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RESPONSE ALLOCATION TO CONCURRENT FIXED-RATIO REINFORCEMENT SCHEDULES WITH WORK REQUIREMENTS BY ADULTS WITH MENTAL RETARDATION AND TYPICAL PRESCHOOL CHILDREN

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The present experiments examined the effect of work requirements in combination with reinforcement schedule on the choice behavior of adults with mental retardation and preschool children. The work requirements of age-appropriate tasks (i.e., sorting silverware, jumping hurdles, tossing beanbags) were manipulated. Participants were presented with their choice of two response options for each trial that varied simultaneously on both work requirement and reinforcement schedule. Results showed that when responding to both choices occurred on the same reinforcement schedule, participants allocated most of their responses to the option with the easier work requirement. When the response option requiring less work was on a leaner reinforcement schedule, most participants shifted their choice to exert more work. There were individual differences across participants regarding their pattern of responding and when they switched from the lesser to the greater work requirement. Data showed that participants' responding was largely controlled by the reinforcement received for responding to each level of work. Various conceptualizations regarding the effects of work requirements on choice behavior are discussed.

DESCRIPTORS: concurrent schedules, fixed-ratio schedules, effort, mental retardation, children

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Research with both humans and nonhumans has shown that response allocation in choice situations, such as concurrent schedules of reinforcement, is affected by several variables. The independent variable in most experiments has been one or more parameters of reinforcement, that is, frequency, amount, duration, immediacy, quality, or rate (Davison & McCarthy, 1988). In the majority of these studies, response allocation has been studied as a function of the schedule of reinforcement that is associated with each response option. Research has shown that response allocation to the choices available can be predicted given a set of concurrent schedules of reinforcement; rate of responding tends to match or be proportional to the rate of reinforcement actually obtained from each response alternative.

Research on this relationship, formalized as the matching law (Herrnstein, 1961, 1970), has evolved over the past several decades, primarily in the context of concurrent variable-interval (VI VI) schedules of reinforcement. When organisms have the choice of responding under concurrent VI VI schedules, they typically do not allocate all of their responses exclusively to the richer schedule; rather, they distribute their responding between the two schedules to match or approximate the proportion of reinforcement that is actually obtained on each independent schedule.

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With concurrent ratio schedules, in contrast, the amount of reinforcement obtained depends on the number of responses allocated to a choice. Organisms generally will not allocate responses to both schedules. Instead, they will maximize their reinforcement by allocating all their responses to the richer of the two or more fixed-ratio (FR) or variable-ratio (VR) schedules available (Herrnstein, 1961; Herrnstein & Loveland, 1975). Given a concurrent choice, for example, between continuous reinforcement (CRF) and FR 5, any responses allocated to the leaner schedule will reduce the total amount of reinforcement obtained. Those same responses could have been emitted to obtain reinforcement more quickly on the richer schedule. The concurrent FR FR findings with nonhumans have been replicated in laboratory research with persons with mental retardation (Schroeder, 1975). More recently, applied research has also shown that a student with profound mental retardation quickly responded to vocational tasks on a FR 1 schedule rather than a VR 2 schedule (Mace, McCurdy, & Quigley, 1990).

In addition to various parameters of reinforcement, another variable that can affect response allocation is the effort that a response requires. The construct of *effort* has been defined in the psychological literature as the subjective sense of the amount of work required to perform some voluntary action (Reber, 1985). According to physicists, work is the product of the force applied to an object and the distance the object is moved by that force, that is, work = force × distance (Cutnell & Johnson, 1989). *Work* is more objectively defined in physical terms, and its manipulation may or may not result in a subjective judgment of increased effort.

Researchers have presumed to manipulate response effort and have operationalized this construct in various ways. In research with nonhumans, the operationalizations of effort tend to align more closely with the definition of work employed in physics. The force required to operate a manipulandum (i.e., move it through space) was used in a number of studies with nonhumans (e.g., Adair & Wright, 1976; Chung, 1965; Hunter & Davison, 1982). Research with humans has also operationalized effort in terms of applying a physical force to move an object through space (Bradshaw, Ruddle, & Szabadi, 1981; Schroeder, 1972; Winston, Torney, & Labbee, 1978).

Some applied research with humans has operationalized effort as academic task difficulty (e.g., Neef, Shade, & Miller, 1994). This approach may be more consistent with a definition that characterizes effort as "intensification of mental activity when it is obstructed" (English, 1958, p. 171). The least effort principle states that, with other variables held constant, organisms will attain a goal using the means requiring the least effort (Sutherland, 1989). For example, in a study with 9- to 12-year-old children, a wheel-turning device was used to manipulate response effort. Subjects lowered their standards for self-reward and minimized response effort when allowed to do so to obtain tokens to watch cartoons (Winston et al., 1978).

In some experiments, the manipulations of effort may be so high that organisms cannot respond effectively. This outcome was shown in a study in which the thermoregulatory behavior of monkeys was studied by having them pull a chain to warm their chamber. When response effort increased considerably, subjects stopped responding and sat in their chamber and shivered (Adair & Wright, 1976). In research with 1 adult with mental retardation in a sheltered workshop, the degree of torque (i.e., 0.45, 0.9, or 1.8 kg) needed to unscrew nuts from studs was manipulated (Schroeder, 1972). The three levels of response effort were presented at FR 5, 50, and 300 schedules.

When response effort was low, responding increased as the schedule was thinned, but at higher levels of effort, the subject virtually terminated responding when the schedule was the most lean. The subject responded to a thinning schedule only when effort was low, but when effort was greater and the schedule was lean, responding was not maintained.

In most concurrent-schedule research, response effort typically has been held constant while reinforcement variables have been manipulated. Several studies, however, have incorporated response effort as an independent variable along with one or more reinforcement variables. In a study with nonhumans, different levels of force to activate a manipulandum were combined with different concurrent VI VI schedules (Chung, 1965). An inverse relationship between responses emitted per minute and force requirement was found, with more responding under concurrent VI 1 than under VI 3. More recently, Alling and Poling (1995) also showed that as the required response force increased, mean interresponse times for rats increased.

There is very little research that has studied the combined effects of response effort and concurrent reinforcement schedules on humans. In a laboratory study with typical adults, concurrent VI VI schedules and two levels of force requirements to pull a lever were presented (Bradshaw et al., 1981). Subjects showed a preference for the lower effort alternative over and above relative reinforcement. This study showed, however, that responding to the richer reinforcement schedule can be overridden when choices differ simultaneously with respect to response effort. In a research program in which the primary variable of interest has been characterized as effort or generalized self-control training, rats (Eisenberger, Weier, Masterson, & Theis, 1989) and elementary school children (Eisenberger, Mitchell, & Masterson, 1985) were trained to choose response options that required the exertion of more effort to attain larger rewards rather than options that required less effort for a lesser reward.

When work requirements are increased, several outcome variables may be affected. One possibility is that the latency to initiate responding or interresponse time may increase (Alling & Poling, 1995); participants may avoid responding. Another possibility is that duration to complete a response may increase as work requirements or response effort increases. The response may be in a participant's behavioral repertoire but may take more time to emit to meet the reinforcement contingency (e.g., more difficult math problems may take longer to solve than easier math problems). Also, as work requirements increase along a continuum, the proportion of responses completed correctly may decrease, eventually to the point that participants may not be able to respond at all (e.g., Adair & Wright, 1976; Schroeder, 1972). As response effort increases, therefore, the probability of emitting a response that results in reinforcement may decrease along some mathematical function until the response effort required no longer is in participants' behavioral repertoires. In addition, these effects of effort may result in a delay of reinforcement. It may be difficult to separate the unique effects of response effort, probability of reinforcement, and delay of reinforcement on performance.

There is a paucity of basic or applied concurrent-schedule research in which persons with mental retardation and children have been participants. The general purpose of the present research, therefore, was to extend the literature on concurrent schedules with typically developing preschool children and adults with mild and moderate mental retardation using applied tasks. Applied tasks often vary simultaneously on more than one reinforcement and response variable. The present series of studies examined performance under concurrent FR schedules, with work requirements manipulated simultaneously. We tested whether participants would shift their response allocation from tasks involving less work to those involving more work when the programmed FR schedule became leaner for the former, or whether participants would continue to select the easier work requirement regardless of a less favorable reinforcement schedule (i.e., conform to the least effort principle). An increase in physical work requirements was associated with a lower probability of meeting the programmed FR schedule requirements and receiving reinforcement. Because reinforcement was contingent on accuracy of responding and not merely choice behavior, there was an underlying effective VR schedule for choices made (i.e., the choice made was reinforced not on an FR schedule but on some variable number of choices based on response accuracy). Choice behavior, therefore, was examined in relation to the effective VR schedules in Experiments 2 and 3.

EXPERIMENT 1

The initial experiment involved concurrent FR FR schedules. The task involved sorting silverware (i.e., picking up pieces of silverware from one container and placing them by type of cutlery in another container across the table), which has domestic and vocational relevance. Although each individual sorting response involved essentially the same amount of work (i.e., force × distance), the greater the number of pieces of silverware sorted, the greater the total work performed. The greater the schedule requirement, the greater the total work requirement. Cumulatively, one must engage in twice as much work to receive reinforcement on an FR 2 schedule compared to a CRF schedule. Defining ratio requirements in terms of effort is not a new characterization. Keehn (1981, p. 333) stated that "different ratios specify different amounts of effort per reinforcer." The research question for Experiment 1 was whether adults with mild and moderate mental retardation would respond exclusively to the choice involving the lesser work requirement (i.e., denser reinforcement schedule), as had been the case in past concurrent FR FR research.

Method

Participants. Six persons with mild and moderate mental retardation attending a day vocational program at a community rehabilitation facility served as participants. They were selected randomly from a list of potential participants referred by a staff member at the facility. All participants lived at either a public or a community residential facility. Their work tasks at the rehabilitation facility involved assembly and sorting tasks. Individuals participated after informed consent was given either by themselves or by their guardians.

Carl, a 32-year-old man with an IQ of 64 (Wechsler Adult Intelligence Scale—Revised, WAIS-R), had an additional label of explosive personality disorder. Although he could count past 60, he could not add or multiply without a calculator.

Sam was a 36-year-old man with an IQ of 46 (WAIS-R) and an additional label of organic personality disorder. Sam could count to 30, but could not add or multiply. During sessions, Sam emitted a variety of stereotypic behaviors (e.g., rocking, teeth grinding, and rubbing his face with his hands).

Mark was a 41-year-old man with an IQ of 46 (WAIS-R) and an additional diagnosis of schizophrenia. Mark neither counted past 10 consistently nor added or multiplied. During sessions, Mark emitted disruptive and aggressive (e.g., feet stomping, spitting, swearing, threatening), off-task (e.g., wandering), and other inappropriate behavior (e.g., constantly talking about food and singing loudly).

Sue was a 31-year-old woman with an IQ of 43 (Stanford-Binet) and an additional diagnosis of dyskinesia. She could count to 30 consistently, but could not add or multiply without a calculator.

Pete was a 59-year-old man with an IQ of 50 (WAIS-R); he attended the Elder Care program. He could count past 60 and perform simple addition independently, but needed a calculator to perform complex addition and multiplication.

Jen was a 38-year-old woman with an IQ of 62 (Stanford-Binet) and with an additional diagnosis of Prader Willi syndrome. She could add and multiply independently.

Materials and setting. Thirteen sets of silverware (i.e., knife, fork, and spoon), two cylindrical (33.02 cm by 17.78 cm by 10.16 cm) plastic containers (blue for the task on the chain schedule and clear for the task on FR 30), and a rectangular plastic kitchen silverware storage receptacle with premade slots for the three different types of utensils were used for the experimental task. The different colored containers provided redundant discriminative stimuli for experimental conditions and helped the secondary observer to discriminate choice responding on the videotape. Pilot work showed no color preference for either of the two plastic containers. Two stopwatches were used to time sessions. Ten index cards (7.62 cm by 12.70 cm), with one of the numerals 1 to 10 on each card, and an additional card with the numeral 1 were also used. A Sony 8-mm Handycam® and tripod, along with a JVC HRD720V VHS VCR, six VHS videocassettes, and two 8-mm cassettes, were used to record sessions for interobserver agreement assessments. Pennies were used as reinforcers. Participants earned small amounts of money in their rehabilitation facility and made purchases there. One session was conducted per day, 5 days per week, for each participant in an office at the rehabilitation facility. The duration of each session was 20 min.

Measurement and data collection. The work requirement was defined as the number of silverware-sorting responses to be performed during a trial. In this operationalization, work requirement was effectively the same as the ratio reinforcement-schedule requirement.

Each participant sat across a desk from the experimenter. The two plastic containers (the clear one filled with 30 pieces of silverware and the blue one filled with six pieces) and the silverware storage receptacle were placed in front of the participant. One knife, fork, and spoon were placed in designated slots in the receptacle as a sample. One penny was placed in front of each of the two containers. Either a stack of numbered index cards arranged in descending order (10–1 or 5–1) or the card with 1, depending on the reinforcement schedule in effect, were placed on top of the pennies. These numbers cued the number of trials remaining to receive reinforcement.

The trial started when the participant made a choice by reaching into either of the two containers for silverware. The trial terminated when the last utensil was placed into the storage receptacle. At the end of the trial, the participant took the penny if the schedule requirement had been met. If it had not been met, the experimenter removed the index card that exposed the next lower numbered card. The silverware that the participant had sorted into the receptacle was replaced in the original container, and the next trial began. The participant was instructed to place the money he or she received in a pile on the desk.

Participants were not allowed to change to the alternative schedule within a trial (i.e., before completely emptying the container they had started). When switching was attempted, the response was blocked and the participant was instructed to finish emptying the container that was initially chosen. When sessions ended during a trial because the allotted time had elapsed, the participant completed sorting that container but reinforcement was not delivered.

Interobserver agreement. Interobserver agreement was calculated between the experimenter and secondary observer, who independently scored 25% of sessions from videotapes. An agreement occurred when both observers scored the same schedule selection and number of reinforcers earned per session. Prior to conducting agreement checks, the two observers simultaneously scored three 10-min videotaped segments of a pilot participant while reviewing response definitions. The two observers then scored actual 20-min videotaped sessions until at least 90% agreement was attained across each dependent variable for three consecutive assessments. There was 100% interscorer agreement during the experiment.

Experimental design and conditions. A combined concurrent operants and reversal design was used. One choice was always FR 30, and the alternative choice was a chain schedule that varied across experimental conditions from chain FR 1 (FR 6), to FR 5 (FR 6), to FR 10 (FR 6). A chain schedule is composed of two or more sequentially presented simple schedules that are signaled by an arbitrary stimulus, the color of the silverware container (Pierce & Epling, 1995b). The baseline condition was always concurrent chain FR 1 (6) FR 30, followed by FR 30 and one of the other two conditions in random order. After the three conditions were implemented, they were replicated in random order, with the only constraint that the fourth condition could not be the same as the third. Phases continued until data stabilized based on visual analysis.

Prebaseline. Participants initially received one 20-min forced exposure session, with a 10-min block of practice on each of the two tasks (i.e., sorting either 6 or 30 utensils). Noncontingent praise and 10 pennies, delivered singly at arbitrary times throughout the session, were provided.

Concurrent chain FR 1(FR 6) FR 30 (baseline). Participants had their choice on each trial of sorting either the 6-utensil (chain FR 1 [FR 6]) or 30-utensil (FR 30) container, using procedures described above.

Concurrent chain FR 5 (FR 6) FR 30. Participants had their choice on each trial of sorting either five containers of 6 utensils each (chain FR 5 [FR 6]) or one container of 30 utensils (FR 30) to earn a penny, using procedures described above. The two conditions were functionally equivalent, because each required participants to emit 30 sorting responses to receive reinforcement.

Concurrent chain FR 10 (FR 6) FR 30. Participants sorted either 10 containers of 6 utensils each (chain FR 10 [FR 6]) or one container of 30 utensils (FR 30) to earn a penny, using procedures described above. This condition required participants to choose between 60 responses on the chain FR 10 (FR 6) schedule or 30 responses on FR 30. Thus, the greater work choice in baseline (i.e., FR 30), became the lesser work choice in this condition. Participants could maximize reinforcement and minimize work by switching exclusively to the FR 30 choice.

Results and Discussion

The number of responses allocated to each of the two choices in each experimental condition is presented in Figure 1. Participants tended to respond consistently between the initial and replication phases of each condition. In baseline, all participants selected the choice involving less work, chain FR 1 (FR 6), on nearly every trial.

When the choices involved equal work (i.e., sort 30 pieces) created by functionally equivalent reinforcement schedules (i.e., chain FR 5 [FR 6] and FR 30), it was ir-

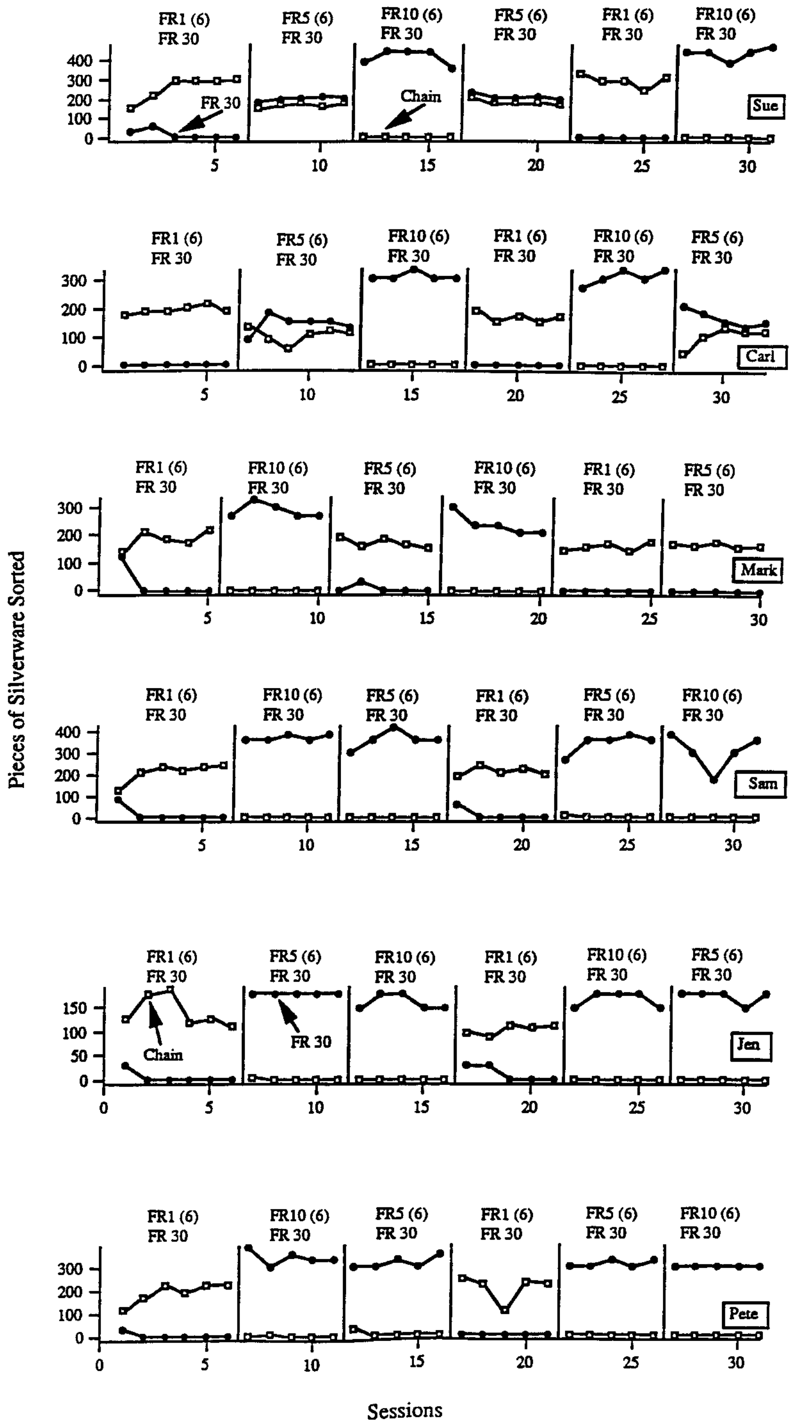

Figure 1. Pieces of silverware sorted in FR 30 and chain experimental conditions by adults with mental retardation in Experiment 1.

relevant whether participants showed a response preference to one option or the other. Sam, Jen, and Pete almost exclusively selected the FR 30 schedule, Mark chose the chain schedule, and Sue and Carl were indifferent with respect to choices.

When the choice was between FR 30 and chain FR 10 (FR 6), participants uniformly selected FR 30. These adults with mild and moderate mental retardation switched from choosing the containers for the chain schedule to selecting the container for the FR 30 schedule. The discriminative stimulus for less work in the initial phase of the experiment, the blue container, became the discriminative stimulus for more work in a subsequent condition, and vice versa for the clear container. Once again, participants maximized reinforcement and minimized work, not only by choosing the response option that required half as much work but also by responding to changes in the discriminative stimuli. These response-allocation data are generally consistent with those from past concurrent ratio schedule research (Herrnstein, 1961). Responding exclusively or nearly so to the denser FR schedule is compatible with the matching law and the least effort principle. Participants expended less work cumulatively for the ratio schedule requirements by choosing the richer schedule.

EXPERIMENT 2

The purpose of Experiment 2 was to systematically replicate Experiment 1, with a change in the type of work requirement, schedules, and participants. Work was manipulated by tossing a beanbag into a box from either a shorter or a longer distance. Participants would have to exert a greater force to throw the beanbag a longer distance; therefore, there was a greater work requirement for the further target. The probability of making a successful throw decreased, however, as distance from the box increased. A decrease in the probability of meeting a response criterion sometimes is an effect of an increased work requirement. The two distances from the box used for most participants, 0.91 m and 1.83 m, had been established by pilot work and showed 75% and 25% success rates, respectively. The task is a preschool activity that might promote gross motor and visual-motor development as well as being recreational.

Method

Participants. Participants (Don, Laura, Lisa, and Mick) were four 4- to 5-year old children of typical development attending a university affiliated preschool program. Participation was solicited by notes sent to the children's homes. There were 2 boys and 2 girls.

Materials, setting, and sessions. A cardboard box (29.21 cm by 45.72 cm by 10.16 cm) and 25 blue plaid beanbags (12.70 cm square, weighing 141.75 g each) were used for the experimental task. Small adhesive stickers depicting animals, designs, people, words, and other popular children's themes served as reinforcers. Stickers were used as reinforcers based on children's verbal expression of interest in them. Sticker books, composed of laminated construction paper pages bound together with yarn, were made for each participant. A kitchen timer was used to time session duration.

The setting was a large open space in the reception area of the preschool that was not isolated from day-to-day traffic of adults and children. Five-minute sessions were conducted once daily 4 to 5 days per week, depending on participants' availability.

Measurement and data collection. Work was operationalized as tossing beanbags underhand into the box from two distances (i.e., 0.91 m or 1.83 m). Mick's baseline responding was indifferent; he tossed from both the 0.91-m and 1.83-m mark. Consequently, the greater work mark for him was moved back to 2.74 m. The box was secured to the floor with Velcro® tape, and tossing distances were indicated on the floor with masking tape. A correct response was defined as one in which the beanbag went into and stayed in the box.

Interobserver agreement. Two university students served as secondary observers for 25% of the sessions. They were given the definition of a correct response, and they observed and recorded one actual session of the CRF/low CRF/high condition during data collection. Both secondary observers achieved 100% scoring agreement with the experimenter.

Experimental design and conditions. The experimental design was similar to that in Experiment 1, with different concurrent schedules and work requirements.

Prebaseline. Participants received one preexperimental forced exposure session of five tosses each from the two distances to provide experience with the two levels of work. The task was modeled first by the experimenter.

Concurrent CRF/low CRF/high (baseline). Participants had their choice of tossing the beanbag from either the closer or further distance each trial. They received one sticker for each correct toss regardless of distance. Participants were asked to state the "rules of the game" for the condition in effect periodically throughout the session.

Concurrent FR 5/low CRF/high. Procedures were similar to baseline, except that reinforcement contingencies were changed to FR 5 from the close line (i.e., tossing five beanbags correctly into the box) and CRF from the far line.

Concurrent FR 10/low CRF/high. Procedures were similar to baseline, except that reinforcement contingencies were changed to FR 10 from the close line (i.e., tossing 10 beanbags correctly into the box) and CRF from the far line.

Each time participants met the reinforcement contingencies, the experimenter arbitrarily selected one sticker from a bag and set it face down on a table. At the end of each session, participants took their stickers and either placed them in their books or took them home.

Results and Discussion

Figure 2 shows response allocation to the two levels of work across experimental conditions for preschool participants. All participants allocated considerably more beanbag tosses from the shorter distance, which involved less work and a higher probability of success, when both options were on CRF during both baseline phases. Laura persisted with the easier, more probable response option during initial sessions of the next condition when reinforcement for that choice was thinned to FR 10. Eventually she switched choices and achieved a steady state from the longer distance, which remained on CRF. Don persisted with his baseline pattern of making low work choices on only one session when reinforcement was thinned; he then switched to the greater work option on CRF. Mick also allocated most of his responses to the longer distance choice when reinforcement was thinned for the closer alternative. Lisa, in contrast, showed a clear preference for the less work and higher probability of reinforcement choice during initial phases with partial reinforcement, despite increasingly thinner schedules. During replication of these conditions, in contrast, Lisa went from initial indifference to a preference for the longer distance choice. These data show that when the programmed FR schedules were identical for the two choices, participants chose the option with lesser work and higher probability of success. When the relative density of reinforcement was thinner for the easier option, however, participants tended to switch to the option that was

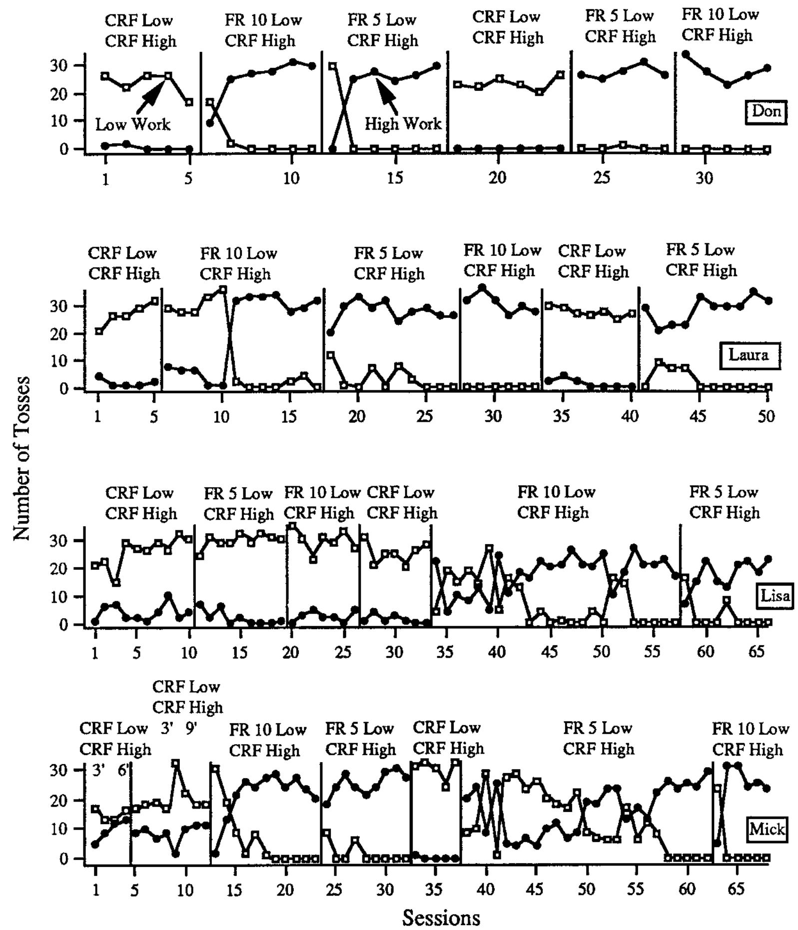

Figure 2. Number of beanbag tosses in CRF high-work and FR low-work experimental conditions by preschool children in Experiment 2.

more difficult and had a lower probability of success with the richer FR schedule.

Figure 2 shows participants' performance as a function of the two work levels and their programmed concurrent FR schedules. In this experiment, however, the physical work affected response accuracy and probability of receiving reinforcement. Not every toss resulted in a response that counted toward the programmed FR schedule requirements, because children's beanbags sometimes did not land in the box. As a consequence, participants effectively were on VR schedules for tosses made from each level of effort; the effective VR schedules for tosses were thinner than the programmed FR schedules for response accuracy because of response errors. Consequently, participants' choice performance may have actually been influenced by the underlying VR schedule rather than by the programmed FR schedules.

To examine this possibility, data are presented in Table 1 that show percentage of responses allocated, percentage of reinforcers received, and effective VR schedules for the two work levels in each experimental condition. As a comparison to the effective VR schedules shown in Table 1, the ratios of accurate responses to reinforcement available by the programmed FR schedules were 1:1,

Table 1
Response and Reinforcer Results for Experiment 2

Participant	Phase	% of responses allocated Low	% of responses allocated High	% of reinforcers delivered Low	% of reinforcers delivered High	Effective VR schedule Low	Effective VR schedule High
Don							
Concurrent CRF/low CRF/high							
	1	98	2	100	0	1.67	NR
	2	100	0	100		1.30	
Concurrent FR 5/low CRF/high							
	1	18	82	7	93	10.00	3.50
	2	1	99	0	100	NR	4.25
Concurrent FR 10/low CRF/high							
	1	11	89	4	96	19.00	6.25
	2	0	100		100		5.00
Laura							
Concurrent CRF/low CRF/high							
	1	94	6	98	2	1.60	4.50
	2	96	4	99	1	1.43	8.00
Concurrent FR 5/low CRF/high							
	1	10	90	4	96	10.00	3.34
	2	7	93	3	97	7.67	2.60
Concurrent FR 10/low CRF/high							
	1	40	60	10	90	20.25	3.24
	2	0	100		100		4.23
Lisa							
Concurrent CRF/low CRF/high							
	1	86	14	98	2	1.60	11.50
	2	87	13	98	2	1.44	9.00
Concurrent FR 5/low CRF/high							
	1	96	4	96	4	10.13	11.00
	2	13	87	5	95	12.00	3.81
Concurrent FR 10/low CRF/high							
	1	92	8	75	25	23.11	5.67
	2	29	71	6	94	21.36	3.13
Mick							
Concurrent CRF/low CRF/high							
	1	67	33	88	12	1.72	6.00
	2	99	1	100	0	1.28	NR
Concurrent FR 5/low CRF/high							
	1	6	94	7	93	7.50	9.00
	2	42	58	47	53	7.14	8.54
Concurrent FR 10/low CRF/high							
	1	23	77	13	87	23.00	11.19
	2	14	86	8	92	11.50	6.04

Note. NR, no reinforcement.

1:5, and 1:10 for the CRF CRF, CRF FR 5, and CRF FR 10 conditions, respectively. Discrepancies between the programmed FR and effective VR schedules reflect response errors.

The table shows that during the CRF CRF condition there was a general correspondence between the percentage of responses allocated to each level of work, the programmed schedule for it, and the effective VR schedule for all participants. For example, Don allocated 98% and 100% of his responses to the low-work choice in both phases of that condition. He received 100% of his reinforcers from the shorter distance, and the effective VR schedule resulted in his choices being reinforced on average between one and two tosses. Across experimental conditions, the choices made by Don and Laura were consistent with expectations based on the programmed FR and effective VR reinforcement schedules.

Lisa and Mick present some discrepancy between choice and effective VR schedule. For the first phase of the FR 5-CRF condition, Lisa allocated the majority of her responses (96%) to the easier choice; however, her effective VR schedules produced nearly equal reinforcement densities for both choices (i.e., a reinforcer every 10 to 11 responses, on average). Although CRF and FR 5 were programmed, the effective VR schedules resulted in one tenth or one half the programmed schedules, respectively, because of response errors. When this condition was replicated, Lisa switched her choices in favor of the greater work option, and there was a closer correspondence between choice and effective VR schedule.

Mick responded opposite to Lisa in the first phase of the FR 5 CRF condition. He made the majority of his responses from the longer distance (i.e., 94%), but the effective VR schedules were relatively close for the two choices. Although he made more choices of the longer distance, he was more accurate from the shorter distance, resulting in effective VR schedules that were not very discrepant. Although Mick's choices eventually stabilized, favoring the greater work option when this phase was replicated, Table 1 shows that his percentages of response allocation for the entire phase were closer to indifference (i.e., 42% vs. 58%). This performance is consistent with the effective VR schedules for that phase (i.e., 7.14 vs. 8.54, for low- and high-work response options, respectively).

The results of Experiment 2 suggest that, for the most part, preschool children chose the alternative associated with the richer obtained VR schedule. This finding is noteworthy because it suggests that children are sensitive to probabilities of reinforcement within phases. They generally chose the closer distance from which to throw when schedules were equivalent. When the schedule was thinned for the easier choice, participants tended to allocate their responding to the riskier alternative with a richer programmed schedule. In general, the results show that the effective VR schedule was richer for the riskier choice; therefore, participants' choice making was under the control of the underlying VR schedule. They were willing to exert more work or take more risk for the positive reinforcers that were the consequences.

EXPERIMENT 3

The purpose of Experiment 3 was to systematically replicate Experiment 2, with a change in the type of work requirement and schedules. In Experiment 3, work was operationalized in terms of jumping over hurdles of different heights by preschool children. The task was a preschool physical activity that might be used to promote gross motor and visual-motor development. To jump over a hurdle requires that one exert a force to move one's body through space a given distance. The greater the distance that one moves an object of constant mass (e.g., one's body), the more work that is performed. Also as in Experiment 2, the greater work choice was the riskier choice because the probability of jumping the higher hurdle successfully and receiving reinforcement was reduced.

Method

Participants. Seven 4- to 6-year-old children (Jerry, Pat, Doug, Jack, Cathy, Cory, and Emily) of typical development, who attended a university day-care facility different from that in Experiment 2, participated. Five participants were male and 2 were female. Participation was solicited as in Experiment 2.

Materials, setting, and sessions. Two identical wooden apparatuses were constructed with horizontal bars whose height could be adjusted on vertical columns. They were placed side by side, with the bar on one apparatus set lower than the one on the other. This provided participants with concurrent low- and high-height response choices for jumping.

Each apparatus consisted of two vertical boards (5.08 cm by 10.16 cm by 52.07 cm), spaced approximately 76.20 cm apart, with the 5.08 cm sides facing and stabilized by a wooden base. Each upright board had holes drilled in the 5.08-cm side at 2.54-cm intervals in which a wooden dowel (0.51 cm diameter) could be inserted. A white plastic PVC bar was placed horizontally on the wooden dowels to construct a hurdle. The dowels were moved so that the height of the bar could be adjusted for each participant. The bar easily came off the wooden dowels when contact was made with it to prevent injuries. The apparatus was placed on a gym mat to prevent injuries.

A kitchen timer was used to time session duration. Plastic poker chips, which served as token reinforcers, were exchanged for reinforcers (e.g., stickers, puzzles, Play-Doh,® plastic stars) that had been identified by participants' verbally stated preferences. Sessions were conducted once daily 4 to 5 days per week, depending on participant availability, in a small conference room at the participants' day-care center.

Measurement and data collection. Jumping over the apparatus with the lower bar was the low-work response, and jumping over the apparatus with the higher bar was the high-work response. A correct response was operationally defined as jumping with both feet over the bar, landing on both feet, and remaining standing without touching the mat with any other body part other than the feet, with the bar remaining horizontally across the dowels. For each trial, the following were recorded: which schedule of reinforcement was in effect, which jumping height was chosen, whether the jump was completed correctly, and whether the child received a token.

Interobserver agreement. Interobserver agreement procedures and results were similar to those in Experiment 2.

Experimental design and conditions. The experimental design was similar to that in Experiment 2, with a difference in the concurrent schedules and work requirements. Intertrial intervals were 3 to 5 s, the time necessary to record responses and for participants to return to the two hurdles to make a choice.

Prebaseline. Prior to baseline, participants had three 5-min sessions to establish their two levels of work individually. During the first session, the participant jumped over the bars to establish the height of the low-work bar. Both hurdles were placed side by side with the bars at the same height, and the participant chose one over which to jump. Body size, gender, and age were considered when making the initial estimate of height for the bars. The height was adjusted either up or down depending on each participant's previous response. Participants jumped only in the direction of the experimenter so that she could catch them if they fell. The criterion for the low-work height was to jump correctly over the bar on 8 of the 10 trials. For each correct jump, the experimenter placed a token on a couch in the participant's view. Tokens were exchanged for reinforcers at the end of each session throughout the experiment.

During the second session, the height of the high-work bar was established using procedures similar to those for the low-work bar. Participants were required to jump correctly over the bars on 3 of the 10 trials. During the third session, participants repeatedly jumped alternately over the low- and high-work bars to allow them to experience both choices during the same session. During these sessions, participants received response-contingent feedback and token reinforcement for correct jumps.

Concurrent CRF/low CRF/high (baseline). Participants were told that they had 5 min to earn tokens by jumping over a bar of their choice on each trial. The reinforcement contingencies and criteria for correct responding were stated. After each correct jump from either level of effort, the experimenter placed one token on the couch in the participant's view. After every fifth trial, the reinforcement contingencies were restated. The hurdles with the two different levels of work were counterbalanced for position each session. Trials continued until 5 min elapsed. This condition served as a baseline to test the effect of work differences on choice behavior when reinforcement schedule was held constant.

Concurrent FR 4/low CRF/high. This condition was similar to CRF/low CRF/high, except for the reinforcement contingencies. Participants continued to earn CRF for the high-work choice, but the reinforcement schedule for the low-work choice was thinned to FR 4. This condition tested

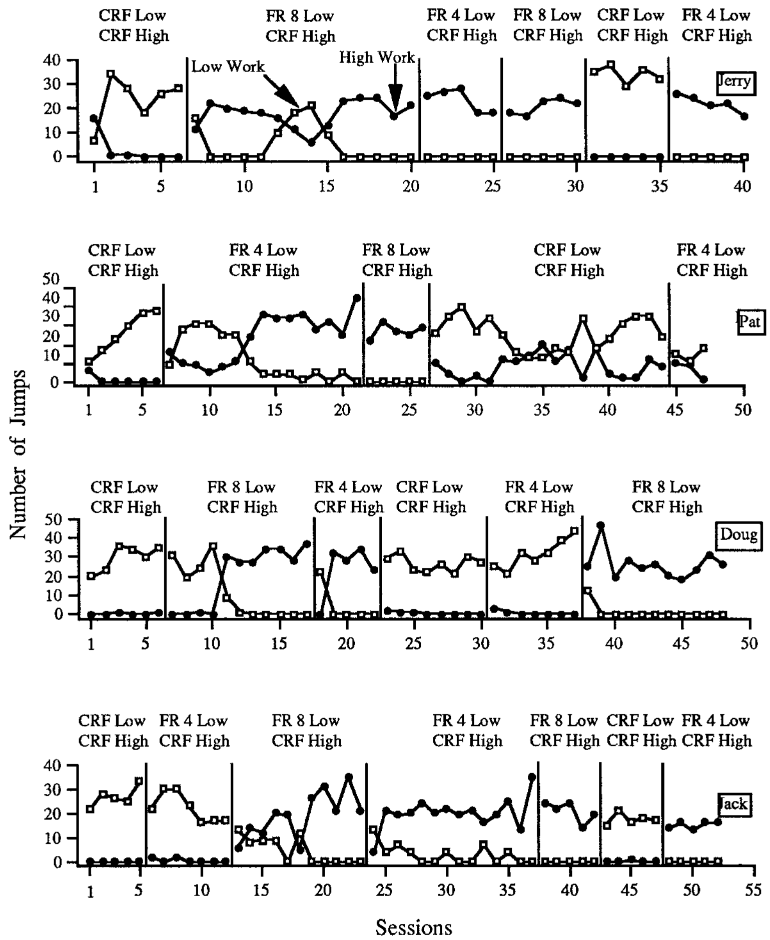

Figure 3. Number of jumps in CRF high-work and FR low-work experimental conditions by 4 preschool children in Experiment 3.

whether response allocation to the greater work response would increase over baseline levels when the reinforcement schedule for the low-work response was thinned.

Concurrent FR 8/low CRF/high. This condition was similar to CRF/low CRF/high, except for the reinforcement contingencies. Participants continued to earn CRF for the high-work choice, but the reinforcement schedule for the low-work choice was thinned to FR 8. This condition further tested whether response allocation to the greater work response would increase when the reinforcement schedule for the low-work response was thinned further.

At the conclusion of a session, tokens could be either traded for reinforcers (e.g., stickers) or saved for larger tangible items (e.g., puzzles, dinosaurs, toy jeeps, Treasure Rocks, crayons). Reinforcers were determined by asking participants what "prize" they wanted. No edible reinforcers were used.

Results and Discussion

Figures 3 and 4 show response allocation to the two levels of work across experimental conditions. All children clearly chose the lower height more frequently when both levels of work were on CRF in the initial baseline, and did so substantially when it was replicated. Pat and Cory, however, allocated

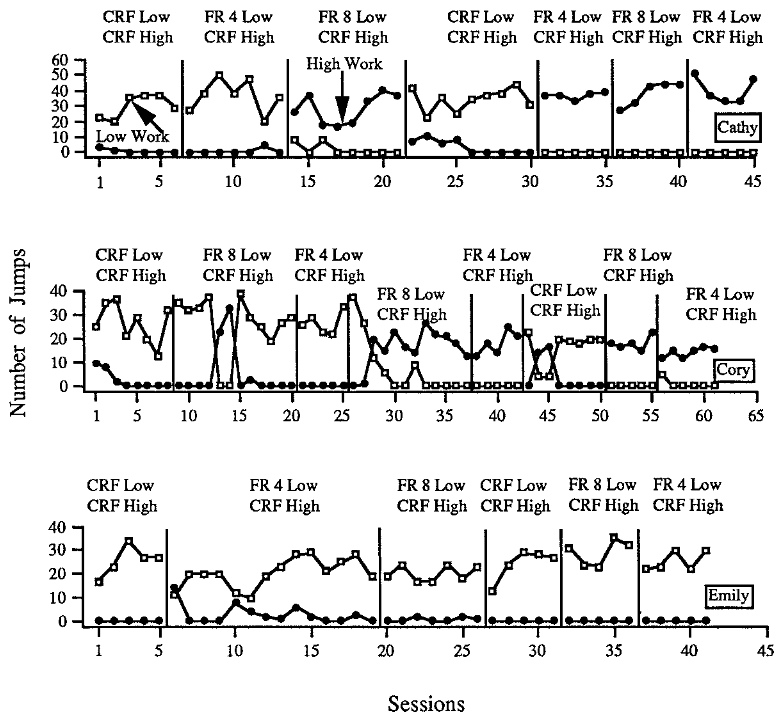

Figure 4. Number of jumps in CRF high-work and FR low-work experimental conditions by 3 preschool children in Experiment 3.

some responses to the higher alternative in the baseline replication. Pat adopted a win-stay, lose-shift strategy in the middle of that phase. He tended to make the same choice on a subsequent trial after receiving reinforcement for that choice on the previous trial; he also tended to switch responses if his response was not reinforced on the previous trial. Cory received almost as much reinforcement on the greater work option for two sessions in the baseline replication. Jerry's responding seems to have been controlled by the programmed CRF schedule, because he almost exclusively emitted the greater work response when the lesser work choice was on partial reinforcement conditions. For several sessions during the middle of the initial FR 8/low CRF/high condition, Jerry said that he switched to the easier option because he was tired and sore from playing soccer, and he was not feeling well. He switched back to the CRF/high condition "to get the prize."

All other participants verbalized their apprehension about jumping over the higher hurdle in partial reinforcement conditions after baseline. They continued responding to the easier choice for idiosyncratic lengths of time. Typically, they switched to the higher height after having responded successfully to that option during some trials. This was the case for Doug, who switched to the greater work option when it was on FR 8 and continued when that option became even richer (i.e., FR 4). At the point of switching, Doug said that he wanted to jump higher so he could "practice slam dunks." During replication conditions, Doug chose the easier response option when it was FR 4, which continued his pattern of responding from the baseline replication; however, he switched choices when the low-work choice was thinned further to FR 8. Pat moved and terminated participation prior to the completion of the partial reinforcement condition replications; however, he achieved steady states for the greater work option in the initial phases of these conditions.

For Jack, Cathy, and Cory, a third replication was implemented because of steady-state differences between the first two phases. These participants tended to persist with the easier response option when the schedule was thinned immediately after baseline. They verbalized a fear of the higher height; however, after experiencing some success with it, they subsequently allocated more of their responses to it. Corey said that his choice was influenced by the shoes he was wearing that day; the more difficult task was chosen when he wanted to practice slam dunks. Emily was the only participant who consistently favored the easier response option because of a fear of jumping the higher hurdle; she accepted thinner schedules to do so.

Table 2 presents choice and reinforcement data for Experiment 2. Overall, the table shows that the effective VR schedules were generally consistent with the programmed values. There were deviations of response allocation predicted from the schedule values for 5 children in one phase and for Emily in three phases. This result supports the finding in Experiment 2 that preschool children are sensitive to probabilities of reinforcement; however, work requirements can disrupt schedule-induced responding in some instances.

Past research shows that humans and nonhumans prefer predictable or certain outcomes, such as reinforcers, over unpredictable or probabilistic ones (Steinhauer, 1984). That would argue for participants' selection of the lower hurdle when the probability of reinforcement was more certain. The effect of the greater reinforcement density for the higher jump in the present experiment,

Table 2
Response and Reinforcer Results for Experiment 3

		% of responses allocated		% of reinforcers delivered		Effective VR schedule	
Participant	Phase	Low	High	Low	High	Low	High
Jerry							
Concurrent CRF/low CRF/high							
	1	88	12	95	5	1.10	3.00
	2	100	0	100		1.42	
Concurrent FR 4/low CRF/high							
	1	0	100		100		1.81
	2	0	100		100		1.36
Concurrent FR 8/low CRF/high							
	1	23	77	6	94	10.57	2.33
	2	0	100		100		1.04
Pat							
Concurrent CRF/low CRF/high							
	1	96	4	100	0	1.34	NR
	2	76	24	79	21	1.23	1.55
Concurrent FR 4/low CRF/high							
	1	34	66	12	88	5.55	1.49
	2	69	31	36	64	5.50	1.43
Concurrent FR 8/low CRF/high							
	1	0	100		100		1.45
Doug							
Concurrent CRF/low CRF/high							
	1	99	1	100	0	1.24	NR
	2	98	2	98	2	1.04	1.00
Concurrent FR 4/low CRF/high							
	1	16	84	5	95	4.40	1.19
	2	98	2	94	6	4.76	1.33
	3	0	100		100		1.05
Concurrent FR 8/low CRF/high							
	1	36	64	5	95	12.00	1.22
	2	7	93	1	99	12.00	1.13
Jack							
Concurrent CRF/low CRF/high							
	1	100	0	100		1.38	
	2	99	1	99	1	1.18	1.00
Concurrent FR 4/low CRF/high							
	1	97	3	90	10	5.54	1.33
	2	13	87	3	97	5.38	1.07
	3	0	100		100		1.14
Concurrent FR 8/low CRF/high							
	1	20	80	3	97	10.20	1.24
	2	0	100		100		1.16

Table 2
(*Continued*)

Participant	Phase	% of responses allocated: Low	High	% of reinforcers delivered: Low	High	Effective VR schedule: Low	High
Cathy							
Concurrent CRF/low CRF/high							
	1	98	2	100	0	1.13	NR
	2	91	9	92	8	1.04	1.23
Concurrent FR 4/low CRF/high							
	1	98	2	100	0	4.32	NR
	2	0	100		100		1.21
	3	0	100		100		1.20
Concurrent FR 8/low CRF/high							
	1	7	93	1	99	8	1.18
	2	0	100		100		1.11
Cory							
Concurrent CRF/low CRF/high							
	1	92	8	98	2	1.18	6.67
	2	81	19	89	11	1.10	2.21
Concurrent FR 4/low CRF/high							
	1	100	0	100		4.62	
	2	0	100		100		1.69
	3	5	95	2	98	5.00	1.58
Concurrent FR 8/low CRF/high							
	1	84	16	88	12	1.20	1.69
	2	33	67	8	92	10.44	1.85
	3	0	100		100		1.86
Emily							
Concurrent CRF/low CRF/high							
	1	100	0	100		1.27	
	2	100	0	100		1.06	
Concurrent FR 4/low CRF/high							
	1	88	12	90	10	2.57	3.33
	2	100	0	100		4.88	
Concurrent FR 8/low CRF/high							
	1	97	3	91	9	14.20	5.00
	2	100	0	100		12.06	

Note. NR, no reinforcement.

which was less probable or more uncertain to be reinforced, was to override participants' likely preference for the more probable reinforcement of the lower jump. In general, that choice was reinforced, as shown by the effective VR schedule data.

Participants' choices seem to have been affected by their within-experiment histories. After experiencing reinforcement for the lower height option in baseline, some participants persisted with this choice in the next condition with partial reinforcement. This easier response was also made because participants verbalized a fear of jumping over the higher height until successful responses at that height reinforced their switching. Participants' verbalizations suggest that the task manipulated not only physical work but also the more subjective response effort. Maturation or practice effects also seem to have been a factor that affected switches to the more difficult task. Participants had between 40 to 52 sessions over 4 months, and their physical skills improved to the point that the more effortful choice became easier over time. For some of the shorter participants, there was as little as 2.54 cm difference between the two choices.

This experiment also demonstrated the difficulty of controlling reinforcers in applied tasks for children. In addition to the stickers, achievement of more difficult responses (i.e., jumping the higher hurdles) or other idiosyncratic factors may have been reinforcers for some participants. Furthermore, children's health status, shoes that they were wearing, and outside activities were factors that influenced choice.

GENERAL DISCUSSION

The three experiments examined the effects of two levels of work in combination with three concurrent FR FR schedules of reinforcement on responding by preschool children and adults with mental retardation. One anticipated general response pattern was that participants would respond primarily to the lesser work option (i.e., least effort principle); however, only Emily in Experiment 3 responded consistently across the three conditions to that option despite its thinner programmed reinforcement schedule. Her risk-averse responding may have been under the control of negative reinforcement by avoiding the choice that was more effortful and had a lower probability of success. In addition, her choices for the less risky alternative were usually positively reinforced.

Across the three experiments, responding by all other participants was influenced by both response effort and reinforcement schedule to varying degrees. Participants tended to maximize reinforcement and minimize work in baseline by selecting the easier task when both alternatives were equated on reinforcement schedule. This maximization performance would be predicted from an economic model of choice (Pierce & Epling, 1995a).

Some participants, paradoxically perhaps, favored the greater work alternative in baseline even when reinforcement schedules were equivalent. In Experiment 2, Mick's greater work distance was moved from 1.83 m to 2.74 m. Two pilot children were discontinued from participation because their responding was indifferent between the shorter and longer distances during baseline and did not stabilize.

After responding primarily to the lesser work choice in baseline, preschool participants in Experiments 2 and 3 generally switched to the greater work choice when reinforcement on the easier choice was thinned. This switch occurred despite the lower probability of completing the response correctly and earning the reinforcer. The effective VR schedule results suggest that, for the most part, participants' choices were controlled by the underlying VR schedule. These results with preschool children, showing that they increase work for larger rewards, are consistent with a small body of nonhuman (e.g., Eisenberger et al., 1989) and human research (e.g., Eisenberger et al., 1985).

Engaging in a greater work requirement associated with a richer reinforcement schedule would be characterized by some researchers as self-control or learned industriousness, because participants paid a higher cost to achieve a larger goal (Eisenberger, 1992; Eisenberger et al., 1989). This conceptualization seems to be analogous to that from studies in which magnitude and delay of reinforcement are manipulated. In that research, subjects who choose a larger but delayed reward over a smaller immediate reward are also said to exhibit self-control (e.g., Green & Snyderman, 1980). Greater work and reinforcement delay options may be chosen if the other reinforcement variables (e.g., schedule, quality) are sufficiently favorable.

Another similarity between work and delay of reinforcement may be in the discounting of delayed rewards. Delay discounting may result in an organism choosing a smaller immediate reward, which is a sure thing, over a larger delayed reward, which is less certain. Subjects tend to discount the value of delayed rewards of a given magnitude in relation to the length of delay. A delayed reward is not worth as much as an equivalent immediate reward; there also may be a reduced probability of actually receiving the delayed reward (Green, Fry, & Myerson, 1994). Research also suggests that organisms discount probabilistic rewards (i.e., those that are uncertain; Rachlin & Siegel, 1994).

In the research involving delayed and probabilistic choices, the response work or effort requirements typically are negligible and are held constant. Work or effort requirements, however, may contribute to both delayed and probabilistic rewards. It is speculated that as work requirements or task effort increases, tasks become less probable of being completed successfully. In addition, effortful responses may take longer to complete successfully, thereby delaying reinforcement. Work requirements, therefore, may result in both probability and delay discounting in relation to the size of the work requirement. The effects of the work variable, therefore, may be confounded with delay and probability of reinforcement.

Emily in Experiment 3, and other participants on some trials, may have discounted the programmed CRF for jumping the higher hurdles. Incorrect jumps actually resulted in a leaner VR schedule of reinforcement for response attempts than the programmed CRF for correct jumps. Perhaps these participants engaged in effort discounting because the higher hurdles involved more probabilistic responding and more delayed reinforcement.

This speculation about the effect of response effort on reward is analogous to that of Navarick's (1982) description of the effect of delay on magnitude of reinforcement. Navarick stated that in a two-choice situation, the data set can best be described conceptually by a pair of ratios in which the amount of delay is subtracted from the amount of reinforcement for each choice. Responding will be determined by which choice offers the more favorable ratio. In natural environments, organisms are faced with a complex context of reinforcement and response variables, such as work or effort, for concurrent choices. The performance of organisms may be based on even more complex ratios than that described above (Schwartz & Robbins, 1995), and those ratios may change continuously over time as reinforcer satiation, fatigue, maturation, and other variables affect choice.

This research illustrates the contextual nature of responding. In natural environments, frequency, duration, immediacy, rate, magnitude, and quality of reinforcement occur simultaneously, along with work or response effort requirements to determine response allocation. The applied implication is that teachers and others who influence behavior should be sensitive to the need to adjust certain parameters of reinforcement or task variables as the performance context changes over time. Despite the potentially negative effect of work or task effort, the present series of studies showed that those effects can be compensated for by a greater density of reinforcement. The effective schedules of reinforcement in all three studies were potent variables that controlled choice behavior.

Researchers have provided conceptualizations regarding why work or response effort may affect responding. In his attempt to explain the differentiation of a response, Skinner (1938) speculated that the greater the difficulty or "awkwardness" of a response, the more negatively reinforcing stimulation it may produce. The simplest and easiest member of an inductive group may be strengthened by positive reinforcement "without emotional depressant effect" inherent in difficult responses (1938, p. 310). Chung (1965) drew the analogy between the suppressing effects of response force and that of electric shock reported by Azrin (1960). Chung did not conclude, however, that effortfulness is an aversive stimulus, because of the absence of data to show that organisms respond to avoid an effortful situation. Chung tied his findings to Hull's (1943) theory in which inhibition subtracts from reaction potential. Nevertheless, the aversiveness of response effort has been presumed by researchers such as Hull, James, Logan, McDougall, and Solomon (Eisenberger, 1992). Blough (1966) also suggested that effort and punishment operate in similar ways to improve stimulus control. Despite the potentially aversive effects of task work requirements or response effort, the present research suggests that these deleterious effects can be offset by an adequate positive reinforcement schedule.

Finally, this research addressed some conceptual issues regarding work and task effort. Work is an objective concept that can be physically measured. Response effort, in contrast, is a subjective construct that may or may not have physical referents (e.g., math problem difficulty). Both work and response effort have received much less attention by researchers compared to reinforcement variables. The present series of experiments adds to the small body of applied literature that has examined the effect of concurrent schedules of reinforcement and work or task effort on responding by preschool children and adults with mental retardation. Future studies should extend the present research on work and response effort by investigating their interaction with reinforcement variables in applied contexts with various subject populations.

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STUDY QUESTIONS

1. Describe several ways in which effort (work requirement) has been manipulated in applied research. How have these manipulations affected performance and the subsequent delivery of reinforcement?

2. What were the responses examined in each experiment, and how did the authors manipulate each response to increase the effort?

3. In what way was there a discrepancy between the dependent variables (shown in the graphs) and the measures for which interobserver agreement was assessed?

4. Briefly summarize the participants' response patterns. Under what conditions did the participants respond idiosyncratically?

5. Which data from Experiment 2 suggest that the results obtained may have been influenced by practice effects?

6. How were the two levels of work established in Experiment 3?

7. What variable other than response effort probably influenced performance in Experiments 2 and 3? How did the authors examine the potential effects of this variable? Can you suggest a way the experimental arrangement could have been altered to eliminate this source of confounding?

8. How might a teacher use the results of this study to develop a treatment for a student whose problem behavior is maintained by escape from difficult tasks?

Questions prepared by Jana Lindberg and Rachel Thompson, The University of Florida