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EFFECTS OF DIFFERENT ACCESSIBILITY OF REINFORCEMENT SCHEDULES ON CHOICE IN HUMANS

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Based on the delay-reduction hypothesis, a less profitable schedule should be rejected if its duration exceeds the mean delay to reinforcement. It should be accepted if its duration is shorter than the mean delay. This was tested for humans, using a successive-choice schedule. The accessibility of the less profitable (variable-interval 18 s) schedule was varied by changing the duration (in terms of a fixed interval) of the waiting-time component preceding its presentation. Forty-eight students were randomly assigned to three groups. In Phase 1, the duration of the less profitable schedule equaled the mean delay to reinforcement in all groups. In Phase 2, waiting time preceding the less profitable schedule was reduced in Group 1 and increased in Group 2. Thus, the schedule was correlated either with a relative delay increase (Group 1) or a delay reduction (Group 2). In Group 3, conditions remained unchanged. As predicted, acceptance of the less profitable schedule decreased in Group 1 and increased in Group 2. The increased acceptance in Group 2 was accompanied by a decreased acceptance of the more profitable (variable-interval 3 s) schedule, resembling a pattern of negative contrast. Response rates were higher under the component preceding (a) the more profitable schedule in Group 1 and (b) the less profitable schedule in Group 2. Implications for the modification of human choice behavior are discussed.

Key words: choice, delay-reduction hypothesis, successive-choice schedule, contrast, response rates, button pressing, adult humans

The analysis of choice is relevant for basic and applied behavior analysis. In basic research, the analysis of variables modifying response strength (Williams, 1988) and the development of quantitative models of conditioned reinforcement (Preston & Fantino, 1991) are of predominant interest. The analysis of choice is also of practical importance for applied problems, such as self-control versus impulsiveness (Logue, 1988), risk aversion versus risk proneness (Hamm & Shettleworth, 1987), foraging (Fantino, 1991), and drug-taking behavior (Hursh, 1991).

Up to now, most of the experiments on choice have used concurrent schedules, including concurrent-chains schedules. Preference for one of the alternatives, indicated by the relative response rates distributed between two simultaneously available schedules (in the case of concurrent schedules) and between two simultaneously available initial links (in the case of concurrent-chains schedules), is taken as an indicator of the reinforcing effects (values) of the schedules or of entering each terminal link, respectively (Davison & McCarthy, 1988). In recent years, there has been an increased interest in studying behavior under the so-called successive-choice schedule. Successive-choice schedules (Figure 1) are regarded as good models for studying naturally occurring behavior (e.g., foraging behavior) in the operant laboratory (Fantino, 1991; Fantino & Abarca, 1985). Thus, the ecological validity of the analysis of schedule-controlled behavior has been enhanced by using this procedure (Fantino, Abarca, & Ito, 1987; Lea, 1981; Shettleworth, 1987).

A concept guiding many theoretical accounts of choice is optimality: It is assumed that an organism chooses or should choose the alternative maximizing reinforcement rate. Any deviation from optimality is of special interest (e.g., impulsiveness instead of self-control, i.e., choice of a small immediate reinforcer instead of a large delayed reinforcer). In terms of biological models of optimality (e.g., optimal diet model; Charnov, 1976), the assumption is made that natural selection favors the most economic of alternative foraging patterns. On the other hand, models developed in operant condition-

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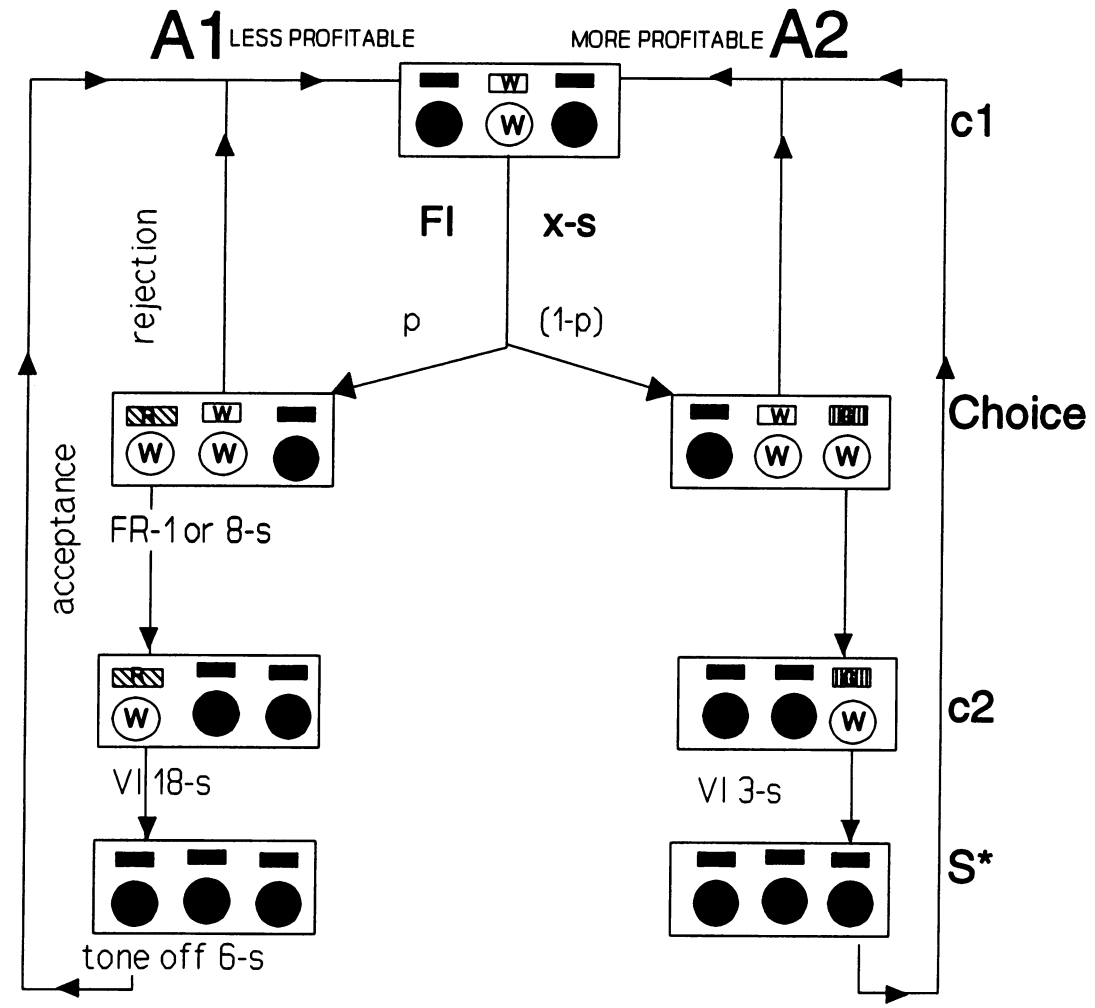

Fig. 1. Flowchart of the successive-choice procedure with the schedule parameters used in the present experiment. Rectangles stand for lights, and circles are operant buttons. Filled symbols: dark (i.e., not illuminated), unfilled and hatched symbols: illuminated (w = white; g = green; r = red). c1: c1 component (initial link), ch = choice; c2: c2 component (terminal link); S* = reinforcement.

ing predict how organisms obtain optimality: The delay-reduction hypothesis (DRH) provides a decision rule (Fantino & Preston, 1988) that can result in reinforcement maximization (Fantino et al., 1987). Fantino et al. argue that the optimal diet model and DRH complement each other: Many optimality models developed by behavioral ecologists hypothesize that natural selection has shaped organisms to maximize rate of energy intake per unit time. DRH, on the other hand, states the conditioning principle by which this may generally be accomplished: Outcomes will be chosen in terms of the correlation with a reduction in time until the onset of the next reinforcer. DRH was originally developed to account for conditioned reinforcement and to predict the value of a conditioned reinforcer (Fantino, 1969). Analyzing the relevant parameters for conditioned reinforcement, Herrnstein (1964) and Chung and Herrnstein (1967) first favored relative immediacy of reinforcement. Thus, it was assumed, that the value of a conditioned reinforcer is inversely related to the reinforcer delay in its presence (reinforcement density account). However, relative immediacy could predict only a small number of results in concurrent-chains schedules. Several experimental results led to a modification of the assumption that relative reinforcement density is the critical variable for choice, instead favoring relative delay reduction as the controlling variable. Choices become less selective (i.e., relative response rates tend to an indifference point) when initial-link duration is increased; choices become more selective when initial-link duration is shortened (Belke, Pierce, & Powell, 1989; Fantino, 1969; Hursh & Fantino, 1973; Wardlaw & Davison, 1974). Thus, degree of preference for the more profitable alternative is inversely related to the length of the choice phase.

When the terminal links are lengthened (conserving a constant ratio between the terminal links), there is a higher selectivity for the more profitable schedule (i.e., response rates are relatively higher under the schedule leading to the more profitable schedule: Davison & Temple, 1973, 1974; Duncan & Fantino, 1970; Killeen, 1970; MacEwen, 1972; Wardlaw & Davison, 1974; Williams & Fantino, 1978).

Given the same reinforcement rate for two alternatives A1 and A2 (e.g., A1, initial link: fixed-interval [FI] 30 s, terminal link: variable-interval [VI] 90 s and A2, initial link: FI 90 s, terminal link: VI 30 s), subjects prefer the alternative correlated with the higher relative delay reduction. In the type of example given above, organisms should favor A2. This was shown for pigeons by Fantino (1969) and Belke et al. (1989). However, humans behaved indifferently under the same conditions (Belke et al., 1989). There is a greater preference for the shorter terminal link when subjects' responses are reinforced under a concurrent-chains schedule compared to a (unsignaled) tandem schedule (Fantino, Freed, Preston, & Williams, 1991; Leung & Winton, 1985).

The following formula summarizes the relative response distribution under the initial links of a concurrent-chains VI-VI schedule as predicted by DRH:

$$\frac{B_1}{B_1 + B_2} = \frac{r_1(T - tc2A1)}{r_1(T - tc2A1) + r_2(T - tc2A2)} \quad (\text{for } tc2A1 < T \text{ and } tc2A2 < T)$$

$$= 1 \quad (\text{for } tc2A1 < T,\ tc2A2 > T)$$

$$= 0 \quad (\text{for } tc2A1 > T,\ tc2A2 < T).$$

B_1 and B_2 are the responses on the operant device of Alternative 1 and Alternative 2, respectively, measured during the concurrently available initial links (choice phase); r_1 and r_2 are the overall rates of reinforcement delivered on Alternative 1 and Alternative 2; $tc2A1$ and $tc2A2$ are the average times (or delays) during the terminal links (or outcome phase) under Alternatives 1 and 2, respectively. T is the average overall time to primary reinforcement measured from the onset of the choice phase, and $(T - tc2A_x)$ represents the degree of delay reduction correlated with the onset of the terminal link of the alternative (A1 or A2; cf. Fantino, Preston, & Dunn, 1993).

When the predictions of relative immediacy and delay reduction were opposed, Dunn and Fantino (1982) found preference to be best described by delay reduction: (a) When conditions changed so that relative immediacy predicted large changes in preference but delay reduction predicted no change, no change occurred; and (b) when conditions changed so that the two theories required sharp preference changes in opposite directions, preference was well described by delay reduction.

DRH, developed to predict preference between simultaneously available VI-VI schedules of reinforcement in the concurrent-chains procedure, has been tested using different procedures (Fantino et al., 1993). Results in accordance with predictions from DRH were obtained for aversive consequences (Fantino, 1981), observing in pigeons (Case & Fantino, 1981) and humans (Case & Fantino, 1989; Fantino & Case, 1983), self-control (Ito & Asaki, 1982; Navarick & Fantino, 1976), percentage reinforcement (Dunn & Spetch, 1990; Spetch, Belke, Barnet, Dunn, & Pierce, 1990; Spetch & Dunn, 1987), serial position effects in short-term memory (Wixted, 1989), three-alternative choice (Fantino & Dunn, 1983), simultaneous-encounter experiments in nonhumans and humans (Fantino & Preston, 1989), and foraging, typically analyzed using successive-choice procedures (Abarca & Fantino, 1982; Fantino & Abarca, 1985).

A successive-choice schedule is a special form of a chained schedule (Figure 1), combining (typically) two chained reinforcement schedules. The alternatives are abbreviated as A1 and A2 in the following discussion. The procedure was developed by Lea (1979) and Collier and collaborators (Collier, 1982, 1983; Kaufman, 1979) and was introduced as a "foraging procedure." Each chained schedule consists of the following components: an initial link (or search component) (called the c1 component here), an explicit choice situation (ch), and a terminal link (called the c2 component here). The c2 component leads to reinforcement (S*). Initial links are successively rather than simultaneously available. Each trial starts with the initial link (i.e., c1 component). After fulfillment of the schedule criterion (typically an FI schedule), the choice situation is initiated, signaled by the simultaneous illumination of the c1 component stimulus and one of the terminal-link stimuli (c2 components). The c2 components (and thus the reinforcement schedules) are presented with probability p (for Alternative 1) and $1 - p$ (for Alternative 2), respectively. A choice of the c2 component (i.e., response on the operant button) leads to the initiation of a reinforcement schedule, resulting in reinforcement after fulfillment of the schedule criterion (e.g., VI). This choice is called "acceptance." A response on the c1 button in the choice situation effects a "rejection," leading to the initiation of the next trial ($n + 1$), again starting with the c1 component. In the flowchart of Figure 1, the conditions used in the present experiment are indicated. Instead of the typical two-key procedure in nonhuman experiments, a three-button procedure was used.

DRH makes predictions for choice behavior in such a situation: If schedules are successively presented as in Figure 1, the more profitable schedule (i.e., schedule of shorter interval length) is always accepted. The central prediction of DRH for successive-choice situations concerns the acceptance or rejection of the less profitable schedule. According to DRH, the less profitable schedule should be rejected if the length of the schedule (tc2) exceeds the mean interreinforcement interval T (i.e., $tc2 > T$). Under those conditions the organism specializes on the more profitable schedule. The less profitable schedule should be accepted if the length of the schedule (tc2) is shorter than the mean interreinforcement interval T (i.e., $tc2 < T$). Under those conditions the organism "generalizes" (i.e., accepts both schedules). The mean interreinforcement interval (T) is calculated as $T = S + p\ tc2A_L + (1 - p)\ tc2A_S$, with S as the time in the initial links (or search state). The term $[p\ tc2A_L + (1 - p)\ tc2A_S]$ adds up to the total time under the c2 components and is calculated by the length of the less profitable (here long VI) schedule plus the length of the profitable (short VI) schedule, each weighted by the probability of presenting the schedule in the choice situation. To summarize, in terms of DRH, a schedule should be accepted if there is an improvement in waiting time to reinforcement correlated with the onset of the schedule (Fantino & Preston, 1988). In this case the schedule represents a reduction in mean delay to reinforcement. On the other hand, a schedule should be rejected if it represents an increase in mean delay to reinforcement. By responding in accord with this comparator mechanism of relative temporal proximity, an organism should behave optimally.

Assuming that the temporal context modifies the value of a schedule, there are similarities between DRH and the comparator theories of classical conditioning (e.g., relative waiting time hypothesis, RWT; Jenkins, Barnes, & Barrera, 1981; and scalar expectancy theory, SET; Gibbon & Balsam, 1981). These theories also emphasize the comparison between two waiting times: the mean waiting time (interstimulus interval T) until the onset of the unconditioned stimulus (US) in the presence of the conditioned stimulus (CS) in comparison to the mean waiting time in the whole conditioning situation (cycle time C). Gibbon and Balsam (1981) used the ratio C/T (i.e., cycle to trial ratio) in order to quantify the associative strength of a CS. Thus, the predicted strength of a conditioned reaction (CR) is not determined by the strength of the CS–US association per se, but by the strength of the CS–US association relative to the strength of the association between context and US (see Brown, 1985, Fantino, 1984, Fantino et al., 1993, and Preston & Fantino, 1991, for discussion of similarities of DRH and comparator theories).

Based on DRH, choice behavior is assumed to be modified by changing the temporal context in which schedules are embedded. The successive-choice schedule permits variation in several important variables, such as length of the waiting time (c1 component) preceding the choice situation (Fantino & Preston, 1988; Lea, 1979), the probability of schedule presentation in the choice situation (Fantino & Preston, 1988; Hanson & Green, 1989; Lea, 1979), the length of the c2 component, or the delivery of reinforcement on a percentage basis (Abarca, Fantino, & Ito, 1985).

Up to now, some of the central assumptions of DRH were tested for the successive-choice situation (Fantino et al., 1993) in experiments with nonhumans and led to results that resemble those obtained in concurrent-chains schedules. As search duration (analogous to initial link) is increased, there is a shift from rejecting to accepting a less profitable of two outcomes (Abarca & Fantino, 1982). When terminal links (i.e., c2 components) are increased, there is a shift from acceptance to rejection of the less profitable outcome (Ito & Fantino, 1986). As in concurrent-chains schedules (Abarca, 1982), there is a pattern of asymmetry: Using a modified version of the standard concurrent-chains schedule with only one alternative available at a given moment and an FI requirement for changeover, Fantino and Abarca (1985) showed that varying the accessibility of the more profitable schedule by changing the duration of the choice phase (in terms of VI) had a greater effect than varying the accessibility of the less profitable alternative by the same manipulation.

For the present study, the experiments of special interest are those which vary the accessibility of the alternatives, especially those experiments which exclusively vary accessibility of the less profitable alternative. The prediction that there should be an increased choice of the less profitable schedule when making it less accessible by increasing waiting time is made only by DRH. This special prediction of DRH also has implications for quantitative models of conditioned reinforcement (Preston & Fantino, 1991).

By testing a model that has been nearly exclusively tested with nonhumans, the present experiment also investigates whether choice in humans is controlled by variables analogous to those controlling nonhuman choice. There have been several investigations showing that reward delay has a different influence on human behavior in comparison to nonhuman operant behavior (see Logue, 1988; Logue & Chavarro, 1992, for discussion). In a choice situation between self-controlled versus impulsive behavior, humans often behave in a self-controlled manner: They prefer the delayed large reinforcer rather than the immediate small reinforcer (e.g., Flora & Pavlik, 1992, in those conditions with postreinforcement delay; King & Logue, 1987; Logue, King, Chavarro, & Volpe, 1990; for ratio schedules: Blakely, Starin, & Poling, 1988; Weiner, 1967), thus resulting in reward maximization. However, this pattern is influenced by the quality of the reinforcer: When directly consumable reinforcers are used, humans also behave impulsively (e.g., Millar & Navarick, 1984, using video-game playing; Navarick, 1982, and Solnick, Kannenberg, Eckerman, & Waller, 1980, using noise termination as the reinforcer). Flora and Pavlik (1992) demonstrated impulsive choice in humans with nonconsumable reinforcers (points) only when overall density favored impulsiveness. Furthermore, there are differences between nonhumans and humans when there is a choice between variable rather than constant conditions of reinforcement, with humans preferring constant conditions when the separate phases are not explicitly signaled (Kohn, Kohn, & Staddon, 1992) and nonhumans showing a preference for variable conditions.

There are very few experiments that have explicitly addressed the validity of predictions of DRH for humans, using different procedures. Belke et al. (1989) analyzed behavior under concurrent-chains schedules. Case and Fantino (1989) and Fantino and Case (1983) examined observing behavior. Fantino and Preston (1989) used a simultaneous-encounter procedure, and Leung (1989) compared behavior under segmented versus unsegmented schedules. Results in at least qualitative accordance with the predictions of DRH were obtained in four of these experiments (Case & Fantino, 1989; Fantino & Case, 1983; Fantino & Preston, 1989; Leung, 1989).

To summarize, there are several differences between operant choice behavior in nonhumans and humans, especially when token reinforcers are used for humans. Up to now, there have been only a few experiments that have tested the central assumptions of DRH with humans. No experiment has tested human choice behavior under a successive-choice schedule, exclusively varying the accessibility of the less profitable schedule.

The experiment conducted in the present study is based on a nonhuman experiment done by Fantino and Preston (1988). They varied the search time (i.e., the c1 component in Figure 1) preceding the less profitable of two equally probable VI schedules while holding the search time to the more profitable outcome constant. The less profitable schedule was a

Table 1

Experimental manipulations (i.e., FI [tc1A1] preceding the less profitable schedule [A1]), resulting delay conditions, and predicted choice patterns for Groups 1, 2, and 3 in Phase 1 and Phase 2. DI: delay increase; DR: delay reduction; IND: indifference; *T*: mean interreinforcement interval; tc1A1, tc2A1: duration of the c1 and c2 components of Alternative A1.

Group (Shift: ph1 → ph2)	Phase 1			Phase 2		
	tc1A1	Delay condition	Choice pattern	tc1A1	Delay condition	Choice pattern
1 (IND → DI)	FI 7.5 s	tc2A1 = *T* 18 s = 18 s	Indifference	FI 2.5 s	tc2A1 > *T* 18 s > 15.5 s	Rejection
2 (IND → DR)	FI 7.5 s	tc2A1 = *T* 18 s = 18 s	Indifference	FI 22.5 s	tc2A1 < *T* 18 s < 25.5 s	Acceptance
3 (IND, IND)	FI 7.5 s	tc2A1 = *T* 18 s = 18 s	Indifference	FI 7.5 s	tc2A1 = *T* 18 s = 18 s	Indifference

VI 45 s, and the more profitable schedule was a VI 5 s. Search time preceding the profitable VI was constant (FI 15 s). Using a within-subject design, search time preceding the less profitable schedule was varied as FI 10 s, FI 25 s, and FI 40 s, resulting in a mean interreinforcement interval (*T*) of 37.5 s under FI 10 s (Condition 1 here), 45 s under FI 25 s (Condition 2), and 52.5 s under FI 40 s (Condition 3). In terms of DRH, the less profitable schedule (VI 45 s) constituted either a delay increase (Condition 1), an indifference point (Condition 2), or a delay reduction (Condition 3). Thus, it should be completely rejected under Condition 1, equally often rejected and accepted in Condition 2, and completely accepted in Condition 3. The results did not reveal the all-or-none pattern of exclusive rejection and acceptance, but were in qualitative agreement with predictions of DRH. Acceptance (proportion of times accepted) of the less profitable schedule was .53 under the condition of FI 10 s, .75 under the indifference condition of FI 25 s, and .96 under the FI 40-s schedule (Condition 3). Thus, making a less profitable schedule less accessible (by increasing waiting time preceding the schedule) increases acceptance. Making it more accessible by reducing waiting time reduces acceptance; thus, as accessibility increased so did selectivity. Similar results were obtained when availability was varied.

In the following experiment the effects of different accessibility to a less profitable schedule were analyzed in humans using a three-group design. In contrast to Fantino and Preston (1988), a design with independent groups was used. The following hypotheses, derived from DRH, were tested: A less profitable schedule (i.e., a long VI) is more likely to be rejected if it is made more accessible (by decreasing waiting time), thus arranging a condition of relative delay increase. A less profitable schedule is more likely to be accepted if it is made less accessible (by increasing waiting time), thus arranging a condition of relative delay reduction. When length of the schedule ($tc2A_x$) equals *T*, there is indifference; thus, the schedule should be accepted and rejected equally often. The hypotheses were tested in a two-phase experiment. Phase 1 served as a baseline, and Phase 2 contained different experimental conditions in the three groups.

METHOD

Subjects

Forty-eight students (24 females and 24 males) of the University of Duesseldorf (excluding psychology students) were randomly assigned to one of three groups (see Table 1) of 16 subjects each. Age varied between 19 and 34 years. The mean age was comparable in the three groups: 22.56 years (*SD* = 2.53) for Group 1, 23.75 years (*SD* = 2.70) for Group 2, and 24.69 years (*SD* = 4.36) for Group 3. Subjects were asked to participate in an experiment lasting 1 hr. All subjects received a preexperimentally defined amount of money (7 Deutsche marks). The experiments were conducted individually for each subject.

Apparatus

Sessions were conducted in a room (4.5 m by 3.1 m). During the experiment, the room was darkened, except for illumination of a desk

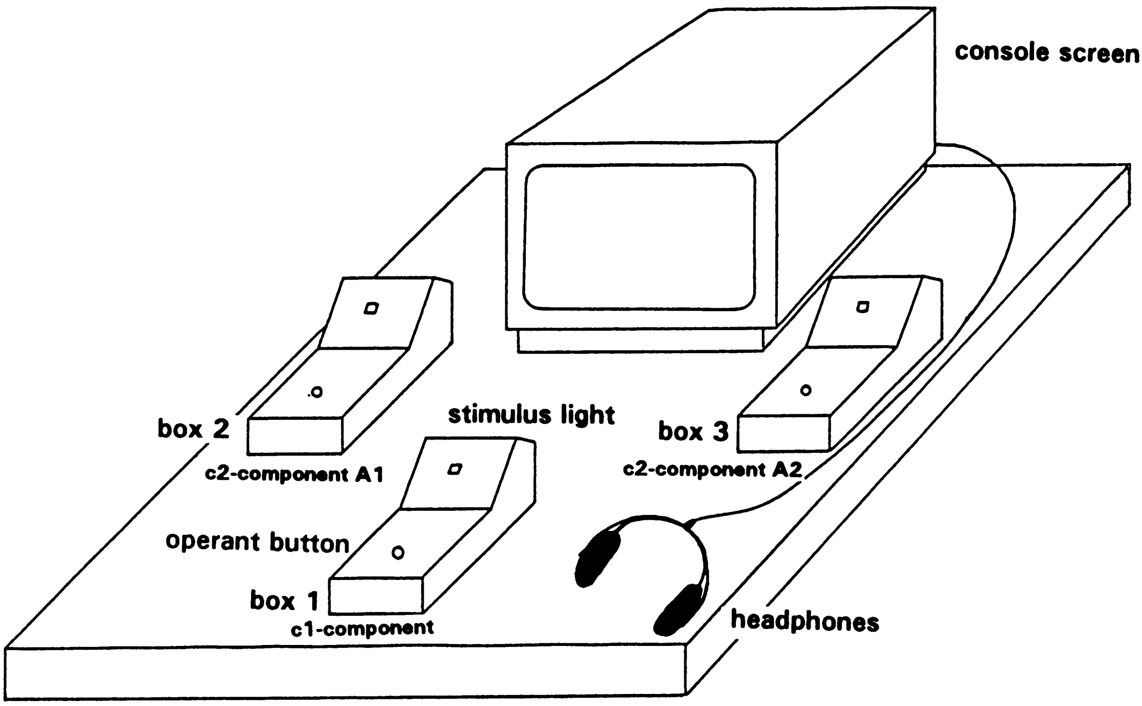

Fig. 2. Operant desk: response boxes (each with operant button and stimulus light), headphones, and console screen.

light (40 W) and illumination of the response buttons and signal lights of the operant response boxes. The experimental equipment is shown in Figure 2. It was placed on a table (78 cm wide, 78 cm deep, and 75 cm high) and consisted of three operant response boxes, a console screen to present instructions, and headphones to apply a tone. The subject was seated in front of the table. The experiment was controlled by a microcomputer (286 AT) that was located behind a wooden wall to the right of the subject. The program to conduct the experiment was written in Turbo Basic. In deviation from the typical two-key procedure in nonhuman experiments, a three-button procedure (Figure 1) was used.

The three operant response boxes (Figure 2) were placed in a triangle. Box 1 (centered in the middle) operated as the c1 component, and Boxes 2 and 3 (left and right) operated as the c2 components of Alternative 1 and Alternative 2. Each response box consisted of a translucent button for operant responses (operant button). The button had to be pushed with a force of at least 1 N and was illuminated by white light whenever it was in operation. A square translucent disk was placed in the upper center of each box and served as a discriminative stimulus light. It was illuminated with either white (c1 component), green (c2 component), or red (c2 component). The position (left or right) of the lateral response boxes and color of the stimulus lights (red or green) were balanced across subjects. The component actually in operation was signaled by illumination of the respective stimulus light and of the corresponding operant button. A monochrome (black and white) screen was used to present instructions twice in the experiment (Part 1 was presented prior to the start and Part 2 was presented after the prephase). The headphones (Sennheiser®) served to present a moderately loud tone (85 dBA, 3000 Hz). The experimental equipment (response boxes) was connected to the computer by a parallel port. The interface was assembled by digital elements of the "Marburger system" (Kalveram, 1975).

Procedure

Subjects were trained under a successive-choice schedule using the schedule parameters shown in Figure 1. Table 2 outlines the actual procedure (number of trials and schedules).

Table 2

Schedules operating under the c1 and c2 components of Alternative 1 (A1) and Alternative 2 (A2); criterion for the choice response (choice); probability of presenting A1 (p) and A2 ($1 - p$) in the choice situation.

Alternative component	A1 (less profitable)				A2 (more profitable)			
	c1A1	Choice	p(A1)	c2A1	c1A2	Choice	p(A2)	c2A2
Prephase (10 trials: five A1, five A2, semirandom)								
Group 1	—	—	—	VI 18 s	—	—	—	VI 3 s
Group 2	—	—	—	VI 18 s	—	—	—	VI 3 s
Group 3	—	—	—	VI 18 s	—	—	—	VI 3 s
Phase 1 (50 trials: 25 A1, 25 A2, semirandom)								
Group 1	FI 7.5 s	FR 1[a]	.50	VI 18 s	FI 7.5 s	FR 1[a]	.50	VI 3 s
Group 2	FI 7.5 s	FR 1[a]	.50	VI 18 s	FI 7.5 s	FR 1[a]	.50	VI 3 s
Group 3	FI 7.5 s	FR 1[a]	.50	VI 18 s	FI 7.5 s	FR 1[a]	.50	VI 3 s
Phase 2 (60 trials: 30 A1, 30 A2, semirandom)								
Group 1	FI 2.5 s	FR 1[a]	.50	VI 18 s	FI 7.5 s	FR 1[a]	.50	VI 3 s
Group 2	FI 22.5 s	FR 1[a]	.50	VI 18 s	FI 7.5 s	FR 1[a]	.50	VI 3 s
Group 3	FI 7.5 s	FR 1[a]	.50	VI 18 s	FI 7.5 s	FR 1[a]	.50	VI 3 s

[a] FT 8 s if subject did not press operant button within 8 s.

Two chained schedules (A1 and A2) were successively in operation, each consisting of three components: (a) c1 component, (b) choice situation, and (c) c2 component, a VI schedule leading to reinforcement (S*). The experiment consisted of 120 trials, divided into a prephase (10 trials), including only the c2 components of the successive-choice schedule, and two phases (Phase 1 contained 50 trials and Phase 2 contained 60 trials) with the complete successive-choice schedule in operation (Table 2).

The prephase served to provide experience with the different VI schedules. A VI 3-s schedule (ranging from 2.25 s to 3.75 s) served as the more profitable c2 component (A2), and a VI 18-s schedule (ranging from 13.5 s to 22.5 s) served as the less profitable VI schedule (A1). A1 and A2 were presented in a semirandom order, five times each (2, 1, 2, 1, 2, 2, 1, 1, 2, 1). Interrupted by Part 2 of the instructions, Phase 1 started with the illumination of the translucent disk and the response button of the c1 component. During Phase 1, there was an FI 7.5-s schedule preceding both schedules, the presentation of the less profitable VI 18-s schedule and the more profitable VI 3-s schedule. There were 25 trials with presentation of VI 18 s and VI 3 s each. The sequence of A1 and A2 was generated for 20 trials and repeated for the remaining trials. In Phase 2 (shift phase) different c1 durations preceding the less profitable schedule (A1) were introduced for the experimental groups (Table 2).

Duration (in terms of FI) of c1A1 was decreased in Group 1 (FI 7.5 s → FI 2.5 s), increased in Group 2 (FI 7.5 s → FI 22.5), and remained unchanged in Group 3 (FI 7.5 s). Thus, the less profitable schedule (A1) was correlated either with a delay increase in Group 1, a delay reduction in Group 2, or still constituted an indifference condition (Group 3). Phase 2 consisted of 60 trials, 30 under A1 and 30 under A2 (Table 2).

At the end of the experiment, subjects filled in a questionnaire on the experimental equipment, hypotheses about the experiment, aversiveness of the tone, reinforcing effect of tone termination, preference, and effort under the different alternatives.

Instructions

Subjects were given the following instructions (translated literally from German) on the console screen. They were presented on separate pages and were available for a defined period of time.

> Part 1: (page 1, 15 s) In the following experiment a tone will be presented to you through headphones. You can stop the tone. To do this, the response boxes with the response buttons are available. The illumination indicates that a response box is in function.

(page 2, 20 s) Please, put on the headphones now.
(page 3, 2 s) The experiment starts!
Part 2: (page 4, 30 s) During the consecutive trials the response box placed in the middle position is also in function.
At the beginning of each trial, only the middle box is illuminated. In the sequence of a trial there is a condition where two response boxes are simultaneously illuminated. Whenever two boxes are illuminated, you can choose which one you would like to work on.
(page 5, 2 s) The experiment goes on!

Based on results showing that the effect of reinforcement delay in humans more closely resembles its effect in nonhumans when the reinforcer is directly consumable (e.g., Logue, 1988; Millar & Navarick, 1984; Navarick, 1982, 1986; Ragotzy, Blakely, & Poling, 1988; Solnick et al., 1980), subjects' responses were reinforced using negative reinforcement. A moderately loud tone (85 dBA, 3000 Hz) was applied during all components of the successive-choice schedule and could be terminated by the operant response. Negative reinforcement consisted of the interruption of the tone for 6 s at the end of the c2 component (Figure 1). Monetary payment was preexperimentally defined, delivered after the experiment, and constant for all subjects. We determined the amplitude and frequency of the tone by referring to conditions used in self-control experiments (Navarick, 1982; Solnick et al., 1980) and those used in experiments on learned helplessness (Cole & Coyne, 1977; Hiroto & Seligman, 1975; Jones, Nation, & Massad, 1977).

Dependent Variables

The following data were recorded: (a) proportion of acceptance of A1 (i.e., number of accepted trials of the less profitable VI 18-s schedule relative to the number of presentations of A1 in the choice situation) and proportion of acceptance of A2 (analogous to A1) and (b) button pressing during the programmed FI schedule operating under the c1 components of A1 and A2 expressed as responses per second. Calculation of response rates was based on the number of operant responses during the programmed interval (e.g., for the FI 7.5-s schedules, the number of button presses during the 7.5-s interval was summed and divided by 7.5). In addition, the actual duration of the interval under the c1 components of A1 and A2 was recorded to measure the adaptation to the programmed schedule duration.

Data for Phase 1 (ph1) and Phase 2 (ph2) were analyzed in blocks of trials, identified as ph1(1), ph1(2), ph1(3), ph2(1), ph2(2), and ph2(3). Ph1(1) consisted of 10 trials (five A1 and five A2); all the other blocks consisted of 20 trials (10 of each alternative). For button pressing and for the actual duration of the FI schedule, means were calculated for each subject per block of trials. Based on these means, the descriptive statistics were calculated for each group (group medians for button pressing and group means for FI duration). Statistical tests for distribution-free data were conducted as follows: Intergroup comparison for interval-scaled data (acceptance proportion and FI duration) were done using the Fisher–Pitman randomization test; intragroup comparisons were calculated using the randomization test for dependent samples (Krauth, 1988). Intergroup comparisons for ordinal-scaled variables (button pressing during FI) were calculated using the Mann–Whitney U test, and intragroup comparisons were made using a modified Wilcoxon rank sum test (Lam–Longnecker test for paired data, Lam & Longnecker, 1983). Inferences were made only for the acceptance proportion of A1; a significance level of 5% was adopted for all comparisons, leading to a nominal significance level of 2.5% for each individual test. All other p values reported below are descriptive.

RESULTS

Acceptance

Acceptance of the less profitable schedule (A1). Figure 3 shows the proportion of acceptance of A1 and A2 for the blocks of trials of Phase 1 and Phase 2 for Group 1 (triangles), Group 2 (squares), and Group 3 (circles). (See Appendix A for individual data.) Over the course of Phase 1, there was a steady differentiation between the acceptance of the less profitable schedule (A1; i.e., VI 18 s) and the more profitable schedule (A2; i.e., VI 3 s). At the end of Phase 1 (ph1(3)), mean acceptance proportion for A1 was .419 (SD = .317) in Group 1, .413 (SD = .342) in Group 2, and .431 (SD = .394) in Group 3 (Figure 3). At the end of Phase 2 (i.e., ph2(3)), there was a different

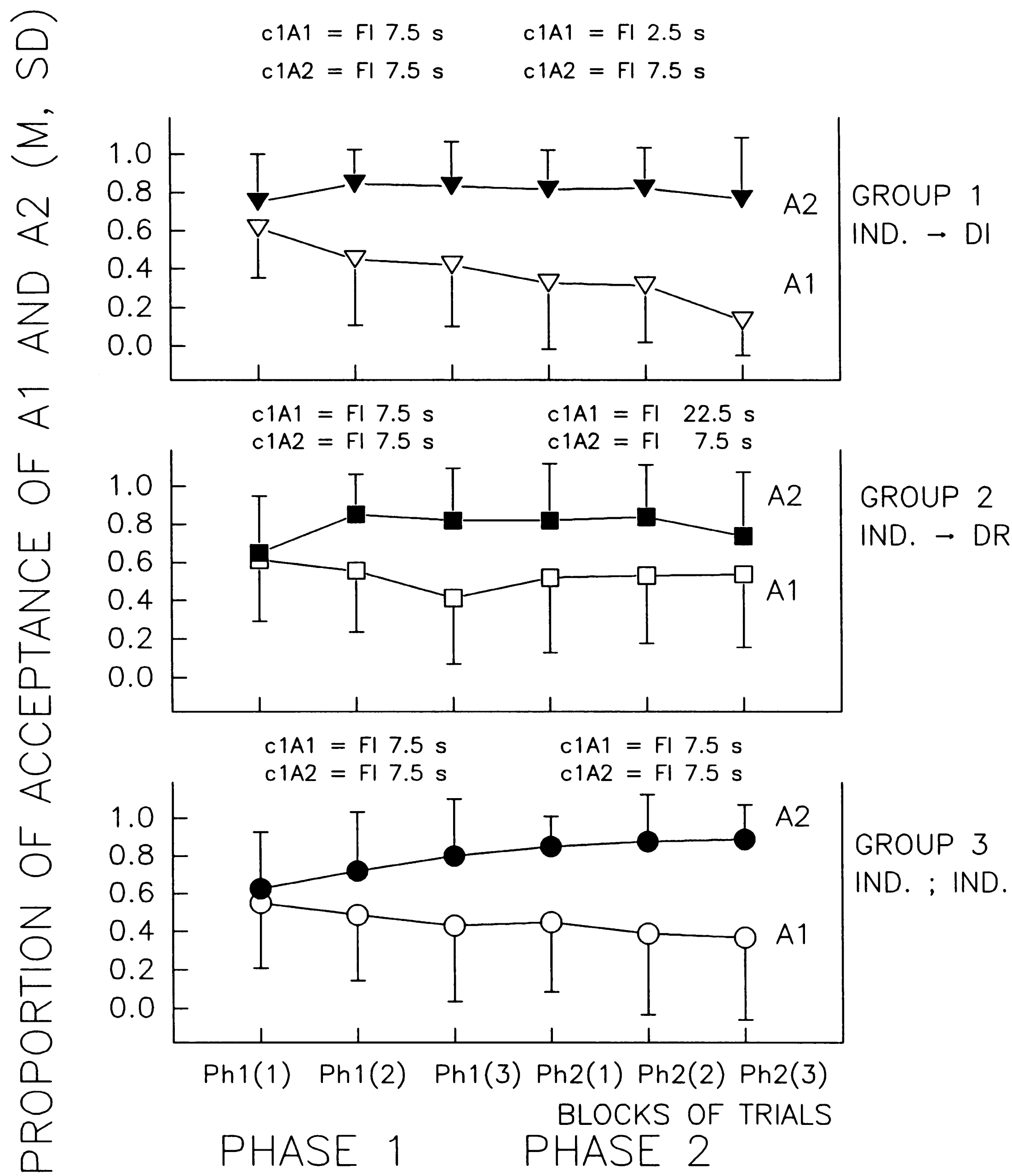

Fig. 3. Acceptance (arithmetic mean and empirical standard deviation) of Schedule A1 (VI 18 s) and Schedule A2 (VI 3 s) per block of trials of Phase 1 and Phase 2; A1: unfilled symbols, A2: filled symbols for Group 1, Group 2, and Group 3. The delay conditions of Phase 1 and Phase 2 for the less profitable schedule (A1) (VI 18 s) are indicated for the three groups in terms of indifference (IND, i.e., the delay to the less profitable schedule constitutes neither a delay increase (DI) nor a delay reduction (DR)). Conditions in the two phases of the experiment: Group 1 (IND→DI); Group 2 (IND→DR), and Group 3 (IND, IND).

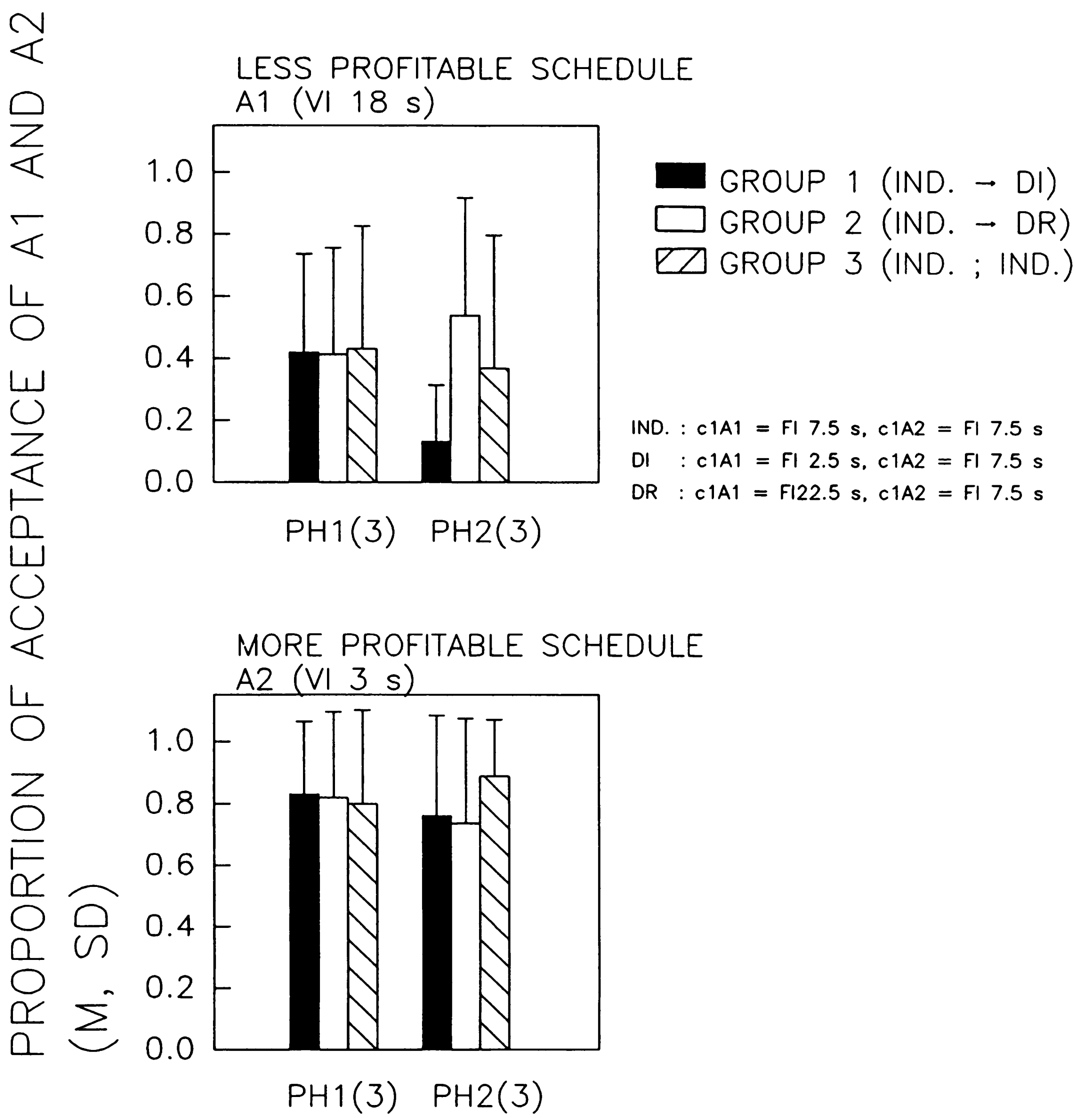

Fig. 4. Acceptance (*M, SD*) of Schedule A1 (VI 18 s) and Schedule A2 (VI 3 s) at the end of Phase 1 (ph1(3)) and Phase 2 (ph2(3)).

pattern of acceptance of the less profitable schedule: As expected, mean acceptance proportion for A1 was less in Group 1 (M = .131, SD = .182), whereas Group 2 showed the highest acceptance rate (M = .538, SD = .381). Mean acceptance proportion in Group 3 was .369 (SD = .427). Intergroup comparisons using the Fisher–Pitman randomization test (Krauth, 1988) were conducted. At the end of Phase 2 (ph2(3)), there was a lower acceptance of A1 in Group 1 compared to Group 3 (ph2(3), $Z = -1.89838$, $p_L = .02882$), nearly reaching the α-adjusted level of $p = .025$, and a higher acceptance in Group 2 than in Group 3, but the difference between Group 2 and Group 3 did not reach statistical significance (ph2(3), $Z = 1.12878$; $p_U = .12949$).

Intragroup comparisons using the randomization test for dependent samples revealed results in accordance with DRH. In comparison to acceptance proportion at the end of Phase 1 (ph1(3)), acceptance proportion of the less profitable schedule (VI 18 s) at the end of Phase 2 decreased in Group 1 ($Z = -2.52458$, $p_L = .00579$) as a result of delay increase; acceptance proportion increased in Group 2 ($Z = 2.04124$; $p_U = .02061$) as a result of delay reduction. The decrease in Group 3 does not indicate any significance ($Z = -0.81111$; $p_L = .20865$). These comparisons are illustrated in Figure 4.

Especially in Group 1, there was a very strong correspondence of the statistical summary statements with the individual case; 14 of 16 choice cases (see Appendix A) were in the predicted direction (i.e., a decrease in the acceptance proportion of A1); only 1 subject (113) showed an increase and 1 subject (112) showed no change from ph1(3) to ph2(3). In Group 2, 9 subjects showed the expected increase of acceptance proportion and 2 subjects retained the acceptance proportion of ph1(3). Although 5 subjects showed a decrease, this was minimal in all cases (change of .10). Thus, again, the statistical summary statement corresponds to the pattern in most of the individual cases. The pattern of Group 3 was mixed: 8 subjects showed a decrease of acceptance proportion of A1 from ph1(3) to ph2(3), and 3 subjects showed a further increase. Five subjects retained the acceptance proportion of ph1(3). Although this pattern was heterogeneous, it is in accordance with the experimental condition of Group 3: Here, the less profitable schedule constituted neither a delay increase nor a delay reduction, but rather was an indifference condition that might have induced some degree of variability in choice. The intragroup comparison did not reveal any relevant change.

Acceptance of the more profitable schedule (A2). There were also effects of the change of the accessibility to the less profitable schedule (A1) on the acceptance of the profitable schedule (A2) for Group 2 (Figure 4). At the end of Phase 2 (ph2(3)), the profitable schedule was less accepted ($M = .738$, $SD = .336$) than at the end of Phase 1 (ph1(3)) ($M = .819$, $SD = .276$; Group 2: ph2(3)/ph1(3) $Z = -2.08167$; $p_L = .01869$). Thus, the increased acceptance of the less profitable schedule was accompanied by a decrease in the acceptance of the profitable schedule. This response pattern can be classified as a negative contrast. In Groups 1 and 3, the acceptance of A2 did not change in a systematic manner, although there was a slight decrease of acceptance proportion in Group 1 from the end of Phase 1 ((ph1(3) $M = .831$, $SD = .233$) to the end of Phase 2 (ph2(3) $M = .763$, $SD = .321$).

To summarize: As a result of increased accessibility of the nonprofitable schedule (A1) in Group 1, there was a reduced acceptance proportion of the less profitable schedule. A simultaneous decrease in the acceptance proportion of the profitable schedule remained statistically not significant. As a result of decreased accessibility in Group 2, the acceptance proportion of the less profitable schedule increased. At the same time the acceptance proportion of the profitable schedule decreased, illustrating a possible reallocation of choice behavior under the condition of delay reduction. In Group 3, there was no hint of a statistically significant change in the acceptance of either alternative.

Instrumental Activity

Button pressing under the c1 components was analyzed to determine whether there was a correspondence between choice, indicated by the acceptance of the alternatives, and a response-rate measure. Figure 5 shows rates of button pressing for Groups 1 to 3, indicated by the medians of the response rate over blocks of trials in Phase 1 and Phase 2. Response rates were calculated for the programmed interval. The median was used because of a high interindividual variation in button pressing (see Appendix B for individual data). Accordingly, dispersion is expressed by the interquartile difference (Q3 − Q1) illustrated by the box plots in Figure 5: The box encompasses the 25th (Q1) through 75th percentiles (Q3), and the median is indicated as a line. The additional horizontal lines outside the boxes mark the 10th and 90th percentiles; the 5th and 95th percentiles are shown as dots above.

In Phase 1, subjects showed nearly the same activity under the c1 component preceding the less profitable VI 18-s schedule (A1) and the c1 component preceding the more profitable VI 3-s schedule (A2) in all three groups. This changed over the course of Phase 2. Intragroup comparisons between response rates at the end of Phase 1 versus Phase 2 (Lam–Longnecker test for paired data, ph1(3) vs. ph2(3)) reveal (Figure 6) that, for Group 1, there was a slight decrease of response rate under the c1 component preceding the less profitable schedule

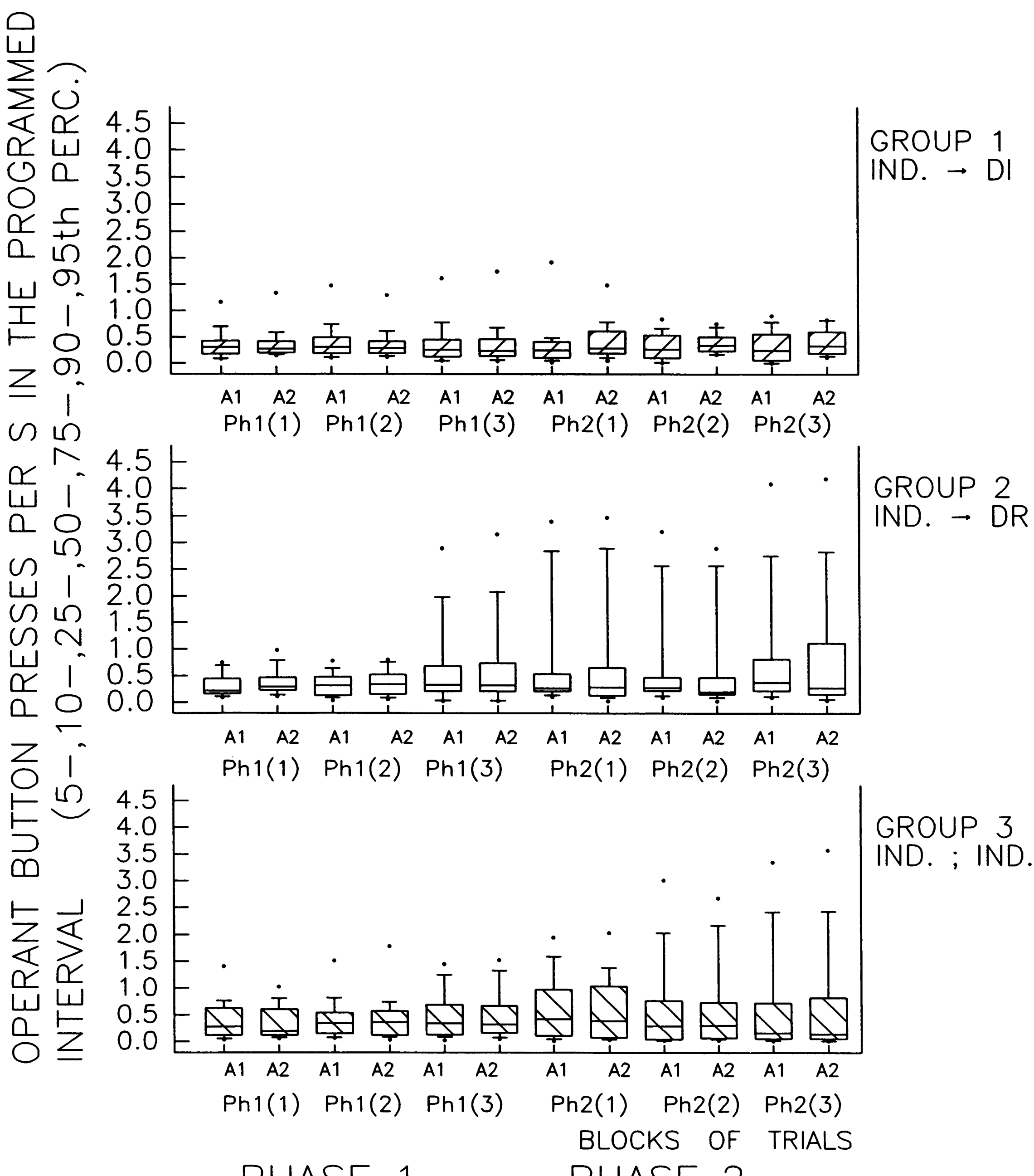

Fig. 5. Button-pressing rates under the c1 component preceding the less profitable schedule (A1) (VI 18 s) and the more profitable schedule (A2) (VI 3 s) per block of trials of Phase 1 and Phase 2. Box plots: Each box encompasses the 25th through 75th percentiles, and the median is indicated as a line; the additional horizontal lines mark the 10th and 90th percentiles, and the 5th and 95th percentiles are given as dots.

(A1) ($Z = -0.691$, $p_L = .24478$) and an increase under A2 ($Z = 1.995$; $p_U = .02302$). For Group 2, there was a slight increase under A1 and a slight decrease under A2, but without statistical significance. The results have to be interpreted in relation to the response pattern of Group 3, which showed a decrease in response rate under both c1 components (p val-

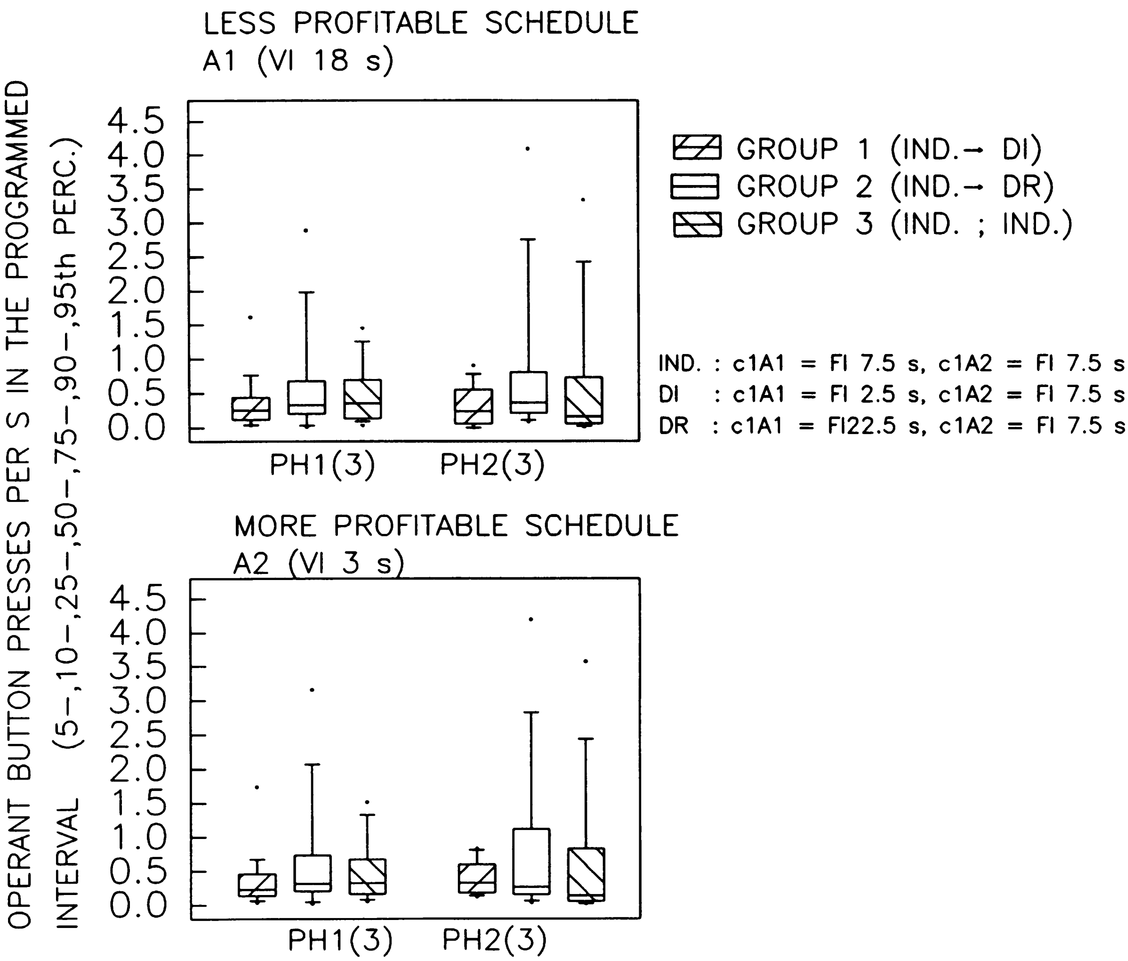

Fig. 6. Rate of button pressing under the c1 component preceding the less profitable schedule (A1) and the more profitable schedule (A2) at the end of Phase 1 (ph1(3)) and Phase 2 (ph2(3)). Details as in Figure 5.

ues < .05 for both intragroup comparisons: A1 $Z = -1.877, p_L = .03026$; A2 $Z = -2.137$, $p_L = .01630$). The response rates in Group 1 and Group 2 reveal a pattern that resembles the predicted pattern of choice behavior: In Group 1, there was a slight increase in rate on the more profitable schedule (A2), whereas in Group 2 the value of the less profitable schedule (A1) increased while the value of the more profitable schedule (A2) decreased.

Comparing the response rates under the c1 component of A2 versus A1 at the end of Phase 2 (ph2(3)) more clearly reveals the above-described pattern. In Group 1, response rate was relatively higher under A2 (median = 0.32550) than under A1 (median = 0.23750; $Z = 5.386$, $p_U = .000$), whereas the opposite was true for Group 2: There was a relatively lower rate under A2 (median = 0.26550) than under A1 (median = 0.36400; $Z = -2.891, p_L = .00192$). Response rates for Group 3 were low and were similar under both c1 components (A1 median = 0.15950; A2 median = 0.13980, $Z = 0.511$, $p_U = .30468$). Thus, the difference between the response rates of A2 and A1 might also be an indicator of the changed value of the less profitable schedule (A1) induced by the experimental manipulation: In Group 1 it was devalued, whereas its value was increased in Group 2.

Duration of c1 Components

In addition, we analyzed whether the variation of the FI duration of the c1 component

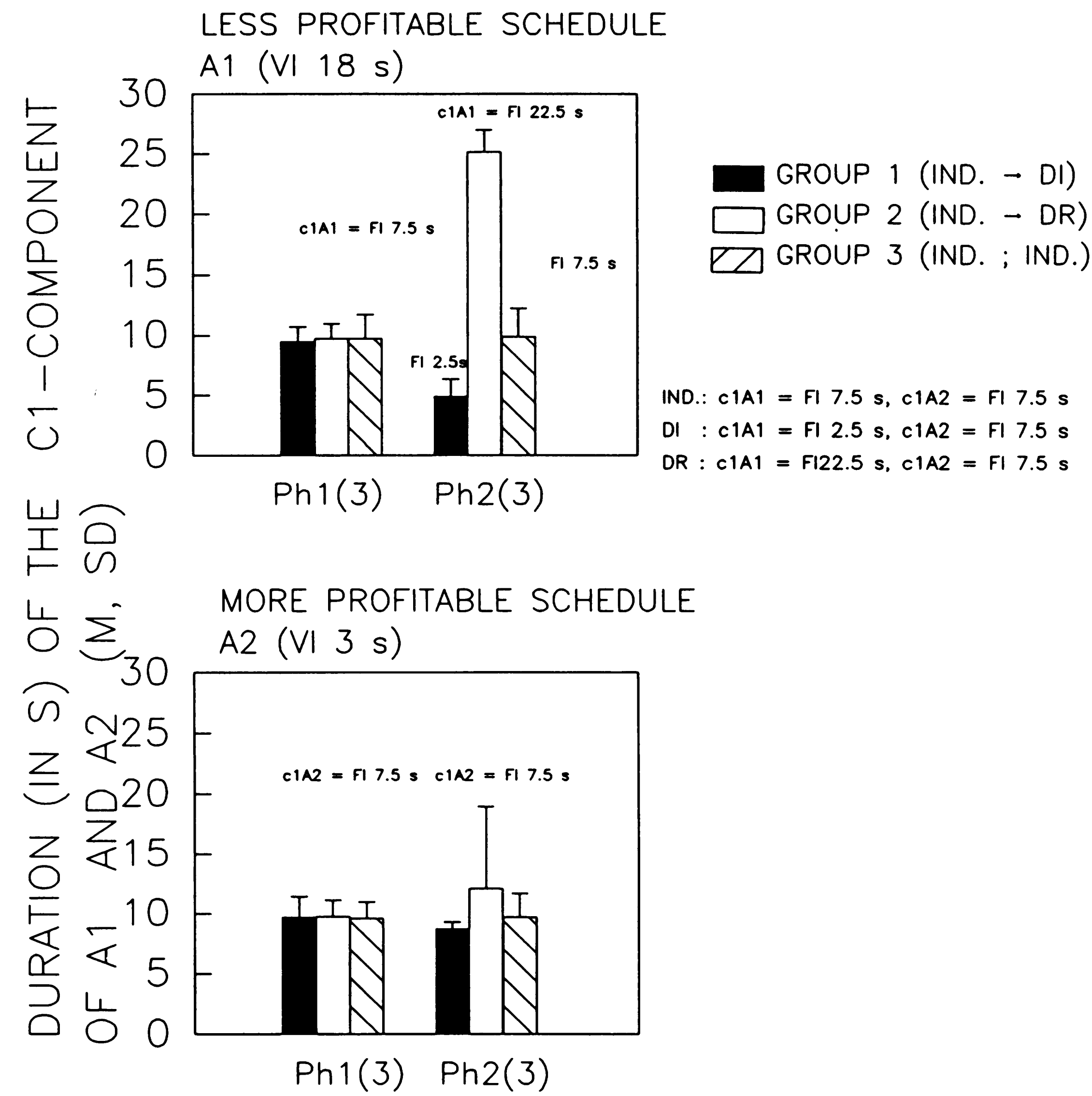

Fig. 7. Actual duration in seconds (*M, SD*) of the c1 component of Schedules A1 and A2 at the end of Phase 1 (ph1(3)) and Phase 2 (ph2(3)). The programmed interval (FI schedule) is indicated.

of A1 (Group 1 and Group 2) influenced the actual duration of the unchanged c1 component of A2 in Phase 2, which still was an FI 7.5-s schedule for all groups. In comparison to the mean interval duration in Group 3 ($M = 9.705$, $SD = 1.957$), the mean duration of the c1 component was lower in Group 1 ($M = 8.707$ s, $SD = 0.600$) and higher in Group 2 ($M = 12.067$ s, $SD = 6.883$) (see Appendix C for individual data). The intergroup comparisons support this description (Group 1 vs. Group 3, ph2(3), $Z = -1.86575$, $p_L = .03104$; Group 2 vs. Group 3, ph2(3), $Z = 1.30416$, $p_U = .09609$), resembling a pattern of induction in temporal adaptation (Figure 7).

DISCUSSION

The results support the interpretation that human subjects are sensitive to the conditions of delay reduction and delay increase associated with a reinforcement schedule in a successive-choice situation. Greater accessibility (i.e., shorter waiting time) resulted in decreased acceptance. Thus, a relative delay increase enhanced rejection. Less accessibility (i.e., longer waiting time) preceding a less profitable schedule led to increased acceptance. Thus, relative delay reduction enhanced acceptance. Rejection of a schedule seems to be more readily influenced than acceptance; there might be a bias for rejection with humans under negative reinforcement, although the amount of relative delay increase induced by the less profitable schedule in Group 1 (18/15.5) was less than that of relative delay reduction in Group 2 (18/25.5).

In accordance with experiments using nonhuman subjects in successive-choice schedules (Abarca & Fantino, 1982; Fantino & Preston, 1988; Lea, 1979), an all-or-none choice pattern was not observed with humans. Lea (1979) reported a marked bias towards rejecting the less profitable outcome for pigeons: The less profitable outcome (FI 20 s) was rejected at FI values under the c1 component for which the optimal diet model (and also DRH) would require total acceptance. This might be the case in our experiment as well. There might be adaptive significance of deviation from an all-or-none pattern, in that variability in behavioral and biological systems might enhance adaptability (see Hackenberg & Hineline, 1992, for a recent discussion).

Under the assumption that there is adaptive significance for deviation from optimality (in nonhumans and humans), thus leading to a certain amount of variability in choice situations, and noting the choice pattern in Group 3 (no hint of a statistically significant change of acceptance rate from the end of Phase 1 to the end of Phase 2), one can argue that the choice behavior obtained in the present experiment can be interpreted as a quite stable behavior pattern despite the brief schedule exposure in Phase 1 (50 trials) and Phase 2 (60 trials). Nevertheless, it might be of interest to increase the number of trials.

The concordance between the predicted and the obtained choice patterns in the present experiment and the relatively high correspondence to data obtained with nonhumans might result from the use of an "unconditioned," directly "consumable" reinforcer (noise termination as negative reinforcement). This type of reinforcer has been shown to be effective in inducing behavior similar to nonhuman behavior in those procedures that have analyzed impulsiveness versus self-control in humans (e.g., Millar & Navarick, 1984; Navarick, 1982, 1986; Ragotzy et al., 1988; Solnick et al., 1980). In contrast, token reinforcers often lead to a pattern of maximization. In addition, in comparison to nonhumans, humans show a low sensitivity for delay reduction in concurrent-chains schedules when behavior is reinforced with tokens (Belke et al., 1989). Thus, it seems worthwhile to use directly consumable reinforcers when human subjects have to be sensitive to delay.

It was also shown in our experiment that the acceptance ratio of the more profitable schedule was not complete. The majority of nonhuman experiments in seminaturalistic and laboratory settings (Abarca & Fantino, 1982; Collier & Rovee-Collier, 1981; Fantino & Preston, 1988) reveal an acceptance proportion of at least .90 of the profitable schedule. But there are also exceptions with nonhumans; for example, data reported by Snyderman (1983, Experiment 2) revealed a nonoptimal acceptance rate. When increasing the delay component of the handling period for the large prey and decreasing it for the small prey, the predicted specialization on the (now) more profitable alternative did not occur for all subjects.

The data of the present experiment suggest a possible interaction between the change in accessibility to the less profitable schedule and the acceptance of the more profitable schedule. An increase in the acceptance of the less profitable schedule was accompanied by a decrease in the acceptance of the more profitable schedule in Group 2. This resembles a pattern of negative contrast usually described for response rates in multiple schedules (Reynolds, 1961a, 1961b; Williams, 1983). Interaction effects in choice behavior should be systematically analyzed in order to assess whether these effects are responsible for the observed deviations from optimality.

Additional data analyses (intragroup comparisons) reveal effects of the experimental manipulation on instrumental activity under the c1 components. In Group 1 (under the condition of delay increase), there was a higher response rate under the schedule component preceding the more favorable schedule, whereas in Group 2 (trained under the condition of delay reduction) the median was higher under the c1 component preceding the less favorable schedule. In the literature, there has been an active discussion on the dissociation of measures of preference versus response rate under actual reinforcement conditions. The question is whether response rate can be taken as an indicator of reinforcement value (Williams, 1991, 1992). Using a four-component multiple schedule with schedule components of different reinforcement value to arrange conditions for positive and negative contrast, Williams (1992) revealed interesting results: He demonstrated that there is a dissociation between response rate under the schedule components (response-rate measure) and preference, measured when the stimuli originally signaling the schedule components were presented simultaneously in a probe test. In addition, there was a functional dissociation between positive and negative contrast in relation to stimulus value. A central conclusion was that "response rate cannot be taken as an index of reinforcement value when reinforcement value is indexed directly by choice tests" (p. 312).

Response-rate data obtained in the present experiment support the preliminary interpretation that response rate under the c1 components of a successive-choice schedule might be taken as an indicator of the value of the provided alternatives. But it would also be necessary to measure the value of the stimuli originally signaling the c2 components in a probe test, thus constituting a direct test of the conditioned reinforcement effect of the stimuli associated with the different schedules (c2A1 and c2A2). A similar question on the validity of response-rate measures has been discussed with regard to resistance to change and its correspondence to preference (Nevin, 1988). Recently, Pavlik and Flora (1993), using multiple VI-VI schedules of different reinforcement density, demonstrated that subjects responded more to the high-density component than to the low-density component during the early phase of extinction, thus supporting a correspondence between response rate during acquisition and value, indicated by response rate during extinction.

In the present experiment there were also effects of the experimental manipulation on the actual duration of the c1 components: The decrease in the duration of the c1 component of the less profitable schedule (A1) in Group 1 resulted in a shorter duration of the obtained FI schedule operating under the unchanged c1 component of the profitable schedule (A2). Conversely, an increase in the duration of the c1 component of the less profitable schedule (A1) in Group 2 was accompanied by a longer duration of obtained FI interval operating under the c1 component of A2, when both results are compared to the temporal adaptation in the control group (Group 3). This effect might be relevant for those models of choice behavior that consider the obtained instead of the scheduled durations of the links (see Luco, 1990, for discussion).

Results reported here may have implications for the modification of human choice behavior. In order to increase the acceptability of a relatively nonaccepted alternative, it is adequate to increase the waiting time preceding the choice situation. On the other hand, selectivity for the better alternative is favored by decreasing waiting time. Similar manipulations have been effective in experiments on behavioral economics. In terms of behavioral economics, the variation of search time in a successive-choice schedule resembles the manipulation of income. In behavioral terms, income manipulations are restraints on total reinforcement within a session (DeGrandpre, Bickel, Rizvi, & Hughes, 1993). Income is typically manipulated by varying the number of trials while keeping session length constant (thus affecting the duration of the intertrial interval; see Elsmore, Fletcher, Conrad, & Sodetz, 1980; Silberberg, Warren-Boulton, & Asano, 1987), or by varying the number of trials per session while simultaneously changing session length (Hastjarjo & Silberberg, 1992; Hastjarjo, Silberberg, & Hursh, 1990). Several experiments using food or drugs of different profitability or quality as reinforcers reveal that subjects choose an initially less preferred alternative when income is reduced (Silberberg et al., 1987, for monkeys; Hastjarjo et al., 1990, for rats). Similarly, Hastjarjo and Silberberg (1992) reported an increase in the choice of a larger delayed reinforcer instead of a small immediate reinforcer in rats when income (the number of trials per session) was reduced. Analogous effects have been reported for humans. Using puffs on the usual (own) brand versus puffs on a less preferred brand of cigarette, DeGrandpre et al. (1993) varied income by varying money available to spend during the experimental session. For nicotine-dependent cigarette smokers, increasing income led to an increase of consumption of their own puffs, whereas there was an inverse relation between income and consumption of the other puffs, qualifying the other puffs as an inferior good. It would be of interest to use qualitatively different reinforcers in a successive-choice schedule as well. Instead of using interval schedules, it might be relevant to use fixed-ratio (FR) schedules in a successive-choice situation, thus manipulating the "price" for access to a reinforcement alternative. The change of price (FR) for access to a drug reinforcer is an effective tool to alter the choice between a drug versus a nondrug reinforcer, thus modifying drug consumption (see Carroll, Carmona, & May, 1991, for review).

In order to test further the predictions of DRH for humans, the availability of the provided reinforcement alternatives should be varied. The prediction is that the choice of a less accepted alternative increases when it is made available with a higher probability. This manipulation would constitute another way of revealing information on possible interaction effects between the acceptance of the more favorable and the less favorable alternatives, and on the effects on instrumental activity and temporal adaptation. By changing the waiting time preceding the choice situation (as was done in the present experiment), the subject is confronted with the changed accessibility of the less favorable schedule whenever it is provided, whereas adapting to a changed availability requires the subject to be even more sensitive to the whole economic context. Thus, the manipulation of availability would reveal additional information on the time frame (Hackenberg & Hineline, 1992) or time horizon (Timberlake, 1984; Timberlake, Gawley, & Lucas, 1987) of choice behavior in humans.

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APPENDIX A

Individual subjects' data: acceptance proportion (number of accepted trials divided by choice opportunities) for subjects in Group 1 (Subjects 101 to 116), Group 2 (Subjects 201 to 216), and Group 3 (Subjects 301 to 316). Blocks of trials of Phase 1 (ph1) and Phase 2 (ph2) under Alternative A1 (c2 component = VI 18 s) and Alternative A2 (c2 component = VI 3 s). IND: indifference; DI: delay increase; DR: delay reduction.

	Ph1(1)		Ph1(2)		Ph1(3)		Ph2(1)		Ph2(2)		Ph2(3)	
Subject	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2
Group 1 (IND → DI)												
101	.60	.80	.20	1.00	.70	1.00	.10	.80	.60	.90	.50	1.00
102	1.00	1.00	.60	.90	.80	.80	1.00	1.00	.90	1.00	.00	1.00
103	.40	.40	.10	.80	.20	.90	.00	.70	.20	.60	.10	.70
104	.40	.80	.50	.80	.40	.30	.60	.60	.30	.60	.30	.50
105	.40	.80	.10	1.00	.10	1.00	.20	1.00	.10	1.00	.00	1.00
106	.40	.20	.70	.70	.50	.70	.00	1.00	.10	.80	.00	.60
107	1.00	1.00	1.00	.90	1.00	1.00	1.00	1.00	.60	.90	.00	1.00
108	.60	.80	.50	1.00	.40	.90	.00	1.00	.00	1.00	.00	.80
109	.80	.80	.50	.40	.40	.30	.40	.40	.80	.60	.30	.80
110	.80	1.00	1.00	1.00	.80	1.00	.60	.80	.20	.90	.20	.90
111	.60	.40	.20	.90	.10	1.00	.00	.90	.00	1.00	.00	1.00
112	.20	1.00	.00	1.00	.00	1.00	.10	1.00	.00	.90	.00	1.00
113	.40	.60	.50	.50	.10	1.00	.30	.60	.50	.60	.50	.00
114	1.00	.60	.20	.90	.10	.70	.00	1.00	.00	1.00	.00	1.00
115	.80	1.00	1.00	.90	.80	.80	.40	.50	.40	.30	.00	.10
116	.40	.80	.10	.80	.30	.90	.50	.70	.30	1.00	.20	.80
Group 2 (IND → DR)												
201	1.00	1.00	.90	.90	.40	1.00	.70	1.00	.80	.90	.90	1.00
202	.60	.60	.90	1.00	.90	1.00	.90	1.00	.70	1.00	1.00	1.00
203	.80	.60	.30	.90	.30	1.00	.30	.90	.30	.90	.70	1.00
204	.60	.80	.50	.40	.30	.80	.80	.60	.60	.70	.30	.40
205	1.00	1.00	.90	1.00	.20	.90	.80	.90	.80	.90	.50	.80
206	.80	.80	.30	.90	.30	.40	.30	.30	.50	.40	.40	.10
207	.40	.20	.90	.30	1.00	.00	1.00	.00	1.00	.00	.90	.00
208	.60	.80	.20	.90	.10	1.00	.00	1.00	.00	1.00	.00	.90
209	.80	.40	.30	.80	.20	1.00	.40	.90	.30	1.00	.70	.90
210	.00	1.00	.00	1.00	.10	.90	.00	.90	.00	1.00	.00	.80
211	.60	.40	1.00	.80	1.00	1.00	.90	1.00	.90	.90	1.00	1.00
212	.00	.00	.30	.80	.20	.80	.20	.60	.10	.80	.10	.60
213	.80	.80	.40	1.00	.00	1.00	.10	1.00	.20	1.00	.20	1.00
214	1.00	.80	.80	1.00	.90	.80	.90	1.00	1.00	1.00	1.00	.90
215	.60	.40	.40	.90	.20	.90	.00	1.00	.40	1.00	.10	1.00
216	.20	.80	.80	1.00	.50	.60	1.00	1.00	.90	.90	.80	.40
Group 3 (IND, IND)												
301	.40	.20	.00	.60	.20	1.00	.00	.50	.00	.80	.00	.50
302	.40	.60	1.00	.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
303	.40	.60	.30	1.00	.10	1.00	.20	.90	.00	.90	.10	1.00
304	.40	.20	.60	.50	1.00	.20	.90	.90	.90	.90	.90	1.00
305	.40	.40	.30	1.00	.40	1.00	.50	.90	.30	.70	.40	.90
306	1.00	.20	.90	.30	.90	.30	.30	.50	.00	1.00	.10	1.00
307	1.00	.40	.70	.90	.10	.80	.10	.90	.00	.00	.00	.90
308	.80	.80	1.00	1.00	.90	1.00	.70	.90	1.00	1.00	1.00	1.00
309	.40	.40	.40	.50	.80	.60	.40	.70	.70	.90	.30	.40
310	.00	1.00	.30	1.00	.00	.90	.00	.90	.00	.90	.10	.80
311	.40	.80	.00	.60	.30	.90	.50	.80	.40	1.00	.10	.90
312	.00	1.00	.10	1.00	.10	1.00	.10	1.00	.00	1.00	.00	.90
313	1.00	.80	.90	.80	.80	.90	1.00	.80	.90	1.00	.90	1.00
314	1.00	1.00	.60	.40	.00	1.00	.20	1.00	.00	.90	.00	.90
315	.40	1.00	.50	1.00	.00	1.00	.30	1.00	.20	1.00	.00	1.00
316	.80	.60	.20	.00	.30	.20	1.00	.90	.80	1.00	1.00	1.00

APPENDIX B

Individual subjects' data: operant button presses per second during the programmed interval (mean over each block of trials per subject) for subjects in Group 1 (Subjects 101 to 116), Group 2 (Subjects 201 to 216), and Group 3 (Subjects 301 to 316). Blocks of trials of Phase 1 (ph1) and Phase 2 (ph2) under Alternative A1 (c2 component = VI 18 s) and Alternative A2 (c2 component = VI 3 s). IND: indifference; DI: delay increase; DR: delay reduction.

	Ph1(1)		Ph1(2)		Ph1(3)		Ph2(1)		Ph2(2)		Ph2(3)	
Subject	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2
Group 1 (IND → DI)												
101	0.106	0.212	0.106	0.133	0.080	0.027	0.198	0.625	0.079	0.225	0.079	0.159
102	0.505	0.558	0.757	0.611	0.412	0.332	0.277	0.226	0.000	0.159	0.040	0.199
103	0.159	0.186	0.385	0.359	0.359	0.412	0.198	0.584	0.237	0.358	0.277	0.465
104	0.292	0.239	0.133	0.213	0.252	0.226	0.040	0.173	0.119	0.159	0.000	0.146
105	0.213	0.213	0.266	0.438	0.226	0.359	0.317	0.359	0.474	0.491	0.395	0.425
106	0.319	0.292	0.438	0.372	0.465	0.505	0.396	0.797	0.119	0.505	0.316	0.452
107	0.186	0.133	0.319	0.199	0.173	0.199	0.396	0.173	0.356	0.226	0.317	0.292
108	0.080	0.239	0.093	0.106	0.040	0.106	0.119	0.093	0.000	0.172	0.000	0.133
109	0.664	0.452	0.596	0.385	0.784	0.677	0.475	0.624	0.594	0.691	0.709	0.810
110	0.080	0.159	0.292	0.292	0.252	0.226	0.237	0.252	0.670	0.452	0.792	0.718
111	0.344	0.292	0.146	0.133	0.040	0.053	0.040	0.186	0.119	0.319	0.158	0.332
112	0.319	0.372	0.226	0.266	0.159	0.159	0.079	0.252	0.277	0.226	0.198	0.319
113	0.239	0.185	0.305	0.199	0.306	0.213	0.237	0.319	0.356	0.399	0.119	0.279
114	1.356	1.648	1.781	1.580	1.966	2.193	2.533	1.781	0.910	0.597	0.950	0.810
115	0.319	0.346	0.213	0.173	0.040	0.093	0.000	0.027	0.079	0.239	0.000	0.106
116	0.691	0.585	0.544	0.558	0.585	0.624	0.475	0.597	0.594	0.771	0.712	0.836
Group 2 (IND → DR)												
201	0.399	0.452	0.399	0.385	0.346	0.239	0.404	0.292	0.409	0.439	0.400	0.292
202	0.080	0.159	0.013	0.040	0.027	0.013	0.093	0.080	0.075	0.080	0.075	0.053
203	0.106	0.133	0.120	0.146	0.093	0.199	0.204	0.120	0.240	0.120	0.253	0.146
204	0.478	0.425	0.545	0.532	0.465	0.505	0.568	0.571	0.524	0.492	0.511	0.505
205	0.159	0.239	0.093	0.133	0.664	0.637	0.258	0.332	0.311	0.359	0.377	0.239
206	0.691	1.063	0.638	0.731	3.229	3.562	3.551	3.628	3.419	2.975	4.605	4.718
207	0.159	0.106	0.080	0.080	0.013	0.027	0.120	0.000	0.164	0.000	0.120	0.027
208	0.106	0.239	0.306	0.332	0.306	0.345	0.240	0.279	0.240	0.199	0.209	0.159
209	0.159	0.399	0.133	0.146	0.306	0.279	0.209	0.106	0.120	0.146	0.240	0.199
210	0.691	0.691	0.319	0.504	0.691	0.824	0.493	0.731	0.337	0.159	0.218	0.213
211	0.770	0.797	0.638	0.757	0.771	0.824	1.123	1.116	1.310	1.276	1.550	1.595
212	0.399	0.478	0.837	0.810	2.111	2.204	3.028	3.096	2.713	2.709	2.890	2.962
213	0.159	0.213	0.319	0.332	0.266	0.279	0.253	0.213	0.213	0.186	0.107	0.080
214	0.266	0.319	0.412	0.345	0.545	0.492	0.449	0.425	0.404	0.385	0.564	0.824
215	0.239	0.239	0.306	0.279	0.252	0.213	0.253	0.133	0.226	0.159	0.351	0.346
216	0.186	0.266	0.252	0.159	0.159	0.133	0.182	0.146	0.226	0.186	1.048	1.395
Group 3 (IND, IND)												
301	1.673	1.116	1.807	2.214	1.276	1.168	2.086	2.310	3.389	2.840	3.694	4.010
302	0.053	0.080	0.080	0.080	0.093	0.066	0.080	0.040	0.040	0.013	0.080	0.027
303	0.133	0.159	0.106	0.120	0.106	0.213	0.120	0.093	0.080	0.093	0.053	0.133
304	0.638	0.823	0.518	0.545	0.505	0.478	0.571	0.545	0.518	0.505	0.425	0.306
305	0.186	0.212	0.332	0.346	0.359	0.425	0.478	0.372	0.545	0.425	0.505	0.465
306	0.585	0.611	0.558	0.598	1.528	1.594	1.608	1.381	2.113	2.284	2.538	2.546
307	0.133	0.133	0.186	0.226	0.159	0.159	0.159	0.053	0.053	0.066	0.080	0.133
308	0.611	0.611	0.771	0.651	0.771	0.611	0.784	0.824	0.983	0.957	1.356	1.435
309	0.053	0.106	0.120	0.120	0.625	0.731	1.462	1.260	0.213	0.159	0.027	0.013
310	0.372	0.186	0.359	0.385	0.252	0.146	0.239	0.266	0.279	0.359	0.213	0.133
311	0.106	0.159	0.199	0.120	0.159	0.186	0.093	0.133	0.027	0.066	0.106	0.080
312	0.691	0.372	0.824	0.757	1.076	1.342	1.169	1.369	1.276	1.155	0.944	1.183
313	0.771	0.744	0.452	0.532	0.346	0.399	0.372	0.412	0.306	0.252	0.319	0.359
314	0.186	0.106	0.452	0.412	0.372	0.252	0.518	0.545	0.505	0.492	0.053	0.146
315	0.027	0.053	0.066	0.013	0.000	0.040	0.000	0.040	0.027	0.040	0.000	0.027
316	0.505	0.452	0.213	0.226	0.106	0.159	0.040	0.027	0.027	0.053	0.027	0.013

APPENDIX C

Individual subjects' data: duration of the c1 component (obtained schedule duration) under the c1 component of A1 and A2 for subjects in Group 1 (Subjects 101 to 116), Group 2 (Subjects 201 to 216), and Group 3 (Subjects 301 to 316). Blocks of trials of Phase 1 (ph1) and Phase 2 (ph2) under Alternative A1 (c2 component = VI 18 s) and Alternative A2 (c2 component = VI 3 s). IND: indifference; DI: delay increase; DR: delay reduction. The programmed interval (FI schedule) is indicated.

	Ph1(1)		Ph1(2)		Ph1(3)		Ph2(1)		Ph2(2)		Ph2(3)	
Subject	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2	A1	A2
Group 1 (IND → DI)	FI 7.5 s	FI 7.5 s	FI 7.5 s	FI 7.5 s	FI 7.5 s	FI 7.5 s	FI 2.5 s	FI 7.5 s	FI 2.5 s	FI 7.5 s	FI 2.5 s	FI 7.5 s
101	10.645	11.468	11.282	9.425	10.244	10.211	5.674	9.118	7.239	10.710	6.745	9.354
102	13.259	8.480	8.623	8.601	10.299	10.688	6.646	8.662	5.959	8.244	5.844	8.156
103	10.381	9.370	9.689	8.623	8.761	8.964	3.438	8.365	4.735	9.217	4.531	8.255
104	9.403	9.151	9.590	10.315	8.947	9.508	5.333	9.634	5.125	9.112	4.707	8.986
105	9.447	8.634	9.299	9.628	8.865	9.348	4.229	8.838	3.350	8.925	3.609	8.596
106	8.920	11.512	8.739	9.370	9.112	8.563	4.389	8.349	4.323	8.497	5.460	9.464
107	15.083	16.016	12.858	11.836	10.546	12.424	5.839	9.266	7.003	9.947	6.080	9.326
108	10.337	12.128	10.661	9.568	8.080	8.173	7.558	7.937	6.926	7.860	6.910	7.854
109	8.810	8.678	9.134	12.979	10.765	9.628	5.855	10.699	3.944	8.766	4.180	9.255
110	11.842	14.995	9.552	10.727	11.633	14.149	5.339	9.815	3.949	8.530	3.713	9.200
111	10.667	10.062	9.436	9.013	8.101	8.123	5.602	8.294	2.895	8.272	2.971	7.942
112	9.524	9.238	9.579	9.052	9.568	8.618	4.438	10.029	4.553	9.288	4.410	9.041
113	11.490	9.777	10.293	11.122	11.551	11.633	4.367	9.096	3.664	9.606	4.949	9.381
114	7.635	8.217	7.799	8.074	7.717	7.739	3.021	7.893	3.850	8.805	3.356	8.459
115	12.699	8.623	10.084	9.826	8.612	8.838	8.250	8.832	8.667	8.640	7.657	7.942
116	8.470	8.085	8.524	8.590	8.497	8.393	3.351	8.134	3.010	8.008	3.279	8.102
Group 2 (IND → DR)	FI 7.5 s	FI 7.5 s	FI 7.5 s	FI 7.5 s	FI 7.5 s	FI 7.5 s	FI 22.5 s	FI 7.5 s	FI 22.5 s	FI 7.5 s	FI 22.5 s	FI 7.5 s
201	10.249	10.249	11.485	9.151	9.041	12.358	26.123	14.764	24.563	9.799	24.398	9.508
202	10.787	12.062	10.677	10.804	10.820	10.645	25.755	14.522	26.540	17.291	24.865	15.434
203	10.699	12.040	11.562	11.188	11.282	10.386	27.386	10.068	24.700	9.337	24.211	9.930
204	8.645	8.568	8.541	7.959	8.316	8.766	24.239	8.733	23.651	8.678	23.607	8.590
205	10.018	10.952	10.881	13.297	9.288	8.189	25.430	10.551	24.612	13.495	26.545	11.512
206	11.941	8.272	9.134	10.084	8.294	8.508	23.003	7.992	22.756	7.739	23.579	7.734
207	15.423	17.005	9.508	10.079	10.040	10.057	26.524	14.583	26.419	11.820	26.051	11.392
208	12.391	18.510	8.772	9.249	10.293	9.480	24.151	10.128	26.046	9.403	26.068	10.156
209	17.082	11.930	14.555	12.990	10.985	10.189	26.320	18.455	27.611	16.802	29.808	35.965
210	8.689	8.931	10.216	10.897	11.600	12.045	24.881	11.578	28.215	18.455	26.699	16.445
211	8.854	11.974	8.129	8.404	8.546	8.184	23.036	8.036	22.926	7.942	22.783	7.783
212	8.645	8.678	8.173	8.327	7.805	7.728	22.640	7.668	22.618	7.690	22.172	7.662
213	9.348	10.952	8.821	8.827	9.046	9.606	24.980	9.299	25.370	9.085	26.144	11.617
214	9.568	9.348	9.579	9.304	9.206	9.101	24.052	8.843	23.744	9.041	23.689	8.080
215	11.018	10.930	10.183	9.486	9.282	9.985	25.991	9.304	25.667	9.238	24.887	12.144
216	9.326	9.524	11.556	10.947	11.485	11.084	26.221	10.145	27.380	10.815	26.551	9.112

APPENDIX C *(Continued)*

Subject	Ph1(1) A1	Ph1(1) A2	Ph1(2) A1	Ph1(2) A2	Ph1(3) A1	Ph1(3) A2	Ph2(1) A1	Ph2(1) A2	Ph2(2) A1	Ph2(2) A2	Ph2(3) A1	Ph2(3) A2
Group 3 (IND, IND)	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s	**FI** 7.5 s
301	8.129	8.590	12.611	9.134	8.508	8.843	7.712	7.706	7.690	7.723	7.629	7.624
302	13.841	12.951	12.001	10.084	11.880	11.727	10.787	10.167	9.832	8.783	8.387	8.541
303	10.908	11.633	10.656	10.161	8.849	9.469	9.980	9.628	9.519	10.018	8.634	9.315
304	8.107	8.239	8.338	8.442	9.238	8.931	8.360	8.393	10.002	9.634	8.689	12.281
305	9.601	10.183	9.777	9.859	8.667	8.794	8.579	8.870	8.640	8.656	9.041	8.805
306	8.019	8.601	8.497	8.299	7.986	7.871	7.832	7.959	7.734	7.701	7.673	7.690
307	12.853	11.864	10.156	10.112	8.596	8.107	8.486	8.327	8.387	8.371	9.612	8.986
308	8.052	8.151	8.371	8.415	9.442	8.519	8.025	8.354	8.113	8.008	8.420	7.816
309	15.467	21.915	11.205	12.270	8.623	10.315	9.282	9.304	9.090	9.326	14.813	13.869
310	9.260	9.931	9.722	10.002	11.024	9.568	11.342	10.123	9.464	9.436	9.469	10.430
311	10.139	11.260	11.188	10.787	9.722	10.590	11.738	11.260	10.288	11.551	10.551	10.639
312	9.557	8.975	8.233	8.464	7.937	8.398	8.025	7.898	7.986	7.893	8.069	7.953
313	8.217	8.338	21.481	10.826	16.132	13.122	9.293	11.924	11.760	9.930	15.368	13.045
314	9.601	10.293	9.480	8.827	9.249	9.952	8.859	9.019	8.980	8.244	11.600	8.925
315	10.908	11.490	10.029	10.117	8.914	8.673	9.013	9.326	9.123	8.909	8.601	8.574
316	8.986	9.799	9.480	9.403	10.057	10.128	15.121	16.143	9.546	11.919	11.111	10.782