Extending Token Economy Systems with the Operant Demand Framework

Parker Levins

Department of Psychology, Louisiana State University

Shawn Gilroy

Department of Psychology, Louisiana State University

Author Note

Parker Levins

Shawn P. Gilroy https://orcid.org/0000-0002-1097-8366

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Correspondence concerning this article should be addressed to Shawn P. Gilroy, 220 Audubon Hall, Louisiana State University, Baton Rouge, Louisiana 70803.

Email: mailto:sgilroy1@lsu.edu

Abstract

Token reinforcement systems have been applied across various clinical and educational settings. Although effective across various contexts, limited guidance is available for clinicians beyond the initial construction and introduction of the system. Limited information regarding the efficacy of certain token system arrangements can introduce uncertainty whereby certain schedule arrangements could be overly lax or strict and potentially jeopardize the efficacy of an otherwise appropriate intervention strategy. Methods from applied behavioral economics were used in this study to characterize various token reinforcement arrangements using token-exchange and exchange-production schedules as a proxy for reinforcer 'price' across various token-production schedules (i.e., FR1, FR2, VR2). Concurrent chain procedures were used to evaluate preferences regarding token reinforcement system arrangements apart from overall efficacy. Results were largely consistent with basic research on token reinforcement and the varying arrangements yielded overall comparable rates of responding when controlling for the molar reinforcer price. Findings revealed that most participants demonstrated similar performances but distinct preferences regarding token schedule arrangements.

Introduction

Work completion and classroom engagement are critical for promoting student learning (Anderson et al., 2004). Higher levels of engagement facilitate greater opportunities to contact reinforcement (Brophy, 1986) as well as gains in accuracy and/or fluency (Burns et al., 2008). Apart from facilitating achievement, students consistently engaged in instruction often endorse greater interest and enjoyment in school (Schnitzler et al., 2021; Turner & Meyer, 2004) as well as lower rates of disruptive and/or off-task behavior (MacSuga-Gage & Gage, 2015). Various reinforcement-based classroom management strategies have been developed to assist educators and clinicians in maintaining high levels of classroom engagement, such as the Good Behavior Game (Barrish et al., 1969; Foley et al., 2019; Wahl et al., 2016) and token reinforcement systems (Ivy et al., 2017; Kim et al., 2022).

Token reinforcement systems represent a combination of behavior management strategies that include conditioned reinforcers (i.e., tokens), by which terminal or backup reinforcers are later accessed, as a means of reinforcing temporally extended forms of behavior (Kim et al., 2022). These systems have been evaluated across a wide range of settings, behavioral targets, and populations (Kazdin & Bootzin, 1972; Kim et al., 2022). Much of the earliest work in this sector emerged with non-human animals (see Cowles, 1937 and Wolfe, 1936) and practical demonstrations with humans did not begin until the 1960s (Ayllon & Azrin, 1968, 1965). Such systems have been found efficacious in contexts such as group home settings with at-risk youth (i.e., Achievement Place; see Phillips, 1968; Phillips et al., 1971), soldiers in psychiatric wards (Boren & Colman, 1970), and educational settings for students with and without learning and/or developmental differences (Filcheck et al., 2004; Matson & Boisjoli, 2009).

School-based applications of token reinforcement systems often emphasize behavioral targets such as classroom engagement (e.g., following classroom rules) and participating in academic instruction and intervention (Soares et al., 2016). Successful empirical demonstrations have included student responses such as increasing classroom hand-raising (Hapsari & Anni, 2017), in-seat behavior during instruction (Holt et al., 1976), and overall engagement with instruction and classroom expectations (O'Leary & Becker, 1967). Research has demonstrated that including token systems supports student academic performance by way of improving engagement in the areas of reading (Robinson et al., 1981), math (Alter, 2012), and writing (Truchlicka et al., 1998).

Elements of Token Economy Systems

Token economy systems are designed to focus on some target behavior(s) of interest using a combination of procedures and interlocking schedules of reinforcement. These systems typically begin by selecting some neutral stimulus to eventually function as a conditioned reinforcer (e.g., tally marks, coins) and identifying a menu of reinforcers through which tokens will be exchanged for reinforcers (i.e., the backup or terminal reinforcer). From these two elements, three distinct types of interlocking reinforcement contingencies contribute to how tokens relate to target behavior and terminal reinforcers (Hackenberg, 2009; Ivy et al., 2017). These include the token-production schedule (TP), the token-exchange schedule (TE), and the exchange-production schedule (EP).

The token-production TP schedule reflects how and when tokens are delivered relevant to the desired behavior (Hackenberg, 2009). In practice, the TP schedule often begins as FR1 to establish the link between performing a target behavior(s) and the delivery of a token. The basic literature has found that FR TP produced the anticipated 'break and run' pattern of responding (e.g., Kelleher, 1958) and increasingly large post-reinforcement pausing associated with response requirements (e.g., Felton & Lyon, 1966; Powell, 1968). However, the TP schedule is just one of multiple interlocking schedules, and responding on TP schedules is also influenced by how and when those tokens can be exchanged (i.e., EP schedules). Bullock & Hackenberg (2006) evaluated how TP and EP requirements can jointly influence behavior. They found steady state responding on TP schedules to be strongly associated with the EP schedule, which sets the "price" to produce a reinforcer (i.e., # of tokens to produce before a reinforcer is available).

The exchange-production (EP) schedule is the arrangement by which the individual gains the opportunity to exchange tokens (Hackenberg, 2009). In practice, this arrangement could take the form of a set interval of time during the school day (e.g., FI60 minutes) or an amount of behavior (e.g., filling a 10-item token board; FR10). Findings from the basic literature have demonstrated that the *type* of EP schedule used in a token system produces distinct patterns of responding (e.g., Webbe & Malagodi, 1978). Specifically, fixed EP schedules produced the expected 'break-and-run' patterns with associated post-reinforcement pausing and variable schedules produced more steady rates without pausing associated with fixed arrangements. Foster et al. (2001) presented multiple studies to disentangle to influence of TP schedules from EP schedules and found that by holding TP schedules constant, increasingly lean EP schedules were associated with eventual declines in response rates (i.e., a higher 'price' for reinforcer eventually led to lower response rates). However, this finding appeared more pronounced in FR EP schedules than in VR EP schedules. Bullock & Hackenberg (2006) further explored the joint effects of TP/EP schedules and explored parametric manipulations of both while holding the unit price (i.e., reinforcer per amount of work required) constant across open and closed economies, finding that response rates varied inversely with the TP and EP schedules (i.e., higher unit prices eventually led to lower response rates) and that response rates appeared more consistent under more dense TP schedules.

The token-exchange (TE) schedule represents the number of tokens required to “purchase” the terminal reinforcer(s), i.e. a “cost” for the reinforcer in terms of work (Hackenberg, 2009). For instance, a system targeting work completion might deliver tokens on an FR1 schedule (i.e., per each worksheet completed), and upon encountering an opportunity to exchange tokens, but the terminal reinforcer would ‘cost’ 10 tokens to access (i.e., FR10 TE). From a practical standpoint, clinicians may simplify token arrangements such that the EP and TE schedules overlap as a means of simplifying the system. For example, an act of ‘filling up a board’ with 5 tokens to then produce a single reinforcer would essentially equate to an FR5 EP and FR5 TE wherein the two are functionally the same. Malagodi et al. (1975) is one of few studies that directly evaluated TE schedules, finding an orderly relationship between response rate and the ‘cost’ in terms of tokens to purchase a given reinforcer (i.e., food reinforcement). Although research in this regard is more limited than other aspects of token reinforcement systems, the overall literature is consistent regarding the notion that the effects of specific schedule components are inevitably linked to other related schedules.

Operant Behavioral Economics

Behavioral economics is a field of study that integrates behavioral science and economic principles to evaluate how individuals behave when resources are limited and outcomes are uncertain. Whereas mainstream behavioral economics focuses on how phenomena such as cognitive biases can influence choice behavior, the approach used in this work (Operant Behavioral Economics) uses a reinforcement-based approach to characterizing choice behavior (Gilroy, Kaplan, & Leader, 2018; Gilroy, Kaplan, Reed, et al., 2018). This work incorporates methods from the operant demand framework, which is subsumed under the larger Operant Behavioral Economic approach.

Demand for reinforcers can be evaluated to characterize the relationship between schedule requirements (i.e., cost) and reinforcer consumption (see Gilroy et al., 2020, for a review on elasticity). Various prices (i.e., unit prices) are categorized as being either *inelastic* or *elastic*, see Figure 1. Put simply, prices in the *inelastic* range do not produce substantive drops in reinforcer production and are associated with *increasing* work as prices increase (Gilroy, Kaplan, & Leader, 2018). In contrast, prices in the *elastic* range demonstrate rapid decreases in reinforcer production and are associated with *decreasing* work as prices increase. The unit price associated with peak levels of work is termed P_{MAX} (i.e., the price at maximum responding) and this point represents the barrier between inelastic and elastic price ranges. This specific schedule is desirable in that it exists between the extremes that may be too dense (i.e., potentially inefficient use of reinforcers; inelastic) or too lean (i.e., greater risk of ratio strain; elastic range).

Research Questions

The goal of this study was to extend applied research on token reinforcement systems and explore efficacy and preference for varying token reinforcement system arrangements (i.e., TP, EP/TE) when controlling for a consistent unit price. Findings such as Bullock & Hackenberg (2006) suggest that the different combinations of the TP and EP arrangements (i.e., second-order schedule) can yield comparable rates of responding when controlling for unit price. Applied research on this phenomenon could be fruitful for users of token reinforcement systems by revealing whether one or more different arrangements could produce significant improvements in behavior. Furthermore, should multiple arrangements produce desired effects, this allows students to self-select arrangements that best suit their preferences.

The present study used methods from Operant Behavioral Economics and operant demand to identify a useful unit price (i.e., the ratio of work to reinforcer access) and used that unit price to build different token reinforcement system arrangements that varied in terms of TP and EP schedules. Specifically, the present study sought to answer two questions regarding token schedules and how applied research and practice might be enhanced by incorporating concepts and methods derived from the Operant Demand Framework. The specific research questions (RQs) are listed below:

RQ1: Controlling for a unit price (i.e., ratio of work to reinforcer access), would varying types of TP schedules (i.e., FR1, FR2, VR2) produce differential work output despite a comparable overall rate of reinforcement?

RQ2: Given a comparable unit price, but varying TP arrangements, would participants endorse a clear and consistent preference for a token reinforcement system arrangement?

Method

Participants and Setting

Three students participated in the present study. Participant 1 was a 4-year-old White autistic female, and Participant 2 was a 4-year-old African American autistic male. Both Participants 1 and 2 displayed a vocal-verbal repertoire consisting of phrase speech limited to requesting preferred events and routines (e.g., "want ball") and received full-time early and intensive behavioral intervention as part of a comprehensive center-based program designed to support autistic children. Participant 3 was an 8-year-old mixed-race (Asian [Thai], White) autistic female with an age-expected vocal-verbal repertoire, with needs for support in the use of social-communicative behavior with same-age peers (e.g., difficulties with reciprocal social conversation). Participant 3 was diagnosed with autism and had a medical history significant for Stickler syndrome and the Pierre Robin sequence. She received specialized educational programming in a classroom designed to support children with developmental, behavioral, and other learning differences. All study participants had prior exposure to token systems; however, it was deemed unlikely that students had been exposed to the specific methods explored in the study.

Sessions took place in respective educational settings for all participants at a comparable pace and in a comparable timeline. All study procedures and sessions took place across 1-2 days per week, with 2-4 sessions taking place dependent on session type (i.e., sessions not including a reinforcement component were briefer). Sessions and procedures were performed while seated at a small, age-appropriate table with session therapists who were known and familiar to the participants.

Response Definitions

The act of engaging with token reinforcement systems entails a combination of responses and each of the relevant targets is listed here. Target responses included academic responses (i.e., an existing academic instruction or expectation), a session termination response (i.e., a request to end session), a token exchange response (i.e., exchange of a populated token board to therapist), and a condition selection response (i.e., endorsement of preference). Participant responses were recorded by trained observers using the Countee ™ application to capture response frequency as well as session duration (i.e., in the case of session termination). Each response is described in greater detail in the sections below.

Academic Response

Academic responses consisted of an acquired skill that was not yet at a level of fluency (e.g., addition fact fluency). Targets requiring fluency support were prioritized to minimize the risk of a skill being hindered by an underlying skill deficit rather than a motivation deficit. Academic responses for Participants 1, 2, and 3 consisted of shape sorting, 2D-3D object imitation according to a picture model, and answering math facts using a marker on a laminated math fact card, respectively. Incorrect and/or incomplete academic responses were addressed by re-presenting the task and providing a reminder that token reinforcers were available should they desire to continue working.

Session Termination Response

Session termination responses functioned to allow the participants to indicate when they no longer desired to engage in the task provided. Responses for all participants consisted of the exchange of a laminated picture card with the current session therapist. The response was honored if the card was either handed, slid across a table, or the participant otherwise pointed toward the card. Cards were identical across participants and featured an image representing the removal of academic work (i.e., a 'break' card). All participants received training to mastery for independent use of the session termination response before beginning study sessions and procedures.

Token Board Exchange Response

Token board exchange responses were defined as the exchange of a token board fully populated with tokens to the examiner. That is, the response was the exchange of the token board once all tokens necessary to 'purchase' the reinforcer were acquired by the participant. The total number of tokens required for the boards varied across individuals, conditions (i.e., FR1 TP, FR2 TP, VR2 TP), and experimental arrangements (e.g., baseline/control vs. reinforced condition). Any attempts to exchange a board that was not yet fully populated prompted a re-presentation of the initial session instructions and session expectations.

Condition Selection Response

Condition selection responses were defined as the selection of a study condition by way of exchanging the token board associated with the condition for that participant. These responses occurred with a concurrent chain selection procedure and served to establish a relative preference for token reinforcement system arrangement (Herrnstein, 1964). Colors for respective conditions varied across learners to address the potential for color preferences/biases and each board was presented to the participant in a shuffled, equidistant array. Selections were immediately followed by the onset of session conditions that corresponded with the board selected.

Research Design

The effects of multiple token system schedule arrangements were evaluated using an Adapted Alternating Treatments Design (AATD; Sindelar et al., 1985). The AATD design was used to determine the efficacy of multiple reinforced token system arrangements compared to a no-reinforcement baseline/control condition as well as whether any of the multiple reinforced token system arrangements maintained characteristically different levels of work (e.g., FR2 TP vs. VR2 TP). All reinforced token system arrangements were designed around a common unit price which was determined before the introduction of reinforcement components.

Session conditions were signaled verbally and visually via distinct colors for respective conditions. Vocal instructions were presented before the onset of all sessions and procedures and indicated the contingencies for completing work as well as the availability of the option to discontinue work at any time. Visual signals consisted of distinctly-colored tokens and token boards. Varying circles and semi-circles were used to represent a 1-minute ‘countdown’; Specifically, a circle filled with black corresponded with a 1-minute count down (60s reinforcement), a circle filled half with black and half with white corresponded with a 0.5-minute countdown (30s reinforcement), and a circle filled with white corresponded with a 0-minute countdown (0s reinforcement). The specific conditions included in the AATD are explained in greater detail in the sections below.

Baseline/Control

Baseline/Control conditions were introduced following preference assessments (i.e., color and stimulus preference), training to mastery for the session termination response, and the conclusion of the Token Reinforcer Evaluation. The academic response in baseline/control conditions produced 1 token; However, the exchange of the baseline condition token board (FR3 EP/TE) did not produce access to preferred items or activities. Rather than produce access to a preferred item, the stimulus conditions were programmed such that the exchange of a fully populated token board was followed by the re-presentation of academic work.

FR1 TP

The FR1 TP condition in the AATD was identical to that of baseline/control conditions apart from the programmed contingencies following the exchange of the populated token board. The exchange of the token board produced 30s of programmed reinforcement that did not count toward the total session time. The EP/TE schedule for this condition was determined for each participant based on the results of the Token Economy Reinforcer Assessment (i.e., schedule corresponding to P_{MAX}).

FR2 TP

The FR2 TP condition was identical to that of the TP-FR1 condition apart from the increased TP schedule requirement (i.e., FR1 TP became FR2 TP) and the magnitude of the reinforcer delivered. The magnitude of the reinforcer increased from 30s to 60s to mirror the doubled amount of responding required to produce a token and was consistent with a unit price approach to scaling reinforcer delivery (Delmendo et al., 2009; Gilroy et al., 2019).

VR2 TP

The VR2 TP condition was identical to the FR2 TP condition except that academic responding *on average* produced 1 token for every 2 responses. The programmed reinforcement interval remained the same and did not count toward the total session time. The ordering of various token production schedules was shuffled before sessions using a stack of cards that corresponded with the options for TP deliveries (e.g., FR2, FR1, FR3).

Session Termination Response Training

Participants were free to discontinue their participation in any procedures at any point in the study. Participants were taught to mastery criteria to perform a communication response that produced escape from the current task (i.e., ‘break card’) before any experimental procedure.

Training for the termination response began with 2 5-trial sessions using errorless learning prompting procedures. These were followed by 5-trial training sessions using a 5s full physical prompt delay strategy. Criteria for mastery on this response was the unprompted use of the break card on 80% or more of blocks of 5 trials across 2 consecutive sessions. Tasks in the termination training sessions differed from the academic response and were selected based on skills endorsed by the participant's primary clinician or teacher.

Token Reinforcer Evaluation

The TE/EP schedules carried forward into the respective AATD for each participant were determined using a Token Reinforcer Evaluation. This type of procedure was derived from an intermittent subtype of the traditional progressive ratio reinforcer assessment (see Jarmolowicz & Lattal, 2010) and has previously been used to provide a rapid within-session evaluation of responding to sample reinforcer performance across schedules (Gilroy et al., 2019, 2021). The present reinforcer evaluation differed from prior procedures by emphasizing the total work sustained across schedules and by making reinforcers available upon the exchange of a populated token board.

This procedure featured an FR1 TP schedule whereby every target response produced one token. Additionally, the 'prices' explored in the evaluation consisted of differing EP/TE schedules (e.g., FR1, FR2) and these represented the varying 'costs' to produce the reinforcer in terms of tokens. Consistent with Gilroy et al. (2021), responding was evaluated in an ascending sequence from FR1, FR2, FR3, FR5, FR10, and FR20 after 3 reinforcer deliveries at each price. A 30s reinforcement period was constant across all TE/EP arrangements, whereby participants received access to available reinforcers contingent on the exchange of the board. Sessions concluded if participants demonstrated the session termination response, 2 minutes elapsed without additional responding, if all relevant schedules were explored, or if undesired or unsafe behavior occurred.

The token arrangement associated with peak levels of responding was inferred from the peak of a work output curve (Greenwald & Hursh, 2006). The arrangement associated with peak responding was determined to be the empirical P_{MAX} for the given reinforcer and current context (see Figure 1 for an example). The 'price' associated with P_{MAX} was used as the basis for selecting the specific EP/TE schedules used for each participant in reinforced conditions.

Preference Assessment

Participant preferences were evaluated for prospective reinforcers as well as colors featured in token system materials. Color preference was assessed to control for potential biases associated with preferred colors (i.e., preferences biased by preferred color, rather than preferred arrangements). Assessments of stimulus and color preference were conducted consistent with the Multiple Stimulus Without Replacement procedure (MSWO; DeLeon & Iwata, 1996).

Descriptive information regarding participant preference was first gathered using the Reinforcer Assessment for Individuals with Severe Disabilities (RAISD; Fisher et al., 1996) prior to formal preference assessment procedures. The RAISD is a caregiver-completed instrument that asks caregivers about their child's interests and other events believed to be preferred to them. Stimuli endorsed as highly or likely preferred were used as the basis for empirical assessments of individual preference.

Pre-session exposure for each color or item consisted of 10 seconds of access, and arrays presented to participants took the form of a straight, equidistant line, with ordering shuffled before each presentation. The therapist instructed the participant to pick one item (e.g., taking the item, pointing to an item, verbally stating preference) and granted 30s access to the item indicated. After the 30s interval elapsed, the therapist recovered the item, rotated the sequence of the remaining stimuli, and instructed the participant to select again should they wish to do so. This process repeated until all stimuli were selected or until 30s without further selections were observed. The most highly preferred items were selected and used as programmed reinforcers and the least highly preferred colors were used to generate token reinforcement system materials.

Interobserver Agreement and Procedural Integrity

Interobserver agreement (IOA) was computed for all responses across conditions and the information related to agreement is provided in Table 1. The percentage agreement was calculated by the Countee ™ application and consisted of dividing the number of intervals with exact agreement by the total number of intervals and multiplying that by 100. Agreement was calculated for 47% of baseline sessions, 22% of sessions in the AATD, and 77% of sessions in the concurrent chains task. The average overall levels of agreement recorded ranged from 89.4-100%.

Procedural integrity was evaluated using a checklist outlining respective procedures for each condition and session. The elements on this checklist included: 1) the session therapist arranged appropriate materials and session conditions as written in the session protocol, 2) the session therapist informed participants that they may quit at any time, 3) the therapist vocally stated reinforcement schedule(s) to participants as written in the session protocol, 4) the therapist implemented reinforcement schedules as written in the session protocol throughout the entire session, and 5) the session therapist implemented termination procedures as written in the session protocol. Integrity was scored by dividing the number of steps followed by the number of steps followed plus the number of steps not followed. This value was multiplied by 100 to produce a percentage. Procedural fidelity was assessed in 47% of baseline sessions, 22% of sessions in the

AATD sessions, and 77% of sessions for the concurrent chains. Procedural fidelity was assessed at 100% for all observed sessions.

Concurrent Chains

The concurrent chains procedure took place for each participant immediately following the conclusion of respective AATDs. Session conditions for this procedure were identical to those from the AATD apart from the presentation of a choice made by the participant. The selection response made by the participant determined the procedures used for the remainder of the session. The condition selection response was used to examine participant preference for specific types of token arrangements. The concurrent chains procedure consisted of presenting respective token boards in an equidistant array and verbally instructing the participant to select which arrangement (if any) they preferred.

Results

Preference Assessment

Results from individual preference assessments are outlined in Tables 2, 3, and 4. The stimuli made contingent upon token board exchange for Participants 1, 2, and 3 consisted of a shape puzzle and Play-Doh™, a bean bucket and a drawing pad, and kinetic sand and slime play, respectively. The colors that were disregarded in the design of token system materials for Participants 1, 2, and 3 were teal, pink, and orange, brown, pink, and black, and pink, purple, and white, respectively. Information regarding colors for specific schedules and materials is provided in the respective tables.

Session Termination Response Training

Participants 1 and 3 demonstrated independent use of the session termination response following 4 training sessions (i.e., 2 errorless teaching + 2 prompt delay sessions). Participant 2 demonstrated independent use of the session termination response following 8 training sessions but required a second round of errorless teaching to meet mastery criteria. This sequence was essentially identical to that of Participants 1 and 3 but repeated once more before the criteria were met.

Token Reinforcer Evaluation

The results of the Token Reinforcer Evaluation across participants are illustrated in Figure 2. Results from the evaluation supported the use of the FR2 TE/EP schedule (unit price = 0.06; FR2/30s of reinforcement time) for Participants 1 and 2. The results for Participant 3 supported the use of an FR5 TE/EP schedule (unit price = 0.1; FR3/30s of reinforcement time). The total time necessary to perform the evaluation was 13.08, 10.73, and 15.96 minutes for Participants 1, 2, and 3, respectively.

Adapted Alternating Treatment Design

Student levels of responding across conditions are illustrated in Figure 3. This figure reflects the total amount of work performed across conditions as well as the latency to the session termination response (if relevant). Performances during the concurrent chains portion of the study in Figure 3 reflect the overall work that took place in the condition selected by the participant. No instances of problem behavior were recorded for any of the participants.

Academic Responses

All participants displayed low and/or descending rates of responding across baseline and control conditions. Responding across baseline/control and reinforced conditions were clearly differentiated throughout the AATD. The available information did not suggest that any of the reinforced token arrangements in the AATD was consistently superior to another; however, Participant 2 displayed a slightly greater level of responding during the FR2 TP condition.

Session Termination Responses

Information presented in Figure 3 indicates the use and latency of use regarding session termination responses. For baseline/control conditions, termination responses took place in 100% (20.2s average latency), 88.89% (4s average latency), and 80% of baseline and control conditions (48.67s average latency) for Participants 1, 2, and 3, respectively. In contrast, termination responses in sessions with programmed reinforcement took place in 13.3% (4.3 minutes average latency), 6.67% (3.67 minutes average latency), and 5.56% of baseline and control conditions (4.93 minutes average latency) for Participants 1, 2, and 3.

Concurrent Chains

The cumulative selections across participants during the concurrent chains procedure are illustrated in Figure 4. A degree of variability could be observed within the earliest rounds of the procedure; however, the FR2 TP condition emerged as the most consistently selected option across participants. As illustrated in Figure 3, levels of responding during participant-selected conditions remained largely consistent with levels demonstrated during reinforcement conditions in the AATD. Regarding session termination responses, Participant 1 demonstrated the response in 12.5% of sessions (n = 1; 4.23 minutes average latency) and Participant 3 in 11.11% of sessions (n = 1; 2.85 minutes average latency). Participant 2 did not emit any session termination responses in the concurrent chains procedure.

Discussion

Token economy systems have been found to be useful for supporting various forms of desired student behavior (e.g., engagement, participation, work completion; Soares et al., 2016). Various guidelines exist for educators and clinicians in the design and introduction of this approach (e.g., Myles et al., 1992), yet applied studies have seldom explored how to evaluate reinforcement contingencies and design token reinforcement systems to be more targeted for specific responses and reinforcers. The goal of this study was to extend research on token economy systems in applied settings using methods and concepts from Operant Behavioral Economics. Specifically, the primary research questions focused on determining whether various token reinforcement system arrangements based on a common work/reinforcement ratio (i.e., unit price) would produce comparable levels of work output and whether strong preferences would emerge despite an overall comparable balance of work expectations and reinforcement.

This study first identified a favorable unit price within a token economy context to balance reinforcer access and schedule response requirements. This ratio was then used to evaluate various token system arrangements and compare how each fared in terms of reinforcing efficacy (see Gilroy et al., 2021). Results revealed that overall levels of responding across FR1, FR2, and VR2 TP schedules were largely consistent across conditions, a finding consistent with related research from the basic literature on token reinforcement. Basic studies have suggested that responding on token reinforcement schedules is inevitably influenced by the *combination* of schedules involved in the system (i.e., TP and EP schedules; Hackenberg, 2009). That is, some target is reinforced by the delivery of tokens (TP) as well as the opportunities upon which those tokens can be exchanged for some terminal reinforcer (EP). In this view, the ‘token producing’ behavior emitted on a TP schedule can be framed as a unitary response emitted on a second-order schedule, which specifies how and when reinforcement via token exchange is available. Viewed in this way, and controlling for overall unit price, the EP schedules maintained throughout the reinforced conditions were very similar. Given that overall efficacy has been strongly linked to the EP schedule (Foster et al., 2001; Webbe & Malagodi, 1978), it stands to reason various arrangements sharing this common feature should produce comparable levels of responding. Findings from this study mirror those from others evaluating rates of responding or choice when unit pricing arrangements are held constant (Bullock & Hackenberg, 2006; Madden et al., 2000); Specifically, findings here reflected the presumption that work emitted on schedules with comparable unit prices would occur at comparable rates. These findings replicate observations from the basic literature and suggest that it is possible to generate multiple token system arrangements that can be similarly efficacious. Flexibility in this regard has powerful implications in terms of pragmatic application and social validity.

The second research question explored whether participants would demonstrate a clear preference for certain token arrangements when the overall rates of reinforcement were comparable across those arrangements. The available literature suggests that, even when work-to-reinforcer ratios are held constant, many participants can demonstrate clear preferences sensitive to contexts as well as token system arrangements (see Falligant & Kornman, 2019, for an example). Relatedly, research on distributed vs. accumulated reinforcer arrangements has also found that certain types of preferences may emerge for specific reinforcers despite overall comparable quantities of reinforcement (DeLeon et al., 2014; Falligant et al., 2020; Falligant & Kornman, 2019). The findings of this study revealed that there was a relative preference overall for larger magnitudes of reinforcer delivery as well as for fixed TP. The finding that participants may have clear preferences for token reinforcement system arrangements in specific contexts is useful for a number of reasons. Providing choices allows the learner to exercise agency in their programming (i.e., how they prefer to earn tokens and access reinforcement), and incorporating such opportunities has been linked to improved task engagement and completion (Jolivette et al., 2001; Ramsey et al., 2010). Furthermore, designing approaches based on individual preferences and values is consistent with behavior analytic commitments to provide support with strong social validity (Wolf, 1978). Given that multiple variations of token reinforcement systems predicated on an effective, common unit price can be similarly effective, this supports the development of multiple empirically derived token reinforcement arrangements that can be considered when developing plans for individual learners.

Limitations

Results from this study suggest that operant behavioral economics can provide a framework for selecting, arranging, and comparing different TE, EP, and TP token reinforcement schedule combinations. Additionally, procedures from the operant demand framework provide a rapid means of estimating a reinforcer price to base such systems upon, which extends upon the methods and guidelines available for applied users (Ivy et al., 2017; Myles et al., 1992). However, limitations in the present study are worth noting.

Certain types of variability in responding may not have been as apparent when the focus is exclusively on total work output. For example, variability in post-reinforcement pauses across the different TP schedules was not formally evaluated and such variability may exist when exploring differences between fixed and variable arrangements (Felton & Lyon, 1966). However, overall response rates were largely consistent across the various experimental arrangements, and it does not appear as if such pauses could or would negatively influence overall rates within the narrow range of schedules evaluated in this study. Additionally, this study developed comparisons around a single unit price, and inferences drawn here are made specific to a price near the boundary between elastic and elastic demand. It is likely and possible that different patterns may emerge between fixed and variable arrangements when the ratio is much denser (i.e., nearer to FR1 in the inelastic range) or much leaner (i.e., deep into the elastic range). Lastly, no data were collected to determine the generality of this approach beyond the specific context and responses targeted in the study. That is, no data was collected regarding whether responding observed under the contexts in this study would be comparable in other environments or would have persisted across time. Each of these points are areas in need of further study.

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Table 1

Levels of percentage agreement across conditions and procedures

	Total Agreement	Termination Response	Academic Response	Token Exchange Response
Baseline	97.5 [80-100]	100 [100-100]	100 [100-100]	100 [100-100]
AATD	97.9 [86-100]	100 [100-100]	89.4 [53.57-100]	98 [85.71-100]
Concurrent Chains	98.2 [95-100]	100 [100-100]	89.7 [70-100]	96.5 [86.67-100]

Table 2

Results of preference assessments for Participant 1

Ranking	Color	Terminal Reinforcers
1	Teal (not used)	Shape puzzle (used)
2	Pink (not used)	Play-Doh (used)
3	Orange (not used)	Play foam (not used)
4	Black (VR2 TP token board)	Drawing pad (not used)
5	Brown (FR2 TP token board)	Sensory bean bucket (not used)
6	White (conditioned tokens)	
7	Red (FR20 TE/EP token board)	
8	Yellow (FR10 TE/EP token board)	
9	Light Green (FR5 TE/EP token board)	
10	Dark Green (FR3 TE/EP token board)	
11	Light Blue (FR2 TE/EP token board)	
12	Purple (FR1 TE/EP token board)	
13	Gray (control tokens)	
14	Navy blue (control/baseline token board)	

Table 3

Results of preference assessments for Participant 2

Ranking	Color	Terminal Reinforcers
1	Brown (not used)	Sensory bean bucket (used)
2	Pink (not used)	Drawing pad (used)
3	Black (not used)	Play-Doh (not used)
4	White (VR2 TP token board)	Shape puzzle (not used)
5	Yellow (FR2 TP token board)	Bouncy ball (not used)
6	Red (conditioned tokens)	Race car (not used)
7	Light Green (FR20 TE/EP token board)	Coloring sheet (not used)
8	Navy Blue (FR10 TE/EP token board)	
9	Teal (FR5 TE/EP token board)	
10	Dark Green (FR3 TE/EP token board)	
11	Orange (FR2 TE/EP token board)	
12	Gray (FR1 TE/EP token board)	
13	Purple (control tokens)	
14	Light Blue (control/baseline token board)	

Table 4

Results of preference assessments for Participant 3

Ranking	Color	Terminal Reinforcers
1	Pink (not used)	Kinetic sand (used)
2	Purple (not used)	Slime (used)
3	White (not used)	Handprint toy (not used)
4	Brown (VR2 TP token board)	Fidget Spinner (not used)
5	Orange (FR2 TP token board)	Stretchy Worms (not used)
6	Teal (conditioned tokens)	Fidget Spinner (not used)
7	Red (FR20 TE/EP token board)	
8	Black (FR10 TE/EP token board)	
9	Gray (FR5 TE/EP token board)	
10	Yellow (FR3 TE/EP token board)	
11	Navy Blue (FR2 TE/EP token board)	
12	Dark Green (FR1 TE/EP token board)	
13	Light Blue (control tokens)	
14	Light Green (control/baseline token board)	

Figure 1. Reinforcer Production Across Inelastic and Elastic Prices

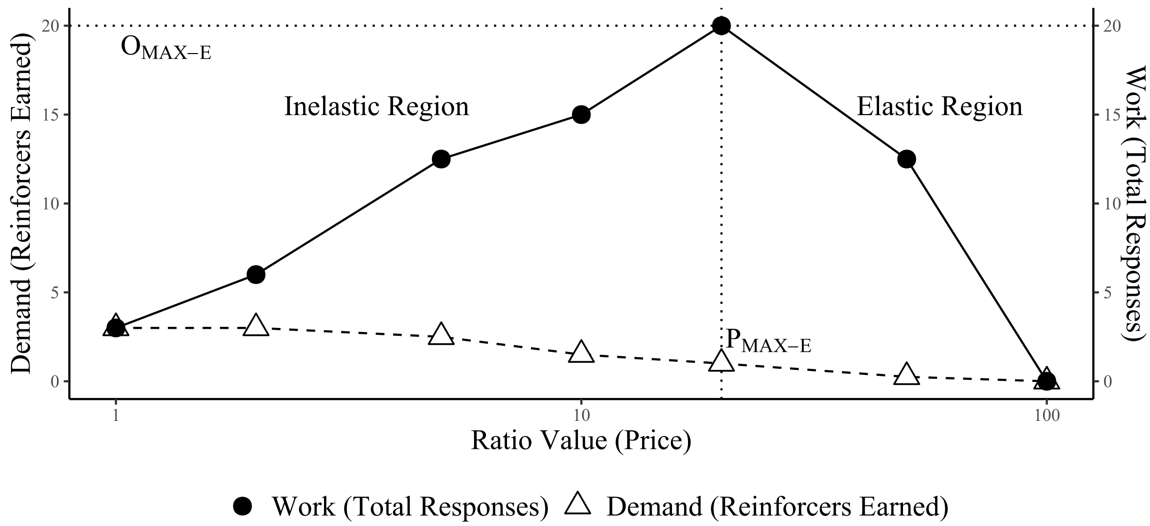

Figure 2. Results of Token Reinforcer Evaluation Across Participants

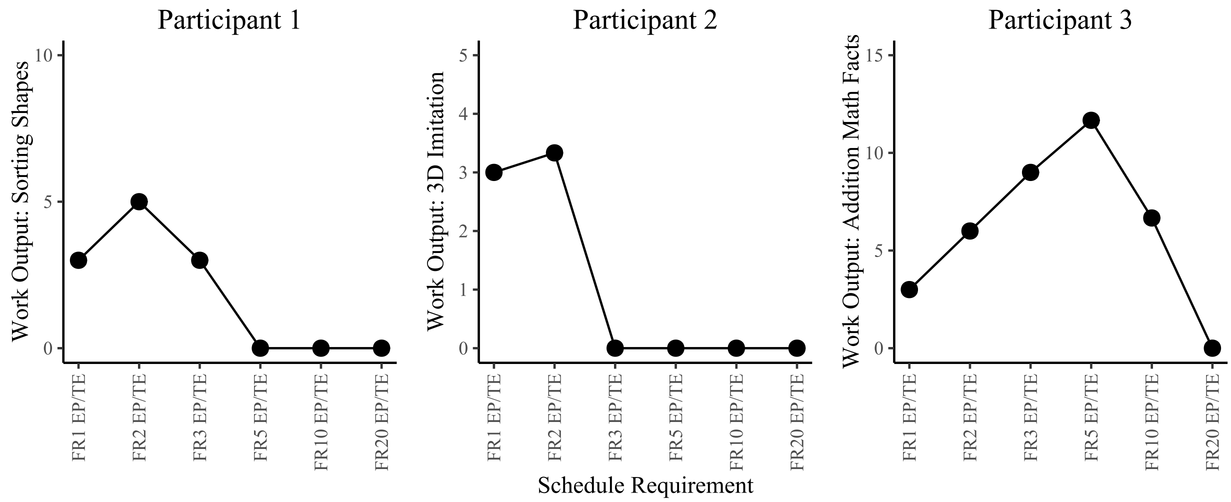

Figure 3. Performances Across Baseline, AATD, and Concurrent Chains Sessions

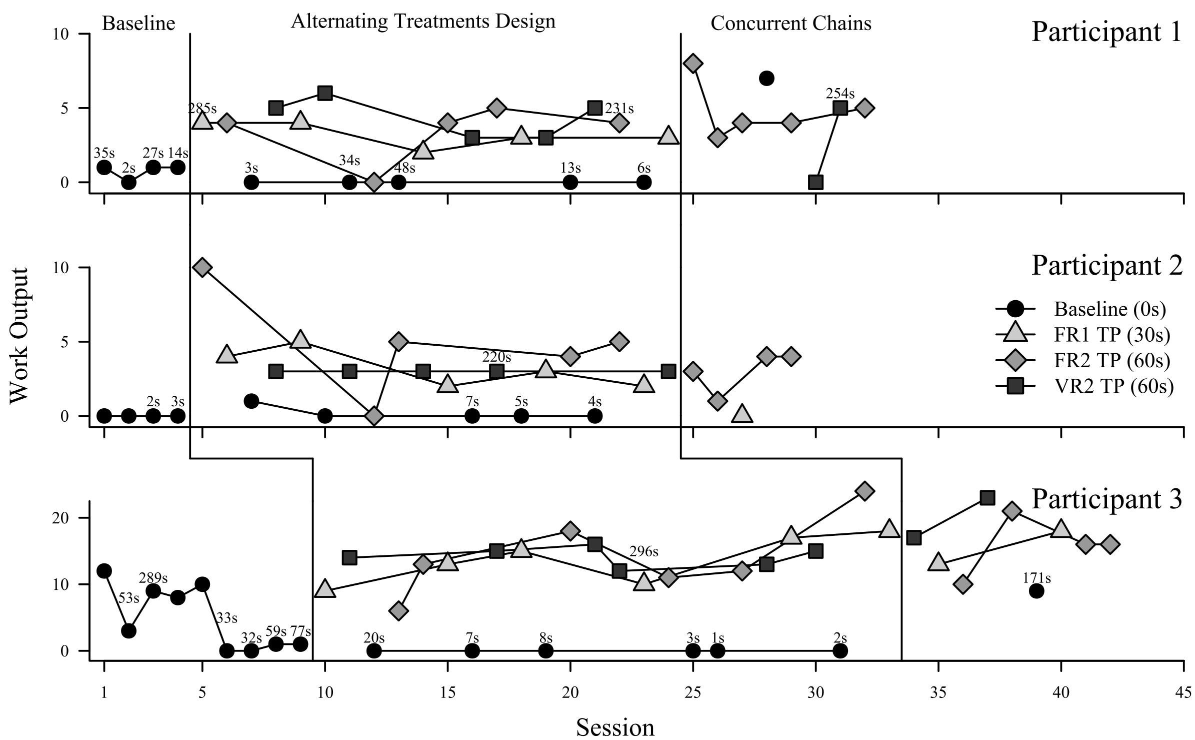

Figure 4. Results of Participant Condition Selections