suggested to be the optimal measure of response probability (Konarski et al., 1981; Premack, 1965), other methods may provide accurate estimates of durations for purposes of evaluating relative probabilities among several responses. To compare the interval estimates used in this study with duration measures, sessions identical to the six-response baseline condition used in the study were videotaped several months after the study was completed. One observer recorded actual durations of responses, while a second observer used the 30-s partial-interval method employed in the study. Data obtained by each method were then used to rank order the responses for each session, with a rank of 1 assigned to the highest probability response. These rankings were compared. The two measurement methods assigned the same rankings in 45 of 54 cases (83.3% agreement), suggesting that the partial-interval method compared favorably with absolute duration measures in assessing the relative probabilities of several responses.

Design and Procedures

A modified multiple baseline design across subjects was used. At least three sessions were conducted per condition for Subject 1, with each subsequent subject remaining in a condition for a minimum of two sessions more than the preceding subject. A condition was terminated when one programmed response could be designated the highest probability response, that is, when it occurred (a) in a higher percentage of intervals per session than the other available programmed responses (excluding residual); and (b) when the percentage of intervals in which that response occurred in a session was no more than one standard deviation above or below the mean percentage for the last three consecutive sessions (stability criterion). The stability criterion was not a stringent one, but in conjunction with the first criterion it provided more objective means than visual inspection to identify the highest probability programmed response. If this dual criterion was not met within three sessions after the multiple baseline requirement was met, the condition was extended until criterion was attained or to a maximum of 10 sessions. When 10 sessions were required (12 of 24 conditions), designation of the highest probability programmed response was based on the mean percentage of intervals in which each programmed response occurred across all 10 sessions.

The baseline condition consisted of providing the subject with access to all six programmed responses. Once criterion was met, or 10 sessions were completed, the second condition was initiated by removing materials for the highest probability programmed response of the initial six, so that only five programmed responses were available. The residual category of other behaviors was always available. Access to the highest probability programmed response was restricted in each of the next three conditions, so that the subject had access to four, then three, then two responses. A return to the six-response baseline completed the design.

RESULTS

Restriction and Substitution

For each restriction condition, proportions of time spent on each response in the preceding condition were treated as indicators of free-access operant levels. Table 3 shows the obtained values (mean percentage of intervals) of each response in baseline and restriction conditions, as well as the values predicted by the constant-ratio and equal-redistribution models. Comparisons between obtained values and values predicted by the constant-ratio model permit inferences as to whether newly available time was distributed proportionately or disproportionately in each restriction condition. A disproportionate increase in a response was defined arbitrarily as an obtained value, calculated on all recorded intervals, at least 10% higher than the value predicted by the constant-ratio model.

According to Bernstein and Ebbesen (1978), response substitution is unselective if time made available by restricting one response is distributed among the remaining responses in proportion to their operant levels. When an unrestricted response increases disproportionately, substitution is said to be selective. In the Bernstein and Ebbesen research with normal adults, only one of the remaining responses increased disproportionately in a restriction condition. As Table 3 shows, if the definition of selective substitution is expanded to include disproportionate increases in either one or two responses, substitution by these subjects was selective in most cases. By this analysis, selective substitution (indicated by asterisks in Table 3) occurred in 13 of 16 cases: in all four restriction conditions for S1 and S2, in three conditions for S4, and in two conditions for S3. Disproportionate increases were evident in only one response in nine of these cases and for two responses in four cases, whereas all other remaining responses occurred at or below levels expected if redistribution were proportional.

Predictive Models

Constant-Ratio and Equal-Redistribution Models

For each of the restriction conditions except those in which obtained values were 0 or 100%, Table 3 shows the obtained value and limits of a 95% confidence interval for each response, followed by the values predicted by the constant-ratio and equal-redistribution rules (cf. Lyons & Cheney, 1984). The obtained values for each condition served as free-access baseline values for comparison with restriction effects in the subsequent condition. These data did not permit analysis of the sequential-dependencies component of the Dunham and Grantmyre (1982) model, because the sequence in which responses occurred was not recorded.

In all, across all four restriction conditions when all the programmed responses and the residual category of other behavior were included, a total of 66 comparisons were made between the obtained response values and values predicted by the constant-ratio and equal-redistribution rules. Fifty-one comparisons were possible when only the programmed responses were considered. In six cases overall, the obtained values were either 0 or 100% so no confidence intervals could be set, but in all other cases it was possible to determine whether the predicted values fell within the confidence intervals around the obtained values.

These results were equivocal with regard to both the constant-ratio and equal-redistribution models. When all responses including the residual other category were considered, values predicted by the constant-ratio rule were within limits of the obtained value in 15 of the 66 cases; values predicted by the equal-redistribution rule were accurate in 10 cases; and both models predicted values within the limits of obtained values in nine cases. Neither model's predicted values fell within the limits of obtained values in the remaining 32 of 66, or almost half, of these comparisons. When the residual category was excluded, the constant-ratio rule predicted accurately in 12 of 51 cases, the equal-redistribution rule held in five cases, both predicted accurately in 10 cases, and neither in 24 cases.

Correlational analyses present a somewhat different picture of the relation between the results obtained here and these two models. Pearson product-moment correlation coefficients were calculated for all comparisons between the obtained response values and values predicted by the constant-ratio and equal-redistribution models. Table 4 displays the coefficients obtained for each of the restriction con-

Table 3

Obtained and predicted response values in two baseline and four restriction conditions.

	Restriction condition (number of available responses)						
	6	5			4		
			Predicted			Predicted	
Response by subject	(Baseline)	Obtained (95% confidence int.)	Constant ratio	Equal redist.	Obtained (95% confidence int.)	Constant ratio	Equal redist.
S1							
Number puzzle	61	—	—	—	—	—	—
Calculator	43	78 (63.6-91.4)	85	53	—	—	—
Letters	3	25 (9.7-40.3)*	6	13	87 (78.4-95.6)*	46	41
Writing	0	5 (0-10.7)	0	10	4 (0-9.9)	9	21
Distar	0	3 (0-7.4)	0	10	6 (.1-11.9)	6	19
Book	0	1 (0-1.8)	0	10	1 (0-2.96)	0	16
(Residual)	(17)	(62) (42.3-81.5)*	(33)	(27)	(16) (4.4-27.6)	(100)	(78)
S2							
Writing	45	—	—	—	—	—	—
Puzzle	23	97 (94.5-99.5)*	42	31	—	—	—
Distar	1	0	1	8	21 (3.3-37.7)*	0	20
Crayons and picture	1	0	1	9	8 (0-16.2)	0	20
Book	0	0	0	8	6 (0-12.5)	0	20
Rocker	0	0	0	8	1 (0-2.96)	0	20
(Residual)	(30)	(4) (1-6)	(55)	(38)	(79) (65.3-92.7)	(100)	(23)
S3							
Puzzle	55	—	—	—	—	—	—
Radio	36	55 (36.5-72.5)	53	45	—	—	—
Book	12	11 (1.1-19.9)	18	21	70 (51-89)*	15	21
Pegboard	21	24 (10.2-36.8)	31	30	27 (10.6-42.4)	34	34
Clothespins	21	20 (7.8-32.2)	21	29	17 (3.8-29.2)	30	31
Pencil & Paper	8	9 (1.7-16.3)	11	16	13 (2.5-22.5)	14	20
(Residual)	(20)	(52) (39.2-63.8)*	(28)	(28)	(50) (37.5-61.5)	(76)	(62)
S4							
Pegboard	33	—	—	—	—	—	—
Crayon & Paper	2	55 (21.2-87.8)*	3	7	—	—	—
Letters	12	42 (26.8-56.2)*	16	18	66 (46.3-84.7)	58	52
Rocker	29	15 (6.3-22.7)	38	34	15 (5.8-24.2)	20	25
Car	5	5 (2.1-6.9)	7	11	17 (7.1-25.9)*	6	15
Book	1	3 (.5-5.5)	1	6	10 (4-15)	4	14
(Residual)	(50)	(72) (59.1-84.9)	(66)	(55)	(69) (59.4-78.6)	(100)	(83)

Note: Values are in mean percentage of intervals. * indicates selective substitution.

ditions and across all restriction conditions. All coefficients were statistically significant ($p < .05$). Overall there was a moderate, positive relation between the obtained response values and each of the models, which was slightly stronger for the constant-ratio than for the equal-redistribution model. Correlations based on the two models were similar for all restriction conditions except the four-response condition, in which the coefficients differed considerably (constant ratio $r = .66$; equal redistribution $r = .46$).

A more meaningful issue for relative response probability problems is the degree of association between the rank orders of responses obtained in the experiment and those predicted by the constant-ratio and equal-redistribution models. Table 5 displays rank-order correlation coefficients (Spearman rho with tied ranks) calculated for each restriction condition and across conditions. Response values of less than 10% of all recorded intervals were judged too unreliable to enter into rankings; therefore the data used in calculating these coefficients were restricted to those cases in which both the obtained and predicted values

Table 3 (*Continued*)

	Restriction condition (number of available responses)						
	3			2			6
		Predicted			Predicted		
Response by subject	Obtained (95% confidence int.)	Constant ratio	Equal redist.	Obtained (95% confidence int.)	Constant ratio	Equal redist.	(Baseline)
S1							
Number puzzle	—	—	—	—	—	—	100
Calculator	—	—	—	—	—	—	8
Letters	—	—	—	—	—	—	3
Writing	45 (27.5–61.5)*	17	26	—	—	—	0
Distar	10 (2.1–16.9)	21	28	54 (31.5–76.1)*	15	25	0
Book	24 (8.7–39.3)*	4	23	4 (0–11.1)	39	39	0
(Residual)	(42) (24.1–58.9)	(68)	(38)	(47) (21.8–73.2)	(66)	(56)	(17)
S2							
Writing	—	—	—	—	—	—	80
Puzzle	—	—	—	—	—	—	13
Distar	—	—	—	—	—	—	1
Crayons and picture	25 (15.6–34.4)*	10	13	—	—	—	5
Book	7 (2.4–10.6)	8	11	49 (34–63)*	8	15	8
Rocker	0	1	6	43 (35.1–49.9)*	0	9	4
(Residual)	(80) (71.2–88.8)	(96)	(84)	(64) (54.6–73.4)	(100)	(89)	(8)
S3							
Puzzle	—	—	—	—	—	—	66
Radio	—	—	—	—	—	—	62
Book	—	—	—	—	—	—	31
Pegboard	21 (11.1–29.9)	44	44	—	—	—	7
Clothespins	13 (.7–24.3)	27	34	9 (4.7–12.3)	18	16	2
Pencil & Paper	9 (0–17.3)	20	30	4 (.3–7.7)	10	12	0
(Residual)	(89) (80.1–96.9)	(83)	(67)	(93) (88.9–97.1)	(100)	(92)	(5)
S4							
Pegboard	—	—	—	—	—	—	21
Crayon & Paper	—	—	—	—	—	—	12
Letters	—	—	—	—	—	—	22
Rocker	41 (27.7–54.3)*	24	32	—	—	—	48
Car	12 (4–20)	26	33	7 (3.5–10.9)	17	26	3
Book	5 (2.1–7.9)	15	26	4 (1.2–6.6)	7	19	2
(Residual)	(85) (73–97)	(100)	(86)	(100)	(100)	(99)	(65)

exceeded 10% so that a ranking could be assigned. Sample sizes are noted in parentheses in Table 5. Coefficients for both models in the five-response and four-response conditions and overall attained statistical significance ($p < .05$). For both models, the magnitude of the correlation decreased across successive restriction conditions, that is, as the subjects had fewer responses available. The overall coefficients for the two models were nearly identical and indicated that there was a moderate positive correlation between obtained rank orders and the rank orders predicted by each of these models.

Most Probable Remaining Response Model

Comparing obtained values from one condition to the next provided evidence about the most probable alternative rule, that is, instances in which the most probable remaining response, determined from the preceding condition, substituted for a restricted response. These comparisons are presented in Table 6, where the value of the second most probable response in each condition is underlined and substitutions by the most probable remaining response in subsequent restriction conditions are indicated by asterisks. All responses were

Table 4
Correlations between obtained values and values predicted by two models.

Model	Restriction conditions—number of responses available				
	5	4	3	2	Overall
Constant ratio	.69*	.66*	.87*	.74*	.73*
Equal redistribution	.66*	.46*	.85*	.78*	.67*
	$n = 24$	$n = 20$	$n = 16$	$n = 12$	$n = 72$

* Significant: $p < .05$.

considered here, including the residual category. For these comparisons, substitution by the most probable alternative was considered to occur when there was an increase, calculated on all recorded intervals, of 10% or more in the level of the most probable alternative response *and* all other responses either stayed the same, decreased, or increased by less than 10% (Dunham & Grantmyre, 1982). As Table 6 shows, the most probable remaining response substituted for a restricted response in only two cases, and in one of those cases redistribution was to the residual category (i.e., anything except one of the remaining programmed responses; S3, three-response condition).

Some interesting redistribution patterns may be noted here. To review, the residual category could never feasibly be restricted; subjects could always engage in behavior other than a programmed response. The response that was restricted was always the *programmed* response that had the highest rank order in the preceding condition. Consequently, the residual category was frequently the first- or second-ranked response category. In fact, for S4 it was the highest ranked category in all conditions, although at least one or two of the programmed responses also occurred in a high percentage of recording intervals in almost every condition. For the other 3 subjects, however, in baseline conditions when six programmed responses were available and in some restriction conditions when at least four programmed responses were available, relatively little time was consumed by unprogrammed responses. In addition, for S1 there were three restriction conditions (four, three, and two responses available) in which the residual category was the most probable remaining alternative, but the subject engaged in one of the remaining programmed responses more than any other, including responses in the residual category. In fact, for S1 a programmed response was the highest ranked in every condition. For S2, once the two most probable programmed responses were restricted, much of the newly available time was redistributed to the residual category. Subject 3 presented a mixed picture: In baseline and two restriction conditions a programmed response was the highest ranked, although responses in the residual category occurred in half of the intervals. In one of those conditions the residual category was the most probable remaining alternative. However, once three high-probability programmed responses were restricted, responses in the residual category occurred most of the time and the remaining programmed responses occurred rarely. In all, there were six cases in which the broadly defined residual category was the most probable remaining alternative, and in only one of those cases was newly available time redistributed to that category instead of to a programmed response category.

Redistribution was also examined with reference to programmed responses only, exclud-

Table 5
Correlations between obtained rank orders and rank orders predicted by two models.

Model	Restriction conditions—number of responses available				
	5	4	3	2	Overall
Constant ratio	.82* (11)	.62* (11)	.36 (11)	−.25 (5)	.65 (38)
Equal redistribution	.72* (12)	.67* (14)	.45 (12)	0 (6)	.66 (44)

Note: * Significant: $p < .05$. Numbers in parentheses are sample sizes.

Table 6
Substitution by most probable alternative: obtained response values and rank orders in two baseline and four restriction conditions.

	Responses by Subject	Condition (number of available responses): 6 (Baseline)	5	4	3	2	6 (Baseline)
S1	Number puzzle	61 (1)	—	—	—	—	100 (1)
	Calculator	43 (2)	78 (1)	—	—	—	8
	Letters	3	25 (3)	87 (1)	—	—	3
	Writing	0	5	4	45 (1)	—	0
	Distar	0	3	6	10 (4)	54 (1)	0
	Book	0	1	1	24 (3)	4	0
	Residual	17 (3)	62 (2)	16 (2)	42 (2)	47 (2)	17 (2)
S2	Writing	45 (1)	—	—	—	—	80 (1)
	Puzzle	23 (3)	97 (1)	—	—	—	13 (2)
	Distar	1	0	21 (2)	—	—	1
	Crayons and picture	1	0	8	25 (2)	—	5
	Book	0	0	6	7	49 (2)	8
	Rocker	0	0	1	0	43 (3)	4
	Residual	30 (2)	4	79 (1)	80 (1)	64 (1)	8
S3	Puzzle	55 (1)	—	—	—	—	66 (1)
	Radio	36 (2)	55 (1)*	—	—	—	62 (2)
	Book	12 (6)	11 (5)	70 (1)	—	—	31 (3)
	Pegboard	21 (3.5)	24 (3)	27 (3)	21 (2)	—	7
	Clothespins	21 (3.5)	20 (4)	17 (4)	13 (3)	9	2
	Pencil and paper	8	9	13 (5)	9	4	0
	Residual	20 (5)	51 (2)	50 (2)	89 (1)*	93 (1)	5
S4	Pegboard	33 (2)	—	—	—	—	21 (4)
	Crayon and paper	2	55 (2)	—	—	—	12 (5)
	Letters	12 (4)	42 (3)	66 (2)	—	—	22 (3)
	Rocker	29 (3)	15 (4)	15 (4)	41 (2)	—	48 (2)
	Car	5	5	17 (3)	12 (3)	7	3
	Book	1	3	10 (5)	5	4	2
	Residual	50 (1)	72 (1)	69 (1)	85 (1)	100 (1)	65 (1)

Note: Values are in mean percentages of intervals. * indicates substitution by most probable alternative. Values of the most probable alternatives for succeeding conditions are underlined. Numbers in parentheses indicate rank orders for responses occurring in at least 10% of recording intervals.

ing the residual category. There were seven cases in which a programmed response became the highest probability response after another programmed response was restricted: In all four restriction conditions for S1, in the five-response condition for S2, and in the five- and four-response conditions for S3. In four of those seven cases, the second most probable *programmed* response in the preceding condition was the recipient of newly available time in the restriction condition.

Individual Response Patterns

Successive restriction of high-probability programmed responses resulted in marked redistribution of available time among remaining responses in most conditions for most of these subjects, but patterns differed for each subject. In addition to the general trends already noted, S3 and S4 tended to spend increasing amounts of session time engaged in responses in the residual category with each successive restriction. For all 4 subjects, the response that occurred at the highest level in the first six-response baseline condition occupied even greater proportions of session time when all six programmed responses were again made available following restriction conditions, although for S4 that increase occurred in the residual category. Except for the latter

Table 7

Possible factors in selective substitution.

Restriction conditions by subject		Selective substitution	Most probable alternative	Stimulus similarity	Topographical similarity
S1	5	X		X	X
	4	X			
	3	X		X	
	2	X		X	X
S2	5	X			
	4	X			
	3	X			X
	2	X		X	
S3	5	X	X		
	4	X			
	3		X		
	2				
S4	5	X			
	4	X			X
	3	X			X
	2				

case, the response reflecting such an increase in free-operant level from the beginning to the end of the study was the one that had been restricted longer than any other, for as long as 2 to 6 months.

Individual data were examined to determine whether factors other than relative probabilities could account for the selective substitution of certain programmed responses for restricted ones. Two logical possibilities were evident. One factor was stimulus similarity, because some of the materials that enabled two or more responses for each subject had common stimulus properties (see Table 2). For example, in the set for S1, the number puzzle and calculator both involved numerals; the alphabet letters, writing worksheet, Distar reading worksheet, and book all displayed letters, singly or in words. Another possible variable was topographical similarity. Certain materials involved similar responses; for example, for S1 the number puzzle and alphabet letters both presented small items that could be manipulated with the fingers of one hand, for S3 the pegboard and clothespins were both manipulable with one hand and set the occasion for pincer grasping, and for S4 the pegboard, letters, and crayons all were small items that he tended to manipulate stereotypically with one hand. Some materials had both stimulus and response properties in common; for example, the writing and Distar worksheets for S1 and S2. Other materials did not share either of these dimensions.

The one or two programmed responses that substituted for a restricted response in each restriction condition were evaluated with regard to these alternative explanations. The response categories and substitution patterns considered in this analysis are shown in Table 3. Table 7 summarizes the restriction conditions in which selective substitution occurred, instances of substitution by the most probable alternative, and conditions in which the one or two substituted responses bore stimulus or topographical response similarities to the restricted response.

Although similarities to the restricted response were present in one or both substituted responses in seven of 16 conditions, neither stimulus nor response topography similarities account fully for the selective substitution patterns evident in these data. In several conditions in which one high-probability response was restricted and several programmed responses with stimulus and/or response topography similarities remained available, the responses that increased disproportionately were the most probable remaining alternative or were unrelated to the restricted response in any obvious way.

DISCUSSION

Relations among responses in human repertoires are probably determined by multiple variables acting and interacting in complex ways. Complexity, however, does not preclude prediction and control, but may require that explanatory models be broad and flexible enough to incorporate diversity. The results of this study, together with those of Lyons and Cheney (1984), suggest that no single existing model for predicting time reallocation following response restriction is adequate when applied to multiresponse repertoires, at least as far as rats and autistic children are concerned. Redistribution of newly available time among remaining responses is rarely proportional to free-operant levels or divided equally among all alternatives. The results of the present study confirm the Bernstein and Ebbesen (1978) finding that substitution by remaining responses was selective, but we propose that the definition of selective substitution be expanded to include disproportionate increases in one *or* *more* responses relative to unrestricted conditions. In this study, time allocated to one or two responses tended to increase when a former high-probability response was restricted. Of course, the number of selectively substituted responses may have been determined in part by the number of programmed responses available to the subject. Interrelations between the number and type of available responses and substitution patterns remain to be investigated.

Another variable that may have influenced patterns of time reallocation among these subjects was the method used to designate the highest probability response for a condition, and therefore the response that was restricted in the following condition. The criteria for changing conditions were clear evidence that the relative probability of one response exceeded all others and an acceptable range of variability (± 1 *SD*) in that response. Where it was necessary to conduct 10 sessions because the criteria were not met, designation of the response to be restricted was based on the overall mean response levels (i.e., taken over all 10 sessions). There was a total of 15 transitions in which substitution for a restricted response could be examined (no such examination was possible for the final transition from two available responses to the six-response baseline). Eleven of those transitions followed a 10-session condition in which the restricted response was the highest probability programmed response overall, but its level did not remain stable for three consecutive sessions. Nonetheless, selective substitution patterns resulted that were similar to those reported by other investigators using different restriction rules with adult humans (Bernstein & Ebbesen, 1978) and animals (Lyons & Cheney, 1984). The role of the method of selecting a response to be restricted cannot be inferred from this study, but it may be a variable that bears investigating.

Given that response substitution is likely to be selective rather than proportional, the problem for prediction is to identify variables that determine which of several responses will be the primary recipients of newly available time when a response is restricted. Three factors, rather broadly construed, were considered here: most probable remaining alternative, stimulus similarity, and response topography similarity. Conclusions about substitution by the most probable remaining alternative were rendered tentative by the fact that individual, discrete responses within the residual category were not recorded. It is possible that specific response classes within our residual category, such as self-stimulatory behavior, actually served as substitutes for highly preferred activities. Despite the continued availability of any number of unprogrammed responses, however, most subjects engaged in one or two programmed responses for large portions of time until the range of programmed responses was narrowed to three or fewer. There was a tendency, though not a strong one, for the most probable remaining programmed response to substitute for a restricted response. This experiment could not rule out contributions to selective substitution by stimulus similarity or response topography similarity. Further research should examine the role of these factors by isolating and combining them experimentally. Another factor that should be examined in this context is sequential dependency between restricted and substituted responses (Dunham & Grantmyre, 1982). The present study was not designed to investigate this factor, and although Lyons and Cheney (1984) found little support for it, further research seems warranted before it can be ruled out.

Children with autism may demonstrate unique patterns of response substitution, because their behavior generally differs from that of normal, same-age peers (e.g., in rates of stereotypic behaviors). Thus, replications of response-restriction studies with other populations seem warranted.

Finally, results of this study might have been quite different if it had been conducted in a "closed" system with more complete control over subjects' access to responses. Using mutually exclusive response categories might also eliminate some of the variability that was evident in these subjects' data and would simplify measurement. But these considerations do not obviate the study of response restriction effects in open systems and in situations in which more than one response can occur at once.

Evidence is accruing to suggest that none of the models of time reallocation that have been proposed thus far fit the experimental data very well, at least when multiresponse repertoires are involved. Replication of multiresponse studies with attention to some of the variables discussed here may well lead to formulation of predictive rules with broader application than those presently available. However, the data from this study lend further support to the view that response substitution and reinforcement effects are idiosyncratic. Results of this and other studies also suggest that the generality of findings from two-response experimental preparations may be limited, and highlight the need for a careful assessment of substitution prior to implementing a behavior-change program, especially when naturalistic repertoires are involved.

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