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Effects of Progressive Ratio Schedules on Responding Following Exposure to Varying Economies

Laura Perry Senn

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by

Laura Perry Senn

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We the undersigned committee hereby approve the attached dissertation, "Effects of Progressive Ratio Schedules on Responding Following Exposure to Varying Economies" by Laura Perry Senn.

Michael Kelley, Ph.D., BCBA-D
School of Behavior Analysis
Major Advisor

David Wilder, Ph.D., BCBA-D
Professor
School of Behavior Analysis

Catherine Nicholson, Ph.D., BCBA-D
Assistant Professor
School of Behavior Analysis

Sherry Jensen, Ph.D.
Assistant Professor of Economics
Nathan M. Bisk College of Business

Lisa Steelman, Ph.D.
Professor and Dean
College of Psychology and Liberal Arts

Abstract

Effects of Progressive Ratio Schedules on Responding Following Exposure to Varying Economies

Laura Perry Senn, M.Ed., M.S.

Major Advisor: Michael Kelley, Ph.D

In the field of behavior analysis, access to reinforcement is generally referred to as being either an open or a closed economy. However, little research exists on the varying degrees of reinforcer exposure that may occur between the parameters of "open" and "closed." The current study compares varying degrees of economies utilizing closed, 33% open, 66% open, and open economy conditions with three participants diagnosed with autism spectrum disorder. Prior to analysis, all participants completed an evaluation to determine whether their preferences remained stable over multiple sessions and whether they were sensitive to a satiation operation. Results are evaluated in terms of response rate, average break point, demand curve, and work-rate function. Overall response rates and break points were highest in the closed economy conditions for all participants. Likewise, demand curves and work-rate functions for all participants indicated the least elasticity under closed economy conditions. Implications and future directions based on these results are discussed.

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Effects of Progressive Ratio Schedules on Responding Following Exposure to Varying Economies

Contingent reinforcement consists of following a behavior with either presentation or withdrawal of a stimulus that results in an increase in the future probability of that behavior and is a fundamental principle of behavior. It has also been demonstrated as a valuable applied tool in numerous studies (e.g., Catania, 2013; Farber, Dube, & Dickson, 2016; Heffernan & Lyons, 2016; Karsten & Carr, 2009; Ortega & Feinup, 2015; Skinner, 1953). Basic researchers often demonstrate reinforcement relations using primary reinforcers (e.g., food pellets for rats; grain for pigeons) under deprivation conditions (e.g, 85% of free-feeding weight). Clinicians and applied researchers typically use a more varied array of stimuli as potential reinforcers, and employ specific assessments to choose the stimuli to deliver contingent on behavior. *Preference assessments* generally refer to a range of procedures in which a therapist provides systematic exposure to a range of stimuli with the goal of objectively identifying a potential reinforcer. The first step often involves asking caregivers or the individual themselves what he or she likes (i.e., informal interview), a formal interview [e.g., Reinforcer Assessment for Individuals with Severe Diabilities (RAIS-D); Fisher, Piazza, Bowman, & Amari, 1996], a free operant observation with duration of engagement interpreted as a measure of preference, or a variety of trial-based methods. Three of the most commonly used trial-based preference assessments are single stimulus, multiple stimulus array, and paired-choice (Cooper, Heron, & Heward, 2007).

Preference Assessments

Pace, Ivancic, Edwards, Iwata, and Page (1985) exposed participants to a *single stimulus preference assessment*, in which one stimulus was presented to individuals in each trial. The therapist provided brief access contingent on approach responses toward the presented stimulus, and removed any stimulus that was not approached. Therapists provided 5 s of access to each stimulus, and repeated the procedure until all stimuli had been presented. Results showed that all participants approached the various stimuli differentially. However, it is possible participants approached a stimulus that would not be likely to function as a reinforcer simply because it was the only option for engagement during the assessment. Researchers evaluated whether the identified preferred stimuli functioned as a reinforcer for listener skills for each participant. After comparing responses followed by contingent presentation of a high preferred (HP) and a low preferred (LP) stimulus, sessions using the HP stimulus produced higher correct responding.

Fisher et al. (1992) compared the single stimulus preference assessment method to a *paired-choice* assessment. In addition to completing a single-stimulus preference assessment using the methods of Pace et al. (1985), therapists conducted a second assessment by simultaneously presenting two stimuli at a time from the larger pool of stimuli. Over the course of the assessment, the therapist presented each item paired with every other item until all items had been presented. Contingent on an approach response, the therapist provided 10 s of access to selected items. Finally, therapists calculated the percentage of trials in which each stimulus was selected, with

a higher percentage indicating higher preference. The paired-choice assessment appeared to eliminate the false positive identification of stimuli that occurred due to the presence of only one option for engagement during the single stimulus assessment. It also provided better information about the relative preference for each item compared to all others. However, since all items identified as HP via the single stimulus assessment were also found to be HP during paired-choice, single stimulus remains a viable option for identifying preferred stimuli for individuals who have difficulty making choice selections.

Established preference assessments have individual advantages and disadvantages. Ringdahl, Vollmer, Marcus, and Roane (1997) combined the advantages of paired-choice and free-operant preference assessments to guide the treatment of three children with automatically maintained self-injurious behavior (SIB). Subjects were placed in a room and provided free access to preferred stimuli identified through paired-choice assessment. The subjects were free to engage with the stimuli or engage in any other behavior, including SIB. Researchers collected data on both engagement with stimuli and SIB. Results indicated that an environment enriched with HP stimuli may be sufficient for reducing at least one topography of SIB for two of the subjects. This was tested with both subjects and environmental enrichment alone was sufficient for reducing one subject's SIB to low levels. Results from the free-operant assessment were also used to select behaviors that could be differentially reinforced in an effort to reduce SIB. Following this treatment implementation, all three subjects displayed reduced rates of SIB.

Ringdahl et al. (1997) combined preference assessment methodology and observation of SIB to provide an objective measure of the efficacy of stimuli to compete with problem behavior. In a similar study, Roane, Vollmer, Ringdahl, and Marcus (1998) compared paired-choice and free-operant preference assessments in an attempt to identify advantages and disadvantages of each. Researchers conducted both assessments with 17 subjects diagnosed with intellectual disabilities. Results indicated that both assessments found similar preferences for only 8 of the 17 subjects. However, 11 of the 13 participants who displayed problem behavior across assessments engaged in fewer of these behaviors during the free-operant assessment. The free-operant assessment also required only 5 min in comparison to an average of 21.67 min for paired-choice. Researchers concluded that while paired-choice may provide more information on relative stimulus preference, a free-operant assessment is also a viable option for clinicians who wish to reduce time and problem behavior associated with conducting preference assessments.

Results of Roane et al. (1998) showed how preference assessments can enhance treatment, and showed how some preference assessment methods can be more time efficient than others. Similarly, DeLeon & Iwata (1996) evaluated a *multiple stimulus array* that retained the pairing of stimuli (unlike Pace et al. 1985), but was more time efficient than the paired-choice preference assessment. The *multiple-stimulus without replacement (MSWO)* preference assessment included placing an array of randomly sequenced stimuli in front of an individual. The therapist directed the individual to select one, and then provided brief access before rearranging

the stimuli for the next presentation. Multiple stimulus arrays may be conducted either by replacing the previously selected stimulus in the next array presentation (MS; Windsor, Piché, & Locke, 1994) or without replacing previously selected stimuli (MSWO). Results from all three assessment types (single stimulus, paired choice, and MSWO) indicated most of the same HP stimuli and similar ranking of preferred stimuli. Both types of multiple stimulus methods evaluated required about half the time or less when compared to the paired-choice method using the same stimuli for all seven participants. When reinforcer efficacy was tested, researchers found the MSWO was more likely to identify lower preferred stimuli that may still function as reinforcers because the highest preference items were systematically removed after each presentation. It was also noted that while multiple stimulus arrays were less time consuming, the paired-choice method may be a better option for individuals who have difficulty scanning and selecting from large arrays.

Carr, Nicolson, & Higbee (2000) conducted a study with the goal of making the MSWO assessment more efficient and to demonstrate its utility in a naturalistic context. Researchers conducted a preference assessment with three children diagnosed with autism using the methods of DeLeon and Iwata (1996) except that three stimulus-presentations were used rather than five. The reinforcing value of the highest, middle, and lowest ranked stimuli were compared in a multielement design in which each was provided contingent on emitting a target response. Results showed preference level of stimuli produced differential rates of correct responding, with the highest preferred producing the highest rate of behavior. Carr et al. also conducted additional preference

assessments using the same stimuli and procedures to evaluate results over time. Researchers noted that preference remained stable for 2 of the 3 subjects.

Other studies have been conducted to specifically evaluate the changes in preference over time (e.g., Hanley, Iwata, & Roscoe, 2006; Kelley, Shillingsburg, & Bowen, 2016). Hanley et al. noted the seemingly idiosyncratic fluctuations in preference over time in previous studies (i.e., Carr et al., 2000; Mason, McGee, Farmer-Dougan, & Risley, 1989; Zhou, Iwata, Goff, & Shore, 2001). Researchers conducted statistical analyses on these studies to determine that the stability of preference over time across participants was generally low. Hanley et al. conducted paired-choice preference assessment for leisure items with 10 adults diagnosed with developmental delay. These assessments were repeated 5 to 6 times over a 2- to 6-month period using the same stimuli each time. Results determined the preference of 7 participants remained generally stable over time. In an effort to identify factors that may influence preference changes over time, researchers selected two participants with stable preference to undergo a satiation and conditioning procedure. During satiation, the subjects were given free access to their highest ranked stimulus 2 to 3 hrs each day in which a preference assessment was not being conducted. A conditioning procedure with the lowest ranked stimuli was also conducted on these days that involved researchers pairing the stimuli with attention and preferred edibles. Results showed an increase in preference over time for the originally low-ranked stimuli and a decrease in preference over time for the originally high-ranked stimuli.

Kelley et al. (2016) replicated the methods of Hanley et al. (2006) for determining whether preference remained stable over time. Twenty-one children in an EIBI program participated in multiple paired-choice preference assessments. Assessment methods were similar to those in Hanley et al. except that edibles were included in addition to leisure items and preference assessments occurred every day rather than intermittently over the course of 2 to 6 months. Statistical analyses were completed in the same manner as Hanley et al. and results showed 16 subjects' preference remained relatively stable over time. This indicates clinicians may be able to reduce time spent completing repeated preference assessments with some individuals.

Reinforcer Assessments

Studies assessing the utility of preference assessments have often demonstrated a correlation between preference and whether a stimulus will actually function as a reinforcer (e.g., DeLeon & Iwata, 1996; Fisher et al., 1992; Pace et al, 1985). Reinforcer assessments reveal the effects of providing a stimulus contingent on a response, thus evaluating whether an increase in behavior occurs relative to a no-reinforcement baseline (Cooper et al., 2007). As in the case of preference assessments, there are also multiple approaches for completing reinforcer assessments. Some common methods for assessing reinforcer value include using a concurrent schedule, multiple schedule, or progressive-ratio schedule. A concurrent schedule involves arranging two or more reinforcement contingencies at the same time and allowing an individual to freely make responses to either. These contingencies often involve

making an arbitrary response with one of multiple sets of similar materials and a response with each set results in presentation of a different preferred stimulus. The stimulus associated with the greatest percentage of responding is considered to be the most reinforcing, but any stimulus that produces an increase in responding may be considered a reinforcer (Hagopian, Rush, Lewin, & Long, 2001; Piazza, Fisher, Hagopian, Bowman, & Toole, 1996).

For example, Piazza et al. (1996) used a concurrent schedule to assess the efficacy of preferred stimuli identified via paired-choice for four males diagnosed with multiple disabilities. Three high, middle, and low preferred items were selected for each participant based on their preference assessment results. In each session, three responses were made concurrently available. The subject could position himself inside of a square on the floor or in a chair to access one of two stimuli being compared or a control with no contingent stimuli provided. Researchers systematically compared high with middle, high with low, and middle with low stimuli. Results showed a higher level of responding for the HP stimuli for all subjects. For two subjects, the middle stimuli also produced higher responding than the low stimuli.

In an extension of Piazza et al. (1996), Hagopian et al. (2001) evaluated the reinforcing effects of stimuli identified via single stimulus preference assessment. High, middle, and low stimuli were identified for 4 subjects diagnosed with multiple disabilities. Researchers conducted a concurrent schedule reinforcer assessment using the same methods and category comparisons as Piazza et al. Their results showed that

the HP stimuli produced the highest responding and middle preference stimuli produced higher levels of responding than LP stimuli for all subjects.

In contrast to concurrent schedules, when response options are available simultaneously, multiple-schedule reinforcer assessments arrange two or more alternating reinforcement contingencies, and include schedule-correlated stimuli. For example, a green light may be paired with the availability of a reinforcer while a red light is paired with extinction. If a stimulus functions as a reinforcer, responding will be higher under the signal for availability (Pierce & Cheney, 2013). The dependent variable is typically depicted as response rate (e.g., Nevin, 1974; Orlando & Bijou, 1960; Saini, Miller, & Fisher, 2016; Shrimp & Wheatley, 1971). In practice, therapists might alternate a contingent reinforcement condition with an extinction or noncontingent reinforcement condition. If responding is elevated when a stimulus is provided contingently, this stimulus is said to have reinforcing value (Cooper et al., 2007; Pierce & Cheney).

Multiple-schedule reinforcer assessments were used by Cividini-Motta & Ahearn (2013) to evaluate treatment for prompt dependency with four subjects diagnosed with ASD. Researchers alternated extinction with reinforcement three times in each component sequence. Extinction always occurred before reinforcement and each component was paired with colored paper. Extinction lasted 5 min, but only the last 1 min of responding was scored to eliminate influence of any extinction bursts. Reinforcement lasted 1 min and subjects were provided a reinforcer following each target response. This was done for three different reinforcers and researchers identified

a high and medium reinforcing stimulus based on responding during the reinforcement component. Researchers then used these stimuli to provide differential reinforcement for independent versus prompted responding on a matching task. All subjects reached mastery through use of both the high and medium reinforcing stimuli.

Multiple-schedules have also been used to assess reinforcer efficacy during functional communication training (FCT; Betz, Fisher, Roane, Mintz, & Owen, 2013; Fisher, Kuhn, & Thompson, 1998; Greer, Fisher, Saini, Owen, & Jones, 2016, Hanley, Iwata, & Thompson, 2001). Fisher et al. taught two children from an inpatient clinic for severe behavior to emit a communicative response only in the presence of a discriminative stimulus under a multiple-schedule. This signal of reinforcer availability was then used during clinical treatment in which each subject underwent FCT training combined with extinction of problem behavior. This resulted in appropriate communicative responses that were under the control of a specific, therapist-controlled stimulus as well as a reduction of problem behavior to access reinforcement whether or not the discriminative stimulus signaling reinforcement availability was present.

Betz et al. (2013) conducted a similar study using multiple-schedule training to facilitate schedule thinning during FCT training with four children undergoing treatment for severe problem behavior. First, subjects were taught to emit an appropriate communicative response to a therapist who then provided access to an HP stimulus. Next, researchers introduced a 60/60 multiple-schedule to teach that reinforcement would be available only in the presence of a discriminative stimulus.

Betz et al. compared rates of responding during the multiple-schedule with a mixed scheduled (reinforcement availability was the same, but no discriminative stimulus used). The multiple-schedule produced highly differentiated responding during the reinforcement and extinction components whereas little differentiation occurred during the mixed schedule. After this discriminative control had been established, researchers attempted a rapid shift to a thinner, 60/240 multiple-schedule. The discriminative stimulus maintained control over communicative responses for all subjects indicating that discriminative signal training could be used to thin FCT reinforcement schedules more quickly.

Preference and Reinforcement Efficacy

Results of various studies suggest that preference does not necessarily indicate reinforcing value (Green, Reid, Canipe, & Gardner, 1991; Paclawskyj & Vollmer, 1995). In fact, some research shows that lower preferred stimuli might function as reinforcers in some circumstances (e.g., Francisco, Borrero, & Sy, 2008; Penrod, Wallace, & Dyer, 2008; Roscoe, Iwata, & Kahng, 1999; Taravella, Lerman, Contrucci, & Roane, 2000). Roscoe et al. found that when HP and LP stimuli were available on a concurrent schedule, subjects allotted the majority of responding to access HP stimuli. When only one schedule with responding that produced the LP stimulus was introduced, 4 of their 8 participants engaged in increased responding relative to baseline levels. Likewise, Taravella et al. found that HP stimuli tend to overshadow LP stimuli rankings during paired-choice preference assessment. However, when tested separately LP effectively increased responding for both subjects in their study.

In summary, the extant research suggests that using preference assessments increases the probability of identifying stimuli that will function as reinforcers in the context of an intervention (DeLeon & Iwata, 1996; Fisher et al., 1992; Pace et al, 1985). However, reinforcer assessments generally demonstrate functional relations between a response and the contingent delivery of some stimulus, and thus increase the probability of selecting a stimulus that will support responding (Skinner, 1953). Identifying multiple reinforcers can be beneficial for creating more successful individualized programming as rotating multiple reinforcers has been found in some cases to produce higher rates of responding than continuously using a single reinforcer (Keyl-Austin, Samaha, Bloom, & Boyle, 2012; Milo, Mace, & Nevin, 2010). Together, this information makes it advisable to also complete a reinforcer assessment of preferred stimuli before relying on them for use in behavior change procedures.

Progressive-ratio Schedules

Progressive ratio (PR) arrangements, one of the focuses of the current study, involve assessment of a single-preferred stimulus that may be accessed by responding under incrementally larger response requirements either over the course of sessions (e.g., Tustin, 1994) or on a within-session basis (Roane, Lerman, & Vorndran, 2001). Response rates typically increase as schedules become progressively thinner until responding reaches an asymptote and then begins to decrease. The *break point* is the last schedule requirement completed to access reinforcement. Higher break points for stimuli indicate that they are more potent reinforcers (Roane, 2008). Progressive ratio

reinforcer assessments have been shown to successfully predict whether a reinforcer will have applied use in behavior change programming (e.g., DeLeon et al., 2011).

Roane et al. (2001) used progressive-ratio schedules to evaluate the reinforcing efficacy of preferred stimuli for four teenagers with developmental delays. A paired-choice preference assessment identified two stimuli chosen on an equal percentage of trials. Both stimuli were then assessed separately on a PR schedule in order to determine which was more durable under increased response requirements (i.e., which functioned as a more potent reinforcer). All participants responded with a higher break point for one of the two stimuli assessed. This demonstrated that even though they were ranked equally during the preference assessment, the stimuli did not have equal reinforcing efficacy as schedule requirements increased.

Roane et al. (2001) followed these findings with an application to reduce the problem behavior of three of their original participants. The researchers provided noncontingent reinforcement (NCR), differentially reinforced alternative behaviors (DRA), and differentially reinforced other behavior (DRO) with both highly reinforcing (HP) and lower reinforcing (LP) stimuli from the assessment above, allowing them to make nine total treatment comparisons among their participants. When the HP and LP stimuli were compared under the NCR treatment condition, two participants emitted less problem behavior when an HP stimulus was used versus an LP stimulus. One of these participants also emitted less problem behavior when provided an HP stimulus under the DRA treatment. These results indicate that for

some individuals, HP stimuli identified during reinforcer assessment will be the most effective reinforcers for applied programming.

Francisco et al. (2008) evaluated the specific effects of PR schedules on responding to HP and LP stimuli. These researchers used a paired-choice preference assessment to identify HP and LP stimuli for three children with developmental delays. They first completed a concurrent schedule in which a single response with one set of materials resulted in the HP stimulus and a response made with another set of materials resulted in the LP stimulus. Results showed a higher level of responding for the HP stimulus for all participants. Additionally, they arranged a condition in which only one response was available to the participant which resulted in the LP stimulus. This resulted in an increased level of responding for two of the participants. In the second part of their study, Francisco et al. arranged the same concurrent schedule with these two participants except that responses were now reinforced on PR schedules that operated independently for each stimulus. The participants once again allocated most of their responding to the HP stimulus. A condition in which only one response was available and resulted in the LP stimulus was also introduced in the second part of this study, except that it was also placed on a PR schedule. Results showed response persistence over the course of sessions with both participants demonstrating that LP stimuli can function as effective and durable reinforcers when not in direct competition with HP stimuli.

In a similar study, Penrod et al. (2008) performed an evaluation of LP stimuli provided under PR schedules with four children who had either autism or ADHD.

These researchers identified HP and LP stimuli for each child using both single stimulus and paired-choice preference assessments. In the first condition, a single response resulted in stimulus presentation throughout the entire session. Responding increased across all participants during both HP and LP presentations. The condition was then repeated using a PR schedule for responding instead. While responding persisted for all participants during these conditions, three allocated more responding to and had a higher break point in the HP stimulus condition. However, these break point differences were somewhat minimal. Penrod et al. also examined cumulative records of responding across participants and found that HP reinforcers tended to result in less pausing between responses. Therefore, it may be more beneficial for practitioners in terms of efficiency to use HP over LP stimuli even though both produce similar break points.

DeLeon, Frank, Gregory, and Allman (2009) also examined stimulus value under PR schedules. Three patients with behavior disorders were provided with a paired-choice preference assessment to determine HP, LP, and medium-preferred (MP) stimuli. Sessions using a PR schedule of reinforcement were conducted individually with each of these stimuli. All participants had a higher break point when HP stimuli were used as compared to LP and three had higher break points for HP stimuli compared to MP. The MP stimuli also resulted in higher break points as compared to LP stimuli for three participants. In addition to demonstrating a correlation between higher levels of preference and greater persistence of responding

under increased schedules, DeLeon et al. provided evidence that the overall continuum of preference is correlated with corresponding levels of reinforcer potency.

Behavioral Economics

Green and Rachlin (1975) first used the term "economic effect" to describe pigeons' behavior that was the result of learning history rather than biological influence. This eventually gave rise to the study of behavioral economics which applies basic economic concepts and principles to individual responding to predict, control, and analyze behavior (Pierce & Cheney, 2013). Utilizing economic framework has allowed for more parsimonious explanations of behavior involving multiple variables, measuring features of reinforcement, and conceptualizing how reinforcers affect behavior (Bickel, Green, & Vuchinich, 1995).

The use of progressive ratio schedules is one way to examine behavioral economic concepts related to reinforcement. One of the concepts that will be a focus of the current study is the *demand curve*. A demand curve is created when the amount of reinforcers consumed is plotted at varying "prices," or the amount of response effort required to obtain the reinforcer. A PR schedule allows an easy method for obtaining these variable values to create a demand curve. Demand curves also reveal the *elasticity* of a reinforcer. Elastic demand for a reinforcer occurs when small increases in price result in large decreases of consumption. Inversely, inelastic demand means that consumption remains relatively unaffected by price increases (Hursh, 1980; 1984). A flatter demand curve due to continued responding as price increases indicates less elasticity (Tustin, 1994). Another concept related to demand curves is

work-rate, which is the rate of responding (work) emitted as price increases (Tustin, 1995). Thus a steep work-rate curve indicates less elasticity.

Though the concepts of demand curves and work-rate have been well established in basic research (Hursh 1980, 1984; Tustin, 1995), they have been the subject of limited translational and applied research. Tustin (1994) performed a study utilizing these concepts with three adult participants who had intellectual disabilities. The participants pressed video game controller buttons in each experimental condition to access one of four types of sensory stimuli via a television or to access therapist attention. The stimuli were presented on a fixed-ratio (FR) schedule in some conditions and on a PR schedule in others. Subject 1 was exposed to one stimulus contingency in each condition, both under a PR schedule. Tustin then plotted the demand curve for each of these stimuli that showed a higher number of reinforcers earned when combined audio-visual reinforcement was earned as opposed to attention under a PR schedule. Using the same set of data, Tustin also plotted a work-rate function that showed greater responding for the audio-visual reinforcement in relation to attention under a PR schedule. Together, these results demonstrated that demand curves and work-rate functions are inversely related and produced similar indications of reinforcer efficacy.

Subjects 2 and 3 were exposed to concurrent schedules of reinforcement and demand curves for their responding were also plotted. For Subject 2, the schedule for auditory reinforcement or attention progressed while the schedule for visual reinforcement remained fixed. An increase in response requirements produced a

decrease in the amount of auditory stimuli earned. At the same time, the amount of visual reinforcement earned increased. Similar results were produced when attention was compared to visual reinforcement, indicating it acted as a substitute for both auditory stimulation and attention. Results from this participant suggest that the availability of similarly preferred stimuli should be considered when using reinforcement as a behavior change agent. Subject 3 was presented with concurrent PR schedules for visual and audio-visual stimuli. During low response requirements, higher responding was allotted to the visual stimuli. However, as the requirements increased this reversed with higher responding associated with the audio-visual stimuli instead. These results indicated that original preference, as identified via common preference assessment methods, reversed for stimuli as response requirements increased.

In the previously discussed study by Roane et al. (2001), demand curves and work-rate were evaluated in addition to response rate prior to application. All participants displayed a consistently higher number of HP reinforcers earned across increasing schedule requirements in comparison to LP reinforcers under the same requirements. When evaluated separately, the demand curve for each reinforcer showed a decrease in reinforcers earned as the schedule progressed. When work-rate functions were compared, each participant engaged in more responses under the PR schedule for the HP reinforcer compared to the LP reinforcer. When work-rate functions were evaluated independently, responses generally increased initially during

low PR requirements, peaked, and then began to decrease as the response requirement grew larger.

Open and Closed Economies

Economies can typically be described as either *open* or *closed.* An open economy occurs when a reinforcer is available outside of the experimental context while a closed economy occurs if reinforcers can only be obtained by emitting a target response within experimental sessions (Hursh 1980; 1984). Reinforcer demand under open economies tends to be more elastic, likely due to alternative availability of the reinforcer (Hursh, 1984).

Several studies have been conducted that compared responding following an establishing operation that could be interpreted similar to that of open and closed economies (e.g., Fragale et al., 2012; Kodak, Lerman, & Call, 2007; McComas, Thompson, & Johnson, 2003; O'Reilly et al., 2012; Rispoli et al., 2011). In one of these studies, O'Reilly et al. evaluated mand responding for three children following a 24-hr period without access to a reinforcer (closed economy) and access to a reinforcer until it was rejected immediately before session (open economy). A leisure item used as the reinforcer for each participant was identified as highly preferred based on a series of five MSWO preference assessments conducted prior to the evaluation of presession access. In addition, the experimenters evaluated only previously mastered mands in order to eliminate differences in responding due to learning. Results indicated that all participants engaged in higher levels of manding following exposure

to the closed economy, with little to no responding occurring following open economy exposure.

Similarly, Fragale et al. (2012) also evaluated the effects of presession exposure to leisure items on manding behavior of three children. These experimenters also identified HP items through MSWO preference assessment. They also completed a communication assessment prior to evaluation of presession exposure in order to identify indicators of satiation for each participant (e.g., pushing an item away or saying “no”). During subsequent trials, these behaviors were used to determine satiation and incorporated into termination criteria for sessions. During the experimental evaluation, participants were either exposed to their HP reinforcer immediately before session until rejection behavior occurred or they were restricted from accessing this reinforcer at least 23 h before session. This resulted in a higher level of previously mastered mands with all participants following the period with no presession access. Further, the experimenters replicated this result across different environments and with unfamiliar therapists.

Rather than leisure items, McComas et al. (2003) used access to adult attention rather than leisure items to evaluate differences in responding following presession exposure to a reinforcer. They also sought to decrease problem behavior responses rather than increase a functional response. Experimenters first completed a functional analysis with each participant to determine a relation between problem behavior and the delivery of attention. Participants were then exposed to one of two 10-min conditions in which they were either provided continuous adult attention or no adult

attention immediately before session. During each session, participants were directed to work on an independent task and the therapist recorded instances of problem behavior. All participants engaged in little to no problem behavior following presession exposure to attention.

Rispoli et al. (2011) also sought to reduce problem behavior by exposing participants to a functional reinforcer before session. Experimenters performed a functional analysis with two children and determined each participant would engage in problem behavior in order to access specific leisure items. After this, participants were either provided continuous access to these items immediately before session or no access to the items for at least 2 hr before session. Each session consisted of a period of independent academic work in a classroom setting. Lower levels of problem behavior were also recorded for these participants following presession access to reinforcers.

Kodak et al. (2007) evaluated responding following access to reinforcers after session rather than before. Experimenters exposed three children with developmental delays to PR schedules when reinforcers were provided non-contingently after session and when they were not. After completing a paired-choice preference assessment to determine two HP stimuli, participants were instructed to choose from two sets of math problems that were each associated with one of the stimuli. In the first condition, the first- ranked stimulus was placed on a PR schedule while the second-ranked stimulus remained on a fixed ratio (FR) schedule (closed economy). The second condition was conducted in the same manner except that the participant received

access to the first-ranked stimulus immediately following session (open economy; the condition change was signaled by a change in poster board color on the work table). All participants engaged in more responses when post session access was not available and break points for stimuli in this condition were nearly twice as high.

Other such studies evaluating responding following establishing operations have manipulated various parameters of exposure to stimuli rather than simply taking a dichotomous approach. These manipulations involve exposure to varying degrees of reinforcement access provided before session (McGinnis, Houchins-Juárez, McDaniel, & Kennedy, 2010; O'Reilly et al., 2009; Sy & Borrero, 2009), establishing and abolishing operations with HP and LP stimuli (Davis, Kahng, & Coryat, 2012; Klatt, Sherman, & Sheldon, 2000), and measurement of responding at progressive time increments since presession access (Kelley, Shillingsburg, & Bowen, 2017).

O'Reilly et al. (2009) measured the problem behavior of two boys following either brief access, no access, or satiation with leisure items before session. A functional analysis was performed with each participant and it was determined that problem behavior was maintained by access to specific leisure items. During the evaluation of presession exposure, participants were exposed to one of three conditions before each session. In the brief access condition, they were provided 5 min of continuous access to their identified leisure item. In the no access condition, this item was withheld for at least 8 hr prior to session. In the satiation condition, participants were provided continuous access to leisure items until they displayed rejection behavior. Each experimental session was analogous to a tangible functional

analysis session in which a participant was provided access to their reinforcing leisure item following each instance of problem behavior. While low levels of problem behavior were recorded following satiation, the brief access and no access conditions resulted in similar, higher levels of problem behavior during session.

McGinnis et al. (2010) performed a similar evaluation using varied reinforcer delivery schedules prior to session rather than manipulating total continuous access time. Three boys whose problem behavior was demonstrated to be maintained by social attention via functional analysis participated in this study. Each presession period was 45 min and was followed by a 15-min session that resembled a functional analysis attention session to determine the reinforcing effect of attention on problem behavior. In presession periods, participants were exposed to either no attention, 5 s of attention on a fixed-time (FT) 120-s (sparse) schedule, or 5 s of attention on a FT 15-s (dense) schedule. Results for all participants showed that problem behavior occurred at the highest levels following the presession condition of no attention. Additionally, both the dense and sparse schedules of attention before session produced similar reductions in problem behavior.

Sy and Borrero (2009) performed a parametric analysis of exposure time to reinforcers prior to session using both edible and nonedible stimuli with two children. Prior to this evaluation, a preference assessment was conducted with each participant to determine both an edible and leisure item to be used as reinforcers during experimental sessions. Each reinforcer was evaluated separately following presession exposure of either small, medium, or large durations of access. The length of access

times for each participant and reinforcer was determined following an assessment to determine how much was typically consumed when provided 15 min of free-access. In each session, participants were provided a small bite of edible or brief access to a leisure item following correct responding to an academic task. Results for the use of edible reinforcers showed variable responding across all experimental conditions. All conditions for both participants had a higher level of responding compared to a baseline with no presession access with the exception of the large duration condition for one participant. Results for the nonedible reinforcers also showed variable levels of responding across all conditions. In addition, both participants' responding increased in all conditions compared to baseline with no presession access.

Rather than manipulating the amount of presession exposure to a reinforcer, Davis et al. (2012) and Klatt et al. (2000) compared the effect of presession exposure to both HP and LP reinforcers. Davis et al. provided access to HP and LP leisure item reinforcers to a child with autism contingent on correct mands following a period of either deprivation or satiation. Deprivation periods consisted of no access to the reinforcer 2 to 3 days before session and satiation periods consisted of continuous access to reinforcers immediately before session until the participant ceased further interaction. An overall higher level of responding occurred for both the HP and LP reinforcers following deprivation periods. However, while responding remained stable and high for the HP item over multiple sessions, responding for the LP item decreased over multiple sessions despite presession periods of deprivation.

Klatt et al. (2000) compared the level of engagement with HP and LP leisure items following periods of deprivation for three men with developmental disabilities. Experimenters evaluated engagement with HP items after 15 min, 2 hr, or 1 to 4 days of deprivation. Engagement with LP items was evaluated only after 1 to 4 days of deprivation. Results showed a low level of engagement with HP items following the 15-min deprivation time. Average engagement with HP items increased incrementally following the 2 hr and 1 to 4 day deprivation periods. Engagement with LP items following 1 to 4 days of deprivation was consistently lower than engagement with HP items following the same amount of deprivation time.

Kelley et al. (2017) examined shift in preference over time following exposure to a satiation operation. During baseline, experimenters completed an MSWO preference assessment with three children. Participants then underwent a satiation operation in which they were given free access to three times a serving size of their most highly preferred edible. An MSWO was then repeated at progressive time increments immediately after satiation to determine the preference rank of the HP item at each time interval. This resulted in an incremental increase in preference rank at each time increase, indicating that satiation and deprivation occur on a continuum rather than dichotomously.

Roane, Call, and Falcomata (2005) performed the first applied evaluation that explicitly compared responding under open and closed economies. Two teenagers with developmental disabilities underwent a paired-choice preference assessment to determine a HP stimulus, followed by a preexperimental observation with this

stimulus. This observation was completed in an effort to determine a baseline of consumption similar to that of the free-feeding weight that had been used previously with animal subjects in basic research on open and closed economies. Participants were observed for a 5-hr period while a therapist recorded the cumulative duration spent engaging with the stimulus (television or videogame). Access to these stimuli were restricted to 75% of baseline consumption for the remainder of the study, a level analogous to those used in basic research.

A PR schedule was used with each participant under two conditions. The amount of reinforcement provided was yoked to the amount of schedules necessary to produce reinforcement (i.e., 2 responses resulted in 20 s access, 4 responses resulted in 40 s, and so forth). This was done based on previous research showing that responding will persist under greater requirements if reinforcer magnitude also increases (i.e., unit price adjustments). It was also based on the existing recommendation that practitioners deliver reinforcement proportionally to the amount of response effort required. Under the open economy condition, any portion of the daily allotted consumption amount that was not earned in session was provided to the participant afterward with no response requirement. The closed economy condition was conducted in the same manner except that no post-session access was provided.

Roane et al. (2005) evaluated the results using the frequency of responses, work-rate functions, and demand curves. For both participants, response frequency increased from baseline during the open economy condition and further increased during the closed economy condition. The work-rate function for both conditions

initially overlapped under lower PR requirements, but began to separate as the response requirement grew. In both cases, the closed economy resulted in a higher work-rate function as compared to the open economy. Similarly, the demand curves overlapped for both participants under lower PR requirements and separated as the requirements increased. The demand curves for both participants indicated that more reinforcers were earned under the closed economy condition. This provides support to basic research findings that open economies result in more elastic reinforcer demand (Hursh, 1984).

Purpose

The overarching purpose of this study is to evaluate the convergence of behavioral economics and motivation beyond the binary extremes of *open* and *closed* economies. The proposed study will utilize established methods of preference and reinforcer assessments (i.e., MSWO and progressive ratio). We will extend the results of previous research (e.g., Roane et al., 2001; Roane et al., 2005) by comparing HP using a PR schedule in the context of open and closed economies. We will also incorporate both past basic research and recent translational research (e.g., Kelley et al., 2017) to demonstrate the dynamic interaction of economy type and response rates. That is, we hypothesize that response rates and reinforcer elasticity will co-vary with degrees of economy openness. Evaluation measures will include frequency of responding, work-rate functions, demand curves, and break points to demonstrate relative elasticity and response rates.

Method

Participants and Setting

Six children diagnosed with autism spectrum disorder (ASD) participated in the study. Dalton was 3-year-old boy and scored within Level 3 (138 points) of the Verbal Behavior Milestone Assessment Placement Program (VB-MAPP; Sundberg, 2014). Evan was a 3-year-old boy and scored within Level 3 (143 points) of the VB-MAPP. Simon was a 3-year-old boy whose scores were splintered across all levels of the VB-MAPP (56 points). Morris was a 4-year-old boy and scored within Level 3 of the VB-MAPP (151.5 points). Miles was an 8-year-old boy and scored in the moderately low range on the Adaptive Behavior Composite of the Vineland Adaptive Behavior Scales, Second Edition (Vineland-II; Sparrow, Cicchetti, & Balla, 2005). Sherry was an 8-year-old girl and scored in the low range on the Adaptive Behavior Composite of the Vineland-II. All sessions took place at an autism treatment clinic in a therapy room with no other children present. Sessions were conducted at a child-size table once per day, one to four days per week.

Interobserver Agreement

A second, independent observer collected data for at least 20% of trials during all progressive ratio sessions (20% for Evan and Miles; 21% for Morris). Interobserver agreement was calculated using a total agreement method in which the smaller number of observer responses is divided by the larger number of observer responses. This is then multiplied by 100 to obtain a percent of agreement for each session (Johnston &

Pennypacker, 2009). The average percentage of agreement for Evan, Miles, and Morris was 98.5%, 93.3%, and 99.5%, respectively.

Preference Stability

Each participant underwent an MSWO (DeLeon & Iwata, 1996) preference assessment to determine potential reinforcers to be used in this study. Preference assessments are commonly used to identify stimuli that may function as reinforcers for an individual and to determine the relative value (high or low) of preference for those stimuli (Cooper et al., 2007). Preference assessments for each participant included edibles chosen based on therapist or caregiver input. Each participant was allowed to sample one small piece of each edible prior to beginning the assessment to decrease the likelihood they would pick an edible based on novelty alone. After this, 4 to 11 items were presented equidistant from each other in front to the participant. The therapist instructed the participant to select one item which the participant was then allowed to consume. The previously selected item was not replaced in the array once chosen. This pattern of selection continued until all items present were consumed.

A minimum of four MSWO sessions were completed with each participant in order to determine whether their preference remained stable over multiple sessions. If a participant's choices remained stable over multiple sessions, an HP edible was selected based on preference across MSWO sessions. The therapist then conducted a preexperimental observation to determine sensitivity to satiation. If their choices did not remain stable, they were eliminated from the remainder of the study.

Preexperimental Observation for Sensitivity to Satiation

Participants underwent a series of preexperimental observations to determine whether they were sensitive to satiation with their preferred edibles and to determine a "free feeding" level of consumption. Basic studies involving non-human animals often limit consumption to a percentage of a baseline or "free-feeding" level (e.g., Catania & Reynolds, 1968). Roane et al. (2005) developed a technique that provided an analogous method for determining the baseline level of consumption for leisure items that would be used as reinforcers. Experimenters utilized a modified version of this technique to establish a baseline free-operant level of consumption by giving each participant free access to a preferred item during a 1-hr session with no demands. The original 5-hr period used by Roane et al. was reduced to 1 hr in order to minimize the amount of time taken away from clinical therapy. The available amount of edibles was limited to three times a serving size per session consistent with Kelley et al. (2017). Edibles were weighed pre- and post-session to determine the total amount consumed. Each observation ended when 1 hr had elapsed, the entire available amount of edible was consumed, or the participant did not consume the edible for 10 consecutive min. In addition, an MSWO was conducted before and after each observation to determine whether a shift in preference occurred following consumption similar to Kelley et al. (2016).

Participants were determined to be sensitive to satiation if their pre- and post-session MSWO showed greater than a one-item shift in preference rank. If a participant displayed sensitivity to satiation, a total of three observation sessions were

completed and consumption was averaged across sessions to find a daily open economy allowance. An exception was made for Miles in which only two observation sessions were completed due to time constraints. Throughout the remainder of the study, each participant's access to their HP edible was restricted outside of consumption during PR assessments. If a participant was not sensitive to satiation, they were eliminated from the remainder of the study.

Evaluation of HP Stimuli under Open, Varying, and Closed Economies

The target response for each participant was a mastered skill and was chosen based on current skill maintenance needs as determined by the participant's clinical case manager or caregivers. Three participants completed evaluation of HP stimuli under open, varying, and closed economies: Evan, Miles, and Morris. Evan and Miles' target response was sorting picture cards of non-identical matching objects (exemplars: dogs, cats, birds, cups, bowls, and spoons). Morris' target response was sorting picture cards by category (exemplars: animals, people, toys, vehicles, foods, and clothing). In each session, the participant sat at the table next to the therapist. The therapist placed six exemplar cards on the table in front of the participant. A stack or small box of additional picture cards was placed to the side of the exemplar cards within reach of the participant. A correct response occurred when the participant took a card from the stack or box and placed it on the matching exemplar card. If the participant placed the card on an incorrect exemplar, the therapist removed the card and placed it on the table in front of the participant. If the participant made three incorrect attempts to place the same picture card, it was removed and the participant

was allowed to select another card to sort. Participants did not have access to experimental stimuli outside of experimental sessions.

A baseline level of responding was established for each participant during a 10-min session. The therapist stated, “Here are some cards to sort. You can sort as much or as little as you want.” The therapist provided no differential consequences for completing the target response and refrained from any further interaction with the participant during the session. Following baseline, the participant underwent one of the presession economy exposures described below before each session.

Open economy. Sessions began with the therapist providing the participant free access to their HP edible up to his or her daily allowance or until 5 consecutive min elapsed with no consumption. Next, the therapist stated, “Here are some cards to sort. You can sort as much or as little as you want. At first, I’ll give you one piece of [HP edible] for sorting one card. If you keep working, you will have to sort more cards each time, but I will also give you more [HP edible] each time.” Throughout the session, the therapist provided reinforcement according to a progressive ratio response schedule.

Open economy-66%. Sessions were conducted in the same manner as the open economy condition above except that the participant’s daily allowance was reduced to 66% of the original amount.

Open economy-33%. Sessions were conducted in the same manner as the open economy condition except that the participant's daily allowance was reduced to 33% of the original amount.

Closed economy. Sessions were conducted in the same manner as the open economy condition except that the participant received no access to the preferred stimulus before session.

Progressive ratio response requirements. The same PR schedule was used during each condition except baseline. As in Roane et al. (2005), the amount of reinforcement provided at each increment of the ratio schedule was yoked proportionally with the amount of response effort required. The PR schedule began at a requirement of one response that resulted in the delivery of one small piece of an edible. Following reinforcement twice at the same ratio level, the schedule progressed by multiples of two so that two more responses were required at each step and the amount of edible was increased by one, starting with the second PR step (i.e., PR 1/1, PR 2/ 1, PR 4/ 2, PR 6/ 3, PR 8/4, etc.). Each session continued under this PR schedule until the participant reached an amount of reinforcement equal to their daily allowance, 5 consecutive min elapsed without responding, or session time reached a total of 20 min. An exception to this PR schedule was made for Morris following exposure to the schedule described above. No differentiation occurred across conditions, therefore each PR step was completed only once per session rather than twice before progressing. It was hypothesized that this would help induce ratio strain and produce differentiation across conditions.

Two exceptions were made to the daily open economy allowance and selection of HP edibles during evaluation of varying degrees of economy. Following an adjustment to Morris's PR schedule, there was still little differentiation among conditions. It was hypothesized this may have been due to long-term shifts in preference, therefore an MSWO was completed immediately before each session to determine the HP item to use for that day. Items presented in the MSWO always consisted of the same edibles originally presented in the preference stability assessment and were also restricted outside of experimental sessions. Three times a serving size was also made the daily allowance for all edibles, including the previously determined HP edible, since determining a "free-feeding" amount for all items would be too time consuming within the current study. It was determined that this method of selecting an HP edible was likely more effective than the previous method used. Consequently, this method was used for all PR sessions with Miles, as well.

Data Analysis

A multielement design was used to evaluate the effects of varying degrees of an open and closed economy on HP stimuli. This design was chosen because it reduces the impact of sequence effects and generally shows treatment effects more readily (Kazdin, 1982). Four measures were used to evaluate the data in this study. One, rate of responding in individual sessions under each progressive ratio schedule requirement served as the primary dependent variable. Two, a work-rate function was calculated by adding the response rate of all sessions under each reinforcer schedule

requirement and dividing this by the number of sessions in which this schedule was in effect to find the average response rate under each schedule requirement (Roane et al., 2001; 2005). Three, a reinforcer-demand curve was constructed for each participant by adding the total number of reinforcers earned in all sessions under each reinforcer schedule and then dividing this by the number of sessions this schedule was in effect to produce the average number of reinforcers earned under each requirement (Roane et al., 2001; 2005). Finally, the average break point was calculated for each economic condition by adding the break point for all sessions under that condition and dividing this by the number of sessions the schedule was in effect (Roane et al., 2001).

Post-Experimental Analysis

Following the evaluation of varying degrees of economy, Morris and Miles completed a post-experimental analysis. Results for both participants were relatively undifferentiated during exposure to varying economic degrees and it was suspected this may be due to carryover effects that sometimes occur when using a multielement design. Post-experimental analysis was identical to the evaluation of HP stimuli under open, varying, and closed economies except that the 33% and 66% open economy conditions were eliminated. This was done to increase the likelihood that the participant could discriminate between conditions and reduce overall carryover effects. Post-experimental analysis with Evan was not possible due to withdrawal from the study.

Results

Preference Stability

Results for preference stability is displayed in Figures 1-4. Dalton initially completed an 11-item MSWO preference assessment. The top panel in Figure 1 shows the undifferentiated results of this assessment. It was suspected the overall array may have been too large to identify preference for any particular item. Therefore, the array size was reduced to four items and the procedure to determine preference stability was repeated. The bottom panel of Figure 2 shows the results from this assessment with Skittles (average rank of 1.2) ranking highest in preference across sessions. Evan initially completed a 9-item MSWO preference assessment. These results are found in the top panel of Figure 2 and show relatively stable preference across sessions with peach rings (average rank of 2) and sprinkle gummy bears (average rank of 2.25) as the most highly preferred items. Preexmerimental observation was begun using peach rings as an HP stimulus. However, Evan displayed a shift in preference during pre-satiation MSWO assessments and failed to show sensitivity to satiation. As in Dalton's case, it was suspected the original MSWO array may have been too large to produce accurate preference results. Another series of MSWO assessments were completed as an evaluation of preference stability using a 4-item array. These results are found in the bottom panel of Figure 2 and show Sour Patch Kids (average rank of 1.2) as his most highly preferred stimulus.

Results from Simon's initial evaluation for preference stability using a 6-item MSWO are found in the top panel of Figure 3. Simon displayed a high level of food

selectivity and Pop-Tarts were reported as a favorite food by his caregivers. An array of different Pop-Tart flavors was initially used for this evaluation, however results across sessions were undifferentiated. It was hypothesized these stimuli may have been too similar to produce a clear preference so the evaluation was repeated with a different 6-item array. These results are shown in the bottom panel of Figure 3 and show Cookies and Cream Pop-Tarts (average rank of 1.4) as the most highly preferred item across sessions.

Sherry and Miles completed the evaluation for preference stability with a 6-item MSWO. Sherry's results are found in the top panel of Figure 4 and show jelly beans (average rank of 1.9) as the most highly preferred across sessions. Miles' results are found in the middle panel of Figure 4 and show sprinkle gummy bears (average rank of 1.9) and Happy Cola (average rank of 2) as his most highly preferred items. Morris' evaluation utilized a 4-item array and the bottom panel of Figure 4 shows his most highly preferred item was Pocky Sticks (average rank of 1.5).

Preexperimental Observation for Sensitivity to Satiation

Dalton, Simon, and Sherry displayed little to no shift in preference following a satiation operation across multiple sessions, therefore all were eliminated from the remainder of the study. Evan's pre- and post-satiation ranks of his HP stimulus (Sour Patch Kids) are displayed in the top panel of Figure 5. The average rank was 1.7 prior to the satiation operation and an average rank of 3.7 after. Miles' results are shown in the middle panel of Figure 5 with his HP stimulus (sprinkle gummy bears) ranking 1.5 prior to the satiation operation and 5 after. Results for Morris are shown in the bottom

panel of Figure 5 with an average ranking of his HP stimulus (Pocky Sticks) being 1.7 before the satiation operation and 3 after.

Evaluation of HP Stimuli Under Open, Varying, and Closed Economies

Evan's results for this evaluation are displayed in Figures 6-9. Figure 6 shows his rate of correct responses across sessions. Responding was initially variable in baseline ending in a steady low rate. Though responding was also somewhat variable across conditions during evaluation of economies, his rate under closed and 33% open economy conditions are at a consistently higher level as compared to the 66% open and open economy conditions. Figure 7 shows the average break point across all conditions with the highest occurring under the closed economy condition, followed by the 33% economy condition.

Figure 8 shows Evan's demand curve across all conditions. The curves for the closed and 33% economy sessions peak at higher PR step requirements and earning of reinforcers persists longer as the requirement increases whereas the curves for the 66% open and open economies peak at the lowest PR step size and rapidly decrease as the requirement increases. This indicates the closed and 33% open economy conditions were less elastic compared to the 66% open and open conditions, with the closed condition being least elastic. Figure 9 shows the corresponding work-rate function for all conditions. The closed and 33% open economy conditions peak at a higher level of responding and responding persists longer as PR requirements increase as compared to the 66% and open economy conditions, indicating less elasticity in the former.

The results for Miles are displayed in Figures 10-13. In Figure 10, his baseline rate of responding was initially low before dropping to zero. Miles' rate of responding was also somewhat variable across conditions, however his rate of responding during the open economy condition was consistently lower than that of the other conditions. During post-experimental analysis comparing only closed and open economy conditions, Miles' responding showed greater differentiation with the highest rates under the closed economy condition. Figure 11 shows the average break point across all conditions with highest occurring under the 33% economy condition and the lowest in the open economy condition.

Figure 12 displays Miles' demand curve across all conditions. The curves for the closed and 33% open economy conditions peaked at higher PR step requirements while earning of reinforcers persisted longer as the requirement increased under the 66% open economy condition. The lowest peak occurred under the open economy condition indicating it produced the most elasticity. Figure 13 shows the corresponding work-rate function for all conditions. The closed and 33% open economy conditions peaked at a higher level of responding and responding persisted longer as PR requirements increased, indicating less elasticity. In comparison, the 66% open and open economy peaked at a lower rate and responding ceased sooner as the PR requirement increased, indicating greater elasticity.

Figures 14-17 display results for Morris. Figure 14 shows his rate of correct responses across sessions in which responding rapidly decreased during baseline. Responding across conditions was variable in the first experimental phase that utilized

two repetitions of each PR step. This phase also ended in a steep decrease in responding across all conditions. Following the procedure change of presenting each PR step requirement only once, responding continued to decrease. In the following phase, an MSWO preference assessment to identify an HP stimulus before each session was added in addition to repeating each PR step only once. Though responding remained somewhat variable in the 33% open, 66% open, and open economy conditions, response rates under the closed economy condition were higher than all other conditions. During post-experimental analysis comparing closed and open economy conditions, Morris' responding also showed greater differentiation with the highest rates under the closed economy condition. Figure 15 shows the average break point across all conditions with highest occurring under the closed economy condition and the break point for all other conditions being similar.

Figure 16 shows Morris' demand curves across all conditions. The curve for the closed economy condition peaked at a higher PR step requirement with earning of reinforcers persisting longest as the requirement increased as compared to all other conditions. All other conditions peaked at a lower PR requirement and earning of responses decreased to zero at similar PR requirements for all. This indicates the closed economy condition is less elastic in comparison to all other conditions. Figure 17 shows the corresponding work-rate function for all conditions. Similar to the demand curves, the closed condition peaked at the highest level compared to other conditions and responding persisted longer as PR requirements increased. This also indicates the closed economy condition was the least elastic.

Discussion

We assessed the extent to which open economies, closed economies, and various levels between open and closed economies might produce differential responding under progressively increasing work requirements (i.e., progressive ratio schedules). It was expected that the overall, general frequency of responding would be highest under the closed economy condition and that the frequency in other conditions would decrease incrementally under the 33% open, 66% open and open economy conditions. This was the case for all three participants who completed the evaluation under open, varying, and closed economies. It was also predicted that a closed economy would produce the highest average break point with average break points decreasing as the degree of open economy increased. While the highest break point for all participants did occur in either the closed (Evan and Morris) or 33% open (Miles) economy conditions, the break point did not decrease systematically as the economy opened to its maximum. However, the lowest break points did occur under 66% open (Evan and Morris) or open (Miles) economy conditions for all participants.

It was also expected that the frequency of reinforcer delivery represented by a demand curve would be higher during low PR requirements and would gradually decrease as the response requirement increased. This was the case for Evan in the 66% and open economy conditions as well as for Morris in the 33% and 66% economy conditions. All other demand curves for the three participants followed an overall pattern of initially increasing, reaching a peak, and then decreasing until the amount of reinforcers earned at each PR step reached zero. This pattern was different from the

demand curve patterns results of Roane et al. (2001; 2005). However, these patterns of responding are consistent with those of mixed demand (Hogan & Roper, 1978). It was also expected that demand curves for each condition would flatten incrementally as the economy increased from closed to open, indicating an increase in elasticity as the economy opened to its maximum. This demand curve pattern was observed with all participants. The work-rate function was expected to reveal the highest number of responses per PR schedule step under a closed economy and to decrease progressively as conditions advanced to the maximum open economy. In all conditions, the work-rate function was expected to increase during initial low PR requirements, peak, and then decrease as requirements increase. The results for all three participants followed the hypothesized expectations for work-rate function, further supporting greater elasticity emerged progressively as the economic conditions opened.

A post-experimental analysis was added due to the undifferentiated results for both Miles and Morris. Following removal of the 33% open and 66% open economy conditions, all overlap between conditions ceased. The initial overlap may have occurred because any exposure to edibles before session came to serve as a discriminative stimulus to complete less work (see Bouton & Todd, 2014). The clear separation of responding under the closed and open conditions during the post-experimental analysis supports this hypothesis. Once the additional varying degrees were removed, pre-session procedures made it easier for the participants to discriminate between conditions.

The clinical implications of these results could help lead to more effective practices in applied settings. Currently, many clinicians may choose to completely restrict reinforcers used during session outside of clinical time based on past research that has taken a dichotomous approach reinforcer exposure. This closed economy approach may become problematic if reinforcers are also needed to affect behavior change in the home or community settings, particularly if an individual has a limited array of reinforcers. In this case, restriction outside of session would be inappropriate. Restriction may also be made difficult if caregivers often find it difficult to adhere to these conditions due to problem behavior in response to restricted access. The results of the current study suggest a closed economy may not be the only effective condition under which responding will continue, as demonstrated by Evan and Miles. For some individuals, a partially open economy would likely cause little to no decrease in responding in clinical sessions.

Alternatively, it appears that some individuals may be more sensitive to smaller degrees of an open economy, as was the case for Morris. In such cases, it may be more important to create a closed economy outside of clinical sessions. It may also indicate that the clinician should be conscientious of reinforcer consumption throughout session and possibly provide additional breaks from session or vary reinforcers in order to reduce the effects of cumulative consumption. In either of the above scenarios, a clinician may find it beneficial to assess various degrees of an open economy on an individuals responding and plan programming accordingly.

This study does contain some notable limitations. First, all sessions were limited to a maximum of 20 min, possibly creating an artificial ceiling to responding similar to that discussed in the study by Roane et. al (2005). In basic research, animals are typically allowed to continue responding for an indefinite amount of time and earn an indefinite amount of reinforcers. This means that the point of equilibrium, or the optimal point at which the reinforcement-rate and work-rate slopes are the same, was not possible to obtain (see Tustin, 1995). However, it was not possible to allow the human participants an indefinite amount of time to respond, as this would take time away from clinical therapeutic sessions. It would also have been unethical to allow human participants, particularly children, to consume an unlimited amount of edibles with little nutritional value.

Second, the PR step requirements in this study were yoked to the amount of reinforcement earned for completing the step in accordance with the procedures of Roane et al. (2005). This was done to limit ratio strain and ensure responding would persist long enough to observe differentiation among conditions. It is unknown if similar patterns of responding would have occurred had the amount of reinforcement been held constant across all PR steps. Third, all caregivers were asked to restrict consumption of all edibles used in session for the duration of the study. To make restriction more likely, the therapist selected edibles participants were unlikely to be exposed to on a regular basis (i.e., foods not commonly used during clinical sessions or kept at the participant's home). However, there is no way to know if all caregivers adhered to this request. Finally, all participants within the current study were children

with a diagnosis of ASD. Therefore, it is unknown whether these results would generalize to other populations such as typically developing children or adults.

The use of behavioral economic concepts in translational and applied evaluations provides several important benefits. First, it provides a parsimonious means of explaining behavioral phenomenon, including explanation of how multiple variables interact with each other (see Bickel et al., 1995). It does so by conceptualizing behavior as "currency" used to purchase reinforcers and conceptualizing response requirements as "price" (Tustin, 1995). Second, methods of predicting future events have been extensively demonstrated in the field of microeconomics. Transferring these methods to the field of behavior analysis may aid in further refining our prediction of behavior more expediently (see Hursh, 1980). Further, behavioral economics provides a unique means of evaluating dependent and independent variables. One such example is the evaluation of reinforcer effectiveness through the use of demand curves and work-rate rather than relying only on response rate (see Bickel et al.). In relation to the current study, behavioral economics also provides a framework for creating a systematic means of defining an open and closed economy and the varying degrees that occur between these two conditions that could be further refined through future research.

Several suggestions for future research can be made following the current study. First, some overlap of responding occurred across conditions for all participants. This may have been due to the methods used to define a closed, 33% open, 66% open, and open economy condition. Though the methods were based on

previous research (Kelley et al., 2017; Roane et al., 2005), no other study has established a means for defining varying degrees of economic exposure in translational or applied settings. Future research should attempt to develop a more nuanced method for defining such parameters.

Future research should also evaluate the effect of the passage of time following consumption of reinforcers outside of session at varying degrees of an open economy. All reinforcers provided as part of an open economy during the current study were given to participants immediately before session. Past research has shown reemergence of preference following a satiation operation as time passes since consumption (Kelley et al., 2017). Similarly, it should also be evaluated whether there are differences amongst varying degrees of economy when additional reinforcers are received after session versus before session as in the methods used by Kodak et al. (2007).

Finally, future research is also needed to replicate the results of this study with a variety of reinforcers and behaviors. The current experimenters chose a previously mastered task as the target response for all participants in order to eliminate the confound of learning a new task from the study results. It remains unclear how exposure to varying degrees of economy would effect responding during novel tasks such as those typically presented in applied settings. The experimenters also chose to use edible reinforcers in this study due to the ease of delivery and quantification of reinforcer amounts when yoking to the PR schedule. Future research should examine

the results of the current procedures utilizing other forms of reinforcement such as leisure items or social attention.

The current study adds to the existing literature regarding the use of open and closed economies by exploring the degrees of economy that may occur between the binary limits of open and closed. It also supports previous findings that while responding may occur at low response requirements under both open and closed economies, responding decreases sooner and reaches a lower break point following exposure to an open economy (Roane et al., 2001; 2005). Though the general results for all participants were similar, some idiosyncratic patterns of responding were observed within each participant. For example, Evan's demand curves and work-rate functions indicated similar persistence in responding under both closed and 33% economic conditions, indicating a small degree of exposure to reinforcers outside of session would likely have little impact on his performance. In contrast, Morris' demand curves and work-rate functions show much greater persistence under closed economy conditions as when compared to all degrees of an open economy making it likely that any exposure to reinforcers outside session would have a much larger impact on his performance. This study underscores the importance of evaluating sensitivity to varying economic conditions on an individual basis rather than applying a general rule of restricted access in applied settings.

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Appendix

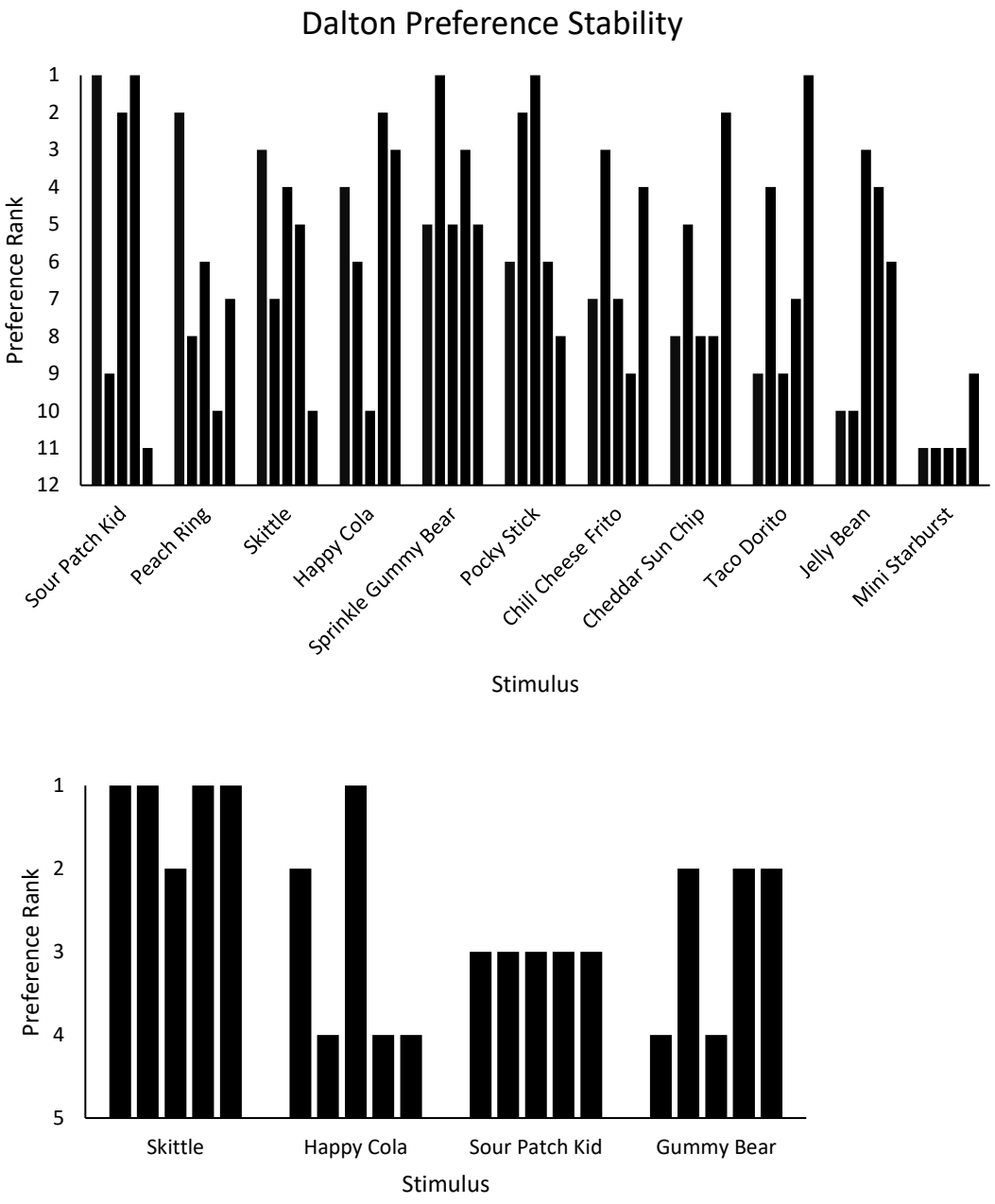

Figure1. Cumulative preference rankings from Dalton's 11-item (top) and 4-item (bottom) MSWOs to assess preference stability.

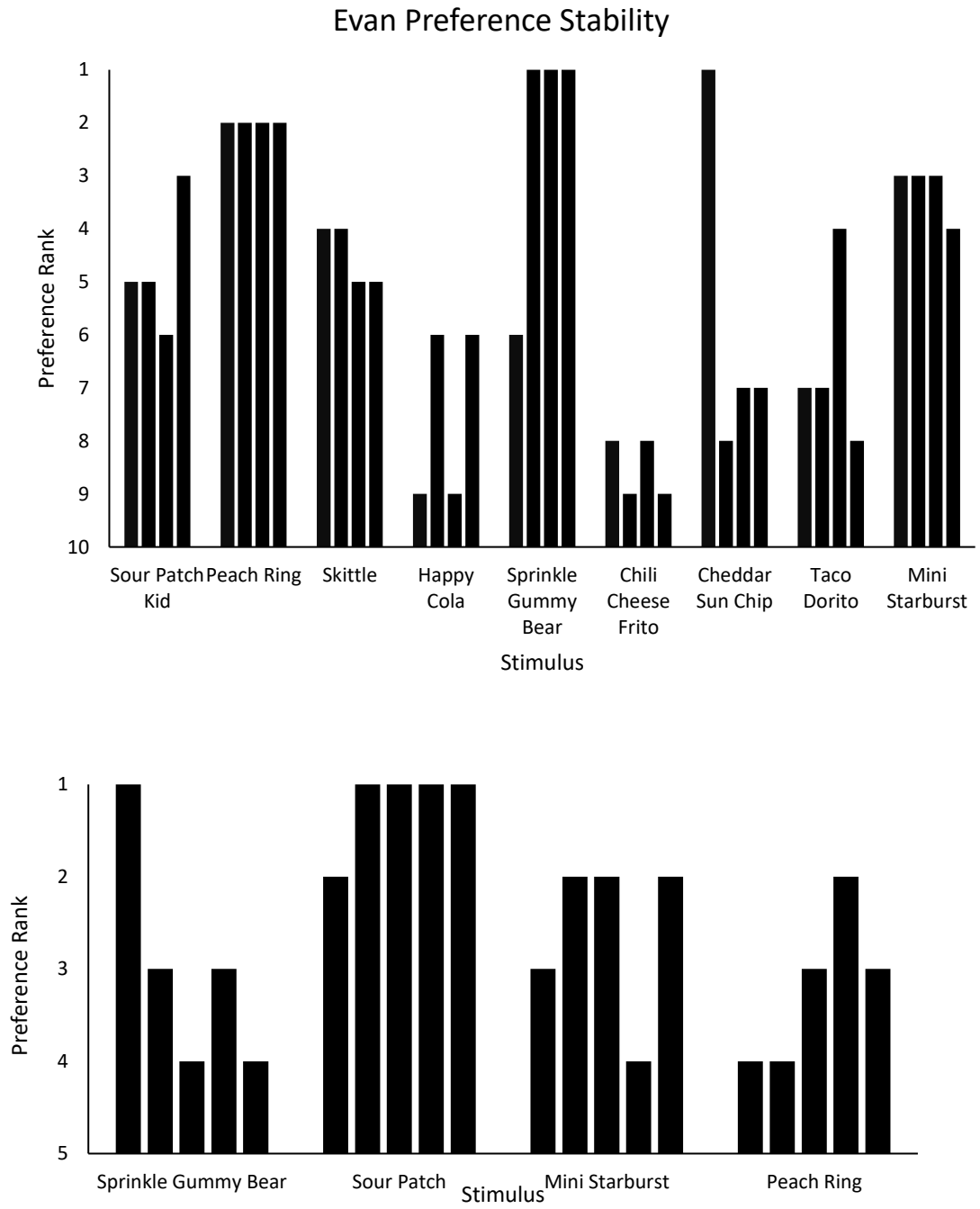

Figure 2. Cumulative preference rankings from Evan's 9-item (top) and 4-item (bottom) MSWOs to assess preference stability.

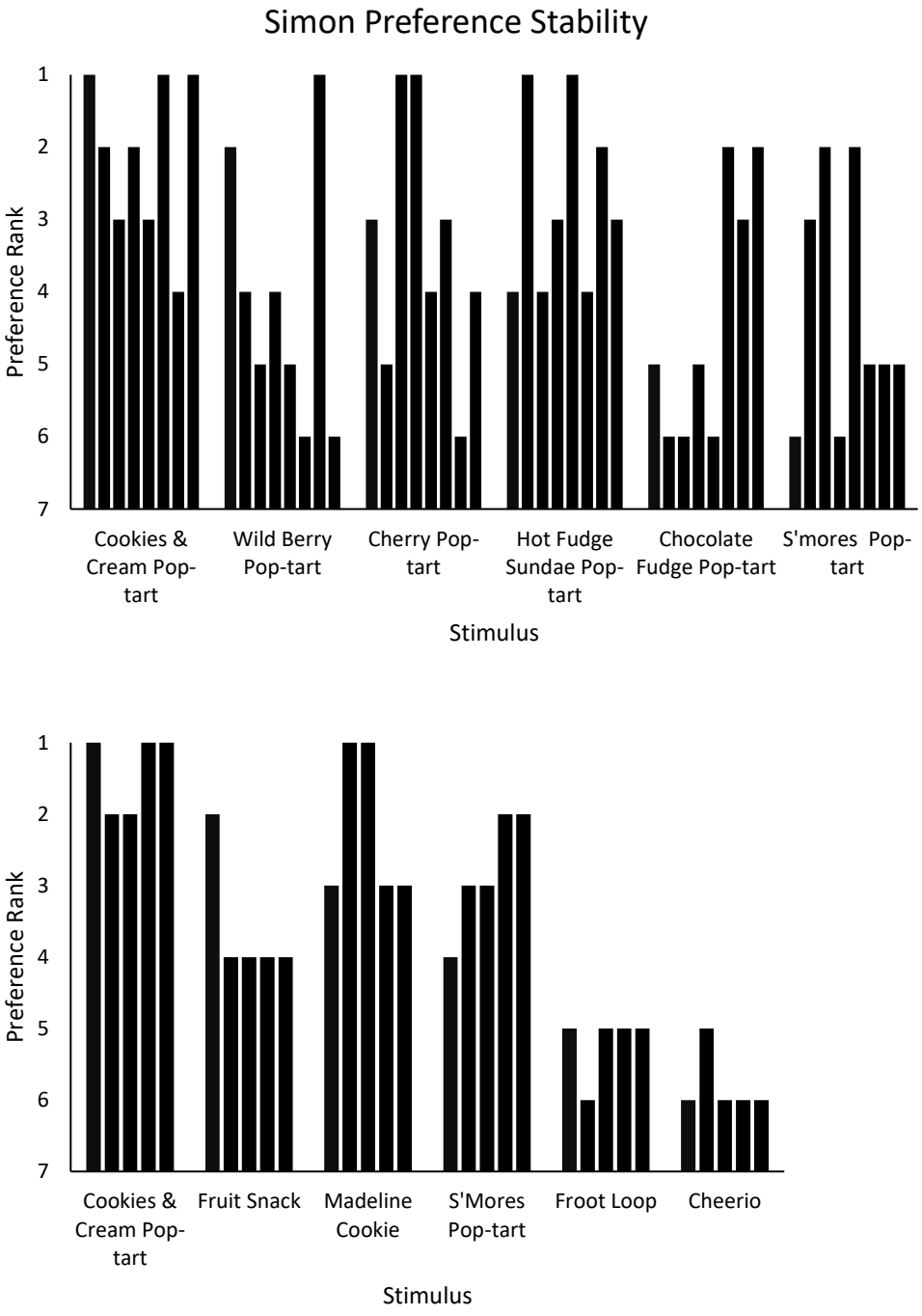

Figure 3. Cumulative preference rankings from Simon's initial (top) and final (bottom) 6-item MSWOs to assess preference stability.

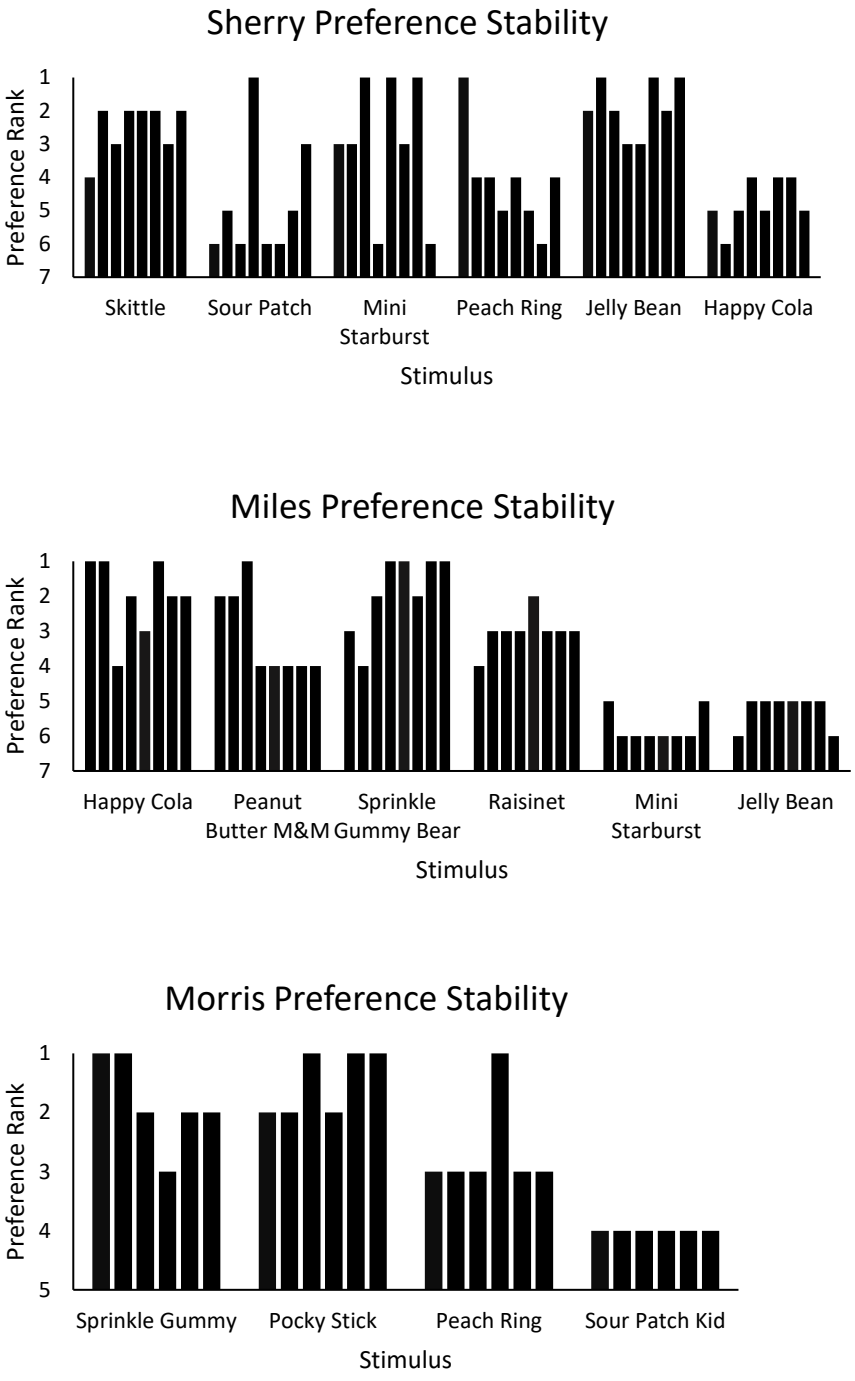

Figure 4. Cumulative preference rankings from Sherry's (top) and Miles' (middle) 6-item MSWOs and Morris' (bottom) 4-item MSWO to assess preference stability.

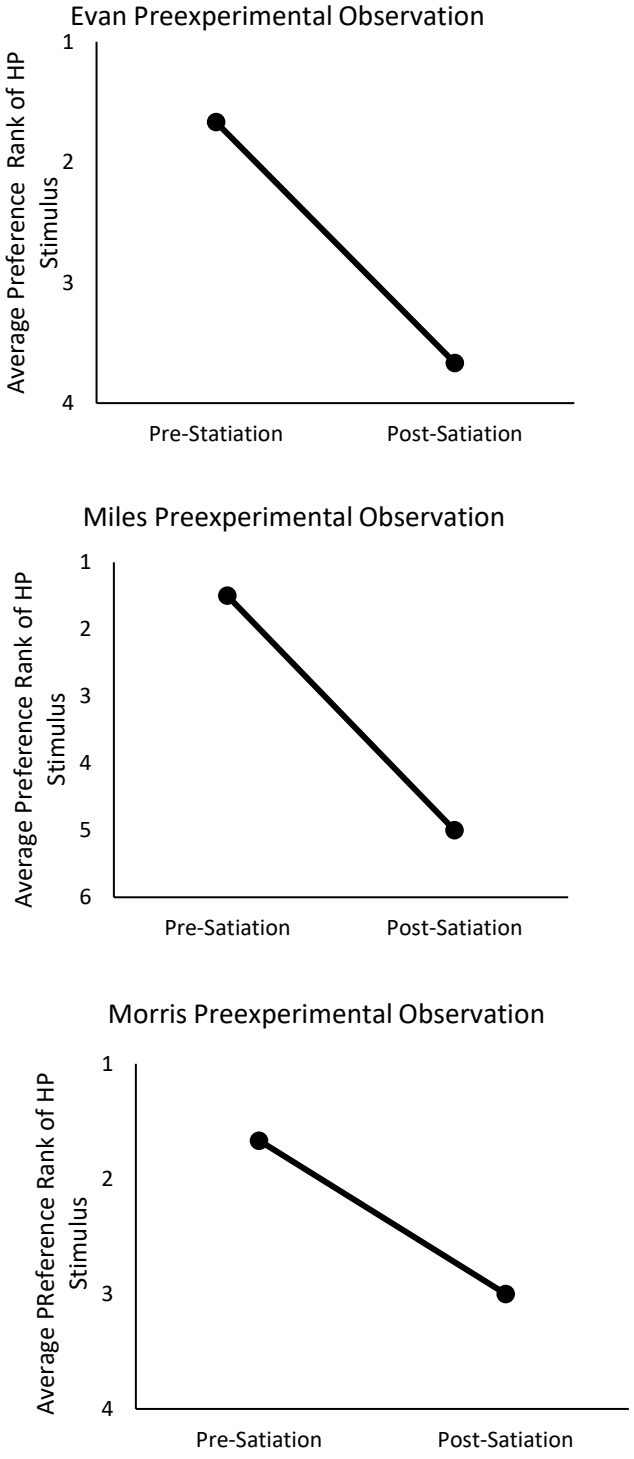

Figure 5. Average shift in preference before and after exposure to a preexperimental satiation operation for Sherry (top), Miles (middle), and Morris (bottom).

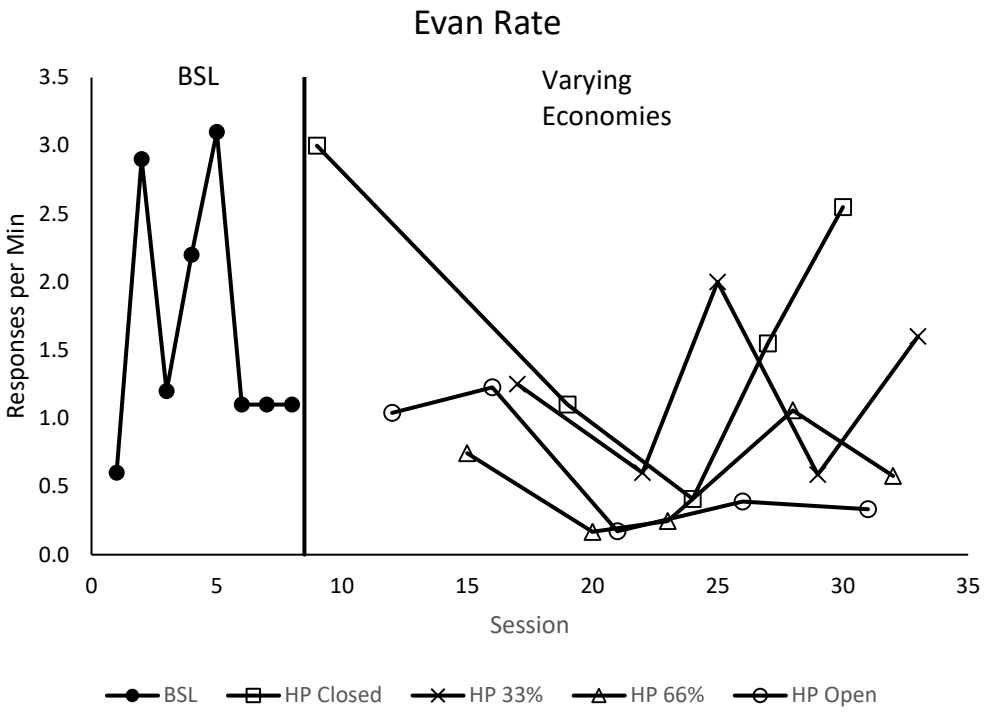

Figure 6. Rate of responding for Evan under baseline and varying economy conditions.

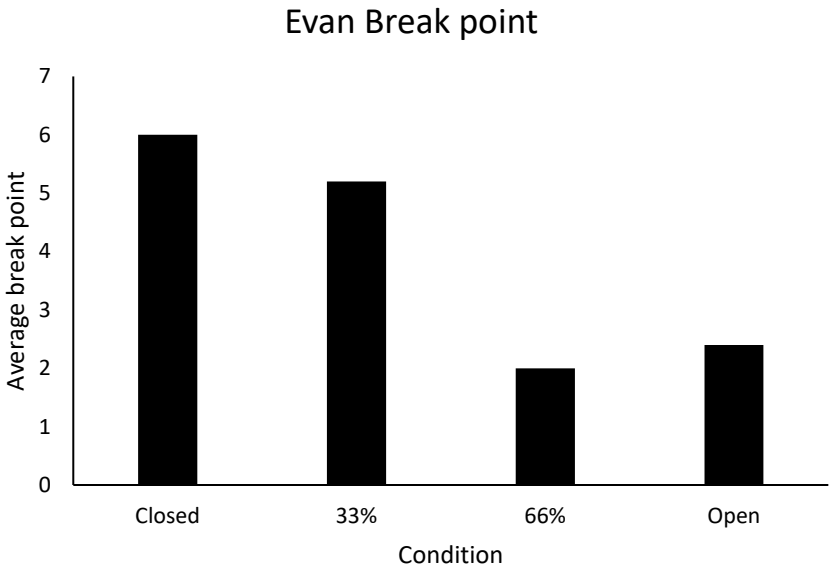

Figure 7. Average break point across varying economy conditions for Evan.

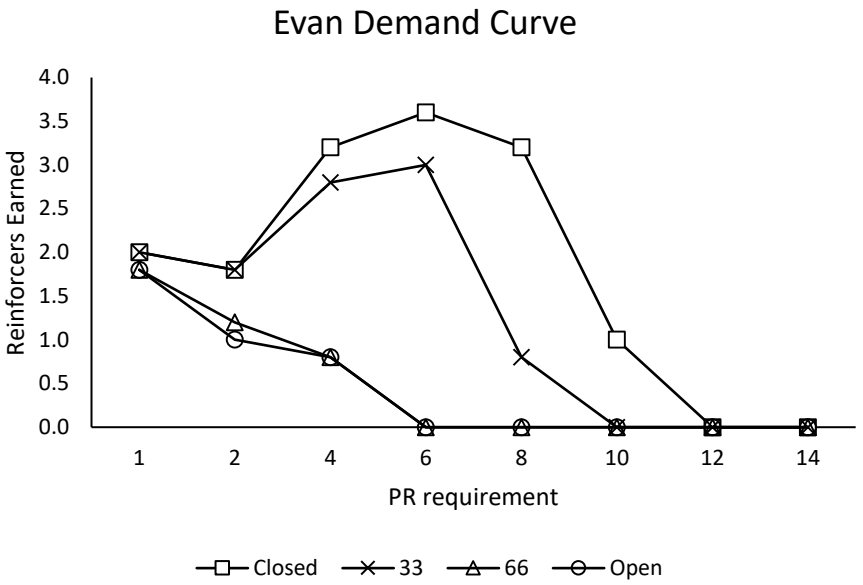

Figure 8. Demand curve across varying economy conditions for Evan.

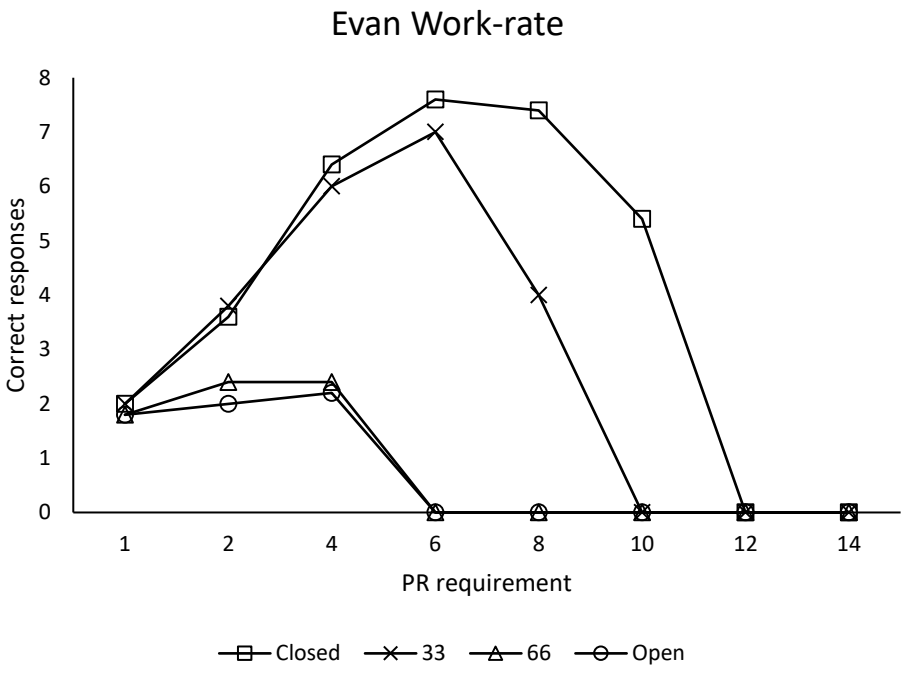

Figure 9. Work-rate function across varying economy conditions for Evan.

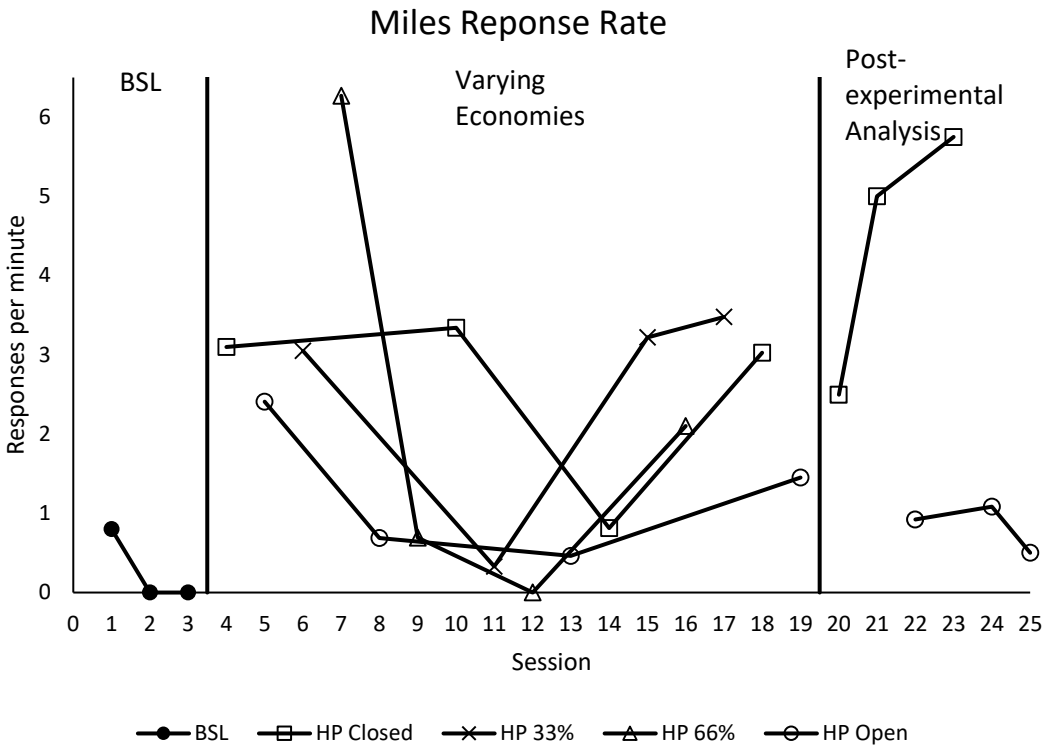

Figure 10. Rate of responding for Miles under baseline, varying economy conditions, and post-experimental analysis.

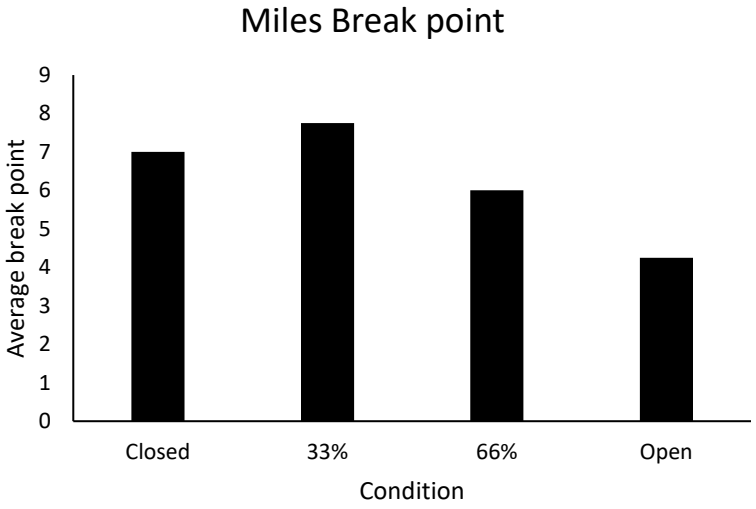

Figure 11. Average break point across varying economy conditions for Miles.

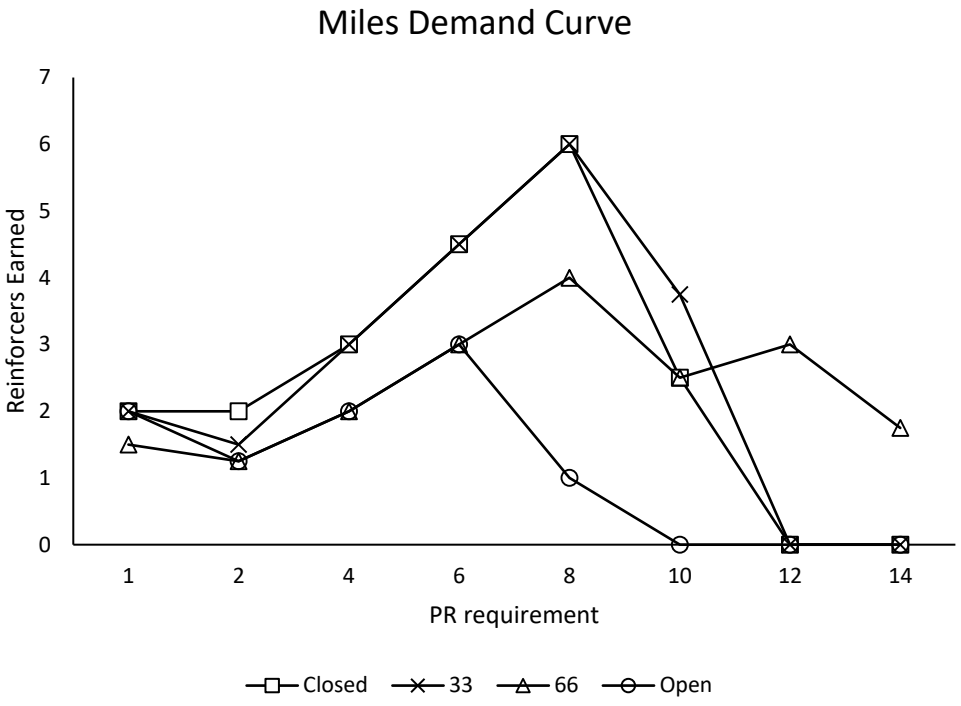

Figure 12. Demand curve across varying economy conditions for Miles.

Figure 13. Work-rate function across varying economy conditions for Miles.

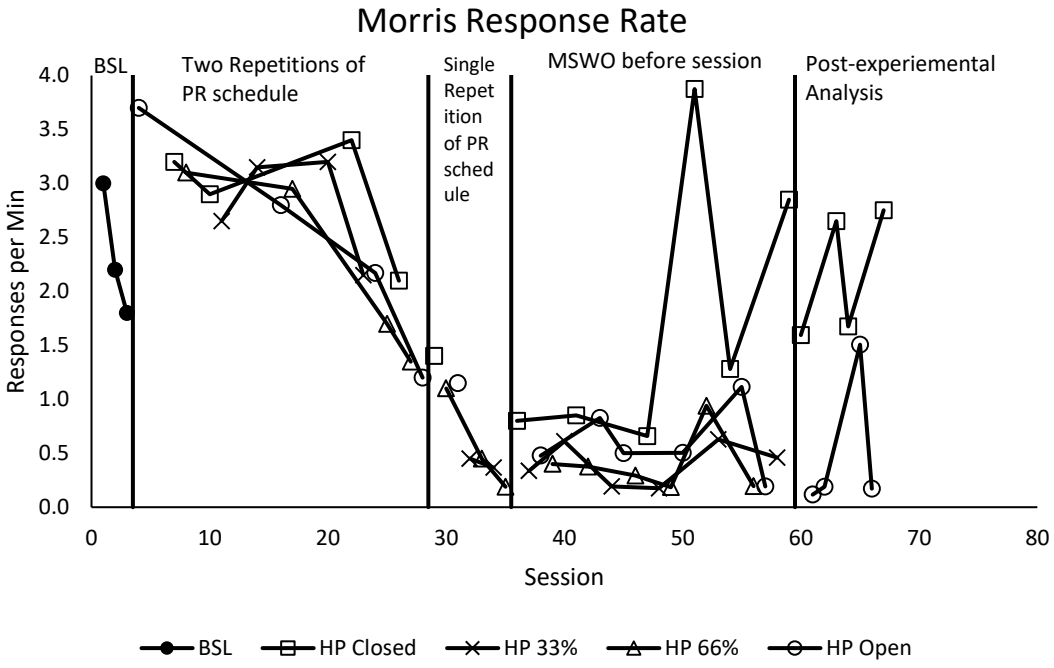

Figure 14. Rate of responding for Morris under baseline, varying economy conditions, and post-experimental analysis.

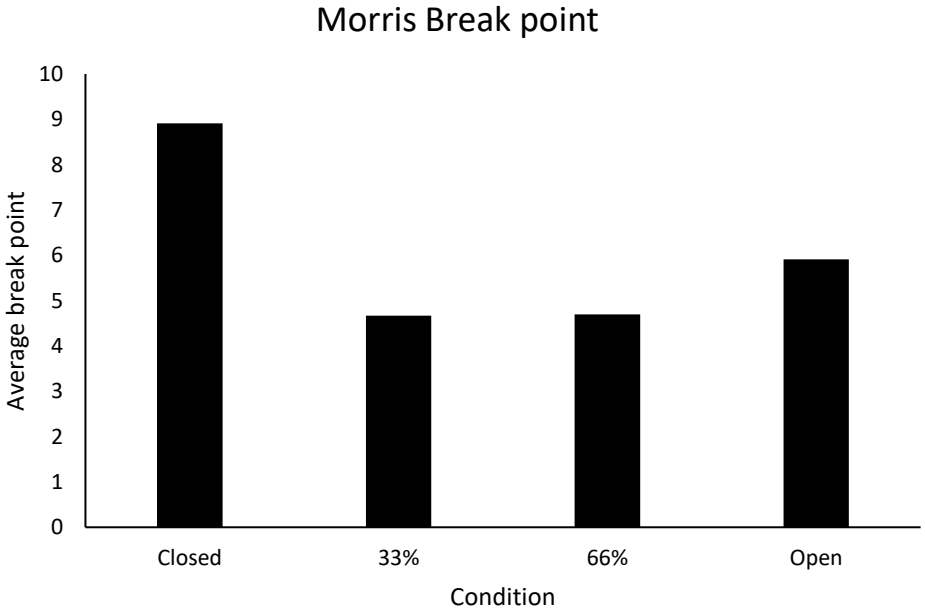

Figure15. Average break point across varying economy conditions for Morris.

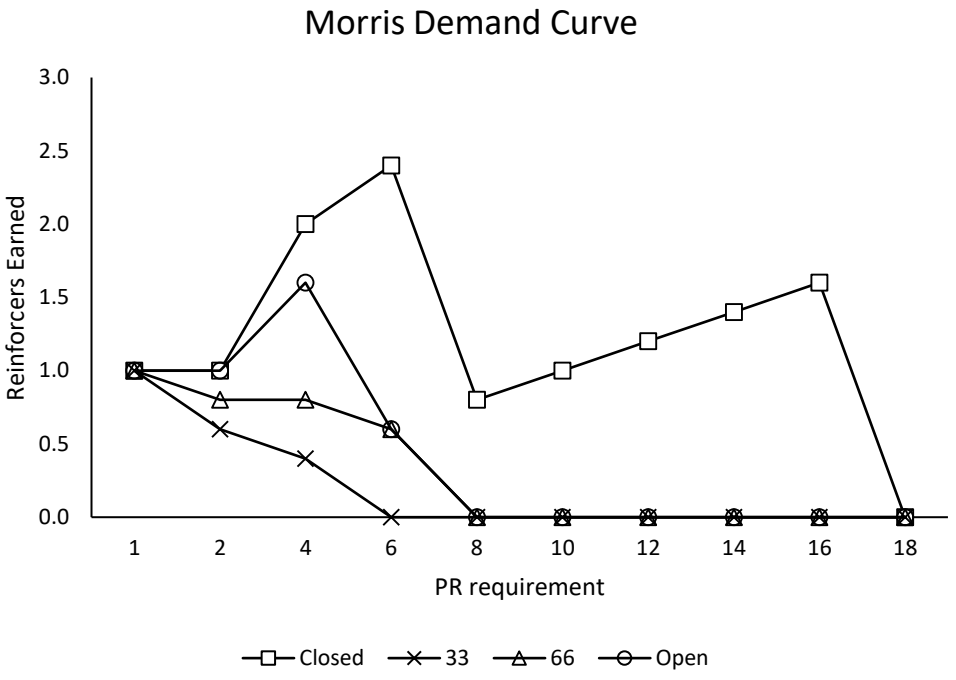

Figure 16. Demand curve across varying economy conditions for Morris.

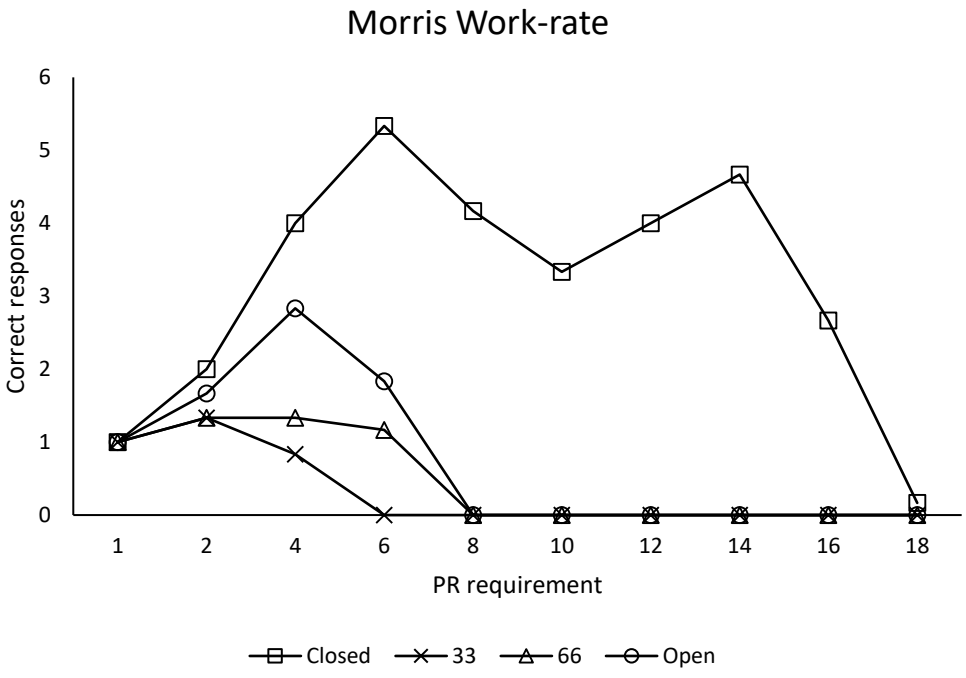

Figure 17. Work-rate function across varying economy conditions for Morris