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AN ANALYSIS OF REINFORCER SUBSTITUTABILITY USING OBJECT MANIPULATION AND SELF-INJURY AS COMPETING RESPONSES

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The concept of reinforcer substitutability proposes a continuum of interactions among reinforcers in a given situation. At one end of this continuum, reinforcers are substitutable, with one reinforcer being readily traded for another. We conducted an analysis of reinforcers that were substitutable with those produced by self-injurious behavior (SIB). Three individuals with profound developmental disabilities, whose SIB appeared to be maintained by automatic reinforcement, participated. Results of three experiments showed that (a) object manipulation and SIB were inversely related when leisure materials and SIB were concurrently available, with participants showing almost complete preference for object manipulation; (b) attempts to reduce SIB using the preferred objects as reinforcers in differential reinforcement contingencies were unsuccessful for all 3 participants; and (c) participants' preferences for SIB or object manipulation systematically changed when reinforcer cost (the amount of effort required to obtain the object) was varied. Results of the three experiments illustrate the importance of examining interactions among concurrently available reinforcers when conducting reinforcer assessments.

DESCRIPTORS: stereotypy, self-injurious behavior, reinforcer substitutability, differential reinforcement of other behavior

Although considerable research has shown that many behavior problems are maintained by social reinforcement, such as attention from caregivers (Day, Rea, Schussler, Larsen, & Johnson, 1988) or escape from task demands (Iwata, Pace, Kalsher, Cowdery, & Cataldo, 1990), it has also been found that some behavior problems persist in the absence of social consequences (Iwata et al., 1994). Persons with severe developmental disabilities have been observed to engage in behaviors that appear to be maintained by directly (automatically) produced sensory consequences. Examples of such behaviors include repetitive and rhythmic stereotypic movements, such as body rocking, object twirling, and complex hand and finger movements (Repp & Karsh, 1990), and occasionally some topographies of self-injurious behavior (SIB), such as hand mouthing (Goh et al., 1995), trichotillomania (Rothbaum, 1992), aerophagia (Barrett, Mc-

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Gonigle, Ackles, & Brukhart, 1987), and pica (Danford & Huber, 1982).

Unlike behavior maintained by social consequences for which reinforcers often can be readily identified (e.g., access to or escape from specific observable events), many automatically reinforced behaviors are maintained by events that are difficult to observe and manipulate. Typically, researchers and therapists assume automatic reinforcement to be the maintaining variable when results of a functional analysis produce undifferentiated results or when the behavior persists in the absence of all social consequences (Shore & Iwata, in press; Vollmer, 1994). Thus, the identification of automatic reinforcement is often tentative and is not always based on direct manipulation of a specific source of control. For example, Iwata et al. (1994) recently presented results of functional analyses of SIB that were obtained for 152 individuals over an 11-year period. Automatic reinforcement was identified as the maintaining variable (through a process of elimination) for 25.7% of the sample.

Based on the assumption that some cases of SIB or stereotypy are maintained by their sensory consequences, one treatment strategy known as sensory extinction (Rincover, 1978) has been used to attenuate the sensory stimulation produced by the behavior. For example, Rincover and Devany (1982) used a padded helmet for one boy who banged his head, covered the floor and walls with padding for another boy who banged his head, and placed rubber gloves on a girl who scratched her face. Results showed decreases in self-injury for all 3 participants. Although this type of intervention has often been effective in reducing stereotypy and SIB, recent data suggest that the procedure's underlying mechanism may be punishment rather than extinction (Mazaleski, Iwata, Rodgers, Vollmer, & Zarcone, 1994).

There are also some procedural limitations associated with sensory extinction. Assuming that the intervention does represent a form of extinction, identification of the behavior's maintaining reinforcer is required. However, many behaviors produce multiple modes of stimulation (e.g., visual, tactile, auditory). For example, hand mouthing produces tactile and gustatory stimulation, and object twirling produces tactile, auditory, and visual stimulation, any or all of which could be the maintaining reinforcer. Another potential limitation of sensory extinction is that the procedure may be impractical (e.g., eliminating visual stimulation) unless it is used intermittently or on a response-contingent basis. Finally, extinction may produce an initial burst in responding or other emotional behavior that could preclude its use (Luiselli, 1981).

Because it may often be difficult to use sensory extinction, researchers have explored the viability of reinforcement-based alternatives. Examples include continuous access to leisure materials (Berkson & Mason, 1965; Davenport & Berkson, 1963; Favell, McGimsey, & Schell, 1982), differential reinforcement of alternative behavior (DRA) (Lockwood & Bourland, 1982; Mulick, Hoyt, Rojahn, & Schroeder, 1978), and differential reinforcement of other behavior (DRO) (Cowdery, Iwata, & Pace, 1990; Repp, Deitz, & Deitz, 1976). These interventions do not include an extinction component and thus produce conditions of choice due to the continued availability of the inappropriate behavior (and its resulting consequences) and the arbitrary reinforcer delivered in the intervention.

Parameters that affect choice between concurrently available reinforcers have been studied extensively by basic researchers. The matching law (Herrnstein, 1961, 1970) was an initial attempt to account for the relativistic nature of reinforcement by predicting that the probability of a given response is influenced not only by the reinforcers contingent upon it but also by other reinforcers contingent on other responses in a given situation. The matching law stated that the ratio of responses emitted for two reinforcers is equal to the ratio of the reinforcement obtained for those responses. A generalized version of the matching law was proposed subsequently (Baum, 1974); it contained additional parameters—sensitivity and bias—to account for cases in which deviations from matching occurred. Most research on the matching law has focused on quantitative parameters of reinforcement such as frequency, amount, or delay (see de Villiers, 1977, for a review). For example, choice has typically been examined with subjects selecting between identical reinforcers whose delivery differs along one or more of the above dimensions. Herrnstein's matching law was accurate in predicting outcomes when concurrent reinforcers were qualitatively similar (usually identical) but was less so when choices were between qualitatively different reinforcers (Baum, 1974, 1979).

Subsequent research has expanded our understanding of the nature of reinforcement by incorporating economic principles into the study of choice among reinforcers that differ qualitatively (Rachlin, Green, Kagel, & Battalio, 1976). The concept of reinforcer substitutability, usually discussed within the context of behavioral economics, was proposed as a possible extension of the generalized matching law (see Green & Freed, 1993, for a review). Substitutability describes a continuum of interactions between concurrently available reinforcers. At one end of the continuum are complementary reinforcers, for which increased consumption of one alternative results in increased consumption of its complement. For example, eating salty food often is accompanied by increased consumption of liquid. At the other end of the continuum are substitutable reinforcers, for which an increase in consumption of one alternative results in decreased consumption of its substitute. For example, a pencil may be readily traded for a pen when writing. In the middle of the continuum, reinforcers are independent: Consumption of one has minimal effect on consumption of another. Substitutability and complementarity, however, are not fixed points along a continuum. One might readily trade a pen for a pencil when jotting down a quick note but use only pencils when doing crossword puzzles. Thus, substitutability and complementarity are not static properties of reinforcers but, rather, are descriptions of the relationship between reinforcers in a given context.

Although their findings have not always been interpreted in terms of reinforcer substitutability, many applied studies have shown an inverse relationship between object manipulation and either stereotypic or self-injurious behavior (Bailey & Meyerson, 1970; Goh et al., 1995; Realon, Favell, & Cacace, 1995; Rincover, 1978). For example, Favell et al. (1982) decreased hand mouthing, pica, and eye poking in 3 individuals by giving them access to manipulable toys, popcorn, and objects that provided visual stimulation, respectively. By matching the presumed source of stimulation produced by the SIB to that produced by object manipulation or food ingestion, the authors were able to replace the more dangerous form of self-stimulation with a more benign topography. Davenport and Berkson (1963), however, showed that this reciprocal relationship varied depending on which objects were used and suggested that intervention may be effective only to the extent that alternative sensory activities are preferred over the self-stimulatory behavior. Thus, although results of some applied studies have shown what appear to be substitutable relationships among reinforcers, the parameters that affect these relationships have not been explored systematically.

The purpose of this study was to examine interactions between stereotypic SIB and the manipulation of objects that appeared to provide substitutable sources of reinforcement. Three experiments were conducted. Experiment 1 provided a basic demonstration of a reciprocal relationship between object manipulation and hand mouthing or arm rubbing; Experiment 2 examined the efficacy of DRO contingencies using the objects as reinforcers; and Experiment 3 examined the effect of altering the cost of the preferred reinforcer (object manipulation) on participants' preference for object manipulation and SIB.

Table 1
Numbers of Sessions per Condition and Results Obtained During Functional Analysis Assessments Conducted Prior to Experiment 1

Assessment condition		Participant		
		Randy[a]	Carly[b]	Mary[b]
Alone	Sessions	11	8	6
	Condition *M*	13.7	67.3	25.7
Attention	Sessions	11	9	6
	Condition *M*	14.7	57.7	4.3
Demand	Sessions	9	9	5
	Condition *M*	13.9	66.3	66.7
Play	Sessions	11	10	5
	Condition *M*	6.4	41.2	4.2

[a] Mean expressed as responses per minute.
[b] Mean expressed as percentage of 10-s intervals.

GENERAL METHOD

Participants and Setting

Three individuals participated in each of the three experiments. All lived in a public residential facility, had been diagnosed with profound mental retardation, and were referred to a specialized program for assessment and treatment of their SIB. Randy was a 33-year-old man whose SIB consisted of frequent arm rubbing against a chair, table, or other stationary object, which produced skin abrasions and interfered considerably with his performance of other activities. Randy walked with an unsteady gait, displayed a few signs, and responded to several one-step requests. Carly and Mary were 30 and 31 years old, respectively, and their SIB consisted of hand mouthing that resulted in tissue damage. Both were nonambulatory, displayed no expressive language, and did not appear to respond to directions from caregivers.

All experiments were conducted at a day-treatment program located on the grounds of the residential facility. Sessions were conducted by graduate students, with the location of sessions held constant within each condition. Therapy rooms contained chairs, tables, and other furnishings, as well as materials that varied according to the conditions of the experiments. Sessions lasted 15 min unless otherwise noted. One to three sessions were conducted daily, usually 4 or 5 days per week.

Functional Analyses

Prior to the study, individuals participated in a functional analysis assessment (Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994), during which they were exposed to four conditions (attention, demand, alone, and play) in either multielement or reversal designs. Table 1 shows the number of sessions per condition and the condition means for Randy, Carly, and Mary. Randy and Carly engaged in relatively high rates of SIB across all conditions (with somewhat less SIB occurring during the play condition), indicating that their SIB was not maintained by social reinforcement. In contrast, Mary's hand mouthing occurred frequently during both the alone and demand conditions. Additional sessions were conducted for all participants, during which it was found that (a) their SIB persisted in the alone condition, and (b) almost all of Mary's hand mouthing during the demand condition occurred between trials (i.e., during the time-out period), when she was functionally alone. Thus, assessment data for all 3 participants indicated that their SIB was not differentially sensitive to social contingencies and that it persisted in the absence of environmental stimulation, suggesting that the behaviors were maintained by directly produced (automatic) sensory reinforcement.

Stimulus Preference Assessments

Leisure materials used during the functional analyses were not selected in any systematc manner, so additional probe sessions were conducted to identify specific individual preferences from among a variety of leisure materials. Sessions were 10 min in length and consisted of continuous access to one object (6 to 10 objects were assessed per individual). An experimenter handed an object to the individual at the start of each session and recorded the percentage of intervals during which object manipulation, SIB, or both occurred. If an object was dropped, the experimenter placed it back on the tray or table in front of the individual. Data from these probes were used to select an object for each individual that had resulted in the lowest level of SIB and the highest level of object manipulation. A vibrating massager was selected for Randy, two large plastic rings were selected for Carly, and a small plastic tube was selected for Mary.

Response Measurement and Reliability

The dependent variables for the experiments were operationally defined as follows: *arm rubbing* (Randy): scraping one arm against the other or against the surface of a stationary object; *hand mouthing* (Carly and Mary): insertion of the hand or fingers past the plane of the upper and lower lips, or protrusion of the tongue out of the mouth onto the hand or fingers; and *object manipulation* (all participants): holding an object (the usual topography of object manipulation consisted of holding the object while placing part of it against the cheek by Randy or in the mouth by Carly and Mary). Experimenter behavior (handing an object to a participant) was also recorded.

Responses were recorded on a hand-held computer (Assistant, Model AST 102) using a partial-interval scoring procedure, in which an observer marked the occurrence of a behavior if it was observed at any time during continuous 10-s intervals. Data were converted to the percentage of intervals during which responding occurred.

A second observer simultaneously but independently recorded data during at least 19% of the sessions in each condition (range across participants, 19.4% to 48%). Interobserver agreement scores for SIB and object manipulation were calculated on an interval-by-interval basis by dividing the number of intervals containing agreements by the total number of intervals and multiplying by 100%. Mean interobserver agreement across participants and experiments was 94.9% for SIB (range, 91.6% to 98.1%) and 95.0% for object manipulation (range, 89.7% to 97.9%).

EXPERIMENT 1

Results obtained during the preference assessments suggested that access to certain leisure objects seemed to reduce the occurrence of SIB. The purpose of Experiment 1 was to demonstrate a functional (reciprocal) relationship between object manipulation and SIB, thereby establishing preference for object manipulation over SIB when both responses were continuously available.

METHOD

During 15-min sessions, individuals were exposed to two conditions alternated in a reversal (ABAB) design. Data were recorded on the occurrence of SIB and object manipulation, as described previously.

Baseline

The participant was alone in the room (with the exception of an observer), with no other materials available. No interactions occurred between observer and participant.

Leisure Materials Available

These sessions were identical to baseline sessions, except that leisure materials were given to participants at the start of each session. A vibrator was handed to Randy, two plastic rings were placed on a tray attached to Carly's wheelchair, and the plastic tube was placed in Mary's hand. If an individual dropped the object during the session, the observer replaced it on the tray or table in front of the individual.

Results and Discussion

Figure 1 shows the percentage of intervals containing SIB and object manipulation for Randy, Carly, and Mary across conditions. Similar results were obtained for all 3 participants. During baseline, arm rubbing (Randy, top panel) and hand mouthing (Carly and Mary, middle and bottom panels, respectively) occurred at moderate to high levels. When the leisure materials were introduced, high levels of object manipulation were observed, whereas SIB was either greatly reduced (Mary) or eliminated (Randy and Carly). A return to baseline was associated with increases in SIB, and reintroduction of the leisure materials again produced increases in object manipulation and decreases in SIB.

Results obtained for each participant showed that SIB was almost eliminated when objects were continuously available. These findings indicated that stimulation obtained from object manipulation was preferred over that obtained from arm rubbing or hand mouthing, and replicated the results of previous studies that showed an inverse relationship between object manipulation and stereotypic behavior (Berkson & Mason, 1965; Davenport & Berkson, 1963; Favell et al., 1982; Goh et al., 1995; Realon et al., 1995). Lower levels of SIB also were observed for Randy, Carly, and Mary during the play condition of their functional analyses relative to other conditions. However, the leisure materials used during this condition were selected in a somewhat haphazard manner. The results obtained in Experiment 1 suggested that even lower levels of SIB might have been observed during the play condition of the functional analyses if more highly perferred leisure materials had been provided.

The reciprocal relationship observed between object manipulation and SIB in Experiment 1 suggested that the stimulation (reinforcement) available from certain types of leisure materials competed with (and might be substitutable for) that produced by certain types of SIB. Results of basic research on reinforcer substitutability, however, have shown that substitution effects are context dependent: Parameters such as rate, magnitude, or delay of reinforcement have been shown to alter baseline preferences. Therefore, it seemed reasonable to explore further the parameters that influenced the inverse relationship demonstrated in Experiment 1.

EXPERIMENT 2

Cowdery et al. (1990) suggested that although continuous (noncontingent) access to stimulating activities may be effective in reducing stereotypic SIB, the intervention may not always be practical: These activities are not always available, they may require one-to-one supervision to ensure continued object manipulation, and they can lose their reinforcing effects due to satiation. In addition, continuous access to leisure materials might interfere with the performance of other adaptive skills. Therefore, Cowdery et al. suggested that DRO contingencies, if effec-

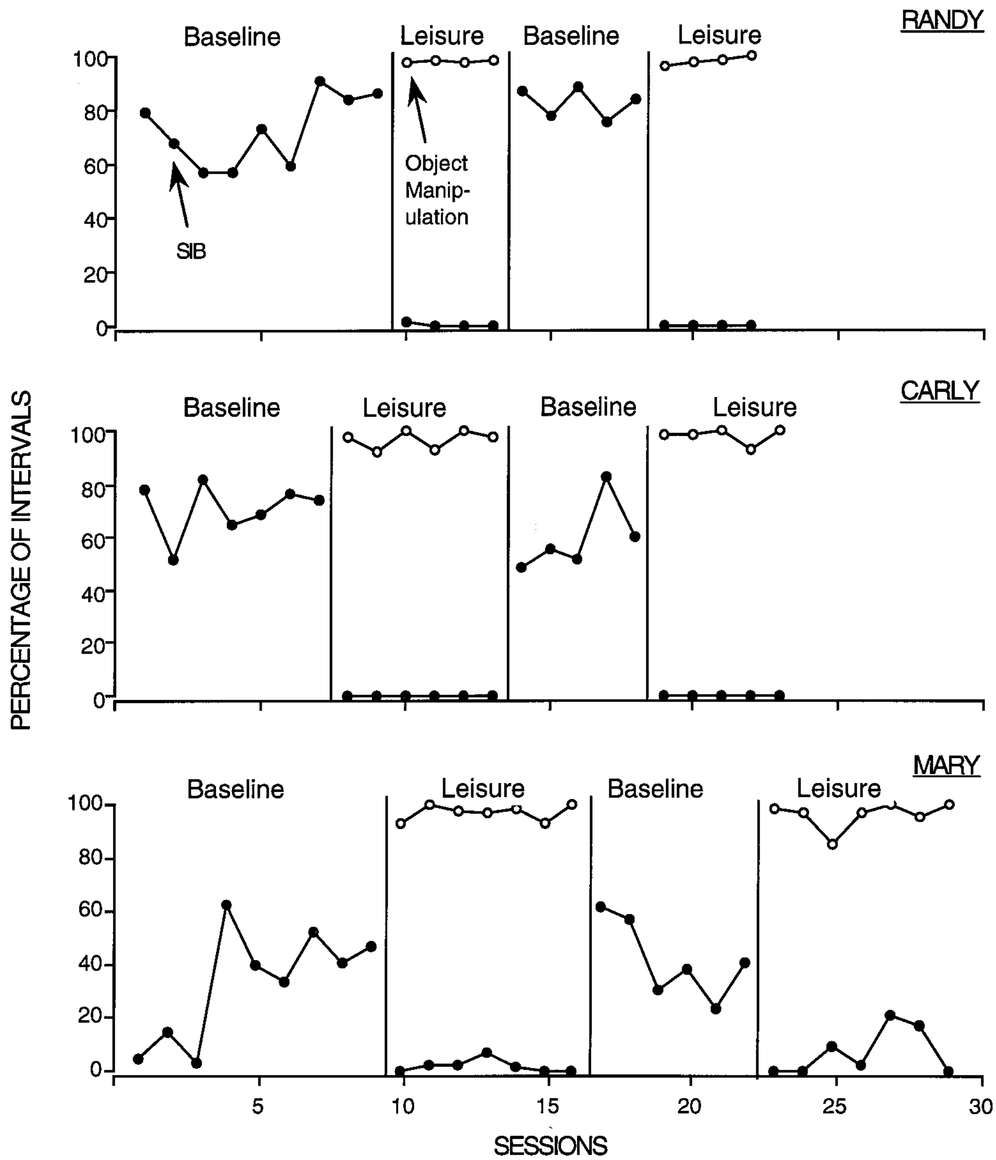

Figure 1. Percentage of intervals containing SIB and object manipulation during baseline and leisure conditions in Experiment 1.

tive, might be used at times when alternative activities are not freely available.

DRO procedures have been used frequently as treatment for stereotypic SIB. Cowdery et al. (1990), for example, showed that access to a variety of games contingent on the nonoccurrence of scratching was an effective intervention, and Repp et al. (1976) decreased the hair twirling, hand biting, and thumb sucking behavior of 3 children by delivering praise and edible reinforcers in a DRO contingency. Other studies have also shown DRO to be an effective intervention for treating stereotypic behavior (Luiselli & Krause, 1981; Repp, Deitz, & Speir, 1974).

Most research on DRO and DRA contingencies applied to automatically reinforced aberrant behavior has involved delivery of arbitrary reinforcers without eliminating access to reinforcement directly produced by the aberrant behavior; that is, there was no extinction component (see Vollmer & Iwata, 1992, for a discussion of this point). Thus, the efficacy of differential reinforcement in such cases may depend on the extent to which the arbitrary reinforcer competes with (i.e., substitutes for) the maintaining reinforcer when both are available concurrently. One method for increasing the potency of arbitrary reinforcers is to conduct a stimulus preference assessment prior to treatment. For example, Steege, Wacker, Berg, Cigrand, and Cooper (1989) successfully treated individuals who displayed stereotypy and SIB by first conducting a preference assessment and then using the most preferred stimuli as reinforcers in DRO and DRA contingencies. Results of Experiment 1 showed that free access to objects that were selected through a preference assessment virtually eliminated Randy's arm rubbing and Carly's and Mary's hand mouthing. These results suggested that access to objects might function as a reinforcer if it were made contingent on either the nonoccurrence of SIB or the occurrence of another response. The purpose of Experiment 2 was to examine this possibility by arranging a DRO contingency in which access to preferred objects was contingent on the absence of SIB.

Method

A parametric analysis of DRO schedules was conducted for all 3 individuals. Each DRO schedule had two manipulable components: the length of the DRO interval and the duration of access to the reinforcer (reinforcement interval). These two parameters were manipulated in various combinations via reversal designs in an attempt to find an effective DRO schedule for reducing SIB.

Baseline

This condition was identical to the baseline condition in Experiment 1.

Differential Reinforcement of Other Behavior

An experimenter handed the individual an object (vibrator for Randy, rings for Carly, plastic tube for Mary) according to a resetting DRO schedule: If SIB did not occur during an interval, the object was delivered at the end of the interval for a specified amount of time; if the individual engaged in SIB, the DRO interval was reset. The experimenter kept track of session time, DRO-interval time, and reinforcement-interval time with two stopwatches. When the individual did not engage in SIB during the DRO interval, the experimenter stopped the session-time watch, handed the object to the individual, and started the reinforcement-interval stopwatch. At the end of the reinforcement interval, the object was removed, and the next DRO interval began. Session time was stopped during the reinforcement interval to keep constant the total amount of time during which the object was unavailable. This control procedure insured that changes in responding from baseline to treatment were not merely a function of increased access to the objects. Therefore, although total session time varied according to how many times an individual met the DRO criterion, the amount of time in session without the object remained constant at 15 min. The DRO and reinforcement intervals varied across conditions. For each individual, the initial DRO interval was slightly shorter than the mean interresponse time obtained during baseline, and subsequent DRO intervals were arbitrarily varied. Reinforcement intervals were 15 s, 30 s, and 60 s. Observers recorded the occurrence of SIB and the number of times an individual received the object, as described previously.

Results and Discussion

Figure 2 shows the percentage of intervals containing SIB across sessions and conditions for all 3 participants. Randy engaged in high levels of arm rubbing during baseline. In the next three conditions, the DRO interval varied (10 s, 30 s, and 45 s), while the reinforcement interval (access to the vibrator) remained at 15 s. There was little reduction in arm rubbing during any of these conditions, and the mean number of times per session that Randy met criterion for reinforcement varied according to the DRO schedule: 0 for DRO 45 s, 2.6 for DRO 30 s, and 15 for DRO 10 s. During the next three conditions (DRO 10 s, 30 s, and 45 s), vibrator access time was increased to 30 s. Slight decreases in arm rubbing were observed during the 10-s and 45-s conditions. The mean numbers of times per session that Randy met the DRO criterion were 1 for DRO 45 s, 1.8 for DRO 30 s, and 21.8 for DRO 10 s. Randy's last condition consisted of a DRO 5-s schedule with a 60-s reinforcement interval. This condition appeared to increase arm rubbing, and the mean number of times he met the DRO criterion was 39.3 per session.

Carly's hand mouthing was variable during baseline but usually exceeded 40% of the observation intervals. In the next five conditions, the DRO interval varied (20 s, 30 s, 40 s, 60 s, and 10 s), while the reinforcement interval remained at 15 s. No reductions in hand mouthing were observed during any of these conditions, and the mean number of times per session that Carly met the DRO criterion varied according to the DRO schedule: 1.8 for DRO 60 s, 3.4 for DRO 40 s, 8.8 for DRO 30 s, 15.1 for DRO 20 s, and 12 for DRO 10 s. During the next four conditions (DRO 10 s, 30 s, 45 s, and 60 s), the reinforcement interval was increased to 30 s. Again, there were no reductions in hand mouthing during any condition. The mean numbers of times per session that Carly met the DRO criterion were 0.8 for DRO 60 s, 3 for DRO 45 s, 2.9 for DRO 30 s, and 15.5 for DRO 10 s. The last attempt to reduce hand mouthing was a DRO 5-s schedule with a 60-s reinforcement interval, which appeared to increase rather than to decrease Carly's hand mouthing (the mean number of times she met criterion for reinforcement was 18.3 per session).

Mary engaged in high and variable amounts of hand mouthing during baseline. In the next five conditions, the DRO interval length varied (30 s, 20 s, 10 s, 45 s, and 10 s), while the reinforcement interval remained at 15 s. No reductions in hand mouthing occurred during any of the conditions, and the mean number of times per session that Mary met the DRO criterion varied according to the DRO schedule: 0.2 for DRO 45 s, 1.3 for DRO 30 s, 4.9 for DRO 20 s, and 11.6 for DRO 10 s. During the next four conditions (DRO 10 s, 30 s, 45 s, and 60 s), the reinforcement interval was increased to 30 s. There was little reduction in hand mouthing in any of these conditions (some decrease occurred during the 45-s and 60-s conditions), and the mean numbers of times per session that Mary met the DRO criterion were 0.4 for DRO 60 s, 3.1 for DRO 45 s, 2.2 for DRO 30 s, and 8.5 for DRO 10 s. Mary's final condition consisted of a DRO 5-s schedule with a 60-s reinforcement interval, during which hand mouthing increased to 100% of the intervals (the mean number of times she met criterion for reinforcement was 21.8 per session).

Results indicated that no clinically significant reductions in SIB were observed during any of the DRO conditions for any of the 3 participants. There also were no consistent parametric differences across schedules, except that all individuals engaged in the most SIB during the DRO 5-s 60-s schedule. These results seem unusual be-

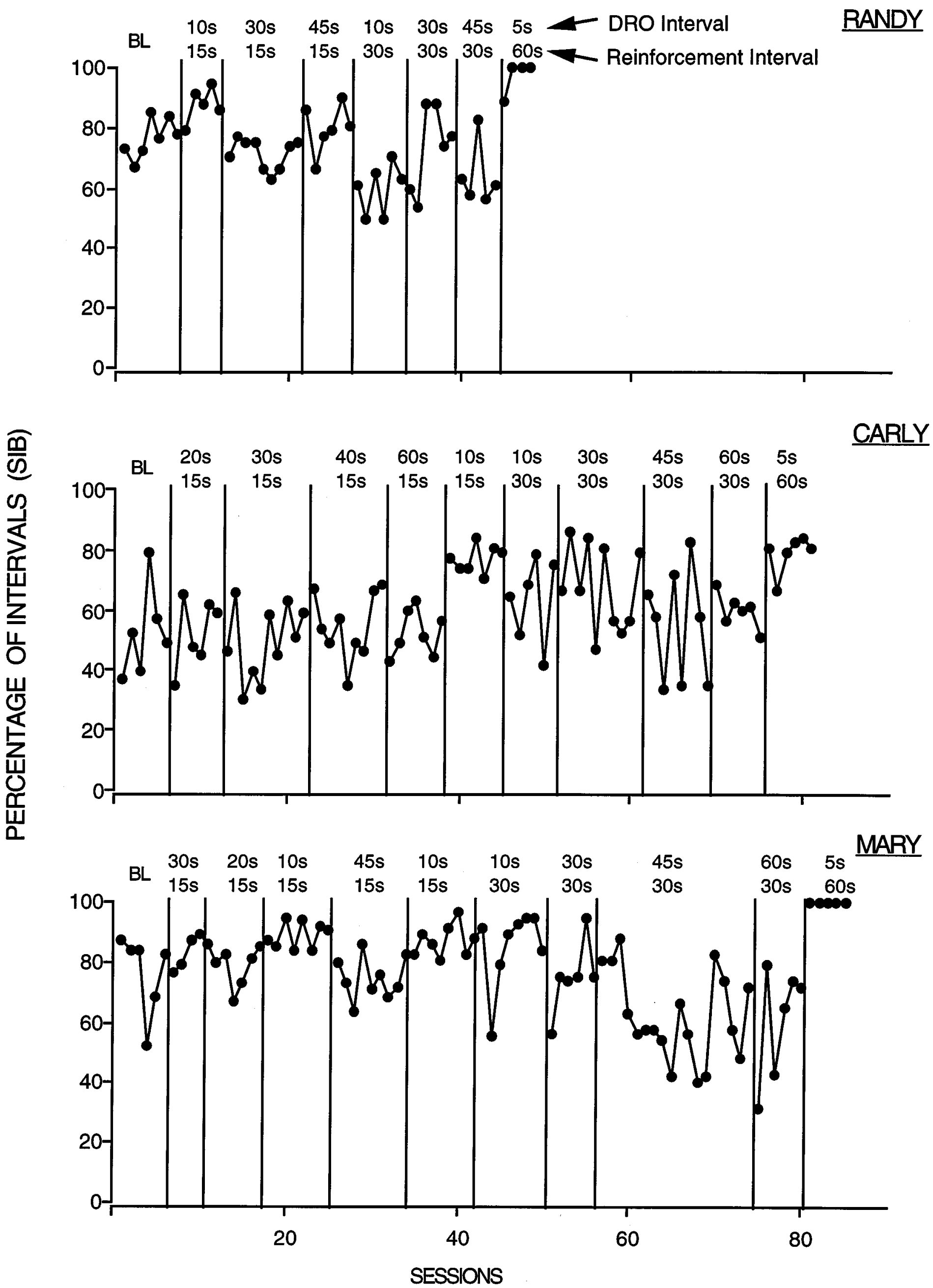

Figure 2. Percentage of intervals containing SIB during baseline (BL) and across DRO conditions in Experiment 2. Numbers above each DRO condition indicate length of the DRO interval (top number) and reinforcement interval (bottom number).

cause SIB was highest in a condition most closely resembling continuous access to the object (DRO 5 s, with 60-s access to the objects). However, at this schedule value, the DRO interval (5 s) was shorter than the observation interval (10 s). Therefore, an individual could emit SIB at the beginning of an observation interval (resulting in a scored interval), yet still meet the DRO criterion within that same scored interval, and this occurred frequently. In addition, short interresponse times (5 s) were being reinforced with very long reinforcement times (60 s).

Results obtained in this experiment were similar to those reported by Harris and Wolchik (1979), who found that access to social interaction and food in a DRO contingency was ineffective in reducing a variety of stereotyped behaviors in 4 boys. In that study, the functional properties of both the target behaviors and the programmed reinforcers were unclear. That is, the contingencies that maintained stereotypy were unknown, although they were assumed to be self-stimulatory in nature, and preference for social interaction or food over stereotypy was not established.

The strong preference for object manipulation over SIB observed for each individual in Experiment 1 indicated that the objects might function as reinforcers in suppressing SIB. The DRO contingencies in Experiment 2 provided such an arrangement by requiring that participants forego an immediate reinforcer (stimulation produced by SIB) to gain access to a more highly preferred one (stimulation available through object manipulation). However, none of the DRO schedules effectively reduced SIB, despite numerous manipulations in both the DRO and reinforcement intervals. In other words, the preference for object manipulation that was evident in Experiment 1 was abolished in Experiment 2 by requiring individuals to refrain from engaging in SIB even for brief periods of time (i.e., 5 s).

Results of previous research have shown that parameters such as rate, magnitude, schedule, or delay of reinforcement, when manipulated as price requirements, can effectively eliminate preferences. Similarly, DRO schedules might be viewed as another sort of price requirement. The requirement in DRO, however, involves *not responding* to obtain the alternative reinforcer. Under these conditions, the responding of our participants was not affected by any of the price manipulations. Perhaps a better way to examine changes in preference would be to alter some other parameter of price that involves *responding* to obtain the alternative reinforcer. We used this arrangement in Experiment 3 to further examine parametric shifts in preference for object manipulation versus SIB.

EXPERIMENT 3

Results of studies on the substitutability of qualitatively different reinforcers have shown that increasing the price of a preferred reinforcer through changes in reinforcement rate, magnitude, or delay can eliminate preference for that reinforcer over a substitutable one (Rachlin et al., 1976). In a basic demonstration of substitutability (Kagel et al., 1975), rats responded for access to either root beer or Tom Collins mix on concurrent fixed-ratio (FR) schedules of reinforcement. Each reinforcer was associated with a different response lever and FR requirement. The rats lived in the experimental chamber and were limited to a fixed number of lever presses in a given 24-hr period. In economic terms, the reinforcers represented different commodities, the FR requirement represented the price of each good, and the total number of lever presses allotted represented the rats' income. By altering reinforcement schedules, the price for each reinforcer could be varied. Results showed that both rats had a strong preference for root beer when the price (FR requirement) and income (total number of lever presses allotted) were equal. This relationship was then altered by reducing the FR requirement (price) for Tom Collins by half and doubling the FR requirement (price) for root beer, while adjusting the allotted number of lever presses (income) to obtain the same combination of root beer and Tom Collins as was obtained in the first condition. Results of this manipulation showed much more consumption of the now cheaper Tom Collins than for the now more expensive root beer. Thus, altering the price of the concurrently available reinforcers eliminated the preference that had been shown when prices were equal.

In a more recent study on reinforcer substitutability in humans, Tustin (1994) examined relative preference for reinforcers shown by individuals with developmental disabilities under several different FR schedules. In three case studies, it was demonstrated that (a) changes in FR schedules can have different effects on response rate and reinforcement rate associated with different reinforcers, (b) preference for one reinforcer available on a rich schedule over another reinforcer available on a leaner schedule can be abolished by altering (thinning) the rich schedule, and (c) preference for one reinforcer over another under identical schedules can be altered as a function of the schedule value.

As the above studies illustrate, reinforcer price in most research on behavioral economics is defined as the number of responses required per reinforcer under FR schedules. Other parameters, such as the amount of work expended per unit of reinforcer (effort), have also been shown to affect choice among concurrently available reinforcers (e.g., Hursh, Raslear, Shurtleff, Buaman, & Simmons, 1988), and results of two recent applied investigations have replicated this finding. Neef, Shade, and Miller (1994) examined the effects of reinforcer rate, quality, delay, and response effort on time allocation across different math tasks presented on concurrent variable-interval schedules to students with emotional disorders, and found that effort affected choice to some degree. Kerwin, Ahearn, Eicher, and Burd (1995) focused more specifically on response effort while treating children who exhibited feeding disorders. Their results showed relatively small but orderly relationships between the response (accepting, expelling, and swallowing food) and the effort (varying the amount of food on a spoon) required to obtain reinforcement: Food consumption decreased as a function of increased effort.

Results of these studies indicate that preference can be altered readily through changes in a variety of reinforcement parameters and that response effort may be one variable that affects reinforcer efficacy. In Experiment 3, we examined the effects of parametrically altering response effort on response allocation between object manipulation and SIB. Effort to obtain one reinforcer (produced by hand mouthing or arm rubbing) would be difficult to manipulate and therefore remained constant, but effort to obtain the other reinforcer (object manipulation) could be (and was) manipulated. This was accomplished by anchoring the objects with string to a fixed location in front of each individual. Response effort was then manipulated by varying the distance between the individual and the object. Thus, as string length shortened, the individual would have to bend over further and further to manipulate the object (i.e., place it against the face or mouth), thereby increasing the response effort.

Method

Following baseline, response effort was systematically altered in reversal designs, beginning with the least effortful condition. When a switch in preference from object manipulation to hand mouthing or arm rubbing was observed, conditions on each side of this switch point were replicated. Data were recorded on occurrences of SIB and object manipulation, as described previously.

Baseline

This condition was identical to the previously described alone sessions in Experiment 1.

Effort Manipulation

Randy, Carly, and Mary consistently engaged in object manipulation while sitting in an upright position. Therefore, the least effortful condition was designed to require no change in body position while manipulating the object. Prior to the study, the distance was measured between the edge of the table or lap tray (where the string would be attached) and the individual's mouth while the individual was seated in an upright position. This distance was considered the least effortful position and was arbitrarily designated as 1.0 (the proportion of string length to that obtained for the upright measurement). These distances were 67 in., 20 in., and 17.5 in. for Randy, Carly, and Mary, respectively. The most effortful condition was one in which the object was tied at its anchoring point on the table or lap tray with no play in the string (0 in. for all subjects, corresponding to 0 proportion of the upright measurement). The proportion of the upright string length was then varied for each individual in an attempt to determine a switch point (e.g., the distance at which preference for object manipulation was eliminated), and conditions on each side of the switch were replicated. For example, the order of conditions for Carly was 20 in. (1.0), 0 in. (0), 20 in. (1.0), 10 in. (.5), 15 in. (.75), 12.5 in. (.62, switch point), 20 in. (1.0), 10 in. (.5), and 15 in. (.75).

Results and Discussion

Figure 3 shows the percentage of intervals containing SIB and object manipulation across all conditions. Randy engaged in high levels of arm rubbing during baseline. During the 67 in. (1.0) condition that followed, arm rubbing was suppressed almost completely and was replaced with high levels of object manipulation. During the next condition, 16.75 in. (.25), arm rubbing occurred at high levels and object manipulation occurred at lower levels, reflecting a change in preference. Therefore, string length was increased to 33.5 in. (.5) during the next condition, in which a switching of preference was observed across sessions, with arm rubbing variable but typically occurring more often than object manipulation. Although the first few sessions of the next condition, 50.25 in. (.75), showed no clear preference for either response, the last few sessions showed an increase in arm rubbing and a decrease in object manipulation. The next condition, 58.6 in. (.875), showed a clear preference for object manipulation over arm rubbing. The 50.25 in. (.75) condition was then reinstated, and preference again switched (arm rubbing increased and object manipulation decreased). The final condition, 54.4 in. (.825), showed decreased arm rubbing and increased object manipulation after the first four sessions.

Carly engaged in high levels of hand mouthing during baseline. The next condition was the least effortful condition (20 in. or 1.0), during which Carly's hand mouthing was virtually eliminated and was replaced with object manipulation. During the next condition, which was the most effortful (0 in. or 0), hand mouthing increased, and object manipulation was completely absent for all seven sessions. When the 20 in. (1.0) condition was reinstated, hand mouthing was initially higher than in the previous 20 in. (1.0) condition, but decreased across sessions, while object manipulation again increased. In the next condition, 10 in. (.5), string length was reduced to one half its original length. During the first two sessions of this condition, object manipulation was higher than hand mouthing; thereafter, preference switched in that object manipulation decreased steadily while hand mouthing increased. The next condition was 15 in. (.75 of string length), which was selected because it was halfway between the 20 in. (1.0) condition, in which object manipulation was

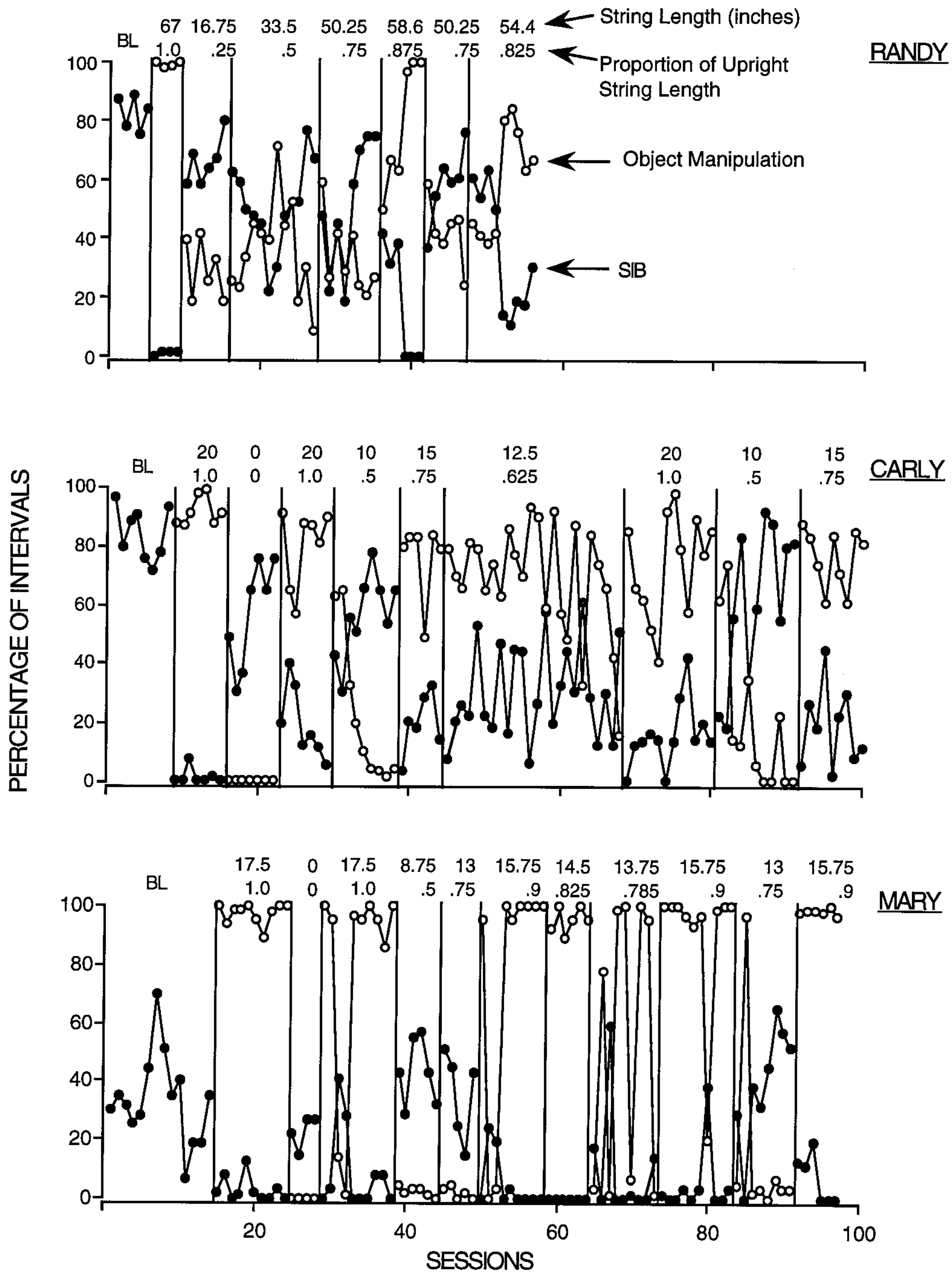

Figure 3. Percentage of intervals containing SIB and object manipulation during baseline (BL) and across effort (string-length) conditions in Experiment 3. Numbers above each condition indicate length of the string attached to an object (top number) and proportion of string length while the participant was seated in an upright position (bottom number).

preferred, and the 10 in. (.5) condition, in which hand mouthing was preferred. Because this condition (15 in. or .75) produced a preference for object manipulation whereas the 10 in. (.5) condition produced a preference for hand mouthing, the next condition was set midway between the two (12.5 in. or .625). During the 12.5 in. condition, most sessions showed less hand mouthing than object manipulation, but both responses showed considerable variability and some crossover. A return to the 20 in. (1.0) condition showed decreased hand mouthing and high but variable amounts of object manipulation. Reinstatement of the 10 in. (.5) condition showed object manipulation initially higher (as in the first 10 in. condition), with hand mouthing eventually increasing to high levels and object manipulation decreasing to low levels. The final condition replicated the 15 in. (.75) condition and showed low hand mouthing and high object manipulation.

Mary engaged in variable amounts of hand mouthing during baseline. In the next condition, 17.5 in. (1.0), Mary's hand mouthing decreased to near-zero levels, while object manipulation was high. In the 0 in. (0) condition that followed, Mary's hand mouthing increased, and object manipulation was not observed in any of the sessions. When the 17.5 in. (1.0) condition was reinstated, hand mouthing decreased, while object manipulation increased to high levels for all but two sessions. In the next two conditions, during which string length was first half (8.75 in., .5) and then three quarters (13 in., .75) of its original length, hand mouthing was higher than object manipulation. During the next condition, 15.75 in. (.9), which was selected midway between the 17.5 in. (1.0) and 13 in. (.75) conditions, object manipulation was high and hand mouthing was low for seven of the nine sessions. Because the 15.75 in. (.9) condition showed a preference for object manipulation, the next condition, 14.5 in. (.825), was midway between the 13 in. (.75) and 15.75 in. (.9) conditions. During this condition, a complete suppression of hand mouthing occurred in all six sessions, and object manipulation was high. Therefore, the next condition was 13.75 in. (.785), midway between 13 in. (.75) and 14.5 in. (.825). During this condition, hand mouthing was suppressed in six of the nine sessions but was higher in the remaining three sessions. Object manipulation showed an inverse pattern, with six of the nine sessions showing high levels of object manipulation and the remaining three sessions showing low levels of object manipulation. A return to the 15.75 in. (.9) condition produced hand mouthing at low levels, except in one session, and object manipulation high, except for that same session. Reinstatement of the 13 in. (.75) condition produced hand mouthing that was again higher in all but one session and low object manipulation in all but that same session. The final condition replicated the 15.75 in. (.9) condition, with low hand mouthing and high object manipulation.

Figure 4 shows the mean percentages of intervals containing SIB and object manipulation for all individuals during each string-length condition. These data show an inverse relationship between the two responses, with SIB increasing and object manipulation decreasing as a function of decreases in string length. The switch points, at which preference for object manipulation was replaced with preference for SIB, occurred roughly at .75, .5, and .75 of the original string length for Randy, Carly, and Mary, respectively.

The present results provide an interesting comparison with those obtained in Experiment 1. In that experiment, free access to a preferred object under ideal conditions (i.e., when the object was placed directly in the individual's hand) substantially reduced or

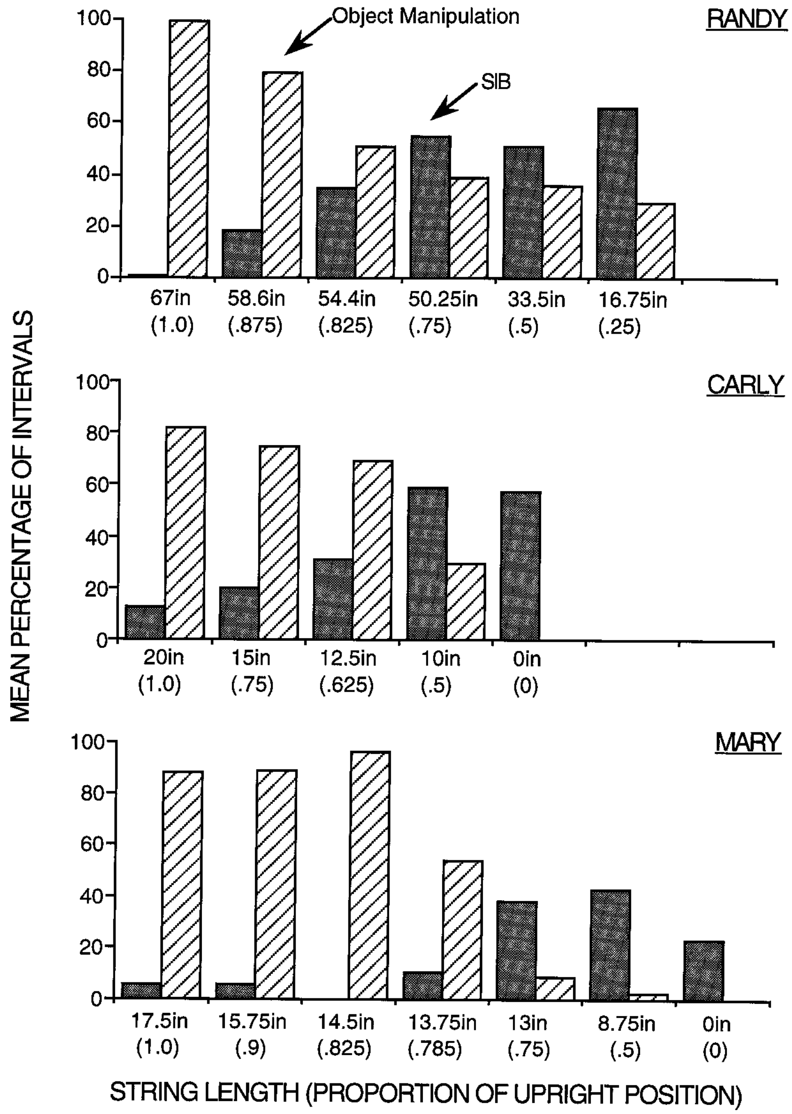

Figure 4. Mean percentage of intervals containing SIB and object manipulation during effort (string-length) conditions in Experiment 3. Numbers at the bottom of each graph indicate length of the string attached to an object (top number) and proportion of string length while the participant was seated in an upright position (bottom number).

eliminated SIB. Similar results were obtained with all individuals during the 1.0 condition in Experiment 3, when no alteration in body position was required to manipulate the objects. However, as movement requirements increased, the individuals engaged in less object manipulation and more SIB, and a movement requirement as little as 4.5 in. (for Mary) was sufficient to abolish her preference for objects. Thus, results from Experiment 3 showed that preference for object manipulation over SIB found in Experiment 1 was quite fragile and could be altered by requiring relatively little effort to obtain the objects.

The shift in preference that was exhibited by participants in Experiment 3 was clearly context dependent and seemed to be consistent with findings from basic and applied research showing that changes in reinforcement parameters can have a strong influence on preference. In behavioral economic terms, these parameters represent price requirements (Kagel et al., 1975; Rachlin et al., 1976), and results of Experiment 3 showed that increasing the price of objects, defined as response effort and measured by the distance of an object to an individual in an upright position, reduced preference for object manipulation over SIB. In a related study, Van Houten (1993) increased the effort required to engage in SIB (face slapping) by placing 1.5 lb wrist weights on an individual, and observed reductions in SIB and increases in object manipulation. SIB was completely abolished during the weights-on condition, and it would have been interesting to determine if changes in the amount of weight on the wrists affected behavior to varying degrees.

At the conclusion of Experiment 3, treatment procedures were developed for each participant and consisted of (a) noncontingent access to specific leisure items during nontraining times, and either (b) response interruption or (c) the use of protective devices (gloves) when continuous access to object manipulation was impractical. Institutional staff members were trained in the use of these procedures, after which they implemented the programs at participants' residences and training sites. Data collected at these locations showed substantial reductions in SIB below pretreatment levels for all participants.

GENERAL DISCUSSION

Three experiments examined substitutability between two responses that were apparently maintained by automatic reinforcement: SIB and object manipulation. For all 3 participants, time spent engaged in SIB (arm rubbing or hand mouthing) and time spent manipulating objects were inversely related when both responses were freely available, with a strong preference shown for object manipulation (Experiment 1). In spite of this obvious preference for leisure materials, access to the objects was ineffective as reinforcement in a series of DRO contingencies aimed at reducing arm rubbing or hand mouthing (Experiment 2). These apparently conflicting results were clarified in Experiment 3, in which preference for object manipulation was found to be readily eliminated when response effort to obtain the object was increased.

These findings are consistent with results of research on variables that affect choice (Green & Freed, 1993); however, the ease with which preference for object manipulation was eliminated was surprising. One explanation for such rapid shifts in preference observed in Experiments 2 and 3 involves reinforcer access time. Because SIB was always available in all conditions of all three experiments, presentation of an alternative stimulus would have to compete with continuous access to SIB. Although object manipulation was preferred when both responses were continuously available, the DRO contingencies (Experiment 2) and string-length manipulations (Experiment 3) showed that when object manipulation was not continuously available, or when access to objects required even a small amount of effort, it no longer competed with SIB.

Another related explanation for these results involves delay between acccess to the two reinforcers, which has been shown to reduce the degree of substitutability between otherwise identical reinforcers. Hursh and Bauman (1987), for example, compared consumption of one reinforcer as a function of its relative price when an alternative identical reinforcer was present in three conditions of delay: concurrent schedules, multiple schedules, and across conditions of the same experiment. (Green & Freed, 1993, suggested that this was similar to comparing prices of items on the same shelf, in different stores, or over months of shopping, respectively.) Results showed that the greater the delay between access to identical reinforcers, the less substitutable they became. The DRO conditions in Experiment 2 and the shorter string-length conditions in Experiment 3 resulted in greater delay between the stimulation produced by object manipulation relative to that produced by hand mouthing (which was always immediately available). In the DRO contingencies (Experiment 2), individuals were required *not* to engage in hand mouthing, which presumably produced stimulation substitutable for that obtained through object manipulation (which was not immediately available). In the string-length conditions (Experiment 3), decreased string length created a delay by requiring participants to engage in additional behavior to manipulate the objects (e.g., bending over to place the object against the face or in the mouth).

There are several notable limitations to these experiments. First, sequence effects may have influenced the results of Experiments 2 and 3. In Experiment 2, for example, all individuals were exposed first to 15-s and then to 30-s reinforcement intervals, and the effect, if any, that this sequence may have had on behavior is unknown. Results obtained in Experiment 3 provided some indication that preceding conditions influenced responding in subsequent conditions, in that initial performance in some conditions showed a switch after the first couple of sessions. Another limitation is that findings reported here may have been specific to the particular responses selected for examination. It is quite possible that different relationships might be observed (e.g., better behavioral suppression with DRO contingencies) with different sources of alternative stimulation.

A number of applied studies have been conducted in recent years on stimulus preference procedures and have demonstrated the effectiveness of assessing preference for stimuli prior to using them as reinforcers to both increase (Pace, Ivancic, Edwards, Iwata, & Page, 1985) and decrease (Steege et al., 1989) behavior. In light of the present results, which clearly indicated that preference in one context may not predict preference in another, it appears that the variables that affect choice in applied settings, and the extent to which assessing reinforcing efficacy in one context is predictive of reinforcer efficacy in another, are in need of further investigation.

Results of these experiments on substitutable reinforcers also suggest additional ways to evaluate or improve the efficacy of interventions for reducing self-stimulatory aberrant behavior (i.e., behavior that is not maintained by social reinforcement). For example, one common method of treatment for such behavior has been to provide ready access to reinforcing activities that appear to be correlated with decreases in the occurrence of the aberrant behavior. This approach is often described in the literature as *environmental enrichment* (Horner, 1980) and can be interpreted in terms of reinforcer substitutability: Alternative sources of stimulation are made available that apparently substitute for stimulation produced by the aberrant behavior. Although interventions based on reinforcer substitutability (environmental enrichment, noncontingent reinforcement, etc.) have the advantage of being relatively simple for caregivers to implement, different strategies may be required when the alternative reinforcer does not substitute completely for that produced by the inappropriate behavior. For example, Lockwood and Bourland (1982) used a combination of praise and physical contact contingent on sustained object manipulation to further reduce SIB below a condition in which the objects were merely available. The identification of stimuli that compete with aberrant behavior when presented in combination but not alone provides a good example of how assessments of reinforcer substitutability may facilitate the development of more effective reinforcement-based interventions.

Because extinction of behavior that is maintained by automatically produced reinforcers is often difficult or impossible to achieve, alternative interventions based on DRA and DRO contingencies, and even noncontingent reinforcement, almost always involve creating a situation in which concurrent schedules are operative. Behavioral suppression in such situations ultimately is a function of choice between reinforcement alternatives, and, as demonstrated in the present experiments, identification of the parameters that influence preference might improve our ability to predict the effects of proposed treatment programs.

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STUDY QUESTIONS

1. Describe and give examples (different than those mentioned in the article) of complementary and substitutable reinforcers.
2. Why is research from the area of behavioral economics (and, more specifically, on reinforcer substitutability) particularly relevant to the treatment of behavior problems that are maintained by automatic reinforcement?
3. What assessments were conducted prior to Experiment 1 and what was their relevance to the overall purpose of the study?
4. Briefly describe the results of Experiment 1 and their most obvious implications for the treatment of SIB.
5. What two parameters of the DRO schedule were manipulated during Experiment 2 and what results were obtained? Given the results obtained in Experiment 1, can you suggest another method for implementing the DRO contingencies that may have been more effective?
6. How did the authors manipulate response effort in Experiment 3? What other types of manipulations have been used in basic research to adjust reinforcer price?
7. What results were obtained from this manipulation, and what was meant by the term *switch point* in referring to the data?
8. Summarize the major discrepancy in results between Experiments 1 and 2, and how the results from Experiment 3 provided clarification.

Questions prepared by Han-Leong Goh and Eileen Roscoe, University of Florida