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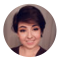

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Extending Stimulus Preference Assessment with the Operant Demand Framework

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Abstract

This study extended earlier research on stimulus preference (SP) and reinforcer efficacy (RE) using the behavioral economic concept of elasticity. The elasticity of demand for different items can be used to simultaneously compare RE across stimuli and schedules of reinforcement. Highly preferred stimuli were identified via SP assessments and evaluated using progressive-ratio reinforcer assessments. Reinforcers were then evaluated across the ranges of elasticity in individual reinforcer evaluations. Results indicated that schedules associated with the ranges of elasticity (e.g., inelastic vs. elastic) corresponded with rates of the targeted behavior (i.e., work) and these trends were consistent with behavioral economic predictions. These findings encourage further inquiry and replication of operant demand methods to identify potential boundary conditions for stimuli identified using SP assessments. Discussion is provided regarding the efficiency of reinforcer assessment and the utility of schedules found to exist in the elastic and inelastic ranges.

Keywords: behavioral economics, reinforcer efficacy, stimulus preference assessment

Extending Stimulus Preference Assessment with the Operant Demand Framework

Practice and research in behavior analysis regularly incorporate the preferences of individual consumers and participants (Hagopian et al., 2004; Heinicke et al., 2019), frequently based upon results from a range of established stimulus preference (SP) assessment procedures (Cannella et al., 2005). These methods demonstrate good convergent validity (Hanley et al., 2006; Verriden & Roscoe, 2016) as well as stability over time (Carr et al., 2000; Ciccone et al., 2007). The primary goal of these procedures is to efficiently predict a reinforcing effect or relation from a brief sample of behavior (e.g., choice, reinforcer consumption). The ability to predict a reinforcing effect has improved the efficiency of behavior analytic services, as direct evaluations of individual reinforcing effects are more time- and resource-intensive (Fisher et al., 1996) and indirect assessments alone entail varying levels of accuracy without empirical validation (i.e., without sampling participant choice; Green et al., 1991).

Preference and Reinforcer Efficacy

The utility of a stimulus in reinforcing behavior has been referenced in several ways, with Pace et al. (1985) terming this as reinforcer value, DeLeon and Iwata (1996) as reinforcement effects, Penrod et al. (2008) as potency, and DeLeon et al. (2009) as stimulus value.[1] Despite a difference in the terms used, each refers to the effect of stimuli on behavior and does not refer to some inherent quality of the stimulus. DeLeon et al. (2009) described these differential effects on behavior by saying, “stimuli that lie along different points of a preference continuum are associated with differing amounts of work they will sustain” (p. 732). Moving forward, we broadly refer to these differential effects on behavior as reinforcer efficacy (RE). This term has previously been used by behavior analysts to reference the degree to which stimuli influence

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[1] These studies are primarily focused on evaluating inter-relationships between relative rankings on SP assessments and estimates of relative reinforcer efficacy, not reinforcer efficacy and applications to treatment.

behavior under various schedule arrangements (Hackenberg, 2018).

Assessments of SP have been effective for predicting a reinforcing effect; however, limits exist to predictions derived from SP rankings (i.e., boundary conditions). That is, only those ranked highly are predictive of a reinforcing effect and such predictions typically refer to efficacy on a continuous schedule of reinforcement (fixed ratio 1 [FR1]; DeLeon & Iwata, 1996; Pace et al., 1985). Although SP assessments have clear utility, there are instances where it is beneficial to evaluate the RE of stimuli and determine its persistence on the kinds of leaner schedules that are more likely to be used in treatment (e.g., FR5, FR10). For instance, such questions are particularly relevant when thinning schedules of reinforcement (i.e., advancing from FR1 to more lean, variable schedules). Additionally, knowledge of the RE of reinforcers may guide the design and implementation of interventions predicated on work output (e.g., demand fading; Gilroy, Ford et al., 2019).

Tustin (1994) was among the earliest researchers to highlight variability in RE between stimuli across schedules of reinforcement. Specifically, Tustin (1994) found that varying stimuli can demonstrate similar RE on FR1 schedules (i.e., sustained comparable amounts of responding) but differing degrees of RE across more lean schedules. That is, certain stimuli may be correlated with ratio strain earlier than others. DeLeon et al. (2009) also evaluated varying degrees of RE but instead used progressive-ratio (PR) schedules of reinforcement to compare reinforcer breakpoints (Hodos, 1961). Briefly, the breakpoint (i.e., BP_0) refers to the schedule on which rates of responding are no longer sufficient to produce the reinforcer. DeLeon et al. evaluated the correspondence between stimulus preference rankings and breakpoints and found that low-preferred stimuli were correlated with lower breakpoints whereas high-preferred stimuli were correlated with higher breakpoints.

Although results from DeLeon et al. are telling, it should be noted that the breakpoint is a relative measure of RE (i.e., RRE; Gilroy, Kaplan, Reed et al., 2018; Johnson & Bickel, 2006; Katz, 1990). Measures such as the breakpoint or the total number of responses maintained by a reinforcer are used to construct a ranking of reinforcers whereby higher ranks represent relative superiority. The RRE approach has good descriptive value and is easily performed, though breakpoints and rankings do not allow for predictions across individual schedules (e.g., FR5 vs. FR10). This limitation exists because measures of RRE do not reflect the overall pattern of responding across schedules and instead focus on a specific aspect of responding (Hursh & Roma, 2013). For example, the breakpoint is derived from the schedule where responding no longer produces reinforcers and knowledge of this point alone offers little guidance regarding the effects of dense schedules in treatment. Others have noted such limitations as well and have suggested that behavior analysts explore alternative methods that offer this type of predictive utility (Hursh, 1980, 1984).

Reinforcer Efficacy and the Operant Demand Framework

Hursh (1980) made a case for using methods from economics to evaluate RE. This approach, the *operant demand framework*, evaluates RE using the economic concepts of demand and elasticity. The term *demand*, as used here, refers to the degree to which an individual or organism will work to defend their bliss point consumption of a reinforcer (i.e., reinforcer consumption involving price or effort when contingencies have not been set; Gilroy et al., 2020). Demand for a particular reinforcer is determined by evaluating responding as the response requirements necessary to produce it increase from low to high. The *elasticity* of demand quantifies the relationship between relative increases in cost and relative decreases in reinforcer production (Hackenberg, 2018; Hursh, 1980, 1984).

Economic concepts such as elasticity are relatively novel in applied behavior analysis (Gilroy, Kaplan, & Leader, 2018), though these have been used extensively in various areas of basic human and nonhuman research (Hursh et al., 1989; Hursh & Roma, 2013; Hursh & Winger, 1995). Elasticity in the operant demand framework varies across prices, and individual schedules can be characterized as being inelastic, elastic, or unit elastic (see Figure 1). The inelastic and elastic ranges reflect differing degrees of change in response to increases in price. The *inelastic range* represents a portion of the demand curve where the relative decreases in consumption are lesser than corresponding increases in price. Given that reinforcer consumption changes less rapidly than price increases, this results in increasing levels of target behavior. In contrast, the *elastic range* is the portion of the demand curve where relative decreases in consumption outpace relative increases in price. This takes the form of decreasing levels of target behavior because consumption decreases more rapidly than the corresponding price increases. The point where relative changes in consumption and price are equal (but in different directions) generally corresponds with the peak level of responding. The price associated with peak responding is termed P_{MAX} (i.e., the price at maximum output) and the maximum level of the observed target behavior is termed O_{MAX} (i.e., maximum output). For interested readers, see Lea (1978) for an application of this concept in basic research and Gilroy et al. (2020) for an exposition on elasticity in the operant demand framework.[2]

Most of the research on RE in applied behavior analysis has focused on comparisons between SP assessment rankings and select measures of RRE (i.e., breakpoint). However, few have directly evaluated RE and its implications in the function-based treatment of problem behavior. Among the few studies that have translated the behavioral economic concept of

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[2] The term operant demand serves to distinguish the approach from mainstream behavioral economics, which focuses on cognitive biases and heuristics rather than ecological factors.

demand into function-based assessment and treatment, Gilroy, Ford, et al. (2019) evaluated the demand for social-positive and social-negative forms of reinforcement. Using demand curve analyses fitted to the levels of target behavior on PR schedules, the elasticity of demand for reinforcers was used to select a schedule from the upper limits of the more stable inelastic range of prices, and this information was used in a functional communication training (FCT) treatment for problem behavior. That is, the schedule requirement associated with the functional communication responses was derived based on P_{MAX}. A schedule less associated with ratio strain (i.e., slightly below P_{MAX}) was selected to better maintain the functionally equivalent alternative to problem behavior. The results of this study indicated that this approach allowed for a rapid assessment of RE that could be incorporated into a treatment package using the concept of elasticity.

Although novel and effective within an evaluation of FCT as a treatment for problem behavior, the Gilroy, Ford, et al. (2019) study only evaluated schedules of reinforcement within the inelastic range of demand in treatment. As such, there is limited evidence confirming that schedules in the upper end of the inelastic range would support higher levels of target behavior than those in the elastic range—the anticipated form assumed in economic theory (see Figure 1 for the prototypical form of the demand and output curve). Without a formal evaluation of schedules drawn from each of these ranges, it is unclear how to empirically derive the more optimal schedule for a given response and reinforcer. The purpose of this study was to replicate earlier methods for quickly evaluating RE and evaluate whether methods informed by elasticity predict superior levels of targeted behavior from different ranges of elasticity.

Method

Participants, Materials, and Setting

Three children diagnosed with autism served as participants: John (5-year-old Caucasian male), Anthony (4-year-old Caucasian male), and Charles (3-year-old Caucasian male). Each participant received full-time early intervention services in a center-based program based in applied behavior analysis. Center staff nominated participants based on challenges associated with identifying consistently effective reinforcers. A therapist conducted sessions in a small room (3 m by 3 m) within the center that contained a table and three chairs. Participants remained seated at a table with a therapist during all study procedures. All session materials were familiar to the participants and consistent with the setting.

Response Definitions, Interobserver Agreement, and Procedural Integrity

Dependent measures included selection responses (i.e., reaching towards and grasping respective stimuli) and target behaviors selected from mastered skill targets listed in the acquisition programs of each respective participant. The target behavior for John consisted of single-word handwriting with a faded trace (three-letter sequence). The target behavior for Charles was crayon-to-paper drawing within a 1 in x 1 in square for 5 s. Lastly, the target behavior for Anthony was whole-word handwriting in the context of a four-word sentence with a faded trace. The target behavior for Anthony was broken into single-word units given the likelihood of partial responses and to limit the potential for handwriting to become aversive.

Interobserver agreement (IOA) was calculated by dividing the number of agreements by the number of agreements plus disagreements between pairs of trained observers and multiplying this value by 100 to produce a percentage. Agreement was calculated for 100% of all SP and PR reinforcer assessments, and IOA was 100% across all observations. For the individual reinforcer evaluations, overall levels of IOA were acceptable for John (89.47% of sessions; IOA = 99.64%, range, 94-100%), Anthony (91.67% of sessions; IOA = 99.09%, range, 80-100%), and Charles (93% of sessions; IOA = 100%) across all conditions.

Procedural integrity was evaluated using a checklist that applied to the PR reinforcer assessment and the individual reinforcer evaluation. The elements on this checklist included: 1) The session therapist arranged appropriate materials and session conditions as written in the session protocol, 2) session therapists informed participants that they may quit at any time, 3) the therapist vocally stated reinforcement schedule(s) to participants as written in the session protocol, 4) the therapist implemented reinforcement schedules as written in the session protocol, and 5) the session therapist implemented termination procedures as written in the session protocol.

Integrity was calculated in 40% of PR reinforcer assessments and was 100% across all observations. Similarly, high levels of integrity were demonstrated for John (36.84% of sessions; average = 94.28%, range, 80-100%), Anthony (25% of sessions; average = 100%), and Charles (62.5% of sessions; average = 97.33%, range, 80-100%) across all conditions.

Procedures

Stimulus Preference Assessment

Individual SP assessments included eight stimuli that were endorsed as preferred by primary caregivers (Fisher et al., 1996). Therapists conducted individual SP assessments with each participant using procedures as described in Fisher et al. (1992). Stimuli were considered highly preferred if selected during 80% or more of trials. On occasions where multiple stimuli met the definition of being highly preferred, each stimulus was considered highly preferred and included in subsequent PR reinforcer assessments.

Progressive-Ratio Reinforcer Assessment

Therapists conducted individual PR reinforcer assessments for each highly-preferred stimulus. Each PR assessment was comprised of multiple series of participant responses on the PR schedule to generate a work output curve based on overall averages. John and Charles were administered three series and Anthony was administered two series for each stimulus. Only two series were performed for Anthony due to both the consistency of his target behavior as well as the increased time necessary to perform a series due to the incorporation of additional schedule requirements. Each series took between 10 and 15 min to complete, and no more than 30 min of session time was necessary to evaluate RE for each stimulus (apart from time for programmed reinforcement). In cases where multiple stimuli were identified as highly preferred, the stimulus evaluated first alternated across days.

Advancements within the PR schedule were consistent with the intermittent PR subtype described in Jarmolowicz and Lattal (2010), whereby an advance in the series of schedules was contingent on the delivery of three reinforcers on the current schedule. Consistent with Gilroy, Ford, et al. (2019), the PR schedule for all participants began at PR1, PR2, PR3, PR5, PR10, PR15, and PR20. These PR reinforcer assessments continued until participants either completed the final schedule, indicated they would like to stop, engaged in disruptive or aggressive behavior, or two minutes passed without observing the targeted behavior. The therapists did not provide prompting apart from the cue that the respective stimulus was available contingent on target behavior and when the schedule requirements had increased.

Reinforcer Evaluation

Each participant completed an evaluation of RE across various schedules of reinforcement conducted within an ABACDC reversal design (Tawney & Gast, 1985). The schedules of principal interest were those drawn from the elastic and inelastic ranges based on the findings of the PR reinforcer assessment. The elastic and inelastic schedules of reinforcement were selected from those above and below the empirical estimate of $\mathrm{P_{MAX}}$, denoted as P_{MAX-E}. This approach, often referred to as the *Observed* P_{MAX} (Greenwald & Hursh, 2006), infers $\mathrm{P_{MAX\text{-}E}}$ from the peak of the empirical response output curve (i.e., $O_{MAX\text{-}E}$) and does not require model fitting or parameter estimation (Gilroy, Kaplan et al., 2019). The specific reinforcer evaluated for each participant was the one with the highest $\mathrm{P_{MAX-E}}$. Before beginning each session, the therapist vocally stated the current response requirements to produce the reinforcer to the participant.

Baseline

Baseline sessions were 5 min in duration. Materials and settings were identical to those of the PR reinforcer assessment. At the onset of the session, the therapist informed participants that they could perform the target behavior if desired but that they did not have to complete the task and repeated this instruction every 30 s until the session concluded. There were no programmed consequences for performing the target behavior nor any error corrections.

FR-Lowest

The purpose of this condition was to confirm that the stimulus functioned as a reinforcer for the target behavior and to provide a comparison for the other FR conditions. At the onset of the session, the therapist informed participants that emitting the target behavior would produce the reinforcer on the densest schedule of reinforcement included in the PR reinforcer assessment (i.e., FR1), but that they did not have to complete the task. Target behavior on this schedule produced 30 s of programmed reinforcement. Programmed reinforcement time did not count towards the overall session time of 5 min. These sessions were identical to those in the baseline condition in every other regard.

FR-Inelastic

The purpose of this condition was to evaluate the RE of the highly-preferred item on a schedule determined to be in the upper end of the inelastic range of prices (i.e., just below $P_{\text{MAX–E}}$) based on target behavior in the PR reinforcer assessment. The procedures were identical to those in the FR-Lowest condition except for the schedules of reinforcement, which were FR3, FR2, and FR5, for John, Anthony, and Charles respectively.

FR-Elastic

The FR-Elastic sessions evaluated the RE of the highly-preferred item on a schedule determined to be in the lower end of the elastic range (i.e., just above $P_{\text{MAX–E}}$). The procedures were identical to those in the FR-Lowest condition with the exception of the schedules of reinforcement, which were FR8, FR4, and FR15, for John, Anthony, and Charles respectively.

Results

Stimulus Preference Assessment

Stimuli found to be highly preferred based on the SP assessment are labeled in Figure 2. Each participant selected two stimuli in more than 80% of the presented trials. John demonstrated a strong preference for the squid toy and the putty, Anthony for the squid toy and the ball, and Charles for the ball and the caterpillar toy.

Progressive-Ratio Reinforcer Assessment

The degrees of participants' target behavior maintained by highly preferred stimuli are illustrated in Figure 3. Although John selected both items in an equal percentage of trials (85.71%) in the SP assessment, the squid toy demonstrated lower RE ($P_{\text{MAX–E}}$ = PR2; $O_{\text{MAX–E}} = 2$) than the putty ($P_{\text{MAX–E}}$ = PR5; $O_{\text{MAX–E}} = 10$). In contrast, Anthony's selections in the SP assessment differed for the two most preferred items (squid toy 100%; putty 83.33%), which corresponded with the RE demonstrated in the PR reinforcer assessment (squid toy P_{MAX-E} = PR3, O_{MAX-E} = 6; putty P_{MAX-E} = PR2, O_{MAX-E} = 3). Charles' selections in the SP assessment also differed for the two most preferred items (ball 100%; caterpillar toy 83.33%). However, this ranking did not correspond with the levels of demonstrated RE (ball P_{MAX-E} = PR10, O_{MAX-E} = 6.67; caterpillar toy P_{MAX-E} = PR10, O_{MAX-E} = 10).

Reinforcer Evaluation

Individual evaluations of RE across schedules and ranges of elasticity (e.g., FR-Elastic, FR-Inelastic) are illustrated in Figure 4. The rates of the target behavior, in aggregate, are summarized in Table 1. Reinforcing effects, as characterized by an increase in the FR-Lowest condition relative to baseline, were demonstrated for John (baseline average = 0; FR-Lowest = 6.67), Anthony (baseline average = 1.333; FR-Lowest = 5.67), and Charles (baseline average = 7.33; FR-Lowest = 14). Consistent with the predictions of the operant demand framework, the overall levels of target behavior were also higher and more consistent under schedules in the inelastic range for John (FR-Inelastic average = 9.43; FR-Elastic = 0), Anthony (FR-Inelastic average = 6.4; FR-Elastic = 4.67), and Charles (FR-Inelastic average = 14.4; FR-Elastic = 14) compared to those drawn from the lower region of the elastic range. However, despite maintaining the orderly and expected trend in target behavior consistent with economic assumptions regarding elasticity and response output, it warrants noting that the average levels of the target behavior in the FR-Inelastic range were only slightly greater for Charles.

Rates of target behavior and reinforcement were aggregated across participants to inspect observed response-to-reinforcer ratios (i.e., schedule efficiency). These ratios are presented across conditions in Table 1. The FR-Inelastic condition was generally the most efficient and maintained the highest response-to-reinforcer ratios. That is, the FR-Inelastic schedule often maintained the most favorable balance between schedule requirements and reinforcer delivery and was the more strategic use of the reinforcer. However, it warrants noting that the low rate of reinforcer production for Anthony in the FR-Elastic phase produced an inflated ratio (i.e., average responding was actually lower than other conditions). The next most efficient condition was FR-Elastic and the FR-Lowest was the least efficient.

Discussion

Effective behavior analytic interventions require durable reinforcers (i.e., reinforcers with sufficient RE to reliably influence behavior). A variety of procedures exist for identifying stimuli with a degree of RE; however, circumstances exist where a certain degree of RE may be necessary to support interventions in real-world settings and under pragmatic constraints (i.e., FR1 schedules are not often practical). The goal of this study was to further explore the utility of the operant demand framework as a means to evaluate the RE of highly-preferred stimuli. Specifically, this study was designed to compare schedules (i.e., prices) in the inelastic range (i.e., the portion below but approaching P_{MAX-E}) to those at low prices (e.g., FR1) and others drawn from the elastic range.

Traditional economic assumptions hold that rates of target behavior should increase across the inelastic range up to P_{MAX} (i.e., increasing work output). In contrast, prices in the elastic range should decrease across the elastic range, moving away from P_{MAX}. The results of this study confirmed that the prototypical pattern of responding was demonstrated across participants in PR reinforcer assessments and that PR reinforcer assessments provided clinically useful information (i.e., informed by elasticity). The findings from this study extend earlier research on RE and the operant demand framework. Most directly, this work provides further support for elasticity-informed approaches to intervention development, such as informing work requirements during demand fading (Gilroy, Ford, et al., 2019) or extending applications of token reinforcement (Hackenberg, 2018).

Although various researchers have incorporated elements of behavioral economics into applied practices (e.g., comparing SP assessment rankings and RRE), most have not explored elasticity (Gilroy, Kaplan, & Leader, 2018). Most evaluations have instead measured RRE using breakpoints and these are less useful in informing treatment. Measures of RRE such as breakpoint are sufficient to describe and compare reinforcers in a very limited sense but these measures are unable to speak to the differential performance of reinforcers across prices (Bickel et al., 2000). It is for this reason that researchers in the area of substance abuse (Bickel et al., 2014) and empirical policy development (Hursh & Roma, 2013) have moved away from these methods and towards others with predictive utility (i.e., elasticity).

Among various possibilities, the elasticity of demand has particular promise for informing several areas of clinical decision making. For instance, clinicians may evaluate the RE for stimuli elegantly and avoid arbitrarily probing various schedules directly. Such an approach better manages the time of both the clinician and the consumer. Similarly, identifying P_{MAX} provides a means of avoiding either under- or over-estimating the schedule that maintains the most work for a given response and that reinforcer. Further, operant demand methods pair quite well as a complement to SP assessments. That is, SP assessments speak to what effect stimuli are likely to have on behavior (i.e., reinforcing or not) and the operant demand framework to the degree that these stimuli influence behavior (e.g., weakly, strongly). Operant demand methods supplement SP assessment in this regard and may be useful as a safeguard against the development of a treatment based on reinforcers with a limited range of utility (i.e., low RE). Similar concerns were noted in Roane et al. (2001), where the authors found that preferred stimuli with similar rankings maintained very different levels of targeted behavior under leaner schedules of reinforcement. Although one could make the case that reinforcers effective when implemented within FR1 schedules are sufficiently useful to influence behavior, such schedules are ultimately inefficient in terms of effort and resources.

The findings presented here extend support for the use of an operant demand framework in applied behavior analysis. Although consistent with earlier findings in this area, various points need to be considered when weighing whether to evaluate RE before developing a treatment. First, programmed reinforcers are often selected for several reasons and not based on RE alone. For example, in the case of severe behavior, challenges associated with later real-world implementation are secondary to the pressing need for the immediate suppression of unsafe behavior. The approach presented here offers little when the initial goal is to completely replace a functional class of problem behavior with an alternative on an approximately continuous schedule. Second, the operant demand framework uses target behavior as a proxy for work or price and different forms of behavior are essentially different units (i.e., currency). That is, the RE of reinforcers is unlikely to remain the same across different responses for several reasons (e.g., more force required, different number of sub-tasks, time necessary to complete). Third, post-reinforcement pauses are known to vary across schedules and this was not explicitly measured in either the PR reinforcer assessment or the individual reinforcer evaluations. As such, this source of variability should be further examined in future evaluations of the protocol presented here. Fourth, modern methods for evaluating the RE of reinforcers capitalize on quantitative modeling to provide high-precision estimates of elasticity derived from fitted curves (as opposed to observed estimates of elasticity). A purely empirical approach (i.e., without model fitting) was employed in this investigation due to the possibility that as few as two or three non-zero consumption values might be observed for each participant. In such circumstances, estimates from quantitative modeling would be questionable if models converged at all. Although the Observed P_{MAX} (P_{MAX-E}) was sufficient to answer the current research questions, formal quantitative modeling is more desirable if a sufficiently large sample of behavior can be evaluated. Lastly, the evidence here more strongly supports the use of schedules in the inelastic range but this determination is limited by the lack of a replication of the FR-Inelastic phase. Further, heavy trending was present in the data for Anthony and clear demonstrations of functional control were only observed for John and Charles across all phases.

In closing, it is relevant to highlight the fact that PR reinforcer assessments have the potential for both use and misuse in research and practice (Jarmolowicz & Lattal, 2010). That is, exposing participants to conditions under which behavior may not produce reinforcement has the potential to be unduly aversive and potentially unethical if not carefully designed and suited to the individual and the task. In practice, this may also result in the emergence of problem behavior. However, problem behavior was not a presenting problem for the participants in this study and no problem behavior was observed in any of the phases of this experiment. As such, further research, replication, and refinement is necessary to establish clear and ethical guidelines for the inclusion of PR procedures if they are to be considered as an element of clinical practice (Poling, 2010).

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Table 1

Aggregated Rate of Target Behavior Across Participants and Phases

John

Phase (*n* sessions)	Average (*SD*)	Range	Response/Reinforcer Ratio
Baseline (*n* = 6)	0 (—)	—	—
FR-Lowest (*n* = 3)	1.33 (*0.31*)	1.0-1.6	1.0
FR-Inelastic (*n* = 7)	1.89 (*0.73*)	1.2-3.0	3.0
FR-Elastic (*n* = 3)	0 (—)	—	—

Anthony

Phase (*n* sessions)	Average (*SD*)	Range	Response/Reinforcer Ratio
Baseline (*n* = 6)	0.27 (*0.41*)	0.0-0.8	—
FR-Lowest (*n* = 3)	1.13 (*0.12*)	1-1.2	1.0
FR-Inelastic (*n* = 10)	1.28 (*0.75*)	0-2.4	2.0
FR-Elastic (*n* = 6)	0.93 (*1.06*)	0-2.4	4.0

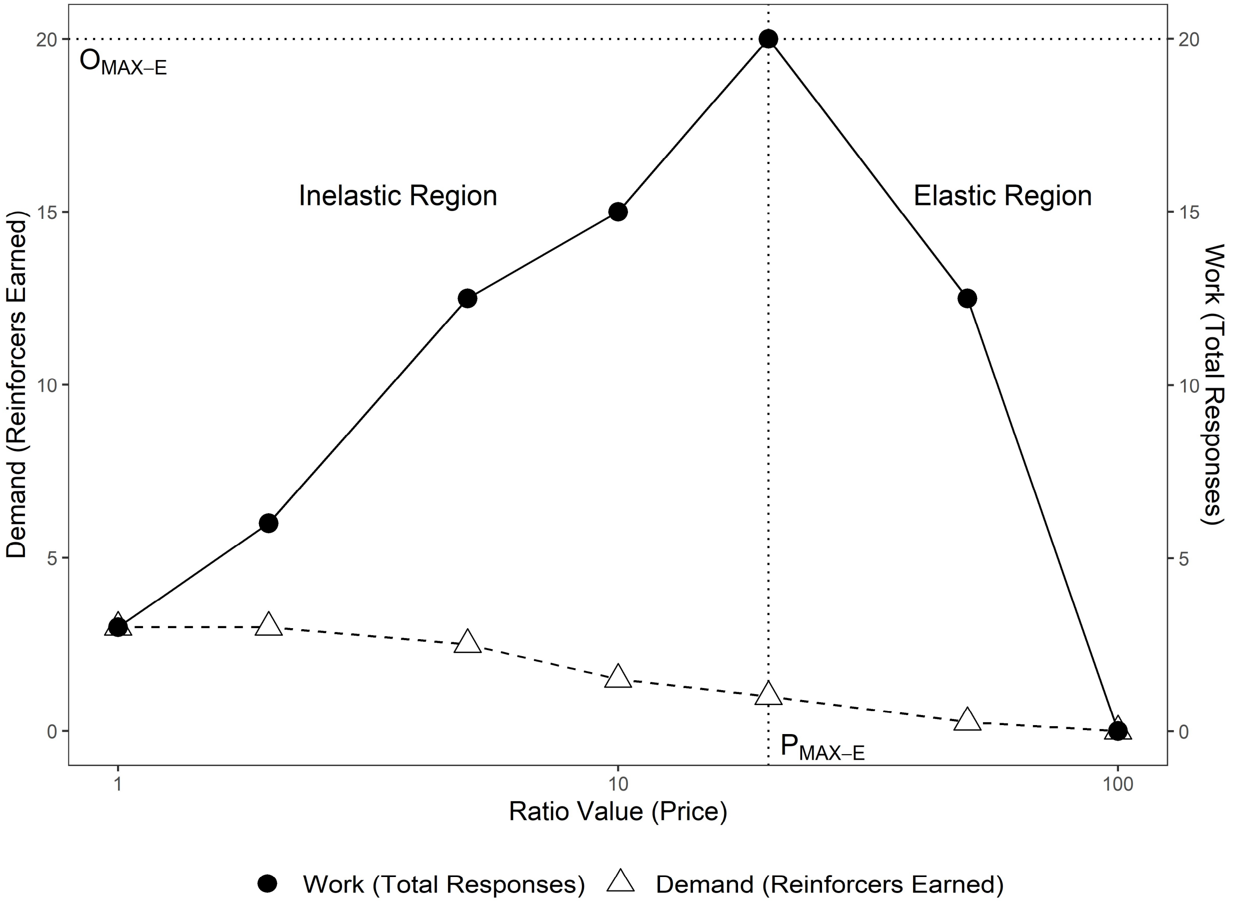
Charles

Phase (*n* sessions)	Average (*SD*)	Range	Response/Reinforcer Ratio
Baseline (*n* = 6)	1.47 (*0.71*)	0.8-2.6	—
FR-Lowest (*n* = 5)	2.8 (*0.70*)	1.8-3.6	1.0
FR-Inelastic (*n* = 11)	2.9 (*0.77*)	1.6-3.8	6.1
FR-Elastic (*n* = 3)	0.47 (*0.12*)	0.4-0.6	—

*Note: All averages and ranges reported as responses/minute.

Figure 1

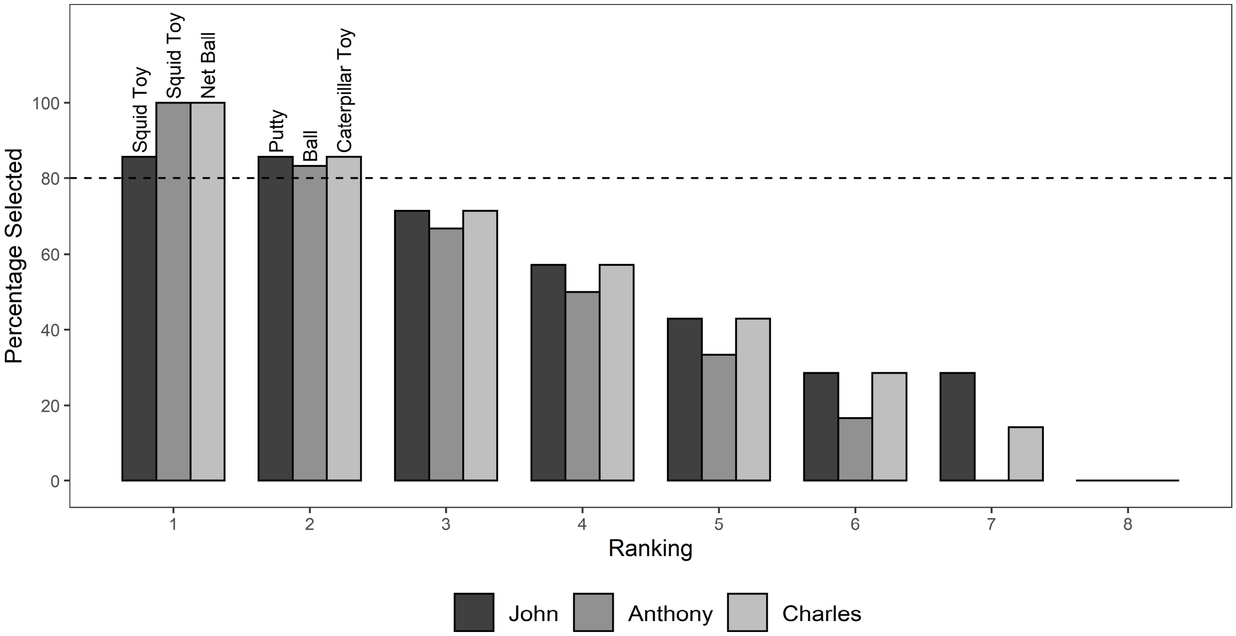
Hypothetical Rates of Responding across Schedules



Note. P_{MAX-E}, the Observed P_{MAX}, corresponds with the peak levels of responding (O_{MAX-E}).

Figure 2

Stimulus Preference Assessment



Note. Stimuli selected in fewer than 80% of presentations are unlabeled.

Figure 3

Demand and Response Output Functions across High-Preferred Stimuli and Participants

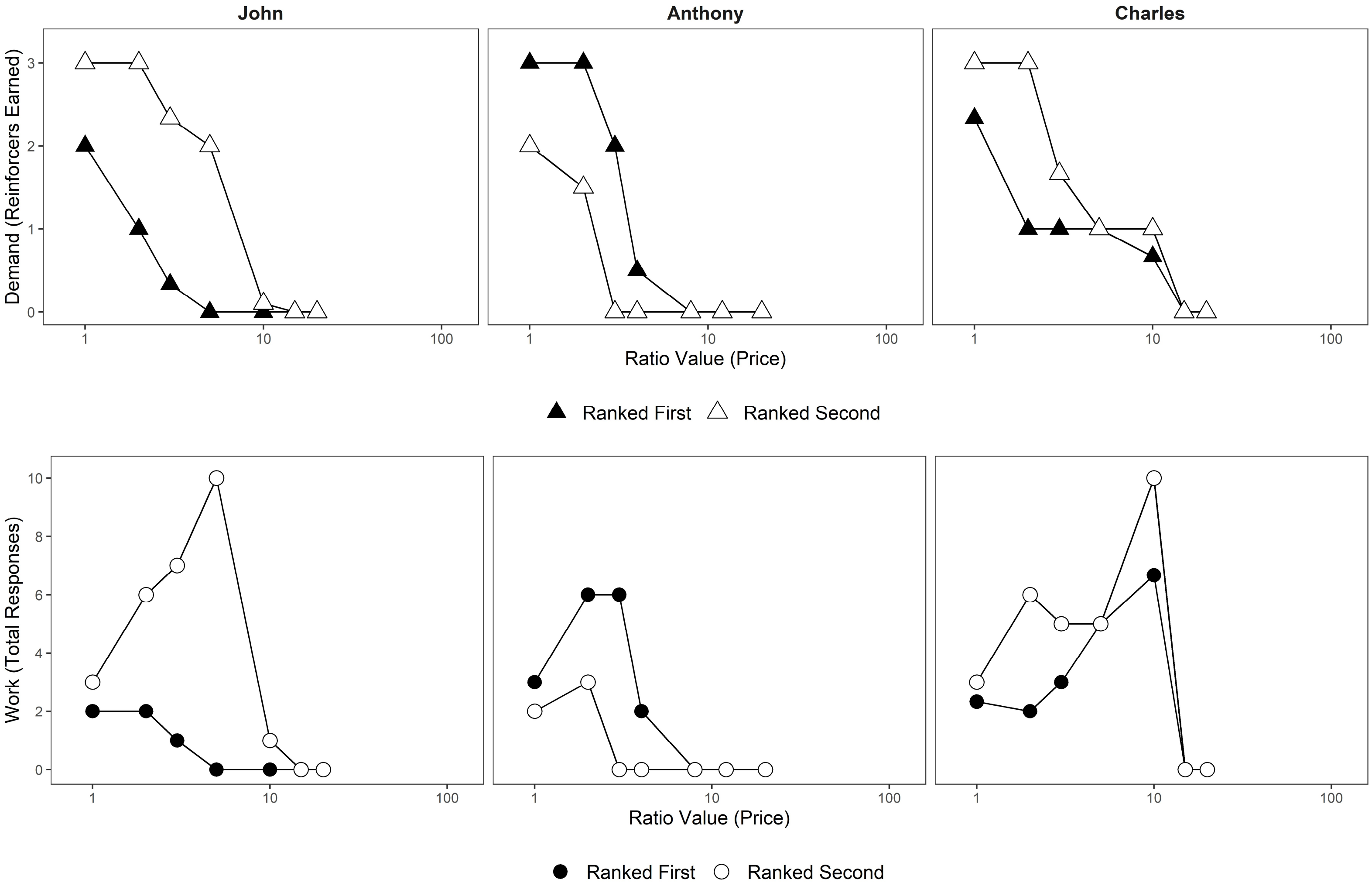
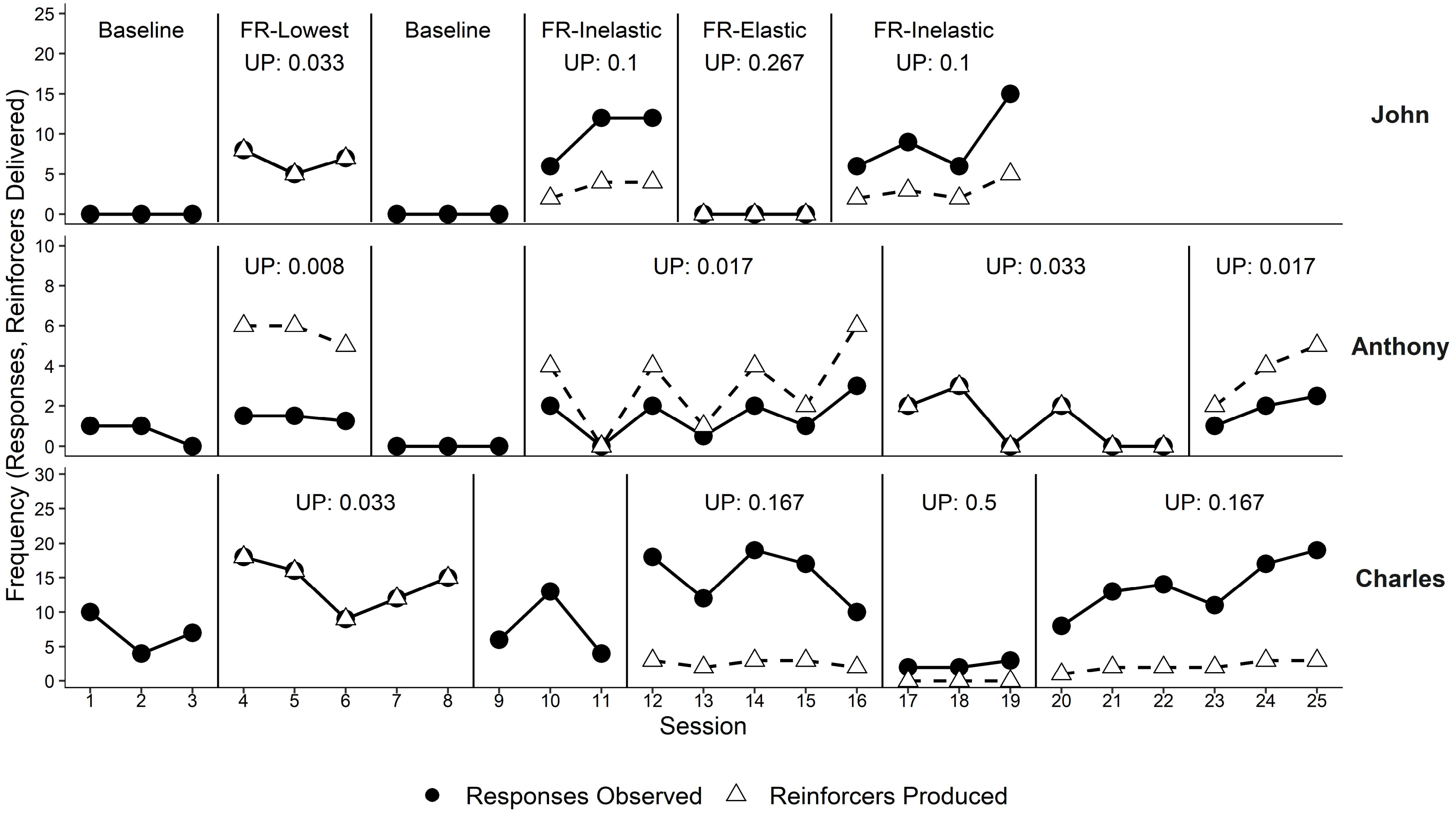


Figure 4

Individual Evaluations of Reinforcer Efficacy and Elasticity across Reinforcers



Note. Unit price is determined by dividing the schedule requirement by the 30 s of the reinforcement interval (e.g., FR1/30s interval = 0.033) and a UP of 0.033 results in a 1:1 correspondence between reinforcer production and response rates here.