# A systematic review of applied behavioral economics in assessments and treatments for individuals with developmental disabilities


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## Abstract

Treatments for individuals with developmental disabilities regularly include assessments of individual choice and preference. These procedures assist in the development, design, and maintenance of effective, evidence-based practices. Despite widespread use, these assessments may or may not accurately identify reinforcers that will be effective in treatments. Procedures and analyses from the area of behavioral economics have been proposed to address this potential source of error, although these procedures are observed relatively infrequently in the current literature. The purpose of this study was to systematically review the elements of behavioral economics that have and have not been incorporated into assessments or treatments for individuals with disabilities. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology was utilized (Prospero: #CRD42017069859) to systematically search the literature and the Scopus, PsycINFO, ScienceDirect, and SpringerLink databases were included. Studies were included if their procedures used behavioral economics and if those procedures were used with individuals with developmental disabilities. Twenty-two studies were identified and the results of this review indicated that only a limited range of behavioral economic procedures have been translated into assessments and treatments for individuals with developmental disabilities. This review discusses the degrees to which these procedures have been extended to this population and outlines additional research and replication to further aide in the translation of these procedures into applied practice.

# 1. Introduction

## 1.1. Choice and Preference

Measures of individual choice and preference are strongly recommended in evidence-based assessments and treatments for individuals with disabilities. In research and applied services, assessments of individual preference have been an established standard in the application and refinement of evidence-based practices (DeLeon & Iwata, 1996; Fisher et al., 1992; Pace, Ivancic, Edwards, Iwata, & Page, 1985). Research has found that empirical assessments of individual preference assist in the development of effective treatments and generally improve outcomes when included as an element of treatment (Fisher et al., 1992; Pace et al., 1985). Clinicians have traditionally assessed preference, or choice behavior, by identifying stimuli that are chosen more often than others and using these stimuli as potential reinforcers in treatment (Fisher et al., 1992; Green, Reid, Canipe, & Gardner, 1991; Pace et al., 1985). Despite widespread use of preference assessments, some research has shown that highly-preferred stimuli may or may not function as effective reinforcers (e.g., improve behavior) when the means for accessing them becomes more effortful (DeLeon, Iwata, Goh, & Worsdell, 1997; Tustin, 1994). For example, puzzles might be highly preferred when they are easily accessed (e.g., available by asking) but may not be as preferred, or preferred at all, when some work or price is required (e.g., must work to access them). Because of these findings, some researchers have suggested that additional procedures may be necessary to confirm whether preferred items might be effective when used in treatment-like conditions (Reed, Kaplan, & Becirevic, 2015; Tustin, 1994).

Tustin (1994) evaluated how strongly a *preferred* item performed in a range of high- and low-effort conditions. In this study, the author highlighted how a typical preference assessment context (e.g., low effort to access reinforcer) differs from a treatment context (e.g., high effort to access reinforcer) and concluded that this mismatch has implications for the development of behavioral treatments. For example, treatment conditions are much more likely to require more effortful responding to earn access to something preferred (e.g., high effort) than simply indicating that one desires it (e.g., low effort). In efforts to better understand whether a preferred item would effectively improve behavior, additional approaches have been used to enhance the conceptualization and quantification of individual choice and preference. Two of the most frequently used approaches to quantify choice have been the matching law (Herrnstein, 1961) and behavioral economic theory (Foxall, Olivera-Castro, Schrezenmaier, & James, 2007; Hursh, 1980, 1984; Rachlin, Battalio, Kagel, & Green, 1981).

**1.2. Choice and the Matching Law**

The matching law, as well as the generalized matching equation that extended it (Baum, 1974), is a framework for understanding individual choice (Herrnstein, 1961). The matching law states that an individual should respond at levels that proportional to the reinforcement produced by that response (de Villiers & Herrnstein, 1976; Herrnstein, 1961). That is, choices that lead to more frequent and substantial outcomes tend to be observed more often. Research using this approach to study choice have used "matching" calculations to measure an individual's choices when the reinforcers that follow them are systematically manipulated (Herrnstein, 1961; Reed & Kaplan, 2011). For example, researchers have used these formulations to measure how changes in reinforcement (e.g., sizes, delays, etc.) affect individual preferences and choices (Fuqua, 1984; Green & Freed, 1993; Rachlin et al., 1981). While extensions of the generalized matching equation have been used to compare qualitatively different reinforcers (e.g., time playing a videogame vs. time watching a type of video), some have noted that this single-dimension approach to measuring choice may be insufficient to measure choice in more complex situations when many types of options are available (Foxall et al., 2007; Green & Freed, 1993; Hursh, 1980).

### 1.3. Choice and Behavioral Economics

As stated in Hursh (1980), “Because reinforcers differ in elasticity and because reinforcers can be complementary, no simple unidimensional choice rule such as matching can account for all choice behavior.” Hursh and colleagues highlighted the need to assess choice in complex situations, where multiple and varying types of reinforcers were available, and proposed incorporating methods used to measure behavior in economics (Bickel, DeGrandpre, & Higgins, 1993; Kagel, Battalio, & Green, 1995). This combination of behavioral science and economics, hereafter referred to as *behavioral economics*[1], refers to an interpretation of choice that integrates economic principles and behavioral science (Allison, 1983; Foxall et al., 2007; Hursh, 1980, 1984; Rachlin et al., 1981; Reed, Niileksela, & Kaplan, 2013). In this new interpretation, established behavioral terms such as “response”, “reinforcement schedule”, and “reinforcer” are expressed using the economic equivalents “work”, “price”, and “commodity”, respectively. When referenced in this way, clinicians and researchers can view and interpret an individual’s choices and preferences in the context of function markets (e.g., many items available, varying costs), consistent with the economic approach (Foxall et al., 2007; Hursh, 1980, 1984; Reed et al., 2013).

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[1] We make two notes with respect to the term *behavioral economics*. The first is that the present review focuses on the behavioral economics that is an outgrowth of the operant behavior framework, rather than the behavioral economics that has been recently popularized as an outgrowth of mainstream psychology (Ariely, 2008; Camerer, 1999; Kahneman, Slovic, & Tversky, 1982; Thaler & Sunstein, 2008). Second, we note that operant behavioral economics also subsumes frameworks of delay discounting and matching law, but here we focus on the aspects of behavioral economic demand.

The behavioral economic framework allows researchers and clinicians to examine, measure, and interpret behavior in complex, real-world situations. In this approach, the assessment and treatment situations can be viewed and analyzed as functioning markets—each unique in the types of commodities available and costs for consuming them. In these markets, the individual is the consumer and they are presented with many opportunities for different types of reinforcers—with varying costs. This type of view and approach has strong applicability for behavioral assessment and intervention approaches. For example, Reed et al. (2013) provided a good example of how the token economy, an approach used in many settings, can be viewed and interpreted in the behavioral economic approach. In this example, the "commodity" is the token earned, which is exchangeable for some other type of backup reinforcer (i.e., time playing video games). For this example, "consumption" is that individual's interaction with the reinforcer, following some "work" or "cost." The *cost* or *price* to consume the reinforcer in this example would be the response requirement (e.g., FR1, FR5). The incorporation of behavioral economic terms and concepts allows clinicians to view behavior in an economic framework and this extends traditional assessments and treatments in several ways.

**1.3.1. Reinforcer Efficacy and Reinforcer Preferences.** Behavioral economic approaches are especially suited to assessing reinforcer *efficacy*. Reinforcer efficacy refers to another dimension of reinforcers—one that extends beyond relative preference. It warrants noting that that "efficacy" is not some attribute necessarily inherent within the reinforcer. Rather, it is a quality that is revealed when examining an individual's behavior with respect to a given reinforcer. That is, efficacy refers to how *strongly* some stimuli maintains behavior as the levels of effort, or cost, vary from low-to-high (e.g., Fixed Ratio [FR] 1, FR5, FR10, FR20; Reed, Kaplan, & Becirevic, 2015). For example, a *more efficacious* reinforcer is one that would continue to reinforce behavior even when the cost to consume it becomes high. In comparison, a *less efficacious* reinforcer is one that would only reinforce behavior when the cost to consume it is quite low (e.g., FR1). While all goods ultimately reach some point where prohibitive costs negatively impact consumption, reinforcers will vary in the extent to which the individual will continue to work in the face of increasing *costs* or levels of *effort*. The right panel of Figure 1 illustrates a *work output curve*, a calculation that visually represents the point at which a reinforcer loses efficacy and an individual's overall responding (e.g., working towards a reinforcer) begins to decrease[2]. Curves such as these correspond with the findings in Tustin (1994). Tustin (1994) observed that highly-preferred stimuli are more often efficacious under low effort conditions (i.e., free, FR1) but perform differently when the *cost* or *effort* to obtain them increases (DeLeon, Iwata, Goh, & Worsdell, 1997; Tustin, 1994). This plot demonstrates a relatively efficacious reinforcer that maintains responding until the *cost* for obtaining the reinforcer reaches 6 responses (e.g., FR6). After this point, increasing costs only serve to significantly reduce overall responding.

**1.3.2. Demand Curves and Elasticity of Demand for Reinforcers.** Behavioral economics evaluates the efficacy of reinforcers in multiple dimensions. These dimensions include both an individual's overall responding (e.g., work output) as well as their *demand* for some specific reinforcer. The *demand* for a reinforcer refers to the extent to which an individual will work (e.g., complete math problems, assignments) to obtain and then consume some reinforcer (e.g., videogame access) over a range of costs (e.g., free, FR1, FR10). Like the work output curve, *demand* for a reinforcer also takes the shape of a curve. Consistent with Tustin

[2] Important to note is that these work output curves do not depict rate of responding as is typically seen in traditional behavior-analytic studies, as responses are not standardized over a fixed amount of time (e.g., per min). Rather, one can interpret the work output curve as the rate of responding over the entire session(s) associated with each individual price point.

(1994) and the Law of Demand (Samuelson, 1947), one would expect an individual to consume a reinforcer at the highest levels the most when the *cost* is very low (including when free) and to consume the same reinforcer at lower levels when the *price* rises. The left panel of Figure 1 demonstrates the shape and form of the *demand curve*.

As displayed in the left portion of Figure 1, the *demand curve* depicts how decreases in consumption are associated with increases in price. This overall decreasing pattern is known as *elasticity* and this broadly represents *how strongly* changes in price influence an individual's consumption of a reinforcer. Referring to this plot, relatively slight changes in consumption are observed in the *lower* price ranges (left portion) while relatively larger changes in consumption are observed in the *higher* price ranges (right portion). These two very different regions of the demand curve are referred to as *inelastic* and *elastic* sections, respectively. The *inelastic* portion of the describes a region where an individual's *demand* for some specific reinforcer is relatively unchanged even as costs increase (e.g., consumption is not pulled down by increasing cost). In contrast, the *elastic* portion refers to the range of the *demand curve* when consumption is significantly influenced by changes in cost (e.g., consumption is pulled down as costs increase). This point indicates to clinicians and researchers that a reinforcer is unlikely to be as effective at this point, and beyond, given that the individual no longer exerts the work necessary to access the same amount of the reinforcer consumed with smaller costs. The point at which a demand curve changes from *inelastic* to *elastic* is referred to as the $P_{max}$. In the context of treatments for individuals with disabilities, knowledge of the *elasticity* of a reinforcer informs clinicians and researchers how and when a reinforcer is likely to no longer maintain behavior at the levels desired. This type of information is highly useful when developing interventions for individuals with disabilities, as efficacious reinforcers are prerequisites to effective treatments.

**1.3.3. Economy Type and Substitutability.** Behavioral economics offers methods to analyze the situations that a reinforcer exists within, and most importantly, how the availability of other reinforcers (whether they be similar or different) affect the efficacy of that reinforcer. Individual contexts, or *economies*, exist on a continuum from purely *open* to purely *closed* (Hursh, 1980; Imam, 1993). A purely *closed* economy represents a context in which the individual has only one means to access a *commodity* (e.g., reinforcer) and must *work* for the *entire cost* to access it (e.g., must complete all assignments to earn video game time). The *closed economy* context is one familiar to clinics and other, more highly-controlled settings where the means for accessing a preferred item is closely monitored and maintained. In this situation, the individual has only one means to access a specific reinforcer and that reinforcer can only be consumed for a set cost. From an experimental standpoint, the closed economy is preferred because it completely isolates the response-reinforcer feedback function. That is, the amount of reinforcement obtained is a direct result of the responses emitted. In contrast, the *open economy* context represents a situation where an individual may not have to perform as much (or any) work to access some reinforcer. In this situation, the individual has more than one means to access a specific reinforcer and the *cost* to *consume* that reinforcer can vary. The *open economy* context is likely more common in homes and other more naturalistic settings, where the rules and means for accessing preferred items are less strictly monitored and enforced.

The behavioral economic approach pays special attention to the *type of economy* that a reinforcer operates in because the *demand* for a reinforcer is inevitably influenced by the context it operates in. The *open* and *closed* contexts are highly relevant to treatments because the *efficacy* of and *demand* for reinforcers can be substantially influenced by the context. For example, an intervention using access to video games to reinforce a child's completion of work assignments may be significantly affected by that individual's *economy* for video games. This type of arrangement is very likely to have more powerful effects in a clinic setting (e.g., *closed economy*; video games are only accessible after completing work) and less powerful effect in a less structured home setting (e.g., *open economy*; video games accessed with or without completing all work). As one would expect, the individual is less likely to work towards some *commodity* (e.g., reinforcer) if they can *freely access* the commodity elsewhere at some other *cost*. Figure 2 depicts this type of situation, where the *demand* for some *commodity* in an *open economy* is less than the same *commodity* in a *closed economy* (Roane, Call, & Falcomata, 2005).

In addition to economy type, behavioral economics also includes methods to analyze reinforcer relations. Individual reinforcers fulfill certain functions and a variety of reinforcer relations emerge when multiple reinforcers are available (either concurrently or contiguously). Like the economy continuum, reinforcer relations can vary in several ways. Two reinforcers are considered *substitutes* if the consumption of one reinforcer declines (as is seen with the protypical demand curve) while consumption of another reinforcer increases. For example, two reinforcers may be substitutable if consumption of item A (e.g., access to video games) decreases as costs to obtain it increases, while at the same time consumption of item B (e.g., watching television) increases. A *complementary* relation occurs when consumption of two reinforcers declines in tandem. For example, consider the combination of watching videos and eating popcorn—both items can be consumed independently but have an enhanced value when combined. In this example, a complementary relation, if the price of watching videos were to increase the overall consumption of both watching videos and eating popcorn would decrease together. Lastly, reinforcers can have *independent* relations as well. An *independent* relation occurs when the price of one reinforcer does not affect the consumption of another reinforcer. That is, a reinforcer is likely to be more effective at maintaining behavior if that item, or a substitute for it, is not available elsewhere (e.g., after the session, outside of the classroom; Kodak, Lerman, & Call, 2007).

**1.3.4. Reinforcer Schedules as Unit Prices.** Aside from evaluations of reinforcer efficacy and demand, behavioral economics permits more robust and flexible methods for representing *cost*. Traditionally, assessments and interventions for individuals with disabilities have used time- (e.g., Fixed Interval; FI) and response-based (e.g., Fixed Ratio; FR) units of measurement to represent the *cost* or *effort* required to *consume* a reinforcer. In this approach, the time or responses required to produce reinforcement often increases while the amount of reinforcement remains *constant* (e.g., FR5 and FR10 produces same amount of reinforcement). While traditional approach permit modifications of reinforcer *schedules* (e.g., FR1 to FR2), this type of approach is limiting when one needs to modify both the *schedule* and some dimension of the *reinforcer* (e.g., multi-dimensional changes). For example, a clinician working to increase a child's overall completion of work assignments might desire to increase *both* the schedule of reinforcement (e.g., FR5 to FR10) *and* some dimension of the reinforcer (e.g., five minutes of video game time to fifteen minutes of video game time). Traditional approaches cannot be easily translated to reflect multi-dimensional changes, as the reinforcement levels are traditionally held constant. In contrast, behavioral economics uses *unit price* as one means to flexibly to equate *costs* to *commodities.*

The concept of *unit price* permits comparisons along multiple, related scales (Bickel, DeGrandpre, & Higgins, 1993; Greenwald & Hursh, 2006; Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988; Madden, Bickel, & Jacobs, 2000; Shahan, Bickel, Madden, & Badger, 1999).

In marketing, *unit price* is often observed in terms of how much money, *per unit,* some good costs (e.g., cost per oz., per lb.). For example, a 1-lb. bag of rice that costs $1.00 can have the equivalent *unit price* as a 2-lb. bag of rice that costs $2.00. This allows for a consistent comparison when both *cost* (e.g., reinforcement schedules) and *commodities* (e.g., dimensions of reinforcer) vary. This type of formulation has been used often in research on substance abuse to evaluate how adults *work* to produce complex, multidimensional *commodities* such as nicotine (Madden et al., 2000; Shahan et al., 1999) and opioid substances (Greenwald & Hursh, 2006).

While often used in substance abuse and animal behavior, the *unit price* approach offers additional opportunities for treatments of more general types of behavior. Drawing from the previous example, a clinician working to double a child's completion of work assignments could do so using the *unit price* approach. Rather than doubling the response requirement (e.g., FR5 to FR10) to meet the goal, using a single-dimensional change, a clinician could use the *unit price* approach to modify multiple dimensions of the reinforcement schedule (e.g., FR5 to FR10 with 200% of reinforcer). In this example, this clinician could maintain the same *unit price* by raising the *cost* commensurate with the amount of the *commodity* by 200%. Referring to the earlier rice example, a 1-lb. bag of rice for $1.00 is *as good as* a deal as a 2-lb. bag of rice for $2.00. For educators and clinicians, this type of conceptualization can be helpful in planning how to increase levels of difficulty or overall amount of responding without unnecessarily weakening the demand for specific reinforcers (e.g., by increasing the price substantially). By maintaining consistent *unit prices*, the amount of work (e.g., duration of work, level of difficulty) can be increased while maintaining levels of reinforcement that have been successful previously. This approach has been helpful for systematically adjusting the "price" to consume a "commodity" in treatments (Roane, Falcomata, & Fisher, 2007), though additional research is needed to confirm its utility to all forms of reinforcers.

**1.3.5. Behavioral Economics and Individuals with Disabilities.** The incorporation of economics principles into applied behavioral science has enhanced the conceptualization of the strength, or *efficacy*, of reinforcers (DeLeon et al., 2011; Hodos, 1961; Johnson & Bickel, 2006; Roane, Lerman, & Vorndran, 2001; Roscoe, Iwata, & Kahng, 1999), the *demand* for specific reinforcers (Hursh, 1980; Kagel, Battalio, Rachlin, & Green, 1981; Rachlin, Green, Kagel, & Battalio, 1976), the efficacy of reinforcers in an *open* and *closed economy* (Hall & Lattal, 1990; LaFiette & Fantino, 1989; Roane, Call, & Falcomata, 2005; Timberlake & Peden, 1987; Zeiler, 1999), the *substitutability* of reinforcers (Green & Freed, 1993; Madden, Smethells, Ewan, & Hursh, 2007a, 2007b), and multi-dimensional reinforcement schedules using *unit price* (Allison, 1983; Foster & Hackenberg, 2004; Madden, Bickel, & Jacobs, 2000; Roane, Falcomata, & Fisher, 2007; Romero, Foxall, Schrezenmaier, Oliveira-Castro, & James, 2006). The behavioral economic approach has garnered substantial support in both basic (Hursh, 1980, 1984; Smith & Hantula, 2003; Zeiler, 1999) and applied (Audrain-McGovern et al., 2004; Epstein, Smith, Vara, & Rodefer, 1991; Johnson, Bickel, & Kirshenbaum, 2004) research but substantially less research has been translated into assessments and treatments for individuals having autism or other developmental disabilities (Kodak, Lerman, & Call, 2007; Roane, Call, & Falcomata, 2005). Despite strong face validity for the use of these approaches with children and adults with disabilities, concepts such as *demand curves*, *work output functions*, *open* and *closed economies* and other demonstrations of behavioral economics are observed relatively infrequently. At present, it is unclear to what degree that these concepts have been translated into procedures for use with children and adults with developmental disabilities.

To determine which behavioral economic approaches and procedures have and have not been translated into assessments and treatments for individuals with developmental disabilities, a systematic review of the literature was performed. This review was designed to answer the following questions: 1) which behavioral economic methods and procedures have been evaluated in assessments and treatments for individuals with developmental disabilities and 2) what ages and types of disabilities have been included in applied behavioral economic research. Based on the results of this review, we highlight the methods established in the current literature and discuss areas which could benefit from additional applied research or demonstration.

## 2. Method

### 2.1. Literature search methods

A systematic search was performed to identify publications that had incorporated behavioral economic principles (e.g., reinforcer value, demand, open- and closed-economy) in assessments or treatments for individuals with developmental disabilities. The study authors followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to systematically search, score and report study results. The databases included in the search were Scopus, EBSCOHost, ScienceDirect, PubMed, and SpringerLink. The following keywords were provided in all database queries, with Boolean operators and truncation: (1) “progressive ratio”, (2) “autism*”, (3) “disabilit*.” The study authors used the progressive ratio schedule as a term of principal interest as behavioral economic studies generally include such systematic reinforcer assessments to evaluate an individual’s overall consumption (with and without breakpoints) as levels of response effort, or *price*, are manipulated. Once the initial results of search queries were inspected, the references for included studies were surveyed and incorporated into the review if they met the criteria for inclusion. Following the initial search and review of references, hand searches were conducted for each of the journals identified in the search. Hand searches of individual journals included individual queries for following terms: “progress rati*”, “demand curve”, “open econom*”, “closed econom*”, and “unit pric*.” This was performed to determine if studies either in press or otherwise not included in the search results were suitable for inclusion in the review.

**2.2. Study selection**

In keyword searches for all included databases, initial titles and abstracts were reviewed by the first author and judged to determine if they were relevant to the research questions (e.g., included behavioral economic terms or individuals with disabilities). Full text resources were retrieved for all potential studies and the first author reviewed each methods and results section of the retrieved methods section to determine if the study met criteria for inclusion. All search procedures were repeated by the second author to ensure that search results were screened reliably and objectively. Disagreements were resolved through discussions related to the inclusion criteria until agreement on inclusion and exclusion was met, consistent with the PRISMA guidelines. The initial search results for Scopus, EBSCOHost, ScienceDirect, PubMed, and SpringerLink databases from the period between January and February 2017 were 583, 1, 77, 437, and 600 respectively.

**2.3. Criteria for study inclusion**

Single-case and group-design approaches were included in the systematic review under the condition that studies included methodology that fulfilled inclusion criteria. Studies were included if full-text resources were available, written in English, and published in peer-reviewed research outlets. Studies that included reinforcer efficacy procedures (e.g., progressive-ratio schedules, systematic comparisons of reinforcer efficacy), demand curves or work output functions (with or without elasticity metrics), open and closed economies, or unit-pricing logic as either a primary or supplemental component were included in the review. Studies that included non-human (e.g., rats, monkeys, pigeons) participants or pathologies inconsistent with developmental disabilities (e.g., addiction, gambling) did not meet the search parameters and were not included in the review.

**2.4. Types of procedures**

The methods and results sections for all included studies were examined to determine if they included procedures used in the behavioral economic literature. Reinforcer assessments such as the progressive ratio arrangement (Findley, 1958; Hodos, 1961) and other systematic variations of this arrangement (Tustin, 1994) were procedures of interest. Both single- and concurrent-operant forms of reinforcer assessments were included, as illustrated in Tustin (1994), with and without unit-pricing logic (Hursh, 1980). Beyond reinforcer assessments, analogues of open- and closed-economies (Hursh, 1980; Timberlake & Peden, 1987) and calculated demand functions and work output curves (Hursh, 1980; Allison, 1983) were also components of interest.

**2.5. Reliability and Interobserver agreement**

Studies included in the search were scored independently by the first and second study authors. Each study was scored based on the procedures included in assessments or treatments for individuals with disabilities. Studies were scored on the methods, procedures, and results as written in published works. All information was extracted from studies using a checklist that included: 1) “How many single-operant reinforcer assessments were used?”, 2) “How many concurrent-operant reinforcer assessments were used?”, 3) “Did the study compare open- and closed-economy analogues?", 4) "Was unit-pricing logic used?", 5) "How many children and adults were included?", and 6) "What types of developmental disorders were included?"

## 3. Results

The systematic review yielded twenty-one unique studies that incorporated behavior economic procedures in assessments or treatments for individuals with developmental disabilities. The initial search results produced a total of 1,698 publications. From the initial search, 98.82% of search (*n* = 1,678) results either did not include participants with developmental disabilities, focused on non-human participants (e.g., mice, pigeons) or did not utilize procedures consistent with behavioral economics. Within the twenty initial results that met inclusion criteria, 35% (*n* = 7) were duplicates and 15% (*n* = 3) were reviews on the topic, yielding a total of ten distinct studies. The reference lists of the ten included studies were reviewed for each study and individual hand searches were performed for each of the journals that contained an included study. Eleven additional, distinct studies were obtained through reference reviews and hand searches, increasing the total number of included studies to twenty-one. Each of the included studies were scored based on the specific behavioral economic approaches included in the study methods. The individual behavior economic components included in each of the studies are indicated in Table 1.

### 3.1. Assessments of Reinforcer Efficacy

This review found that most included studies utilized single-operant reinforcer assessments to measures reinforcer efficacy (*n* = 19), as shown in Table 1. In these assessments, the efficacy of an individual reinforcer was assessed either in isolation using either a progressive ratio arrangement or some other systematically varied reinforcement schedule. Single-operant reinforcer assessments (i.e., only one item assessed in isolation) accounted for most of all reinforcer assessments (*n* = 101; 85.59% of assessments). Significantly fewer studies utilized concurrent-operant arrangements (i.e., more than one item assessed at a time; *n* = 7, 31.82% of studies) and concurrent-operant reinforcer assessments composed the remainder of all reinforcer assessments (*n* = 17, 14.41% of assessments).

The studies included in the search interpreted the efficacy of a reinforcer in several ways. The strength, or efficacy, of a reinforcer was inferred by either combining the total responses that occurred at specific costs (*overall consumption*) or by instead identifying the highest price that maintained responding before consumption became zero (*breakpoint*). The breakpoint is usually met in progressive ratio schedules, as costs escalate in increasingly large increments, but may or may not be observed if only a few costs are compared (e.g., FR1 vs. FR5 vs. FR10). In systematic comparisons of fixed ratio schedules (i.e., not progressive ratio schedules), it is possible that a breakpoint may not be observed because the cost has not increased enough to significantly change consumption. In the studies included in this review, all studies included some measure of overall consumption on individual schedules and most (*n* = 15, 68.18% of studies) included breakpoints. Two studies measured overall consumption in terms of a percentage of opportunities: Kerwin, Ahearn, Eicher & Burd (1995) constructed a metric of consumption from the number of accepted bites in a feeding session and Kodak et al. (2007) used a percentage to compare consumption when concurrent options were available.

**3.2. Reinforcers in Open- and Closed-Economies**

Only two of studies in the systematic review (*n* = 2, 9.09% of studies) evaluated the effects of open and closed economies, as indicated in Table 1. While all reinforcers inevitably operate in some type of economy, only two included studies explicitly evaluated the effectiveness of reinforcers in these contexts. In these two studies, only a single study (*n = 1*, 4.45% of studies) evaluated the substitutability of a reinforcer. The two studies evaluating economy types arranged contingencies to determine the effects of being able to access reinforcement outside of a programmed contingency (e.g., open economy) and treatment conditions as normal, with reinforcement provided only for a programmed contingency (e.g., closed economy). Reinforcer efficacy was assessed in both single- (Roane et al., 2005) and concurrent-operant (Kodak et al., 2007) arrangements in both open and closed economies.

**3.3. Reinforcement Rates as Unit Prices**

The results of the systematic review revealed that only three studies (*n = 3*, 13.64% of studies) included unit price formulations (see Table 1). The unit-pricing approach, as defined in this search, was considered using procedures where a ratio was constructed and used to interpret pricing across multiple dimensions (e.g., amount of work or effort, amount of reinforcer). Borrero, Francisco, Haberlin, Ross and Sran (2007) derived a unit price and used this metric to propose schedules of reinforcement specific to the function of severe behavior and Roane et al. (2007) also used a unit price formulation, though their approach focused on using the unit price ratio to systematically increase a targeted behavior by scaling up the amount of reinforcement and, thus, increasing overall work output. Additionally, DeLeon, Fisher, Herman, & Crosland (2000) included a unit price ratio that equated rates of responding (e.g., mands, aggressive responses) to some varying degree of reinforcement to evaluate bias towards a specific type of to produce reinforcement.

**3.4. Demand Curves, Work Output Functions, and Demand Elasticity**

While nearly all studies included measures of consumption and reinforcer efficacy, only a small number incorporated demand curves (*n* = 7, 31.82% of studies) and work output curves (*n* = 7, 31.82% of studies). Both assessments can be computed from the same information (consumption and price) and were most often presented together, if included. With respect to specific reinforcer assessments and the inclusion of curve figures, single-operant assessments were used to construct most demand and work output functions (*n* = 6). Only one study used a concurrent-operant arrangement to construct these curves and functions. While demand functions were observed in several publications, only one study reported on the elasticity of specific reinforcers (e.g., $O_{max}$, $P_{max}$) in addition to breakpoints or overall consumption.

**3.5. Scope and Range of Procedures in Studies**

The results of this review indicated that the behavioral economic concepts represented in the literature for developmental disabilities are represented in ranging degrees. All included studies included some degree of reinforcer efficacy, characterized by either a single- (*n* = 19, 86.36% of studies) or concurrent-operant (*n* = 7, 31.82% of studies) reinforcer assessment. Components such as demand curves (*n* = 7, 31.82% of studies) and work output functions (*n* = 7, 31.82% of studies), assessments of open- and closed-economies (*n* = 2, 9.09% of studies), and unit pricing approaches (*n* = 3, 13.64% of studies) were substantially less represented in the applied literature. Additionally, the studies that made up the present literature in this area often contained just one or two of the behavioral economic procedures outlined in this review. The distribution of included components was as follows: One (*n* = 10, 45.45% of studies), two (*n* = 5, 22.72% of studies), three (*n* = 4, 18.18% of studies), four (*n* = 2, 9.09% of studies), and five (*n* = 1, 4.55% of studies) of the six components included in the review. No studies contained all six of the included components.

**3.6. Populations Included**

Behavioral economic procedures were applied to a range of clinical populations, as shown in Table 2. Participants were coded as described in the methods section of published works. A total of 56 children (*M* = 2.54; Range: 0-7) and 17 adults (*M* = 0.76; Range: 0-3) were included in these studies, yielding a total of 73 participants (*M* = 3.43; Range: 1-7). The specific conditions included in these samples were as follows: Autism (*n* = 44; 60.27%), Asperger Syndrome (*n* = 1; 1.37%), Attention-Deficit Hyperactivity Disorder (*n* = 2; 2.74%), Intellectual Disability (*n* = 36; 49.32%), Pervasive Developmental Disability (*n* = 3; 4.11%), Feeding Disorder (n = 3; 4.11%), Down Syndrome (*n* = 2; 2.74%), Sanfilippo Syndrome (*n* = 1; 1.37%), Smith-Magenis Syndrome (*n* = 1; 1.37%), Stickler Syndrome (*n* = 1; 1.37%), Cerebral Palsy (*n* = 1; 1.37%), Seizure Disorder (*n* = 2; 2.74%), Communication Disorder (*n* = 1; 1.37%), Fetal Alcohol Syndrome (*n* = 1; 1.37%) and Cri-du-chat Syndrome (*n* = 1; 1.37%). These findings suggest that these procedures have been used with a range of populations, though they have predominantly been used with individuals with autism spectrum disorder and/or intellectual disabilities.

## 4. Discussion

### 4.1. Present State of the Literature

Behavioral economics is an active and evolving approach to understanding individual choice and preference and offers new methods and tools that could enhance assessments and treatments for individuals with disabilities. The methods used in behavioral economics offer a fresh perspective on how reinforcers perform in complex environments and conditions. This new perspective extends our ability to predict the effectiveness of clinical elements, such as reinforcers, in complex, real-world environments. As many applied clinicians would attest, many treatments formally evaluated in clinics will often warrant additional modifications to support their use when a range of other, competing reinforcers may also be available (e.g., homes, schools, communities). While behavioral economic approaches and procedures have strong potential for use in the field of developmental disabilities, the present support for using behavioral economic approaches with these populations is still emerging.

This review found that the present literature applying behavioral economic concepts to developmental disabilities has focused predominantly on assessing relative reinforcer effectiveness. Serving as the most direct extension of stimulus preference assessments, these studies have found that highly-ranked stimuli often function as reinforcers under dense schedules of reinforcement (i.e., FR1) but may perform much less effectively on even slightly more lean schedule arrangements (Tustin, 1994; DeLeon et al., 1997). Procedures for quantifying the efficacy of potential reinforcers are well-documented in these studies but relatively less was done to evaluate individual characteristics of reinforcers.

In assessments of reinforcer effectiveness, which all the referenced studies included, few constructed demand functions or work output curves. The demand curves provided in these studies generally took the form of line graphs depicting the overall consumption of a reinforcer under increasingly lean schedules of reinforcement (e.g., as costs increase). While these demand curves often provided a means to visual compare reinforcers relatively, only one study included a means to evaluate elasticity of demand. In lieu of empirical assessments of elasticity, such as the $P_{max}$ value, the majority of included studies inferred the strength or efficacy of a reinforcer from its breakpoint. Reporting a demand curve without a measure of efficacy, such as the $P_{max}$, is potentially troublesome for several reasons. First and foremost, simply displaying a general line graph of decreasing consumption (plotted against increasing costs) has the potential for misinterpretation by readers new to behavioral economics. For example, a novice reader might assume that the most suitable “cost” to incorporate into treatment would be the leanest schedule of reinforcement (e.g., highest cost) that maintained some degree of responding before reaching a breakpoint. Second, the breakpoint is a measure that is greatly increased by the progression of increasing prices. For example, breakpoints may be observed at a very high price (e.g., FR50) largely because of the progression from a price of FR10 to FR50. It is entirely possible that a breakpoint might be observed at a much lower price (e.g., FR20) because this alternative price immediately followed the last price with some level consumption (e.g., from FR10 to FR20). While this might be successful in some circumstances, one would ideally design a contingency using a cost within the inelastic-to-elastic range of the demand curve (e.g., near the $P_{max}$). Utilizing a cost that exists in the elastic region is likely to produce lower levels of responding, produce ratio strain, and be an inefficient use of time and resources—jeopardizing a potentially effective treatment.

Despite strong relevance to generalizing treatments from controlled to more naturalistic settings, investigations of reinforcers in open and closed economies were one of least explored topics. As most clinicians in clinic and pediatric settings would attest, there are numerous challenges migrating an effective treatment and reinforcer from a controlled environment (i.e., closed economy) to a less controlled environment (i.e., open economy). While treatments established in controlled settings ultimately end up being translated into more naturalistic settings, knowledge of the demand for a specific reinforcer in an open economy could be potentially useful in planning for generalization in the initial stages of treatment development (Stokes & Baer, 1977). Similarly, only a single study evaluated the substitutability of a programmed reinforcer. As such, additional research on the demand for specific reinforcers could identify which items or activities are less likely to suffer from an open economy, and be easily substituted in the natural environment, and instead identify items or activities which may be more efficacious in these contexts.

Like open and closed economies, unit price was explored relatively infrequently. Only two studies used unit price in either the assessment of reinforcer performance or as an approach incorporated into treatment. While largely an extra dimension of the traditional reinforcement schedule, the unit-pricing approach provides an incredibly flexible means to interpret, adapt, and modify contingencies in assessments and treatments. The use of a unit price measure in treatment provides an extra dimension that clinicians can easily adjust and modify when actively developing an intervention. For example, including a unit-pricing formulation would allow clinicians to make changes to both the cost (i.e., ratio requirement) as well as the benefit (i.e., magnitude of the reinforcer, quality) components associated with the reinforcer. This permits a more flexible and adaptable approach to designing and evaluating treatments, as both the reinforcement schedule and some extra dimension of the reinforcer can be easily manipulated as necessary. Through using a unit-price approach throughout assessment and treatment, clinicians and educators could more easily maintain a consistent balance between the increasing expectations (i.e., cost) of a student and the incentives (i.e., consumption) provided.

**4.2. Implications for Future Research and Practice**

The behavioral economic approach has many applications to the field of developmental disabilities and warrants considerably more attention in the applied literature. The present literature would benefit from numerous replications and extensions of the works included in this review. For researchers in these areas, many behavioral economic concepts commonplace in basic research have yet to be fully extended to applied practices for individuals with disabilities. With respect to the concepts of demand, the literature would benefit significantly from expanding on how the elastic and inelastic ranges, and various metrics such as $P_{max}$ and $O_{max}$, for specific reinforcers could be used to determine reinforcer efficacy, rather than inferring potency arithmetically from overall consumption or by a breakpoint. In addition, measures such as $P_{max}$ and $O_{max}$ provide more robust information than breakpoints and allow researchers and applied clinicians to predict how and when the demand for a specific reinforcer is likely to weaken. In the broader sense, demand for specific reinforcers should be researched more often within both open and closed economies. Given that programmed reinforcers are likely to be used in both controlled and naturalistic settings, evaluations of reinforcer efficacy and demand for reinforcers should be assessed in both.

**4.3. Next Steps and Future Directions**

While this study employed a systematic approach to reviewing the support for applied behavioral economics in the field of developmental disabilities, some limitations warrant noting. Most of the emerging behavioral economic procedures in the area took the form of a reinforcer assessments—a type of procedure used beyond the context of behavioral economics specifically. While the authors agree that this collection of publications is representative of the current literature base, it should be noted that reinforcer assessments have been used well-beyond the publications included for a range of purposes and applications. Additionally, the authors note that most articles were gathered from nearly a single research outlet. Since many of these works emerged from a singular venue, the specific presentations and reporting of results may have been influenced by this fact to some degree.

Conflict of Interest:

The authors declare that they have no conflict of interest.

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Table 1.

*Systematic review of studies applying behavioral economics with developmental disabilities*

| Study | Single/ Concurrent Operant | Demand/ Work Functions | Closed/ Open Economy | Unit Pricing |
|---|---|---|---|---|
| Tustin (1994) | 2/3 | */* | --- | --- |
| Kerwin, Ahearn, Eicher & Burd (1995) | 3/0 | ---/--- | --- | --- |
| DeLeon, Iwata, Goh & Worsdell (1997) | 0/2 | ---/--- | --- | --- |
| DeLeon, Fisher, Herman & Crosland & Crosland (2000) | 0/2 | ---/--- | --- | --- |
| Roane, Lerman & Vorndran (2001) | 3/0 | */* | --- | --- |
| Roane, Call & Falcomata (2005) | 2/0 | */* | * | --- |
| Roane, Falcomata & Fisher (2007) | 0/0 | ---/--- | --- | * |
| Borrero, Francisco, Haberlin, Ross & Sran (2007) | 6/0 | */* | --- | * |
| Kodak, Lerman & Call (2007) | 0/3 | ---/--- | * | --- |
| Jerome & Sturmey (2008) | 3/0 | ---/--- | --- | --- |
| Francisco, Borrero & Sy (2008) | 3/3 | ---/--- | --- | --- |
| Glover, Roane, Kadey & Grow (2008) | 3/3 | ---/--- | --- | --- |
| Penrod, Wallace & Dyer (2008) | 8/0 | ---/--- | --- | --- |
| Trosclair-Lasserre, Lerman, Call, Addison & Kodak (2008) | 3/0 | */--- | --- | --- |
| Reed, Luiselli, Magnuson, Fillers, Vieira & Rue (2009) | 6/0 | */--- | --- | --- |
| DeLeon, Frank, Gregory & Allman (2009) | 12/0 | ---/--- | --- | --- |
| Tiger, Toussaint & Roath (2010) | 3/1 | ---/--- | --- | --- |
| DeLeon, Gregory, Frank-Crawford, Allman, Wilke, Carreau-Webster & Triggs (2011) | 21/0 | ---/--- | --- | --- |
| Call, Trosclair-Lasserre, Findley, Reavis & Shillingsburg (2012) | 7/0 | ---/--- | --- | --- |
| Fiske, Cohen, Bamond, Delmolino, LaRue & Sloman (2014) | 6/0 | ---/--- | --- | --- |
| Jerome & Sturmey (2014) | 6/0 | ---/* | --- | --- |
| Peterson, Lerman & Nissen (2016) | 8/0 | ---/--- | --- | --- |

Table 2

*Individuals Demographics in Systematic Review (n = 72)*

| **Disabilities** | Counts | Total Percentage (%) |
|---|---|---|
| Autism | 43 | 59.72 |
| Intellectual Disability | 35 | 48.61 |
| Pervasive Developmental Disorder | 3 | 4.17 |
| Feeding Disorder | 3 | 4.17 |
| Attention Deficit-Hyperactivity Disorder | 2 | 2.78 |
| Down Syndrome | 2 | 2.78 |
| Seizure Disorder | 2 | 2.78 |
| Asperger Syndrome | 1 | 1.39 |
| Sanfilippo Syndrome | 1 | 1.39 |
| Smith-Magenis Syndrome | 1 | 1.39 |
| Sticklers Syndrome | 1 | 1.39 |
| Cerebral Palsy | 1 | 1.39 |
| Communication Disorder | 1 | 1.39 |
| Fetal Alcohol Syndrome | 1 | 1.39 |
| Cri-du-chat Syndrome | 1 | 1.39 |
| **Age Ranges** | | |
| Total Children | 55 | 76.39 |
| Total Adults | 17 | 23.61 |

Figure 1. Hypothetical demand and work output curves

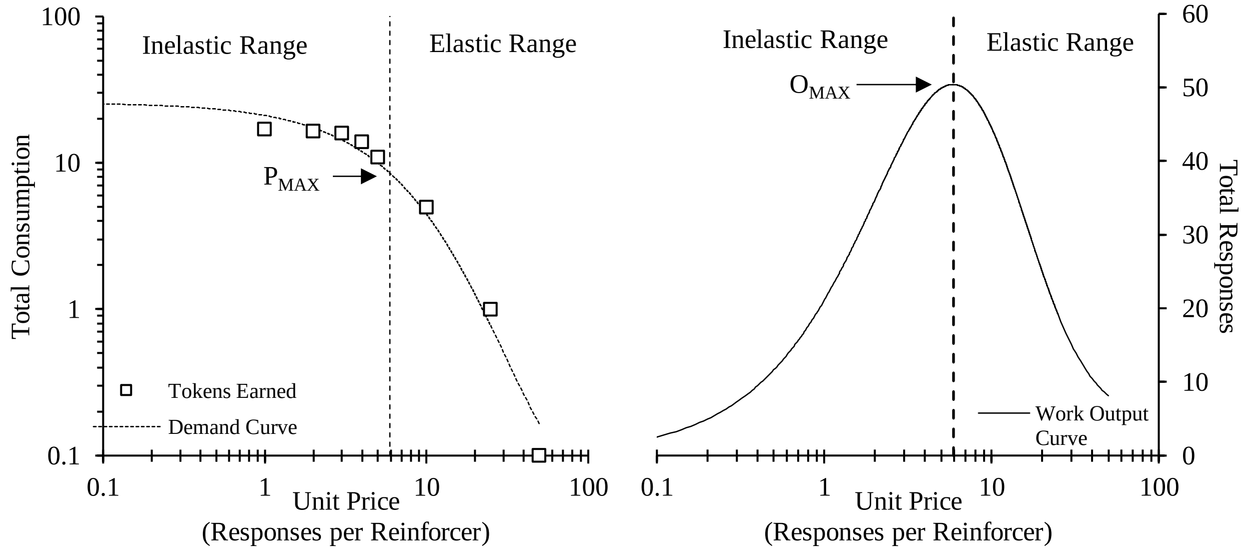

Figure 2. Differences in demand elasticity in open- and closed-economies