BRIEF REPORT

DIFFERENTIATED REINFORCEMENT ALTERS CHOICE PREFERENCES OF HUMANS

Craig A. Marrer and Benjamin N. Witts

DEPARTMENT OF COMMUNITY PSYCHOLOGY, COUNSELLING, AND FAMILY THERAPY, ST. CLOUD STATE UNIVERSITY

Understanding preference for choice is valuable in accounting for how different organisms respond to different environmental conditions. Part of this understanding comes from studying preference (or non-preference) for choice under differing and changing conditions, and in-the-moment flexibility to chain arrangements and reinforcer delivery will aid in this pursuit. When an arrangement contains two or more concurrently available alternatives, each of which functions as a discriminative stimulus (SD), the arrangement is called free choice whereas, when only one SD is available, it is considered a restricted choice (Martin, Yu, Martin, & Fazzio, 2006). Generally, both human and non-human organisms tend to prefer stimulus arrangements containing choice compared to arrangements with no choice (e.g., Catania, 1975, 1980; Catania & Sagvolden, 1980; Fisher, Thompson, Piazza, Crosland, & Gotjen, 1997; Sellers et al., 2013; Skowronski & Carlston, 1982; Tiger, Hanley, & Hernandez, 2006.)

Concurrent-chains schedules of reinforcement arrange two or more affixed simple schedules and are often used to study preference between free and restricted choice arrangements (see Fisher & Mazur, 1997). In a concurrent-chains design, the first simple schedule or initial link is signaled by the presence of two stimuli; one paired to the free choice arrangement and one to the restricted choice arrangement. When the schedule requirement under either of the initial links is met, the corresponding terminal link schedule is presented, and satisfying the terminal link requirement produces the consequence: a putative reinforcer. When terminal link work requirements and outcomes are equal, and only reinforcer presentation differs (free versus restricted choice), initial link responding can be used as a measure of preference. For example, Schmidt et al. (2009) found that when eight typically developing children were provided the opportunity to choose between 5 identical preferred items (free choice) or receive the same but therapist-selected item (restricted choice), responding was generally allocated towards the free choice initial link. As preference was not distributed randomly between options, these results suggest that the opportunity to choose is reinforcing beyond the terminal reinforcement available.

However, when it becomes advantageous to change preference due to some variation between the free and restricted terminal link outcomes, organisms tend to allocate their responding to whichever schedule terminates in quantitatively or qualitatively more valuable reinforcement (Hayes, Kapust, Leonard, & Rosenfarb, 1981; Karsina et al., 2011). Fisher, Thompson, Piazza, Crosland, and Gotjen (1997) found that while three children in an inpatient program initially preferred free choice arrangements when receiving contingent access to either high preference or low preference items, their preferences changed to the restricted choice arrangement when low preference items were delivered contingent on selecting the free choice initial link and high preference items contingent on selecting the restricted choice initial link. Thus, while free choice arrangements can be preferable, likely due to the opportunity

Address correspondence to: Craig Marrer (camarrer@gmail.com) or Benjamin Witts (bnwitts@stcloudstate.edu), Department of Community Psychology, Counseling, and Family Therapy, St. Cloud State University, 720 4th Ave S, St Cloud, MN 56301

to choose, the putative reinforcer can develop selective control over subsequent response allocation.

The exact mechanisms responsible for the general finding that organisms prefer free choice arrangements are not clear. Additionally, there have been studies in which participants have shown a restricted choice preference. Karsina, Thompson, and Rodriguez (2011) demonstrated that for seven college-aged students who preferred restricted choice to free choice (4 participants) or did not show a preference (3 participants), choice preference was amendable to a differential reinforcement procedure. Much like research that has shown free choice preference to be amenable to change when terminal link variables are altered, these researchers demonstrated the same for participants that showed a restricted choice preference. Additionally, Karsina et al. found that the conditioned free choice preferences for 5 of the 7 participants persisted during a withdrawal to baseline conditions where reinforcement for both the free and restricted choice contingences was equal.

The results of the above-mentioned studies support that both free and restricted choice preferences are amendable to prevailing contingencies when adequate selection pressure is placed on responding (e.g., via differential reinforcement). However, few studies have presented equivalent procedures to participants preferring free or restricted choice arrangements within the same experimental study. The current study presents greater flexibility in researching choice through the use of a computer-based game with built-in algorithms that allow for intervention condition assignments to be carried out for each participant based on baseline choice arrangement preferences.

A parametric differentiated reinforcement procedure (see van Haaren, 2017, for a review of differentiated reinforcement) was used in which points for the non-preferred choice arrangement progressively increased while diverging from the points available for the preferred choice arrangement. Through the use of an algorithm and an automated software function, an equivalent intervention procedure was presented across both groups of participants. It was anticipated that regardless of baseline preference, each participant's responding would come under the control of the prevailing contingencies, as has been demonstrated previously within the research. Additionally, in keeping with previous research findings, it was anticipated that most participants would show a preference for the free choice arrangement during the baseline condition. Lastly, it was anticipated that there would be no clear differentiation between the response patterns of those with a free choice preference and of those with a restricted choice preference, showing that regardless of choice arrangement preference in a given context, contingent differentiated reinforcement would come to control response allocation.

METHOD

Participants and Setting

Twelve undergraduate students (8 female, 4 male; M age = 21.90; range = 19-27) enrolled at a mid-sized Midwest university participated. All sessions were conducted in an approximately 6.5 m by 2.6 m research room. The participant space consisted of two long tables (1.21 m and 1.05 m), each with a computer monitor and a chair. Participants completed the study one at a time. All participants were compensated $12.00 for completion of the study. IRB approval was obtained, and informed consent procedures were followed for each participant. Due to the use of deception, each participant was given a debriefing statement at the end of the study, which explained how and why deception was used.

Materials

A computer program, built using Java programming language, was used to present the informed consent, demographic questionnaire, participant training, training quiz, and the experimental procedure. Participants used a standard computer mouse to input information into the program. The computer program was hosted on a private server and was accessible via a web address. The software recorded all mouse clicks related to the demographic questionnaire, training quiz, and responses towards initial and terminal links for each trial into a comma-separated value format stored on the program server. Participants were assigned a username and a password. A research assistant

was present to log each participant into the program.

Design and Program Accuracy

An A-B-A or withdrawal design was used. Thirty-one baseline trials were presented, followed by 30 intervention trials and 30 withdrawal trials, resulting in a total of 91 trials. Due to the automatization of the data collection procedure, program accuracy was assessed by taking response data from screen-recorded pilot studies and comparing these data to the automatically compiled data from the software. Data collection accuracy for the software was found to be 100% across three consecutive pilot study sessions.

Procedure

A concurrent-chains arrangement was used to measure participant preference between free and restricted choice arrangements. Trials were presented via a computer-based game in which three different colored squares - blue, red, and green - each measuring 5.08 by 5.08 cm or 600 by 600 pixels, were displayed in a quasi-randomized order from left to right and served as the free choice, restricted choice, and control arrangements, respectively, for every participant. All initial link stimuli were represented as a single-celled square and were activated when the participant clicked the mouse cursor one time anywhere within the cell area (see Figure 1).

Once an initial link response was recorded, the selected array moved to the center of the screen and displayed as a 100-celled array for free and restricted choice terminal link arrangements or a single-celled array for the control arrangement. The free choice terminal link required the participant to select 3 of the 100 available cells of his or her choosing with the mouse cursor. Selections were indicated by a darkening of the selected cell. Similarly, when the restricted choice array was selected, the participant was required to click the mouse cursor three times. However, when the participant clicked the mouse, a single random cell was darkened, indicating it was activated and that the mouse's cursor position at the moment of a

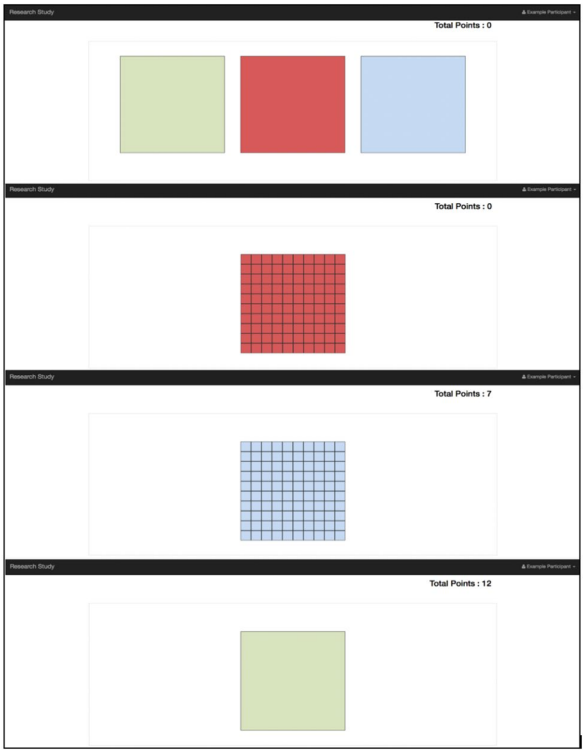

Figure 1. Screen shot of an initial link choice situation (top) with corresponding choice type and display color shown within figures. Screen shot of terminal link choice situation for the forced choice (top), free choice (middle) and control (bottom) array types.

click had no influence on what cell would be activated. Lastly, when the control array was selected, the participant was required to click one additional time anywhere within the array to complete the terminal link requirement. Following the next mouse click, the entire array darkened to indicate that the response requirement had been met. A control array was included to account for non-discriminated scrolling responses (i.e., selecting an array without first visually attending to the stimulus arrangement).

Participants were awarded points when meeting the terminal link requirement of the free or restricted choice arrays. Selection of the control condition always resulted in no points being awarded. Total trial point values were shown to the participant at the end of each terminal link trial, and the sum of points earned across trials was shown in a score box in the

upper right-hand corner of the computer screen. Each response during the terminal link of the choice sequence was assigned an individual cell point value, which ranged from 0 to 4 points. The total point value per trial for the free and restricted choice arrays was always the sum of the three individual cell values activated and ranged from 0 to 12 points. Selection of the control array always resulted in 0 points.

During the baseline phase, total trial points were awarded at an equal probability for both choice arrangements based upon predetermined ratio assignments (see below). After meeting the initial link schedule requirement for the free, restricted, or control arrangements (FR-1) the participant was presented with the terminal link component. The terminal link schedule requirement for the free and restricted choice arrangements was FR-3, while the control array terminated following a single additional response (FR-1).

Baseline terminated following 31 trials, at which time the computer software analyzed the proportion of responding to each choice arrangement and assigned a participant to one of two groups—the differentiated reinforcement of free choice (DRFC) or the differentiated reinforcement of restricted choice (DRRC). Participants that allocated an equal number of responses to each choice arrangement (due to the selection of the control array) were automatically assigned to the DRRC group.

The differentiated reinforcement procedure was a parametric procedure in which total trial point values for the preferred and non-preferred choice arrangements progressively diverged over the course of the experimental condition. For example, if a participant showed a preference for free choice during baseline, restricted choice terminal links terminated with increasingly higher point totals over the course of the intervention condition. The inverse was true for participants that showed a preference for restricted choice during baseline. Regardless of baseline preference, all participants received the same intervention condition in relation to points available for selecting between their preferred and non-preferred choice arrangements. A withdrawal to baseline conditions was conducted for 30 trials to assess the maintenance of the differentiated reinforcement procedure.

Points

To determine individual cell point values, a probability of occurrences out of 10 was set for each possible point value with actual occurrence generated via a randomization formula. During baseline and withdrawal, these probabilities were set to occur at 10% occurrence for 0 and 4 points, 20% for 1 and 3 points, and 40% for 2 points. By arranging probabilities in this manner, total trial point values clustered around the median of 6 points. This minimized the likelihood of any participant receiving relatively high or low points during any trials during the baseline and withdrawal conditions, therefore, minimizing the relative reinforcer value of either choice arrangement over the other.

During the intervention condition, seven ratio modifications occurred over 30 trials (see Table 1). To determine individual cell point values for the intervention condition, 90 numbers (0-4) were generated using the randomization formula (30 trials of 3 numbers each) and assigned to the non-preferred choice condition (either free or restricted, contingent on participant preference). Conversely, the inverse value was determined and assigned to the preferred choice condition (again, contingent on participant preference). For example, if the randomized three number sequence for the non-preferred choice arrangement was 4-3-4, the inverse three number sequence for the preferred choice arrangement relative to the number of points away from the median was 0-1-0, with 2 being the median single cell value

Sessions and Instructions

At the start of each session, participants were shown to the computer by a research assistant and informed that all instructions related to the study would be provided via the computer. Training consisted of a sequence of six static instructional screens in which the initial and terminal link representations of the experimental stimuli were presented, one at a time, with instructions on how the participant must interact with each stimulus. Participants were also informed at this time that for each point

Table 1

Reinforcer Value Assigned Probability Per Phase

Treatment Phase	Points									
	0	1	2	3	4	0	1	2	3	4
Baseline										
1-31	10%	20%	40%	20%	10%					
Intervention	Non-preferred choice situation					Preferred choice situation				
32-34	15%	20%	20%	20%	25%	25%	20%	20%	20%	15%
35-37	15%	15%	20%	25%	25%	25%	25%	20%	15%	15%
38-40	10%	15%	20%	25%	30%	30%	25%	20%	15%	10%
41-43	10%	10%	20%	30%	30%	30%	30%	20%	10%	10%
44-46	5%	10%	20%	30%	35%	35%	30%	20%	10%	5%
47-49	5%	5%	20%	35%	35%	35%	35%	20%	5%	5%
50-52	0%	5%	20%	35%	40%	40%	35%	20%	5%	0%
53-55	0%	0%	20%	40%	40%	40%	40%	20%	0%	0%
56-58	0%	0%	20%	40%	40%	40%	40%	20%	0%	0%
59-61	0%	0%	20%	40%	40%	40%	40%	20%	0%	0%
Withdrawal										
62-91	10%	20%	40%	20%	10%					

Note. Percentages indicate probability of corresponding number occurring when running a quasi-randomized number generating equation.

earned during the study, they would be compensated $0.01 in addition to the $5.00 they were already receiving for completing the study; as points were predetermined by the researcher for two of the three phases, all participants were compensated for the maximum number of points possible in the study, which was 700 points or an additional $7.00, making total compensation $12.00 per participant. However, participants were not made aware of this until the end of the study.

Following training, participants were given a 5-question quiz to ensure understanding of each of the requirements of the study. A score of 100% was required to move onto the next phase of the study. If a participant failed to score 100%

on his or her first try, he or she was provided a printed copy of the training to review a second time and retake the quiz. No participants failed to pass the quiz.

RESULTS

Figure 2 shows the proportion of response allocation between the choice arrangements for all participants during baseline, intervention, and withdrawal conditions. Of the 12 participants, 8 allocated more responses to the free choice arrangement during baseline, 3 to the re-

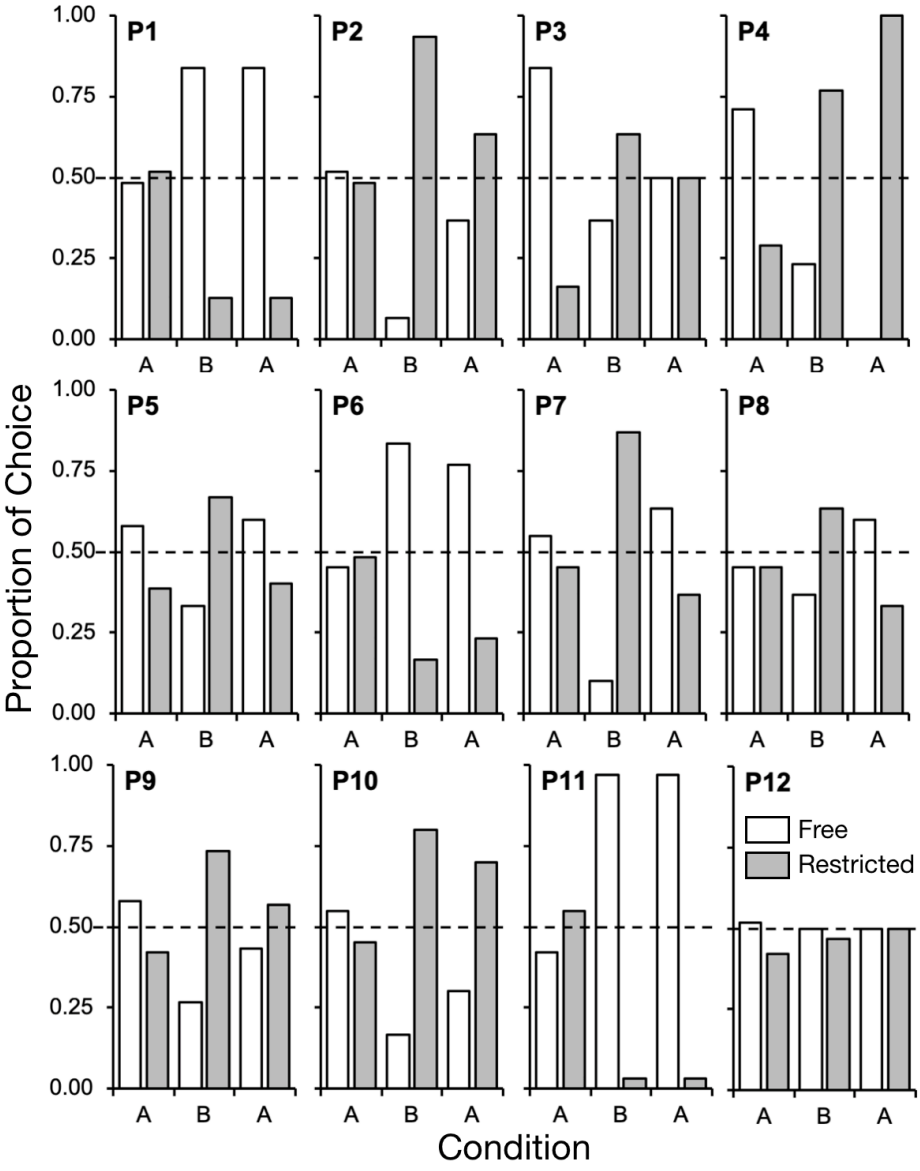

Figure 2. Proportion of responses allocated, per phase, to each choice arrangement, for all participants. White vertical bars represent free choice array selections and gray vertical bars represent restricted choice array selections

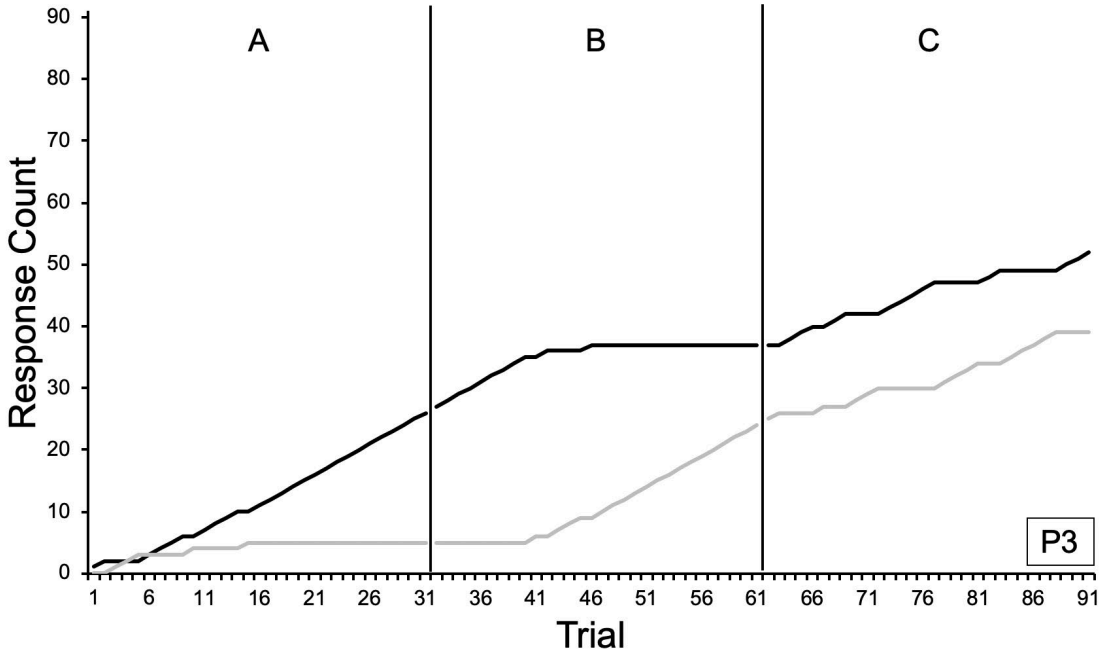

Figure 3. Cumulative response count for participant 3. Responding indicated a clear preference for the free choice array during baseline that persisted until trial 41 during the B phase. Following trial 41, participant 3 allocated all remaining B phase responses toward the restricted choice array. During the return to baseline (phase 3), an oscillation between the two choice arrangements can be seen. Free choice selections are represented by black lines and restricted choice selections by grey lines.

stricted choice arrangement, and 1 participant allocated an even number of responses to each (due to the selection of the control arrangement). However, only two participants, P3 and P4, showed a clearly differentiated preference between the choice arrangements, with both allocating at least 70% of responses to the free choice arrangement (see Figure 3 for a representative example). In general, most participants' responding during baseline indicated a general indifference between the free and restricted choice arrangements, often choosing to alternate responding between each choice arrangement in a relatively patterned manner (see Figure 4 for a representative example).

Following baseline, eight participants were assigned to the DRRC condition and four to the DRFC condition. All but one participant's responding came under the control of the differentiated reinforcement procedure, with P12 continuing to allocate a higher proportion of responding to her preferred choice arrangement. At the end of the intervention condition, eight participants were allocating responding in a manner consistent with a restricted choice preference and four with a free choice preference, which was the opposite of their baseline results. Upon return to baseline conditions, seven participants (P1, P2, P4, P6, P9, P10, and P11) continued to allocate a higher proportion of responding to the recently conditioned choice arrangement preference, indicating maintenance of the recent conditioning procedure, with three allocating a higher proportion to their baseline choice arrangement preferences (P5, P7, and P8), and two showing indifference (P3 and P12).

To assess for the possibility of unintended differentiated reinforcement occurring during the baseline condition, therefore causing a preference and conditioning effect prior to the presentation of the parametric differentiated reinforcement procedure, an analysis of the average total trial point value awarded following each choice condition was conducted. As can be seen in Figure 5, 7 of the 12 participants actually earned more points, on average, during baseline under their non-preferred choice arrangement.

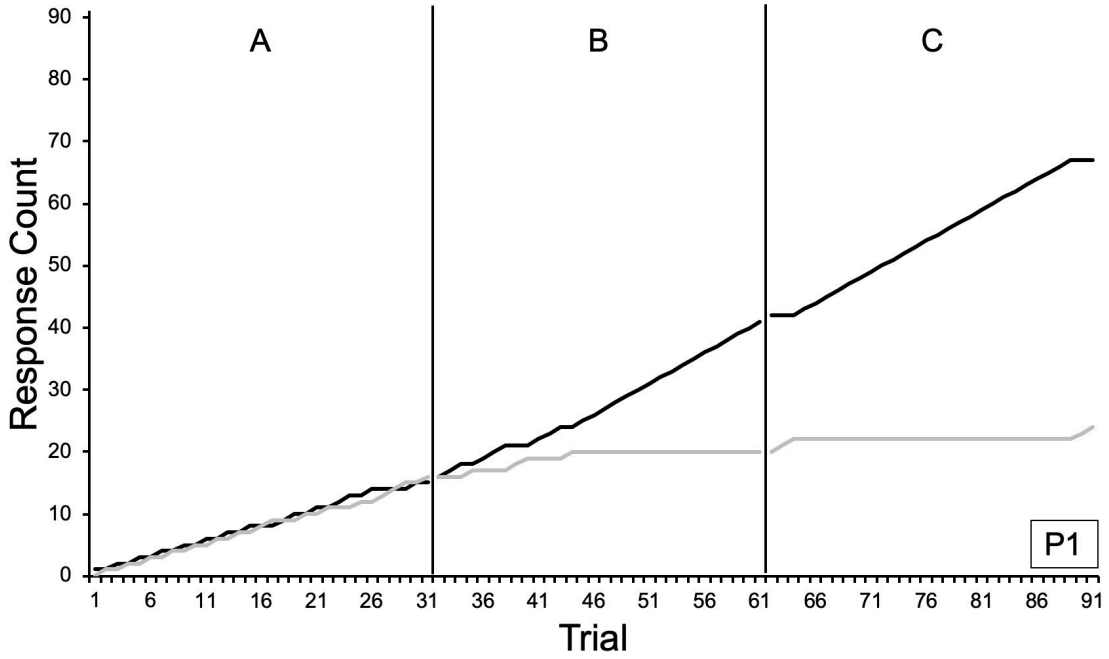

Figure 4. Cumulative response count for participant 1. Responding indicated a general indifference between the free and restricted choice arrays during baseline, with a clear preference emerging during the B phase that maintained following a return to the baseline procedure. Free choice selections are represented by black lines and restricted choice selections by grey lines.

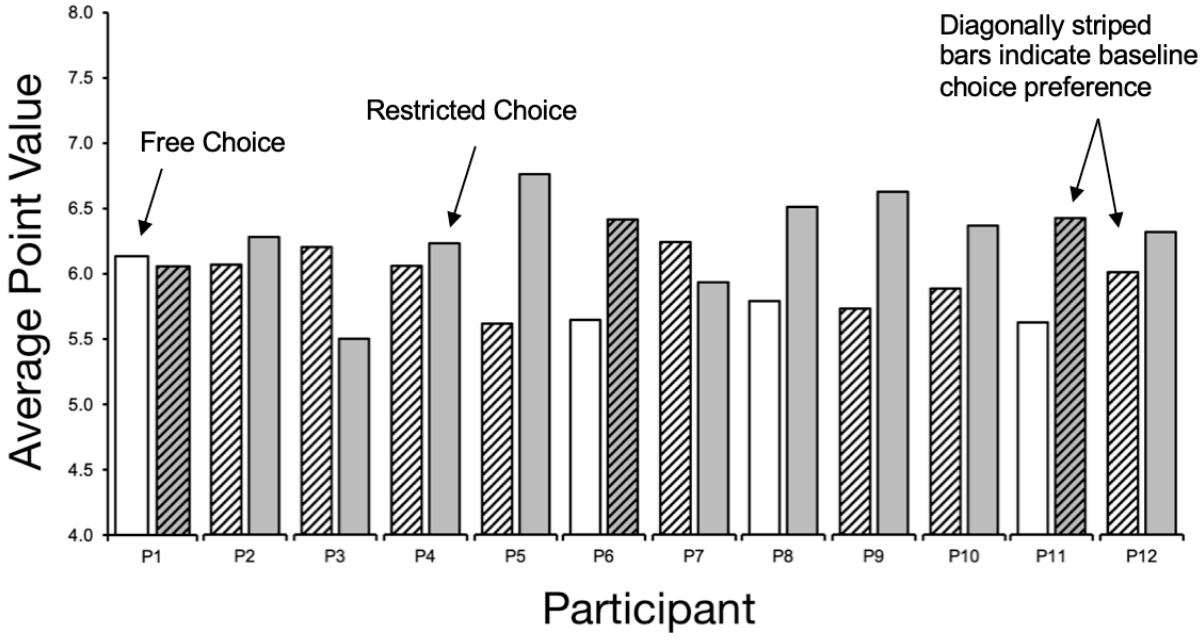

Figure 5. Average point totals earned per choice arrangement per participant during baseline. Free choice averages are displayed as white bars and restricted choice by gray bars. Bars with upward diagonal lines represent the choice arrangement preference for each participant excluding participant 8 who did not show a preference between the choice arrangements during baseline.

DISCUSSION

The current study investigated the effect of a differentiated reinforcement procedure on the choice arrangement preferences of human participants using automated computer software that allowed participants of any choice preference during baseline to participate. While previous studies have successfully altered free and restricted choice preferences of humans and non-humans using differential reinforcement procedures, few have been able to simultaneously investigate both free and restricted choice arrangement preferences and compare and contrast intervention effects using the same experimental procedure.

The results of the current study were consistent with previous research in that differentiated reinforcement, like differential reinforcement, altered the choice arrangement preferences of human participants. Of the 12 college-aged participants, all but one showed a preference for the non-preferred choice arrangement during the differentiated reinforcement procedure. Additionally, for seven of these participants, conditioned choice preferences persisted when reinforcement was returned to baseline levels during a withdrawal condition (maintenance). These findings are consistent with Karsina et al. (2011).

The current study extends some aspects of previous choice research in several potentially important ways. First, the use of a computer algorithm to assign participants to one of two intervention phases, depending on baseline responding, allowed all participants to be included. In previous research, a priori exclusion and inclusion criteria were necessary or deemed desirable, depending on the purpose of the study. However, by including all participants, it was possible to analyze intervention effects for participants that preferred both free and restricted choice arrangements as well as for those that showed little to no pre-intervention preferences.

Second, the current study used monetary compensation that was designed to appear as if it was corollary with a participant's performance. We hypothesized that by establishing motivation for higher point totals, participants would be more sensitive the prevailing contingencies in place during the intervention phase. However, the motivational effect of monetary compensation was not experimentally demonstrated and therefore, cannot be said to have contributed to the data in any meaningful way. Future research might want to investigate this further as it could be found that the use of a potent conditioned reinforcer such as money could more closely capture the motivation of a participant in a naturalistic choice situation.

However, while the design of this study—specifically the use of an algorithm—did demonstrate the potential utility of using computer-assisted interfaces for investigating behavioral phenomena, there are several limitations. First, the data do not indicate why some participant's responding was undifferentiated during baseline, but others was not. It is possible the baseline condition was too brief and, therefore, inadequate to establish a preference for some participants. Alternatively, the contingency arrangement during baseline might have inadvertently reinforced an undifferentiated pattern of behavior in some participants. Lastly, some people might not have a preference between free and restricted choice arrangements. However, since most participants' behavior did come under control of the differentiated procedure, with conditioning effects persisting during the withdrawal phase, inclusion and further analysis of these data are warranted.

A second limitation is related to the limited number of trials presented during each condition. While 91 trials were presented to each participant, it might be that additional trials are required to allow changes in response patterns to be fully recognized. This seems to be especially true during the withdrawal phase. For example, several participants' responding during the withdrawal phase appear to be returning to response allocation more consistent with baseline levels (see Figure 6 for a representative example). It might be found that with a withdrawal phase extended another 30 to 60 trials, more participants' preferences would correspond to baseline preferences as the transitory effects of the intervention procedure loses control. Extending phases would also allow for a better assessment of stability, which could be programmed into the computer algorithm as a means of determining when to switch conditions.

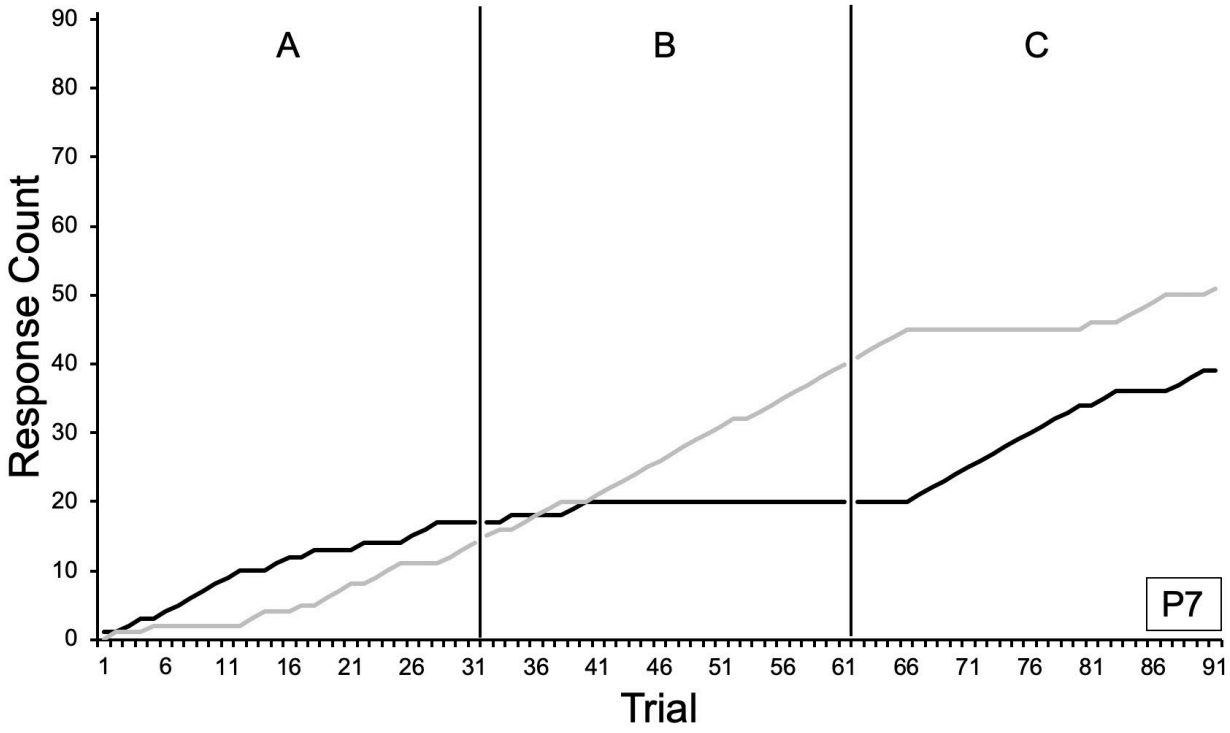

Figure 6. Cumulative response count for participant 7. Responding indicated a slight preference for the free choice situation during baseline, with a clear preference emerging during the B phase that maintained following a return to the baseline procedure. Free choice selections are represented by black lines and restricted choice selections by grey lines.

Thirdly, since the experimental interface relied on the use of colors (blue, red, and green) to function as discriminative stimuli for the different choice arrangements, it is possible that participants who experience color-blindness, would not be able to adequately discriminate between the experimental stimuli. This was not assessed during the current study, but future researchers using similar experimental interfaces would be wise to assess for this prior to implementation of the study. A fourth potential limitation, also related to the use of color, is that the color assignment between each choice type was not randomized between or across participants, meaning a color-based bias could have inadvertently affected participant preference.

The current study sought to investigate choice arrangement preferences in humans that preferred either free or restricted choice situations and was able to show, at least preliminarily, that when individuals with free or restricted choice preferences are exposed to the same experimental procedures, little difference can be found in each group's sensitivity to differentiated contingencies. Consistent with previous research, the majority participants in the current study did show a preference for the free choice arrangement over the restricted choice arrangement. However, the baseline preference was unremarkable.

By conducting additional research in this area, it seems plausible that certain response patterns will be identified that share similarities in the histories of the individual. For example, some participants that showed no preference during baseline ended up showing clear preferences during and after intervention—but others did not. Lastly, for some participants, there appeared to be a "cancelling out effect" in that they showed a preference during baseline, allocated

responding to the more favorable choice option during intervention, and then showed no preference during withdrawal, however, additional research is needed to assess the significance of this finding.

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