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A comparison between traditional economical and demand curve analyses of relative reinforcer efficacy in the validation of preference assessment predictions

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Abstract

Objective: This single-case study examined the degree to which three formal preference assessments (i.e. paired-stimulus, multiple-stimulus without replacement and a free-operant procedure) successfully identified reinforcers from six edibles in a subsequent reinforcement assessment.

Methods: Economical analyses were conducted on the entire hierarchy of low-, moderate- and high-preferred edibles using both traditional (i.e. progressive-ratio breakpoint) and demand curve (P_{max}) accounts of reinforcer efficacy with the data obtained from three reinforcement assessment sessions for each edible.

Results: Across all three preference assessment types, accuracy in the identification of the top three reinforcers was 67%. The correlation between the traditional and demand curve metrics was highly significant, replicating previous research on the substitutability of these analyses.

Conclusions: Moderate-preferred stimuli may serve as efficacious reinforcers in subsequent reinforcer assessments. Additionally, demand curve analyses can contribute to the assessment of reinforcer efficacy and subsequently the validation of preference assessments.

Keywords: *Demand curve*, *progressive ratio*, *behavioral economics*, *reinforcer assessment*, *perference assessment*

Introduction

Many people who have neurodevelopmental disorders benefit from instructional and behaviour support programmes that incorporate positive reinforcement [1]. In order for positive reinforcement to be effective, a person's preferences must be identified and then programmed to ensure motivation during rehabilitation therapy. Within the discipline of applied behaviour analysis (ABA), *stimulus preference assessment* 'refers to a variety of procedures used to determine (a) the stimuli that the person prefers, (b) the relative preference values of these stimuli (high preference versus low preference) and (c) the conditions under which these preference values change when task demands, deprivation states, and schedules of reinforcement are modified' ([2], pp. 275–276).

When conducting a preference assessment, the duration or percentage of time a person is engaged with different stimuli are recorded. Relative preferences are then derived along a low preference–medium preference–high preference continuum. Several preference assessment methodologies have been evaluated based on *single stimulus* [3], *paired stimuli* [4] and *multiple stimuli* [5] presentation formats. The final step in a preference assessment is evaluating whether selected behaviours increase when the identified high preference stimuli are delivered contingently.

Despite the widespread use of preference assessments in both research and clinical applications, there remains a relative paucity of research in the validation of these techniques using the methodology afforded to behaviour analysts from the experimental

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analysis of behaviour literature. Specifically, recent developments in the area of progressive-ratio (PR) schedules of reinforcement [6] have suggested that economic analyses may be advantageous for assessing reinforcer efficacy. In particular, two specific approaches—traditional and demand curves—have been the major foci of behaviour analysts in deriving accounts of relative reinforcer efficacy [7].

Both traditional and demand curve approaches to understanding the reinforcing efficacy of rewards have primarily focused on the ability of a reward to maintain behaviour across a range of response requirements. Specifically, behaviour analysts using such economical measures are interested in a given reward's 'elasticity'—that is, the interaction between response requirements and reward consumption [8]. In these analyses, 'consumption' (i.e. rewards delivered) is plotted as a function of 'cost' (i.e. the response requirement). Within traditional analyses of economics, elasticity—a proxy for reward efficacy—is assessed by identifying the point at which the response requirement in a PR schedule no longer results in reward administration (i.e. the 'breakpoint'). Thus, the greater the breakpoint, the more the reward may be considering reinforcing, relative to other rewards assessed using the same response requirements. Similarly, the quantitative approaches to economics—utilizing demand curves—offer behaviour analysts even greater specificity in their analyses through the derivation of the reinforcer efficacy estimate $P_{\max}$ (i.e. the predicted schedule requirement at which peak response output is observed) [9].

With the exception of recent work by DeLeon et al. [10] (described below), research into the predictive validity of preference assessments using behavioural economics has exclusively compared high- and low-preferred items [11–14], despite emerging literature on the functionally reinforcing properties of moderately-preferred items [15]. Because preference assessments can identify a relative hierarchy of potential reinforcers [16], an understanding of how the entire spectrum of preferred items (i.e. the complete hierarchy of preference) fare within both traditional and behavioural economic approaches to reinforcer efficacy would be informative to researchers and clinicians alike.

The one exception to the application of economical analyses to assess relative reinforcer efficacy across differing preference levels has been the work by DeLeon et al. [10]. In DeLeon et al.'s study, a paired-choice preference assessment identified low-, moderate- and high-preferred stimuli for four individuals with neurodevelopmental disorders. Subsequent reinforcer assessments were utilized using PR schedules to identify the breakpoint. In 83% of the stimuli assessed, higher preference items resulted in larger breakpoint values than those stimuli preferred less. Thus, this study suggests that economic analyses may offer further precision in the identification of efficacious rewards and may be used to validate the predictions of formalized preference assessments.

The first goal of this study was to identify a hierarchy of preference across six edibles using three formal preference assessments to be used in subsequent reinforcer assessments. The second goal of this study was to replicate and extend the traditional reinforcer efficacy analyses reported by Roane et al. [14] using the entire hierarchy of stimuli (i.e. low-, moderate- and high-preferred edibles) across progressively increasing ratio values with the addition of quantitative measures of the predicted response requirement at these peak response rates in a demand curve analysis (i.e. $P_{\max}$). With such data, this study sought to determine whether preference assessment procedures predicted relative reinforcer efficacy as calculated by both traditional and behavioural economic accounts of relative reinforcer efficacy. Finally, it sought to examine the degree to which traditional accounts of relative reinforcer efficacy (i.e. breakpoints) matched demand curve analyses (i.e. $P_{\max}$) in a translational research paradigm.

Method

Participant and setting

Justin, a 19.6-year-old male diagnosed with pervasive developmental delays with autistic features, served as the participant in this study. Justin resided in a residential programme and participated in a classroom for students with developmental disabilities. He communicated using picture icons and was compliant with one-step directions. All sessions were conducted in a 3.65 m by 3.65 m room in his school, which contained a desk, two chairs and a computer. During the reinforcer assessment sessions, a single green switch (6.35 cm in diameter) was connected to the computer, which was programmed to count the number of switch presses. Switch-presses were defined as a depression of the switch with enough force to cause an auditory 'click' of the button and which registered as press on the computer. A session termination criterion of 30-minutes was in place during the reinforcer assessment (see below). The reader should note that any duration-based termination criterion for a reinforcer assessment session could potentially confound data collection—and subsequent data analysis—if the participant is responding at the time the session is terminated. Thus, one could not interpret—or even record—any data that was generated via responding past the time limit. In the present study, no sessions ever exceeded 10 minutes.

Procedure

Preference assessments. Three different preference assessments were conducted with the participant using six edible items: Goldfish®, Sour Patch Kids®, Pringles®, Doritos®, Gushers® and Cheerios®. A random number generator determined the sequence of stimulus presentation for each assessment. A paired stimulus preference assessment ('PS') [5] was conducted once and measured selection of the items. Both the multiple stimulus without replacement ('MSWO') [17] and a free operant preference assessment ('FO') [18] were conducted once per day for three consecutive days. The FO procedure was adapted from the Roane et al. [18] protocol for assessing edible items. Specifically, 30 pieces of each of the six edibles were placed concurrently in front of the participant on plates (in randomized order) and he was given the direction to 'snack'. Free operant sessions were 2 minutes in duration and the total number of edibles consumed was summated. The dependent variable for the free operant procedure was the number of edibles consumed from each edible set, divided by the total number of edibles consumed. Both the PS and MSWO assessments were conducted in accordance with their published protocols. Inter-observer agreement (IOA) was collected across a minimum of 33% of all preference assessment administrations and was 100%. The relative preference for each item is depicted in Figure 1 as a preference hierarchy for each assessment type.

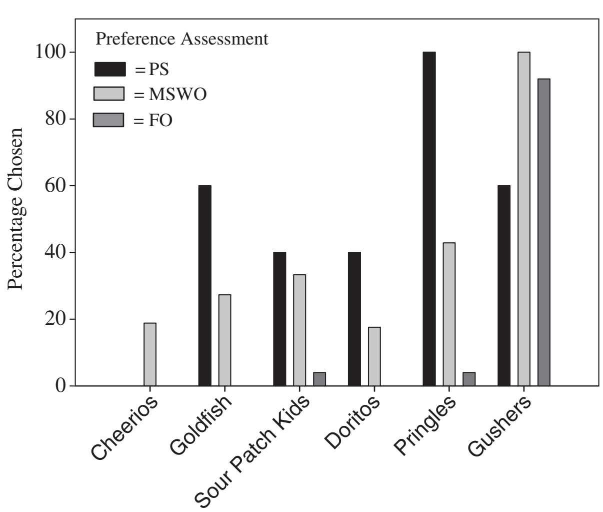

Figure 1. Preference hierarchies for the six edibles generated by the PS, MSWO and FO preference assessment procedures plotted above the x-axis. Below the x-axis are the relative reinforcer efficacy hierarchies (both O_{max} and P_{max}) generated by the non-linear regression of the reinforcer assessments for each of the six edibles.

Reinforcer assessment. The relative reinforcing efficacy of each edible was assessed by evaluating responding under a progressive-ratio schedule. An initial no-reinforcement baseline condition was implemented to ensure experimental control. Following stabilization, each edible was assessed individually during each session in a randomized multi-element design. Prior to each reinforcer assessment session, the researcher modelled responding under the FR 1 schedule twice and then prompted the participant to 'press the switch', thereby beginning the data collection under the PR schedule of reinforcement. During the reinforcement sessions, ratio values progressed in a rapid additive series of FR 1, FR 1, FR 2, FR 2, FR 5, FR 5, FR 10, FR 10, FR 20, FR 20, FR 30, FR 30. Three reinforcement assessment sessions were conducted for each edible in the multi-element design. Sessions were terminated if either of the following criteria were met: (a) 1-minute of no responding or (b) the session exceeded 30-minutes. No session ever exceeded 10-minutes. Both IOA and procedural fidelity (PF) data were collected by a second independent observer for 33% of reinforcer assessment sessions. IOA was collected on the number of reinforcers delivered and the number of switch presses made during the session, while PF data were collected on the correct delivery of reinforcers and termination of the sessions according to the aforementioned criteria. IOA and PF were 100%. One-to-three reinforcer assessments were conducted each day.

Results

Figure 2 depicts the results of the reinforcer assessments for each of the six edibles used in the preference assessments. The cumulative number of responses across all three sessions for Gushers®, Doritos® and Pringles® were substantially higher than Sour Patch Kids®, Goldfish® or Cheerios®, suggesting a relatively higher degree of reinforcer efficacy for these three stimuli. For several of the stimuli, changes in numbers of responses were observed across the respective reinforcer assessment sessions, suggesting that repeated exposure to the stimuli either enhanced preference (increases in numbers of responses; measured by persistence in the form of repeated responding) or decreased preference. For example, the first reinforcer assessment of Sour Patch Kids® featured a relatively high number of responses—however, these levels subsequently decreased across the second and third

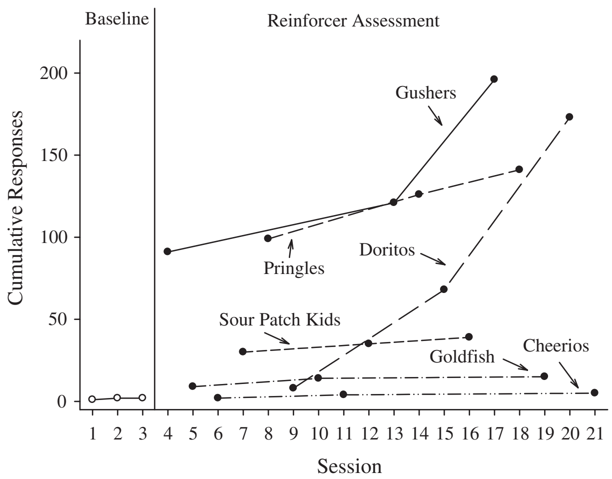

Figure 2. Cumulative number of switch-presses made during a no-reinforcement baseline and subsequent progressive-ratio reinforcement schedules during three reinforcement assessment sessions for all six edibles.

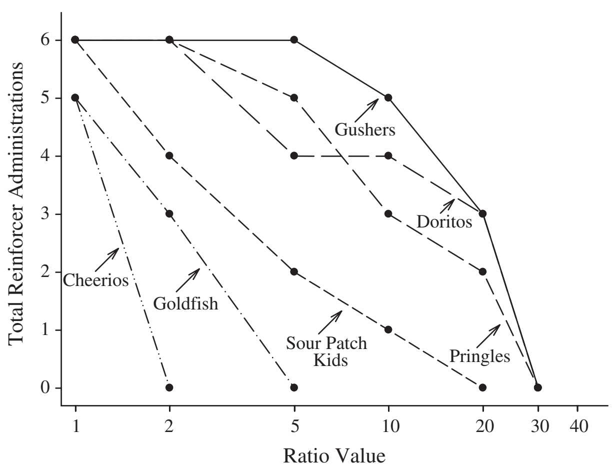

Figure 3. Traditional representation of the relative reinforcer efficacy of the six edibles assessed during the reinforcer assessment. Total reinforcer administrations are plotted as a function of the ratio value in the PR schedule.

assessment session for this stimulus, suggesting a decreased preference over repeated exposures. This pattern was also observed for both Gushers® and Pringles®—however, after the second session, the number of responses for Gushers® increased. On the contrary, Doritos® yielded a low number of responses during the first reinforcer assessment session, but increased substantially over the second and third session—suggesting that repeated exposure may have increased the preference for this edible during reinforcer assessment sessions.

Relative reinforcer efficacy assessments were conducted using the data obtained presented in Figure 3, which were collected during the aforementioned reinforcer assessment sessions. More

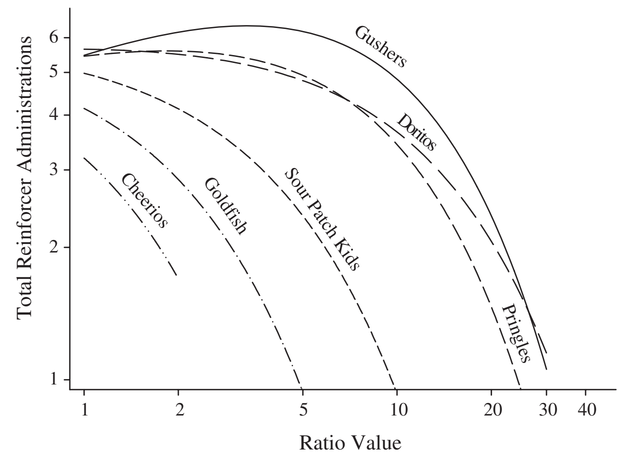

Figure 4. Fitted demand curves to the aggregated number of reinforcer administrations as a function of the ratio value in the PR schedule across all three reinforcer assessment sessions for all six edibles.

specifically, both traditional (i.e. breakpoint assessments) and behavioural economic demand curves were utilized to calculate relative reinforcer efficacy. Figure 3 depicts the breakpoint values for each edible as a function of ratio value, offering a traditional account of reinforcer efficacy. As Figure 3 indicates, Cheerios® had the lowest breakpoint (ratio value = 2), followed by Goldfish® (ratio value = 5) and Sour Patch Kids® (ratio value = 20). Pringles®, Doritos® and Gushers® all featured a breakpoint at the ratio value of 30 clicks, suggesting that all three were equally efficacious under traditional measures of economics.

Figure 4 depicts the fitted demand curves (created using the Regression Wizard function of SigmaPlot® 10.0 with Hursh et al.'s [19] non-linear regression equation (see equation 1 below) to the number of reinforcer administrations for each of the six edibles as a function of the response requirement (i.e. ratio values) during the reinforcer assessment sessions. As depicted by these demand curves, monotonically decreasing trends were observed for five of the six stimuli, consistent with results from laboratory studies [7] and generally replicating the findings during the traditional analysis of efficacy depicted in Figure 3. For Gushers®, there was an initial increasing trend, followed be a decreasing trend—however, this is simply an artifact of the model fitting to the data.

The economic parameter P_{max} was derived from the fitted demand curves (described above) using Hursh et al.'s [19] equation:

$$C = LP^{b}e^{-aP} \qquad (1)$$

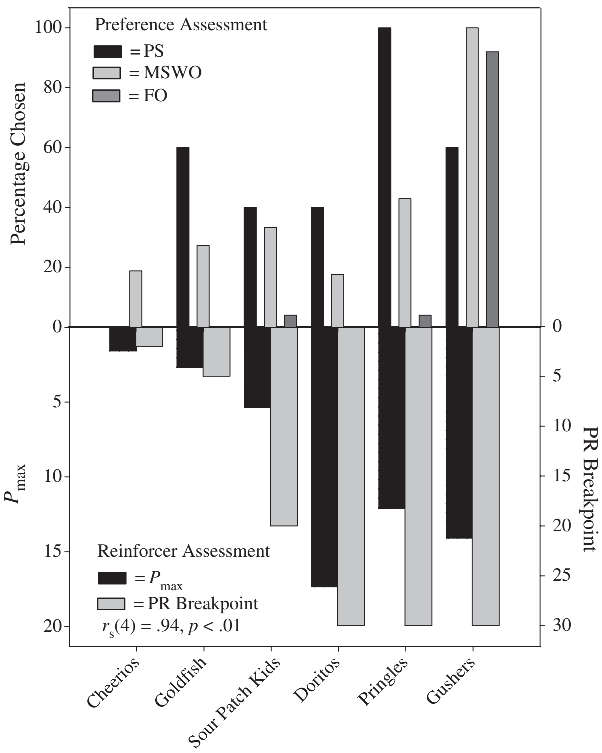

Figure 5. Preference hierarchies (from Figure 1) for the six edibles generated by the PS, MSWO and FO preference assessment procedures plotted above the *x*-axis. Below the *x*-axis are the relative reinforcer efficacy hierarchies (both P_{max} and PR breakpoint values) from the reinforcer assessments for each of the six edibles.

where L is the predicted number of reinforcers earned (i.e. consumption) at a response requirement of FR1, P is the response requirement at the ratio value, exponent b is a derived parameter representing the initial slope of the demand curve with exponent a representing the derived acceleration. These demand curves were then used to derive the predicted schedule requirement at which peak response output is observed (i.e. P_{max}) and the predicted peak response rate (i.e. O_{max}). P_{max} was calculated using Hursh et al.'s [9] equation:

$$P_{max} = (1 + b)/-a \quad (2)$$

using the derived parameters b and a from equation (1).

The breakpoint and P_{max} values for each edible are plotted beneath the *x*-axis in Figure 5 to allow for visual inspection of both the relationships between these values and each of these parameters with the preference hierarchies—which are replicated from Figure 1 in the upper panel of Figure 5. As indicated in Figure 5, the traditional and demand curve metrics of reinforcer efficacy were generally correlated. In fact, a Spearmans *rho* (i.e. rank order) correlation found a statistically significant relationship between these metrics, $r_s(4) = 0.94$, $p < 0.01$. However, the reader is cautioned to interpret this statistic in light of its small number of data pairings comprising the correlation.

As Figure 5 also depicts, the preference hierarchies generated by the PS, MSWO and FO preference assessments generally followed the same relative rank order of the reinforcer efficacy metrics. That is, relatively more preferred edibles were generally relatively more reinforcing using either the traditional or demand curve analyses. With regards to the general accuracy of all three preference assessment types, accuracy was calculated as sum of the number of true positives (the number of the top three preferred items which functioned as one of the top three efficacious reinforcers [highest P_{max} and breakpoint values]) and true negatives (number of bottom three preferred which were in the bottom three efficacious rewards) divided by the total number of possibilities—which in the present study was six. For all three preference assessment types, using both P_{max} and breakpoint as reinforcer efficacy indicators, total accuracy was 67%.

Discussion

This study compared the preference hierarchies obtained from three commonly used preference assessments with results from subsequent reinforcer assessments to assess how valid the preference assessment predictions were in identifying efficacious reinforcers. Specifically, PR breakpoints and P_{max} values were obtained for each edible assessed in the preference assessments to allow for both traditional and demand curve analyses of relative reinforcer efficacy, respectively. The preference hierarchies varied across assessment type, but were generally reliable in the identification of extreme low and high preferred edibles. The reinforcer assessment analyses were reliable, suggesting that traditional and demand curve analyses are generally substitutable—a notion which is beginning to be formally investigated in basic research [7,20,21].

Collectively, these results suggest that moderate-preferred items may indeed serve as efficacious reinforcers in subsequent reinforcer assessments. Moreover, these data demonstrate the utility of demand curve analyses in the assessment of reinforcer efficacy and, subsequently, the validation of preference assessments with these techniques. Through the inclusion of the quantitative analyses afforded by non-linear regression, behaviour analysts can model and predict such reinforcer dimensions under progressive ratio step sizes which were not directly manipulated in the reinforcer assessments.

While the findings from this study suggest relative equality across the three preference assessment types with regards to their predictive validity in the identification of efficacious reinforcers, these results should be interpreted cautiously because only six stimuli were assessed (yielding a relatively liberal interpretation of true positives and negatives), edible items exclusively and a single participant. On a similar note, it should be noted that both the MSWO and FO assessments were administered three times, while the PS was administered only once. Thus, it may be that the PS results were not as valid as those from the MSWO and FO assessments and may not be directly comparable—as such, these comparisons should be made cautiously by the reader. Finally, while progressively increasing ratio values were utilized during the reinforcer assessment sessions, it was not required that the participant experience all ratio values in the sequence. Rather, once the termination criterion was met, the session ended and larger ratio values were not assessed during that session. In addition to addressing these limitations, further studies utilizing these procedures should examine the role of varying step size increments and various response effort manipulations in order to validate preference assessment predictions. In sum, these data suggest that reinforcer assessments using PR schedules may be a suitable—but relatively more efficient and efficacious—alternative to preference assessments in the determination of functional reinforcers in applied settings. It is hoped that further research into the use of PR schedules and demand curve analyses will promote the feasibility of these procedures for clinicians and therapists.

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