An Evaluation of Operant Behavioural Economics in Functional Communication Training for Severe Problem Behaviour

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An evaluation of operant behavioural economics in functional communication training

Objective: This single-case experiment examined the use of behavioural economic concepts in a function-based treatment for problem behaviour.

Methods: Behavioural economic analyses were used to evaluate the strength of functions of problem behaviour and this information was used to inform elements of function-based treatment for one child with a neurodevelopmental disorder.

Results: Findings from this experiment indicated that the incorporation of behavioural economic measures resulted in positive treatment effects that were maintained throughout all phases of the evaluation, including those implemented by caregivers.

Conclusions: These results suggest that behavioural economic concepts and procedures can be successfully adjuncts to evidence-based assessments and treatments for problem behaviour.

Keywords: behavioural economics; demand curve; functional communication training; demand fading; reinforcer assessment

Introduction

Individual preferences are strongly reflected in behaviour analytic research and practices.[1] Assessments of individual preference represent commitments to empirically-supported practices as well as an ethical responsibility to individualize treatments for individuals with neurodevelopmental disorders.[2-5] While these practices are well-supported in treatments for persons with intellectual and developmental disabilities (IDD), individual preferences tend to vary from situation to situation and this naturally invites a degree of uncertainty into clinical practice.[6, 7]

Research on individual choice has found that preferences often vary as the levels of response effort, or cost, increase from low-to-high.[6-10] Tustin (7) noted this variability and raised questions regarding the reliability of individual preferences when assessed under varying schedule arrangements. For example, individual preferences measured in low-effort conditions (e.g., free operant, Fixed Ratio 1 [FR1]) may not be predictive of preferences in more effortful conditions (e.g., FR10). This is potentially troublesome in practice because preferred stimuli are typically assessed in low-effort conditions (i.e., preference assessments) but later used in high-effort conditions (i.e., treatment). In these circumstances, highly-preferred items (as assessed in low-effort conditions) may not function as reliable reinforcers in treatment and this could jeopardize the effectiveness of otherwise appropriate treatment.[11]

Tustin (7) observed changes in preference using increasingly lean schedules of reinforcement. Applying the behavioural economic concept of demand, Tustin (7) examined the relationship between preference and cost (i.e., schedule requirements) as costs increased from low-to-high. Borrowing from Consumer Demand Theory, Tustin (7) evaluated the levels of demand for preferred items using progressively increasing costs (e.g., FR1, FR2, FR5, FR10).[12] This procedure, whereby schedules of reinforcement are systematically adjusted (i.e., from dense-to-lean), is one of several derivatives of Progressive Ratio (PR) schedules of reinforcement and variations of these methods have been used to extend various behaviour analytic procedures.[10, 13-18]

With respect to problem behaviour, Borrero et al (18) used a behavioural economic approach to evaluate the demand for reinforcers maintaining severe problem behaviour. Using findings from a functional analysis (FA), Borrero et al (18) evaluated how the price (i.e., levels of effort) necessary to produce reinforcement influenced rates of problem behaviour. That is, these researchers assessed the elasticity of demand for reinforcers maintaining problem behaviour. Consistent with the expected form of a demand curve, Borrero et al (18) found that the number of reinforcers obtained following problem behaviour predictably decreased as prices increased, and concluded that a behavioural economic perspective could be applied to treatments for severe behaviour.

While a behavioural economic perspective has been proposed by many as an expansion of behaviour analytic practices, support for this approach in applied research with persons with IDD is still emerging.[19] A recent review by Gilroy et al (19) examined the existing literature on behavioural economics applied to assessments and treatments for individuals with IDD and found that many demonstrations of operant demand with this population did not use formal demand curve analysis. Rather, the bulk of support for applied behavioural economics with individuals with IDD has consisted of studies using assessments of relative reinforcer efficacy rather than demand curve analysis.[20-22] For readers seeking further information on applied behavioural economics, Reed et al (23) provides an excellent primer on the application of behavioural economics and performing demand curve analyses.

Formal demand curve analysis has been recommended as a replacement for assessments of relative reinforcer efficacy for several reasons.[24, 25] Briefly, assessments of relative reinforcer efficacy compare the strength or potency of a reinforcer based on some aspect of responding.[26] For example, the strength of a reinforcing relation can be measured by levels of responding (i.e., peak responding), the schedules of reinforcement that maintain responding (i.e., breakpoint), or some other characteristic of a response pattern across varying schedule requirements (e.g., trend).[26] Each of these individual measures represents distinct aspects of the response-reinforcer relationship. In contrast to relative reinforcer efficacy, which indexes reinforcer strength based on a single aspect of responding, demand curve analysis is a unified approach for evaluating qualities of a reinforcer over some domain of increasing costs.[24]

Whereas earlier approaches represented the demand-cost relationship with a single value (e.g., a peak rate of responding, a schedule of reinforcement), demand curve analysis represents this relationship as a fitted curve. In this way, a demand curve provides multiple parameters that each speaks to some aspect of a response-reinforcer relationship. For example, information is provided on the intensity of demand for a reinforcer as well as its sensitivity to specific changes in price.[27] The Exponential model of demand proposed by Hursh and Silberberg (27) takes the following form:

$$log_{10}Q = log_{10}Q_0 + k * (e^{-\alpha * Q_0 * C} - 1) \quad (1)$$

In this model, each parameter represents an aspect of the demand curve. For example, $\underline{Q_0}$ represents the intercept of the demand curve (i.e., when the price is equal to zero). Conceptually, this aspect of the demand curve represents the intensity of demand for a reinforcer. That is, it provides a measure of the levels of demand for a reinforcer when the cost is zero (i.e., freely available). Additionally, the $\underline{\alpha}$ parameter represents how the demand for a reinforcer is affected by changes in price (i.e., the cost or effort). For example, a larger $\underline{\alpha}$ value would represent steep changes in demand as prices increase while a smaller value would indicate more gradual changes. Lastly, the scaling constant k generally represents the range in consumption in logarithmic units. That is, this value jointly represents the slope of the demand curve along with the other parameters. This parameter can be calculated empirically (i.e., from observed data) by subtracting the minimum from the maximum levels of consumption in logarithmic units (optionally adding a small constant) or by fitting as a parameter alongside Q_0 and α. For further information on the design and interpretation of the Exponential model of demand, readers should consult Hursh and Silberberg (27).

While the parameters of the demand curve model each speak to an aspect of the demand curve, there are additional metrics that reveal characteristics of the response-reinforcer relation. That is, the demand for a reinforcer may change slightly when certain prices increase (i.e., from a price of 1.0 to 2.0) but more dramatically when other prices increase (i.e., from a price of 10.0 to 11.0). This differential change in consumption as a function of changes in price is referred to as the elasticity of demand. Regions characterized by relatively small and relatively large changes are referred to as the inelastic and elastic ranges of the demand curve, respectively, and these two regions are separated by P_{MAX} or the point of unit elasticity. Mathematically, P_{MAX} represents a slope of -1 on the demand curve in log-log coordinates and an example of this measure is illustrated in Figure 1, along with its calculation. Given the robustness of operant demand methods, many have since called for these methods to replace earlier assessments of relative reinforcer efficacy, which represent only a single aspect of the complex response-reinforcer relationship.[17, 23, 28]

Among the behavioural economic concepts that can be applied with individuals with IDD, two have strong utility for enhancing clinical research and practice—the elasticity of demand for reinforcers and unit price. The first of these, elasticity, speaks to how certain changes in price differentially affect demand for reinforcers. That is, certain increases in cost (e.g., from FR1 to FR2) may be associated with relatively small changes in demand while others (e.g., from FR10 to FR11) might be associated with much more significant decreases. For example, changing the schedule of reinforcement from FR1 to FR2 represents an increase at a relatively low cost and this change is less likely than others to result in dramatic changes in demand (i.e., prices exist in inelastic range). In contrast, the elastic region of the demand curve is an area where even small increases in cost can significantly affect demand. For example, changing the schedule of reinforcement from FR10 to FR11 represents an increase in price at higher levels of cost and changes in this higher price range are more likely to result in substantial changes in demand[1]. It warrants noting that demand for a reinforcer is likely to decrease much more rapidly in the elastic region of the demand curve and these more pronounced changes are likely to introduce higher levels of variability in demand for that reinforcer. In applied circumstances, costs that exist within the elastic range of demand may not be at levels necessary to consistently maintain the desired rates of some target behaviour.

The second behavioural economic concept suited for use with individuals with disabilities is the unit price. In contrast to traditional behaviour analytic approaches where schedules of reinforcement vary (e.g., FR1, FR5) and the magnitude of reinforcement remains constant (e.g., thirty seconds of access), the unit price represents a ratio of cost to benefit (i.e., two dollars for a two-pound bag of coffee reduces to a ratio to one dollar per pound). This approach allows clinicians and researchers to adjust

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[1] We make note that the change from FR10 to FR11 is only an arbitrary example. Depending on the individual demand curve for a reinforcer, these costs could be in either the inelastic or elastic range.

the costs and levels of reinforcers either together or separately.[29] For example, in the context of treatment for escape from non-preferred demands, if a participant was asked to comply with three tasks to produce three minutes of a ‘break’ from work the unit price of the ‘break’ would be one (i.e., three tasks divided by three minutes equals one). Similarly, the unit price would remain the same if the participant were asked to complete five work tasks for five minutes of a ‘break’ (i.e., five tasks divided by five minutes is equal to one). This approach is desirable as a potential alternative to schedule thinning, where response requirements are systematically increased while levels of reinforcement generally remain constant.[30] Schedule thinning eventually reaches a point where the demand for a specific reinforcer decreases as a function of increased unit price.[16]

In contrast to thinning schedules of reinforcement to advance towards treatment goals, the unit price approach allows for increasing response requirements while increasing reinforcer magnitude—keeping the unit price ratio essentially constant. For example, Roane et al (16) used this approach successfully to systematically increase response requirements in a differential reinforcement program to reduce rates of automatically-maintained problem behaviour. With respect to elasticity of demand for reinforcers, maintaining a unit price that exists within the inelastic range of demand may limit the possibility that the cost to produce the reinforcer intrudes into the elastic range of the demand curve. Remaining in the inelastic range would be desirable because costs in the elastic range of the demand curve are more likely to approach ratio strain and potentially invite the return of undesired behaviour. While conceptually consistent with demand theory, the concept of elasticity has not yet been applied in the context of developing and evaluating behavioural treatments.

The first goal of this study was to evaluate the use of elasticity in the development of evaluation of a function-based treatment for severe behaviour (i.e., P_{MAX}). The elasticity of demand for functions of problem behaviour was assessed using PR schedules of reinforcement along with demand curve analysis.[19, 31] The second goal of this study was to evaluate the use of unit price in advancing towards terminal treatment goals. A unit price just prior to P_{MAX} was targeted and unit price was scaled linearly by doubling response requirements with the magnitude of reinforcement delivered.

Materials and Method

Participant and setting

The participant was a seven-year-old male referred for the assessment and treatment of severe problem behaviour. Participant diagnoses included moderate intellectual disability and autism spectrum disorder. Severe problem behaviour occurred at rates and severity that negatively impacted functioning in both, school, and community settings. Specific topographies of targeted behaviour consisted of aggression and disruptive behaviour. The participant presented with a limited communicative repertoire, consisting of predominantly phrase speech, further compounded by poor vocal articulation. No other sensory or motor impairments were endorsed by caregivers. All study sessions were conducted in either an outpatient clinic setting or the participant's home over the course of four months. Session rooms in the clinic were furnished with a desk, chairs, and session-related materials.

Response measurement and interobserver agreement

Data were collected on occurrences of aggression and disruptive behaviour. Aggressive behaviour included instances of biting, hitting, kicking or throwing objects at or within two feet of others. Disruptive behaviour included hitting objects with a distance criterion of six inches or more and the throwing of objects with a distance criterion of more than two feet from others. Rates of target behaviour (responses per min) were calculated by dividing occurrences of target behaviour by the duration of session time, in minutes. All participant responses were recorded on laptop computers using the BDataPro computer program.[32] Two independent observers collected data for 31.25% of FA sessions, 46.67% of attention treatment sessions, 47.62% of demand treatment sessions, and 100% of generalization probes. Interobserver agreement was calculated by dividing the total number of agreements by the total number of agreements plus disagreements and multiplying this value by 100. Overall agreement was high for FA (*M* = 99.5%; Range = 98.33-100%), attention treatment (*M* = 100%; *Range* = 100%), demand treatment (*M* = 99%; Range = 93.33-100%), and generalization sessions (*M* = 94.20%; Range = 33-100%). Procedural integrity was assessed using a checklist of necessary treatment components and recording accurate implementation for each respective treatment in the home environment. Procedural integrity was calculated by dividing the number of correctly implemented components by the total number of correctly plus incorrectly completed components and multiplying this value by 100. Procedural integrity was high for the assessments for treatment generalization (*M* = 92.25%; Range = 62.5-100%).

Assessment and treatment of problem behaviour

Preference assessment

Descriptive information related to participant preferences was collected via caregiver interview using the Reinforcer Assessment for Individuals with Severe Disabilities

(RAISD).[3] This information was used to inform a subsequent Paired Stimulus (PS) preference assessment, which then informed subsequent functional analysis.[4]

Functional analysis

Functional analysis (FA) was based on procedures from Iwata et al (33) and modified to include a Tangible condition. Target responses produced 30s of programmed reinforcement in each condition. Sessions were 10 min in duration, implemented in the clinic setting, and conducted by trained clinic staff. Tasks in the Demand condition consisted of age-appropriate domestic and pre-academic tasks (e.g., cleaning, handwriting; alternated throughout the session) and the item in the Tangible condition was selected as the highest ranked stimuli from the PS preference assessment.

Attention preference assessment

As an extension of the PS preference assessment, a supplemental assessment was conducted to determine whether social-positive forms of attention functioned as a suitable alternative to social-disapproval attention (i.e., social attention rather than reprimands). Attention preference assessment procedures were based on those from Piazza et al (34), wherein concurrent schedules of attention were presented to determine attention properties most likely to serve as reinforcers. The specific forms of attention included in this assessment consisted of reprimands (e.g., “stop, you have to play nice”; consistent with FA), speaking about preferred topics (e.g., favourite characters, animals), physical play (e.g., tickles), and cooperative play (e.g., ball play). Two staff were positioned on adjacent sides of a small room and the types of attention provided by each staff alternated between sessions. All sessions were 5 min in duration. Attention types were provided in randomized pairs and delivered as the client approached specific staff. Attention was delivered until the client left the area or until the session time elapsed. A measure of attention preference was calculated by determining the total number of seconds spent consuming the attention type, dividing that value by the total duration of the session (in seconds), and multiplying that value by 100. A relative ranking of each attention type was determined via the average levels of consumption for each attention type across presentations. The highly-preferred forms of attention were included in subsequent treatment.

Evaluation of function-based treatments

Following FA, a Functional Communication Training (FC) treatment along with extinction (EXT) was introduced and evaluated.[35, 36] Single-response FC treatments were evaluated across attention and escape contexts with respective sessions from the FA used as a baseline in each treatment. Functional Communication Responses (FCRs) were not present in baseline conditions and FC training was performed immediately prior to treatment in both the attention and escape from demands contexts. All FCRs produced 30s of programmed reinforcement and consisted of handing a laminated picture card to an adult prior to either schedule thinning or demand fading. The initial attention treatment (FC-A + EXT) was evaluated with a single FC option (i.e., preferred topics). Once experimental control was demonstrated and the single-response FCT was determined effective, additional response options from the attention preference assessment were incorporated to extend the range of attention available[2]. The initial FC treatment for escape (FC-E + EXT) consisted of a single, function-matched reinforcer (i.e., brief removal of task demands). In both treatments, programmed advancements were introduced following two consecutive sessions with a 100% decrease in problem

[2] Two additional FCRs (i.e., preferred topics and physical play) were introduced at session 31 of the attention treatment evaluation.

behaviour or three consecutive sessions at an 80% or greater decrease in problem behaviour.

Programmed advancements in treatment

Procedures for advancing towards terminal treatment goals differed across functions of problem behaviour. In the attention treatment, schedule thinning procedures[30] were used in conjunction with discriminative stimuli that signalled the availability (i.e., green colour) and non-availability (i.e., red colour) of reinforcement for respective FCRs. The programmed S^{Δ} duration systematically increased from a period of 5s to 50% of the total session duration. The $\underline{S^{\Delta}}$ increased by 5s intervals up to 15s, by 15s-intervals until 1 min, by 30s-intervals until 2 min. and by 1 min intervals thereafter to a maximum of 5 min.

Advancements in the escape from demand treatment used demand fading procedures defined in terms of unit price. That is, one instance of compliance divided by 30s of reinforcement was equal to a unit price of 0.033. Identical to that of the attention treatment, discriminative stimuli were used to signal the availability (i.e., green colour) and non-availability (i.e., red colour) of reinforcement for the FCR. The re-introduction of demands took place initially by requiring one instance of compliance to signal the availability of the FCR (i.e., 0.033) and programmed advancements were guided by subsequent demand curve analysis (i.e., $\underline{P_{MAX}}$). Following decreases in responding at levels informed by demand curve analyses, both the number of demands and magnitude were increased by 100%, retaining the same unit price while increasing response requirements (i.e., FR3 30s reinforcement increased to FR6 60s reinforcement).

Demand curve analysis and PR schedules

Demand curve analyses were performed following the initial introduction of demand fading. The participant's levels of demand for forms of attention and escape from demands were assessed using individual PR reinforcer assessments.[31, 37] The PR procedures used were consistent with the Intermittent subtype defined in Jarmolowicz and Lattal (13). The PR schedule was adjusted intermittently for both attention and escape, after the delivery three reinforcers at each price, and prices assessed included Free (i.e., freely consumed on request), PR1, PR2, PR3, PR5, PR10, PR15, and PR20. Each change in the schedule was accompanied by vocal instructions specifying the new response requirement and individual responses consisted of developmentally-appropriate domestic tasks (e.g., clean, fold clothes, etc.); they were the same as those used during the demand condition of the FA. As in the escape from demand condition of the FA, three-step guided compliance was instituted to ensure that noncompliance did not inherently produce escape from demands. Sessions continued until there was 2 min without further independent work completion (i.e., compliance).

Responding on the PR schedules was modelled using the Exponential model of demand and analysed using the Demand Curve Analyzer (DCA).[27, 38] The DCA was used with default settings for the Exponential model and scaling constant k was fitted as a shared parameter to facilitate a more consistent comparison of alpha and Essential Value (EV).[27] P_{MAX} and EV were calculated as indicated in Equations 2 and 3, respectively, to evaluate the elasticity of demand as well as reinforcer strength. The P_{MAX} price point was used to determine a schedule of reinforcement to likely to consistently maintain responding.[39]

$$P_{MAX} = \frac{1}{Q_0 * \propto * k^{1.5}} * (0.083 * k + 0.65) \qquad (2)$$

$$EV = \frac{1}{100 * \propto * k^{1.5}} \tag{3}$$

Caregiver training and implementation

Following demonstrations of experimental control and significant decreases in problem behaviour in both treatments, caregivers were trained to implement both treatments in the clinic setting. Caregivers were trained using a Behavioural Skills Training (BST) model.[40] Training consisted of providing verbal and written instructions and taking part in role-play activities with feedback. Parents participated in BST prior to participating in treatment sessions.

Parent implementation phases consisted of both parents implementing all components of the treatment package in each respective treatment. These sessions continued until both parents jointly implemented the treatment with 100% procedural fidelity for at least two consecutive sessions with the terminal treatment package. The in-clinic generalization phases consisted of parent-implemented sessions under conditions resembling that of the home environment (e.g., sibling present, tasks from the home environment). These sessions continued until both parents jointly implemented the treatment with 100% procedural fidelity for at least two consecutive sessions as well. Following the successful use of the treatments by parents in the clinic setting, procedures were subsequently implemented by parents in the home environment.

Generalization programming

Probes for generalization were conducted prior to and following approximately four months of outpatient behaviour therapy. Three problematic home routines were identified by parents prior to treatment and these served as targets for pre- and post-treatment generalization. Specific routines evaluated within the home setting included home-specific demands, low-attention conditions, and activities of daily living. Pre-treatment, baseline generalization probes consisted of naturalistic observations in respective home routines and post-treatment probes for generalization consisted of the same routines with treatment components were in place. All probes for generalization were 5 min in duration, recorded by staff observers, and implemented by the primary parents.

Results

Stimulus preference assessment

Results from stimulus preference assessments revealed a clear hierarchy of participant preferences. Both the ball (100%) and light-up toy (85.71%) were selected in greater than 80% of opportunities. From these results, these items were subsequently used in the Tangible (high-preference item), Attention (low-preference item), and Toy Play (moderately-preferred items) conditions of the subsequent FA.

Functional analysis

A total of 15 FA sessions were conducted across Toy Play, Attention, Demand, and Tangible conditions. The findings from FA are illustrated in Figure 2. Results were strongly indicative of two forms of social reinforcement: contingent attention and escape from non-preferred demands. Based on these findings, individual function-based treatments were developed to address attention and escape functions for problem behaviour.

Attention preference assessment

The results from attention preference assessments revealed a relative preference for social-approval attention over social-disapproval. The relative rankings of preferred attention subtypes are illustrated in Figure 3. Available data indicated that discussing preferred topics (e.g., animals, pets; 60.07% of session time), physical play (e.g., tickles; 60.99% of session time), and interactive play (e.g., turn-taking games; 54.02% of session time) were consumed at higher levels than reprimands (e.g., "don't do that"; 20.45% of session time). Based on these findings, three forms of social-approval attention were selected for use in treatment.

Attention treatment evaluation

The FC treatment was used along with EXT to decrease rates of problem behaviour and increase rates of a functionally-equivalent response.[35, 36] Rates of problem behaviour and FC are illustrated in the upper portion of Figure 4. The introduction of treatment (FC-A + EXT) resulted in a decrease to near-zero rates of target behaviour and these rates were recovered in the return to baseline condition. Treatment was subsequently re-introduced, treatment effects were replicated, and the schedule of reinforcement was systematically thinned by progressively increasing a programmed S^{Δ} period. Treatment effects persisted throughout both parent implementation as well as during generalization sessions in this condition.

Escape from demand treatment evaluation

The FC treatment was used with EXT to both reduce rates of problem behaviour and increase rates of a functionally-equivalent communication response. Rates of problem behaviour and FC are illustrated in the lower portion of Figure 4. This treatment package (FC-E + EXT) resulted in substantial decreases in problem behaviour. Following reductions in problem behavior, demands were systematically faded using the behavioural economic concept of unit price whereby the FCR for escape was made available was one instance of compliance (i.e., 1 response / 30s access = unit price of

0.033). Following a return of problem behaviour to baseline rates, demand curve analyses were performed to evaluate the efficacy of both reinforcers (attention, escape from demand) in increasing compliance to task demands. Demand fading continued using the unit price approach (i.e., based on P_{MAX}) to increase response requirements commensurate with the magnitude of reinforcement (FR6; complete 6 tasks/60 seconds attention = 0.1). FCRs for attention and escape were concurrently available in this condition (FC-A/E + EXT). Following decreases in the rates of the target behaviour, a return to earlier treatment conditions (FC-E + EXT) recovered earlier levels of problem behaviour and effects of the demand fading based on P_{MAX} were replicated following the re-introduction of modified treatment package (FC-A/E + EXT). Using unit price to increase response requirements, rates of target behaviour remained low and rates of FCRs for both attention- and escape-maintained at low levels throughout treatment and post-treatment.

Demand curve analysis

A total of four PR reinforcer assessments were performed with the participant. Two PR reinforcer assessments were performed using for the demand and attention stimuli. The results of demand curve analysis, for both forms of reinforcement, are illustrated in Figure 5 and included in the Appendix. Both functions were fitted using the Exponential model of operant demand, with the scaling constant k fitted as a shared parameter between the two series (i.e., k = 4.583).[27] Results indicated a P_{MAX} of 0.109 (i.e., 3.278 responses) and an EV of 0.007 for attention and a P_{MAX} of 0.038 (i.e., 1.152 responses) and an EV of 0.002 for escape from demand.

Demand fading using unit price

Demand curve analyses provided the basis for further demand fading using unit price, whereby findings from demand curve analyses informed schedules of reinforcement for improving task compliance. Unit prices falling within in the inelastic range of the demand curves (i.e., less than P_{MAX}) were used as the initial schedules of reinforcement for attention (FR3; complete 3 tasks/30s attention = 0.1) and escape from demands (FR1; complete 1 task/30s break = 0.033) in modified treatment package (FC-A/E + EXT). Following successful reductions in target behavior, demand fading proceeded by increasing both response requirements and reinforcer magnitude by 100% (i.e., FR6; complete 6 tasks/60s attention = 0.1). Demand fading proceeded in this manner to maintain a cost-benefit ratio that remained within the inelastic range of demand while increasing response requirements.

Caregiver training and generalization

Treatment effects in the caregiver training phases resulted in stable, continued decreases in rates of target behaviour across both conditions. Stimulus generalization was assessed prior to and following treatment to evaluate the degree to which improvements in the clinic setting would be observed in other environments, such as the home setting. The results of generalization and follow-up are illustrated in Figure 6. Data from all targeted home routines indicated that the treatment package produced similar improvements in both the home and clinic settings.

Discussion

Behavioural economics has been suggested as a framework that can aid in quantifying individual preferences and choice in complex conditions. This approach has been particularly effective in evaluating how environmental factors, along with individual characteristics (e.g., preference), affect how individuals arrive at specific choices.[41] The purpose of this study was to evaluate two behavioural economic concepts that have been infrequently observed in work with individuals with neurodevelopmental challenges.[19] This study evaluated how the elasticity of demand for reinforcers and unit price could be used in the development and evaluation of a treatment for severe problem behaviour. The results of this study indicated that both elasticity and unit price are concepts that can be used to inform the development of a function-based treatment package. Further, the use of individual demand curve analyses allowed for an empirical method of identifying a suitable schedule of reinforcement for replacements to problem behaviour.

With respect to the first research aim, using the elasticity of demand for functions of behaviour, this study extended the existing support for using demand curve analyses to evaluate reinforcers for severe problem behaviour. Whereas earlier work by Borrero et al (18) found that the demand for reinforcers produced by problem behaviour was sensitive to price, this current demonstration used formal demand curve analyses to quantify the response-reinforcer relationship between responding and multiple reinforcers of interest (i.e., the functions of problem behaviour). More specifically, the elasticity of demand identified schedules of reinforcement that existed in the inelastic range of prices. Used this way, demand curve analysis informed the schedule of reinforcement selected to maintain the functionally-equivalent response. Determining this aspect of demand requires formal demand curve analysis and this had not been explored in earlier demonstrations with severe problem behaviour.[18] While selecting a price in the inelastic range may be a more informed clinical decision, compared to simply selecting some arbitrary schedule of reinforcement, it warrants noting that prices in the elastic range of prices may be particularly suitable for other clinical purposes. For example, clinicians might explore such prices if the goal is to predictably decrease levels of consumption for certain reinforcers in an informed manner (e.g., high intake of edible snacks, extensive screen time). Such methods have previously been proposed in areas of empirical public policy, akin to how a tax might be applied to reduce certain types of consumption.[39] While this study emphasized the use of inelastic prices to maintain high levels of demand, further study into the elasticity of demand (i.e., both inelastic and elastic ranges) may reveal additional clinical uses.

Regarding the use of unit price in function-based treatment, this study extended support for using unit price in demand fading. While this concept has been applied demand for reinforcers maintaining severe behaviour and as an alternative means for schedule thinning, this study extended the literature by using unit price to target costs within the inelastic range of demand for reinforcers.[16, 18] Demand curve analyses identified prices within the inelastic range of costs and a price point in this range was maintained when demands were increased. When used in this fashion, schedules of reinforcement used in behavioural intervention might be informed by the demand for a specific reinforcer (or reinforcers). Further, clinicians and applied researchers might use this approach to advance towards treatment goals with a priori information regarding how programmed reinforcers might perform in the future. Additionally, knowledge regarding the elasticity of demand may limit the possibility that clinicians and applied researchers unintentionally venture into the range of unit prices where ratio strain and the return of undesired behaviour are more likely.

Future directions

Applied behavioural economic methods, such as demand curve analyses, offer new opportunities for quantifying how reinforcers perform in various conditions. With respect to interventions for with persons with IDD, these methods have promise for supplementing various elements of current evidence-based practices. Principle among these, the elasticity of demand and unit price are concepts that extend traditional methods for assessing reinforcers. For example, these methods can be used to evaluate how much effort an individual might exert to defend their consumption of certain reinforcers and this information might be directly useful in developing interventions based around such reinforcers.

While traditional reinforcer assessments have provided a relative means to directly compare reinforcers, demand curve analyses provide a more robust set of methods for modelling how reinforcers perform as response requirements (i.e., effort) are vary from low to high. That is, these methods allow for modeling the effectiveness of a reinforcer as response requirements vary. This information can be particularly useful when making decisions regarding how to most effectively use reinforcers in treatment (i.e., setting response requirements), as selecting an arbitrary schedule of reinforcement could potentially underestimate or overestimate how a reinforcer might be most effectively used. For example, knowledge of the elasticity of demand may be useful in modelling how and when certain schedules may not become insufficient to maintain desired responding. Further investigation of the elasticity of demand could allow for a better understanding of these sources of variability and risks to otherwise effective treatments. Additionally, unit price also has the potential for more flexibly adjusting schedules of reinforcement. As first applied in Roane et al (16), the unit price approach can be used as a means for jointly adjusting schedule requirements along with the magnitude of reinforcement. While this should not discourage the use of traditional schedule thinning, the unit price method approach may have utility in cases where attempts to thin schedules of reinforcement might result in the return of problem behaviour.

Limitations

While this study successfully incorporated behavioral economic concepts into the development and evaluation of a treatment for problem behaviour, several aspects of this study limit the inferences that can be drawn regarding these novel components. First and foremost, several aspects of PR schedules of reinforcement make their use in applied situations pragmatically, and potentially ethically, challenging. As noted earlier, the various derivatives of PR schedules each exert different influences on respond and responding on one PR type may differ from responding on another PR schedule. A review by Jarmolowicz and Lattal (13) summarized these subtypes, highlighting observations that the intermittent PR schedule type generally yields more advances but lower breakpoints. Ethically, Poling (42) highlighted concerns that PR schedules often include high response requirements that can be both time-intensive and potentially aversive. These concerns are worth reiterating, as such procedures should be used only insofar as they efficiently and effectively contribute to the development of treatment. Further research is necessary to understand how PR schedules, and perhaps future extensions, could contribute in this regard.

In addition to challenges related to PR schedules, several aspects of the study design also limit the inferences that can be drawn. That is, this study was performed with one single participant and this limits the external validity of these findings. Additional replication is necessary to determine whether results from these procedures efficiently and reliably predict the effectiveness of reinforcers under various conditions. While the PR schedules used in this study took roughly as long as the PS preference assessment to complete, further evaluation continues to be necessary. Similarly, further evaluation is necessary to evaluate to what degree these more advanced methods provide benefits beyond conventional approaches. This was not directly compared in the present study and warrants further evaluation.

Declaration of interest statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. Cannella HI, O'Reilly MF, Lancioni GE. Choice and preference assessment research with people with severe to profound developmental disabilities: a review of the literature. Res Dev Disabil. 2005; 26(1): 1-15. DOI: 10.1016/j.ridd.2004.01.006.

2. DeLeon IG, Iwata BA. Evaluation of a multiple-stimulus presentation format for assessing reinforcer preferences. J Appl Behav Anal. 1996; 29(4): 519-32. DOI: 10.1901/jaba.1996.29-519.

3. Fisher WW, Piazza CC, Bowman LG, Amari A. Integrating caregiver report with systematic choice assessment to enhance reinforcer identification. Am J Ment Retard. 1996; 101(1): 15-25.

4. Fisher WW, Piazza CC, Bowman LG, Hagopian LP, Owens JC, Slevin I. A comparison of two approaches for identifying reinforcers for persons with severe and profound disabilities. J Appl Behav Anal. 1992; 25(2): 491-8. DOI: 10.1901/jaba.1992.25-491.

5. Bannerman DJ, Sheldon JB, Sherman JA, Harchik AE. Balancing the right to habilitation with the right to personal liberties: the rights of people with developmental disabilities to eat too many doughnuts and take a nap. J Appl Behav Anal. 1990; 23(1): 79-89. DOI: 10.1901/jaba.1990.23-79.

6. DeLeon IG, Iwata BA, Goh HL, Worsdell AS. Emergence of reinforcer preference as a function of schedule requirements and stimulus similarity. J Appl Behav Anal. 1997; 30(3): 439-49. DOI: 10.1901/jaba.1997.30-439.

7. Tustin RD. Preference for reinforcers under varying schedule arrangements: A behavioral economic analysis. J Appl Behav Anal. 1994; 27(4): 597-606. DOI: 10.1901/jaba.1994.27-597.

8. DeLeon IG, Frank MA, Gregory MK, Allman MJ. On the correspondence between preference assessment outcomes and progressive-ratio schedule assessments of stimulus value. J Appl Behav Anal. 2009; 42(3): 729-33. DOI: 10.1901/jaba.2009.42-729.

9. DeLeon IG, Gregory MK, Frank-Crawford MA, Allman MJ, Wilke AE, Carreau-Webster AB, Triggs MM. Examination of the influence of contingency on changes in reinforcer value. J Appl Behav Anal. 2011; 44(3): 543-58. DOI: 10.1901/jaba.2011.44-543.

10. Roane HS, Lerman DC, Vorndran CM. Assessing reinforcers under progressive schedule requirements. J Appl Behav Anal. 2001; 34(2): 145-66. DOI: 10.1901/jaba.2001.34-145.

11. Frank-Crawford MA, Castillo MI, DeLeon IG. Does preference rank predict substitution for the reinforcer for problem behavior? a behavioral economic analysis. J Appl Behav Anal. 2018; 51(2): 276-282. DOI: 10.1002/jaba.452.

12. Hursh SR, Bauman RA, The behavioral analysis of demand, In: Green, L, Kagel, JH, editor. Advances in behavioral economics, Norwood, New Jersey: Ablex Publishing Corporation; 1987; 117-165.

13. Jarmolowicz DP, Lattal KA. On distinguishing progressively increasing response requirements for reinforcement. Behav Anal. 2017; 33(1): 119-125. DOI: 10.1007/BF03392207.

14. Trosclair-Lasserre NM, Lerman DC, Call NA, Addison LR, Kodak T. Reinforcement magnitude: an evaluation of preference and reinforcer efficacy. J Appl Behav Anal. 2008; 41(2): 203-20. DOI: 10.1901/jaba.2008.41-203.

15. Kerwin ME, Ahearn WH, Eicher PS, Burd DM. The costs of eating: a behavioral economic analysis of food refusal. J Appl Behav Anal. 1995; 28(3): 245-60. DOI: 10.1901/jaba.1995.28-245.

16. Roane HS, Falcomata TS, Fisher WW. Applying the behavioral economics principle of unit price to DRO schedule thinning. J Appl Behav Anal. 2007; 40(3): 529-34. DOI: 10.1901/jaba.2007.40-529.

17. Reed DD, Luiselli JK, Magnuson JD, Fillers S, Vieira S, Rue HC. A comparison between traditional economical and demand curve analyses of relative reinforcer efficacy in the validation of preference assessment predictions. Dev Neurorehabil. 2009; 12(3): 164-9. DOI: 10.1080/17518420902858983.

18. Borrero JC, Francisco MT, Haberlin AT, Ross NA, Sran SK. A unit price evaluation of severe problem behavior. J Appl Behav Anal. 2007; 40(3): 463-74. DOI: 10.1901/jaba.2007.40-463.

19. Gilroy SP, Kaplan BA, Leader G. A Systematic Review of Applied Behavioral Economics in Assessments and Treatments for Individuals with Developmental Disabilities. Rev J Autism Dev Disord. 2018; 5(3): 247-259. DOI: 10.1007/s40489-018-0136-6.

20. Francisco MT, Borrero JC, Sy JR, Roane H. Evaluation of Absolute and Relative Reinforcer Value Using Progressive-Ratio Schedules. J Appl Behav Anal. 2008; 41(2): 189-202. DOI: 10.1901/jaba.2008.41-189.

21. Goldberg MC, Allman MJ, Hagopian LP, Triggs MM, Frank-Crawford MA, Mostofsky SH, Denckla MB, DeLeon IG. Examining the reinforcing value of stimuli within social and non-social contexts in children with and without high-functioning autism. Autism. 2017; 21(7): 881-895. DOI: 10.1177/1362361316655035.

22. Kodak T, Lerman DC, Call N. Evaluating the influence of postsession reinforcement on choice of reinforcers. J Appl Behav Anal. 2007; 40(3): 515-27. DOI: 10.1901/jaba.2007.40-515.

23. Reed DD, Niileksela CR, Kaplan BA. Behavioral economics: a tutorial for behavior analysts in practice. Behav Anal Pract. 2013; 6(1): 34-54. DOI: 10.1007/BF03391790.

24. Bickel WK, Marsch LA, Carroll ME. Deconstructing relative reinforcing efficacy and situating the measures of pharmacological reinforcement with behavioral economics: a theoretical proposal. Psychopharmacology (Berl). 2000; 153(1): 44-56.

25. Johnson MW, Bickel WK. Replacing relative reinforcing efficacy with behavioral economic demand curves. J Exp Anal Behav. 2006; 85(1): 73-93. DOI: 10.1901/jeab.2006.102-04.

26. Katz JL. Models of relative reinforcing efficacy of drugs and their predictive utility. Behavioural Pharmacology. 1990; 1: 283-301.

27. Hursh SR, Silberberg A. Economic demand and essential value. Psychol Rev. 2008; 115(1): 186-98. DOI: 10.1037/0033-295X.115.1.186.

28. Reed DD, Kaplan BA, Becirevic A, Basic research on the behavioral economics of reinforcer value, In: DiGennaro-Reed, FD, Reed, DD, editor. Autism Service Delivery: Springer New York; 2015; 279-306.

29. Delmendo X, Borrero JC, Beauchamp KL, Francisco MT. Consumption and response output as a function of unit price: manipulation of cost and benefit components. J Appl Behav Anal. 2009; 42(3): 609-25. DOI: 10.1901/jaba.2009.42-609.

30. Tiger JH, Hanley GP, Bruzek J. Functional communication training: a review and practical guide. Behav Anal Pract. 2008; 1(1): 16-23. DOI: 10.1007/BF03391716.

31. Hodos W. Progressive Ratio as a Measure of Reward Strength. Science. 1961; 134(3483): 943-944. DOI: 10.1126/science.134.3483.943.

32. Bullock CE, Fisher WW, Hagopian LP. Description and Validation of a Computerized Behavioral Data Program: “BDataPro”. Behav Anal. 2017; 40(1): 275-285. DOI: 10.1007/s40614-016-0079-0.

33. Iwata BA, Dorsey MF, Slifer KJ, Bauman KE, Richman GS. Toward a functional analysis of self-injury. J Appl Behav Anal. 1994; 27(2): 197-209. DOI: 10.1901/jaba.1994.27-197.

34. Piazza CC, Bowman LG, Contrucci SA, Delia MD, Adelinis JD, Goh HL. An evaluation of the properties of attention as reinforcement for destructive and appropriate behavior. J Appl Behav Anal. 1999; 32(4): 437-49. DOI: 10.1901/jaba.1999.32-437.

35. Carr EG, Durand VM. Reducing behavior problems through functional communication training. J Appl Behav Anal. 1985; 18(2): 111-26. DOI: 10.1901/jaba.1985.18-111.

36. Hagopian LP, Fisher WW, Sullivan MT, Acquisto J, LeBlanc LA. Effectiveness of functional communication training with and without extinction and punishment: a summary of 21 inpatient cases. J Appl Behav Anal. 1998; 31(2): 211-35. DOI: 10.1901/jaba.1998.31-211.

37. Findley JD. Preference and Switching under Concurrent Scheduling. J Exp Anal Behav. 1958; 1(2): 123-44. DOI: 10.1901/jeab.1958.1-123.

38. Gilroy SP, Kaplan BA, Reed DD, Koffarnus MN, Hantula D. The Demand Curve Analyzer: Behavioral economic software for applied researchers. Journal of the Experimental Analysis of Behavior. 2018.

39. Hursh SR, Roma PG. Behavioral economics and empirical public policy. J Exp Anal Behav. 2013; 99(1): 98-124. DOI: 10.1002/jeab.7.

40. Sarokoff RA, Sturmey P. The effects of behavioral skills training on staff implementation of discrete-trial teaching. J Appl Behav Anal. 2004; 37(4): 535-538.

41. Bickel WK, DeGrandpre RJ, Higgins ST. Behavioral economics: a novel experimental approach to the study of drug dependence. Drug Alcohol Depend. 1993; 33(2): 173-92. DOI: 10.1016/0376-8716(93)90059-Y.

42. Poling A. Progressive-ratio schedules and applied behavior analysis. J Appl Behav Anal. 2010; 43(2): 347-9. DOI: 10.1901/jaba.2010.43-347.

Appendix

	Progressive Ratio Schedule*					
Function	**Free (0)**	**PR1**	**PR2**	**PR3**	**PR5**	**PR10**
Attention	6	6	6	2	0	0
Demand	6	4	1	0	0	0

Function	**Model**	Q_0	***Alpha***	***k*********	P_{MAX}	**RMSE**
Attention	Exponential	7.43124	0.12929	4.58352	3.27868	0.121521
Demand	Exponential	7.04067	0.38819	4.58352	1.49276	0.004699

*: Zero values were dropped from demand curve analysis

**: Parameter *k* fitted as a shared, global parameter, using the DCA

Figure captions

Figure 1: This illustrates the Exponential model of demand over hypothetical data. Differential effects of pricing along the curve are referred to the elasticity of demand and the inelastic and elastic portions of the curve are separated by P_{MAX}.

Figure 2: Analogue FA of problem behaviour.

Figure 3: Attention preference assessment evaluation social-positive and social-negative forms of attention.

Figure 4: The FC treatment package produced significant improvements in both the attention and escape from demands contexts.

Figure 5: Demand curve analysis performed across reinforcers for problem behaviour, with P_{MAX} and EV as indicators of reinforcer strength.

Figure 5: Generalization of the FC treatment package to the home environment.

Figure 1. Prototypical Demand Curve

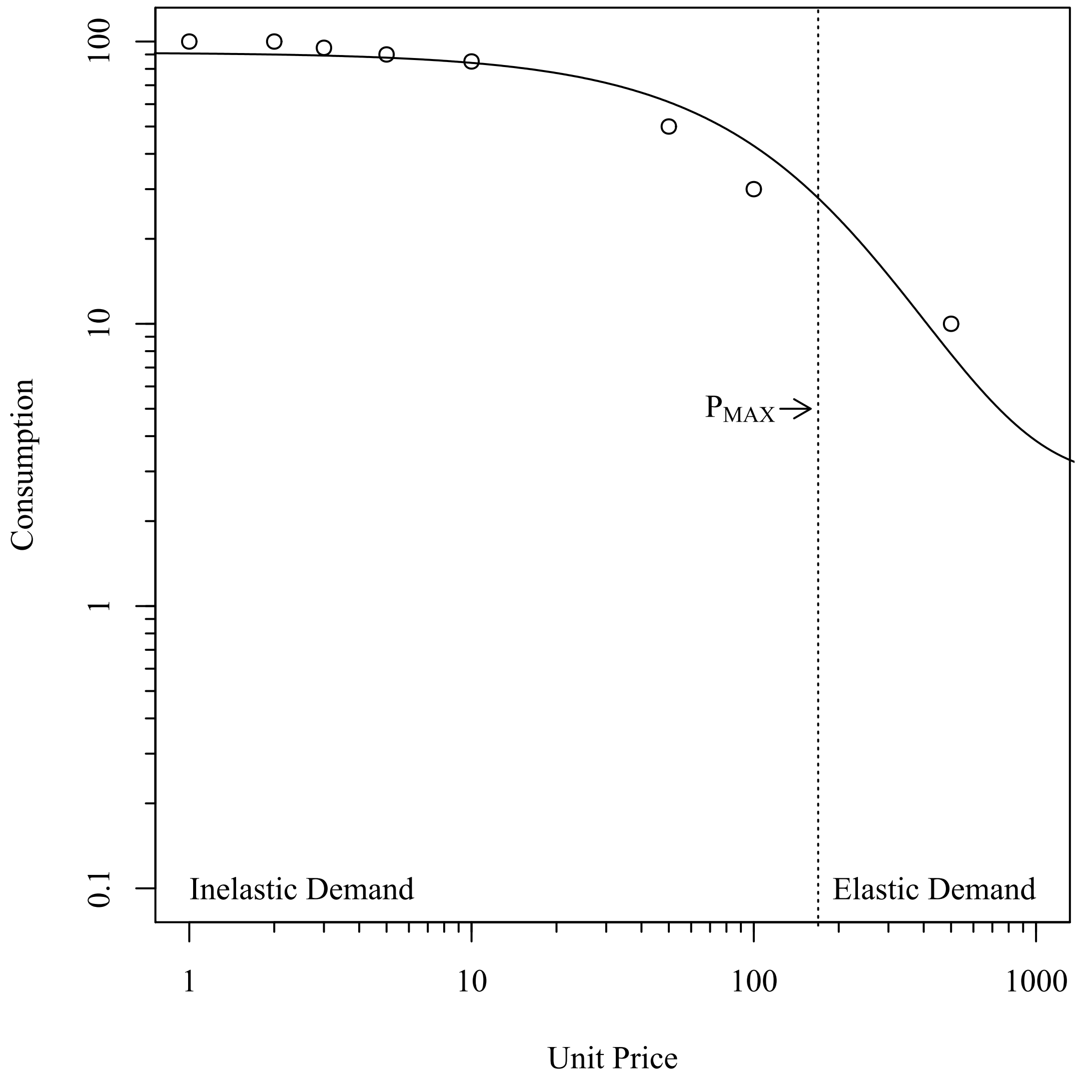

Figure 2. Analogue Functional Analysis

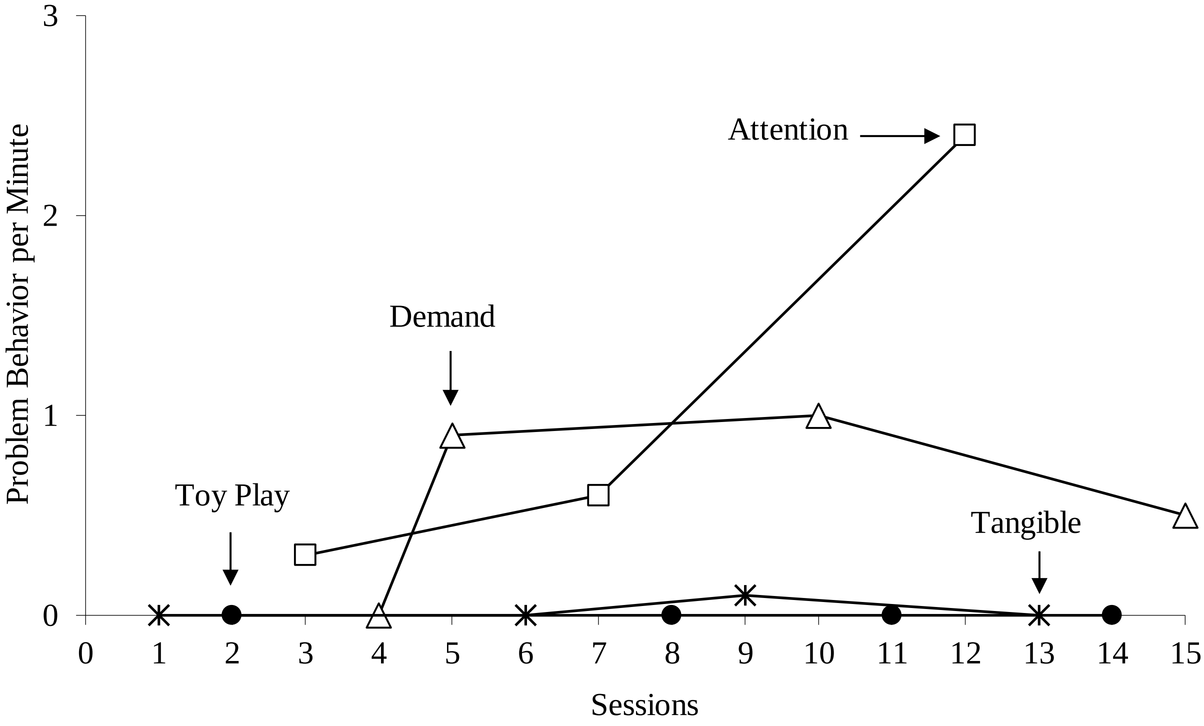

Figure 3. Attention Preference Assessment

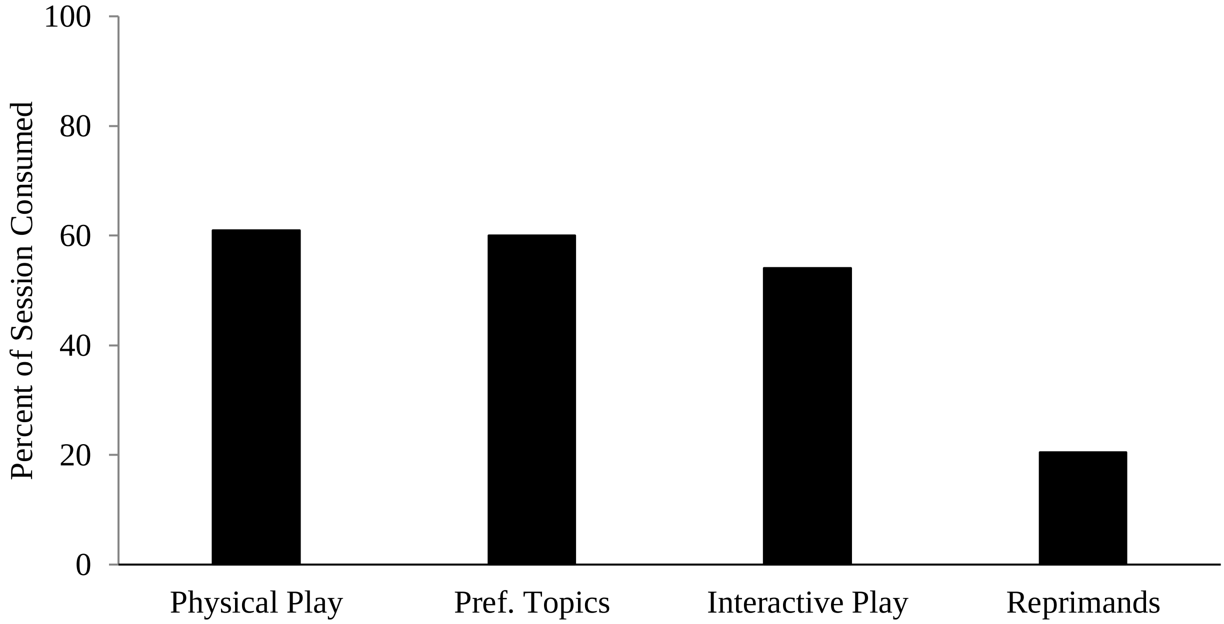

Figure 4. Multiple Baseline with Embedded Reversals Treatment Evaluation

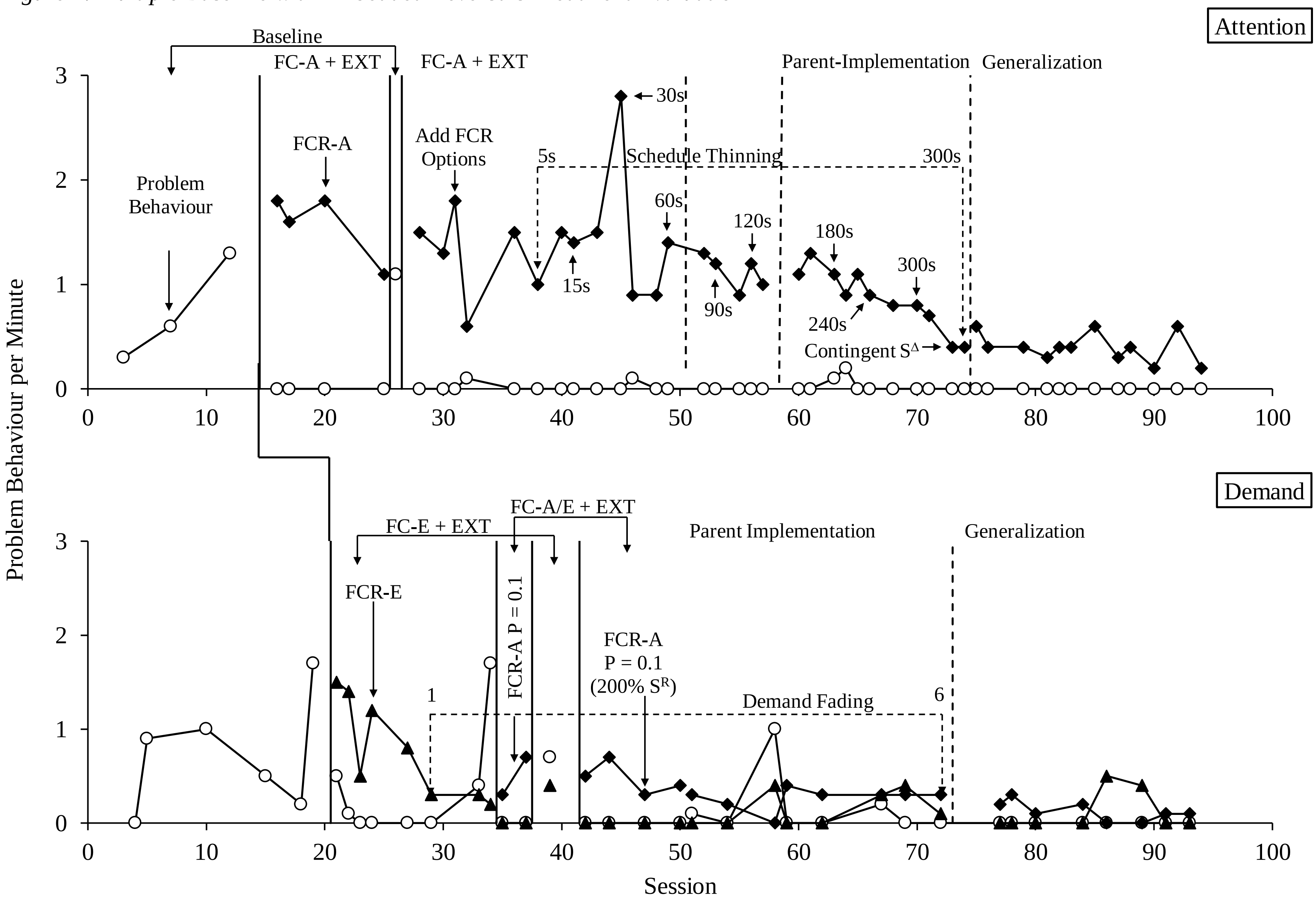

Figure 5. Demand Curves by Function of Target Behaviour

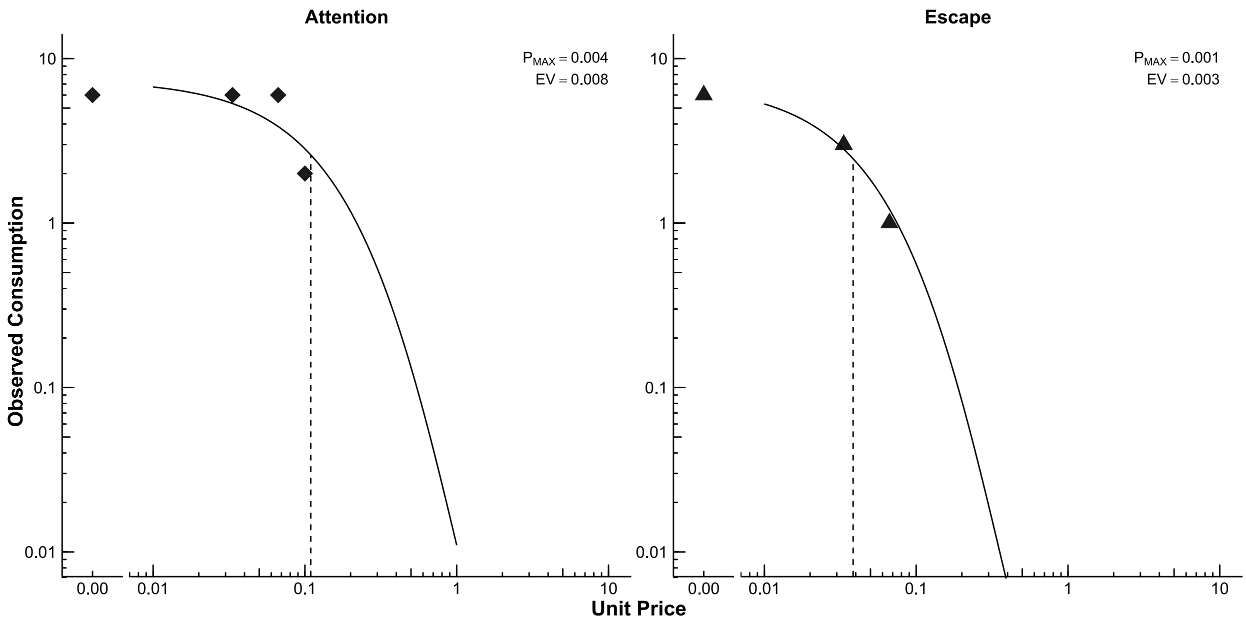

Figure 6. Baseline and Posttreatment In-Home Generalization