BRIEF REPORT

AN EXPLORATORY ASSESSMENT OF HUMAN TOKEN ACCUMULATION

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The accumulation of reinforcers is prevalent in humans and non-human animals. For example, some animals store food, and many more engage in central place foraging, described in models of foraging such as the marginal value theorem (Charnov, 1976), which models the relationship between travel cost and time spent in patches. Humans also accumulate reinforcers, including conditioned reinforcers, such as money, but also others like beanie-babies and toilet paper.

Another example of conditioned reinforcers that are commonly accumulated are tokens. The tokens provided in token economies can serve as a bridge between a response and a reinforcer (Kazdin & Bootzin, 1972), making behavior less sensitive to delays to terminal reinforcement. Token accumulation research has often focused on the manipulation of the (a) token production schedule and (b) the exchange production schedule. This typically involves altering the relevant response requirement. Specifically, the token production schedule is the response requirement for producing tokens, and the exchange production schedule is the response requirement for producing the opportunity to exchange tokens. In a study by Yankelevitz, Bullock, and Hackenberg (2008), pigeons' key pecks were reinforced by delivery of tokens exchangeable for food. The token production schedule varied between fixed-ratio (FR) 1 and FR-10. Pecks to a separate key initiated an exchange period. The exchange production schedule ranged from FR-1 to FR-250. The authors found that accumulation was a combined function of the token production and the exchange production schedules. Token accumulation was positively correlated with increases to the exchange production schedule, and negatively correlated to the token production schedule.

The exchange production schedule is often described as a type of travel or procurement cost (Charnov, 1976; Hackenberg, 2018) and its effect on accumulation is well-documented. For example, Killeen (1974) measured the effects of travel distance between the lever and food dispenser on the accumulation of pellets before consuming them. Rats' lever presses were reinforced with food on an FR-1 schedule. Distance between the food dispenser and the response lever was increased across conditions. Killeen found that as the distance increased, the number of times the rats pressed the lever before traveling to the pellets increased. McFarland & Lattal (2001) conducted a similar study in which they manipulated the FR food schedule and the distance between the earn and collect lever. Overall, accumulation was highest when the earn and collect levers were furthest apart, and the FR food schedule was at its lowest value. This result is consistent with the effects of distance on accumulation (Killeen, 1974), and the effects of the exchange and token production schedules on accumulation (Yankelevitz et al, 2008.)

Over the past ten years, accumulation research has been extended to applied behavior analysis and behavior therapy. This line of research has focused on the preference for accumulated, delayed terminal reinforcers compared to immediate, distributed reinforcers. DeLeon et al. (2014) measured the efficacy of distributed and accumulated backup reinforcers on task completion by increasing the exchange production schedule in a token economy. Response rates were highest when participants were given access to accumulated reinforcers (i.e. several minutes of access to a video game) contingent on multiple response requirements rather than shorter access (i.e. thirty seconds) contingent upon a single response requirement. In addition to increased efficacy, participants also preferred the former over the latter when the reinforcer was an activity (4/4 participants) and an edible (3/4 participants). Participants typically engage in fewer problematic behaviors during accumulated reinforcer conditions as well (Fulton et al., 2020; Robinson & Peter, 2019) and are often successful in skill acquisition programs (Frank-Crawford et al., 2019). Another study assessed the extent to which preferences for larger exchange production schedules was moderated by the token production schedule (Falligant et al., 2020). Preference for larger exchange production schedules was higher during dense token production schedules, but reversed as the token production schedule was increased. These findings are consistent with studies of pigeons in which increases to token production and exchange production schedules had opposing effects on accumulation (Yankelevitz et al., 2008).

Another variable that affects how participants behave in a token economy is token generalizability. Generalizability can be manipulated by varying the number and type of back-up reinforcers available for each token during the exchange period. According to Skinner (1953) behavior maintained by a generalized reinforcer is likely to be under the control of multiple states of deprivation. For example, if a student were to earn a token that can be exchanged exclusively for potato chips, then a motivational operation that relates specifically to potato chips is required for the tokens to serve as effective reinforcers. However, if the student can exchange tokens for a large menu of items, then a much broader set of motivational operations will support the efficacy of tokens as reinforcers.

In one of the first demonstrations of generalized token efficacy, DeFulio et al. (2014) assessed the reinforcing value of three different types of tokens under conditions of water deprivation: food tokens (exchangeable for only food), water tokens (exchangeable for only water), and generalized tokens (exchangeable for food or water) with pigeons. Subjects produced more generalized than specific tokens across several increasing token production schedules, demonstrating a higher reinforcing efficacy for generalized tokens. A similar study extended the procedure of DeFulio et al. by measuring effects of increased token production requirements on the production of generalized and specific reinforcers. As the price of tokens exchangeable for specific reinforcers (food and water) increased, the production of generalized tokens (exchangeable for food or water) increased, demonstrating that generalized token reinforcers are substitutes for specific token reinforcers (Andrade & Hackenberg, 2017). Tan & Hackenberg (2015) used a similar arrangement to assess the efficacy of generalized token reinforcers with progressive ratio schedules, and preference procedures, and by manipulating response requirements to generate a demand function. This study similarly illustrated the substitutability of generalized tokens with specific food and water tokens.

A key gap in human reinforcer accumulation research is that the effects of generalizability on accumulation are not well understood. At most, previous research on humans has shown how preferences for accumulated reinforcers are affected by one of the token component schedules. Therefore, the present experiment was designed to investigate determinants of human token accumulation. Most importantly, token generalizability was manipulated across conditions by increasing the variety of goods that could be purchased with tokens. In addition, the exchange production schedule was manipulated by increasing the distance between the computer that delivered the token production task and the store where tokens were exchanged for other items. The token production schedule was also manipulated.

METHOD

Subjects

Five undergraduate students at a large midwestern university were recruited to participate in this study. Subjects were eligible to join this study if they were (1) at least 18 years old; (2) able to use a computer and be able to perform simple math; and (3) were not colorblind.

Subjects were excluded if they are (1) are suspected of being under the influence of recreational drugs or alcohol before, during, or immediately after any session; (2) had known allergies to any items included in the token exchange center.

Apparatus

A scale was used to weight all food items to the gram. Hot coffee and chocolate were measured using a programmable single cup coffee maker set at 4 ounces. All food items were distributed using paper plates, and sports drinks were poured into a plastic cup.

Procedure

Design

The study featured a single subject, repeated measures design. Each participant received all conditions. Participants completed the study over a minimum of seven and maximum of nine sessions, with no more than one session conducted per day.

Overview of Procedure

Subjects earned tokens on a computerized paint by number task. Completing a full screen of mathematical problems produced one token. Token production requirements were manipulated by altering the number of problems on each screen. All mathematical problems were simple addition, adding two numbers between 0 and 9 (excluding 0 + 0). Each problem was contained in a box on the screen. To fill each box, participants selected a color from an array on the left side of the screen which they dragged into the box using the computer mouse. There were six colors in the array, thus each color represented a three-value range of answers to the problem (e.g., the values 1 to 3 were represented by the color teal, while 4 to 6 was represented by green). In the present experiment, for each paint by number task, participants were asked to complete 100, 200, or 300 paint by number mathematical problems per screen, depending on the condition. The number of tokens participants accumulated were displayed as a running tally in top left corner of the paint by number screen. Participants were informed token production requirements, distance to the store, and menu items available for purchase at the beginning of each session. The menu was placed next to the participant throughout each session. While working on the paint by number task participants could pause at any time to exchange their tokens. All sessions lasted one hour, not including exchange periods. When a participant decided to pause their session to make an exchange, the researcher paused the one-hour timer. Timer pausing was designed to prevent travel time from affecting session duration. There was no time limit or requirement for the token exchange. Each subject could consume back-up reinforcers at any time during the experimental session, including while working on the task. The session timer was not paused for consumption. The token production schedule, exchange production schedule, and generalizability were manipulated as described below.

Phase 1: Token Production Schedule Manipulation

The FR token production schedule began at FR-100 and was increased by 100 responses across sessions, to a maximum of FR-300. Exchange production schedules and generalizability were held constant at their lowest values across these sessions. All subjects started on an FR-100 which increased each subsequent session. Any participant who failed to accumulate tokens at FR-100 or FR-200 was moved immediately to the next experimental phase instead of experiencing higher token production schedules.

Phase 2: Exchange Production Schedule Manipulation

The exchange production schedule was manipulated by increasing the walking distance required to exchange tokens. One distance was used per session. Token exchange centers were at the following locations: (a) next to the participant's work space, in the same room as the paint-by-number game (labeled the "No Walk" condition); (b) in the opposite corner of the experimental room (participants will have to stand up and move approximately 3 m to exchange their tokens, labeled the "Short Walk" condition); (c) across the hall, approximately 10 m to another room, labeled the "Long Walk" condition. The token production schedule and token generalizability were held constant during all exchange production schedule manipulations.

Phase 3: Token Generalizability Manipulation

For this phase token production and exchange production values were set based on the results of the prior phases. Specifically, values were selected such that the minimum amount of accumulation would be expected. These values (FR-200 token production and "No walk") were held constant across the three session of this phase. For the first session tokens could be exchanged for any of eight different snacks. Seven different kinds of salty chips (e.g., potato chips, Doritos®) were included on the menu, along with Welch's® fruit snacks. The second session included 15 items. Eight of these were identical to the eight offered in the previous session. The additional items included chocolate, breakfast cookies, juice, a sports drink, fruit-flavored candy, popcorn, and cheese-flavored crackers. The final condition included 19 items on the menu. Trail mix, beef jerky, coffee, hot chocolate were added to the 15 items included in the prior session.

Data Analysis

The primary outcomes in this study were the number of tokens spent and number of tokens available at each exchange period. The number of tokens available was measured to account for participants that do not spend all available tokens during a given exchange. Mean tokens spent and % multiple exchanges were calculated and averaged across all participants. Mean tokens spent was calculated by averaging the number of tokens spent for each condition, for each participant. A multiple exchange was any instance in which a participant spent more than one token during an exchange period.

RESULTS

Figure 1 contains the mean number of tokens available, tokens spent, and the percentage of exchanges during each condition where the participant spent more than one token. Excluding TA06, participants made multi-token exchanges at least 50% of the time across all conditions. For example, 100% of TA02's exchanges were of at least two tokens across all experimental conditions. However, multiple exchanges were more sensitive to manipulations for participants who spent their tokens more frequently (i.e. TA05 & TA06).

In general, participants' mean tokens available was more sensitive to all three manipulations than mean tokens spent. Three of five participants' tokens available decreased as the token production schedule increased. However, one participant showed a reverse trend. Excluding TA08, whose accumulation was insensitive to all manipulations, mean tokens available increased as the exchange production schedule increased. Tokens spent increased for three participants as exchange production schedule increased. During exchange production manipulations accumulation was highest in the Long Walk condition.

Mean tokens spent and available increased as generalizability increased for two of five participants (TA06, TA07). Three of five participants increased the number of multi-token exchanges as generalizability increased. The remaining two participants made multi-token exchanges across all generalizability manipulations. Overall, accumulation was highest, and multi-token exchanges were most prevalent, in the 19-item menu condition.

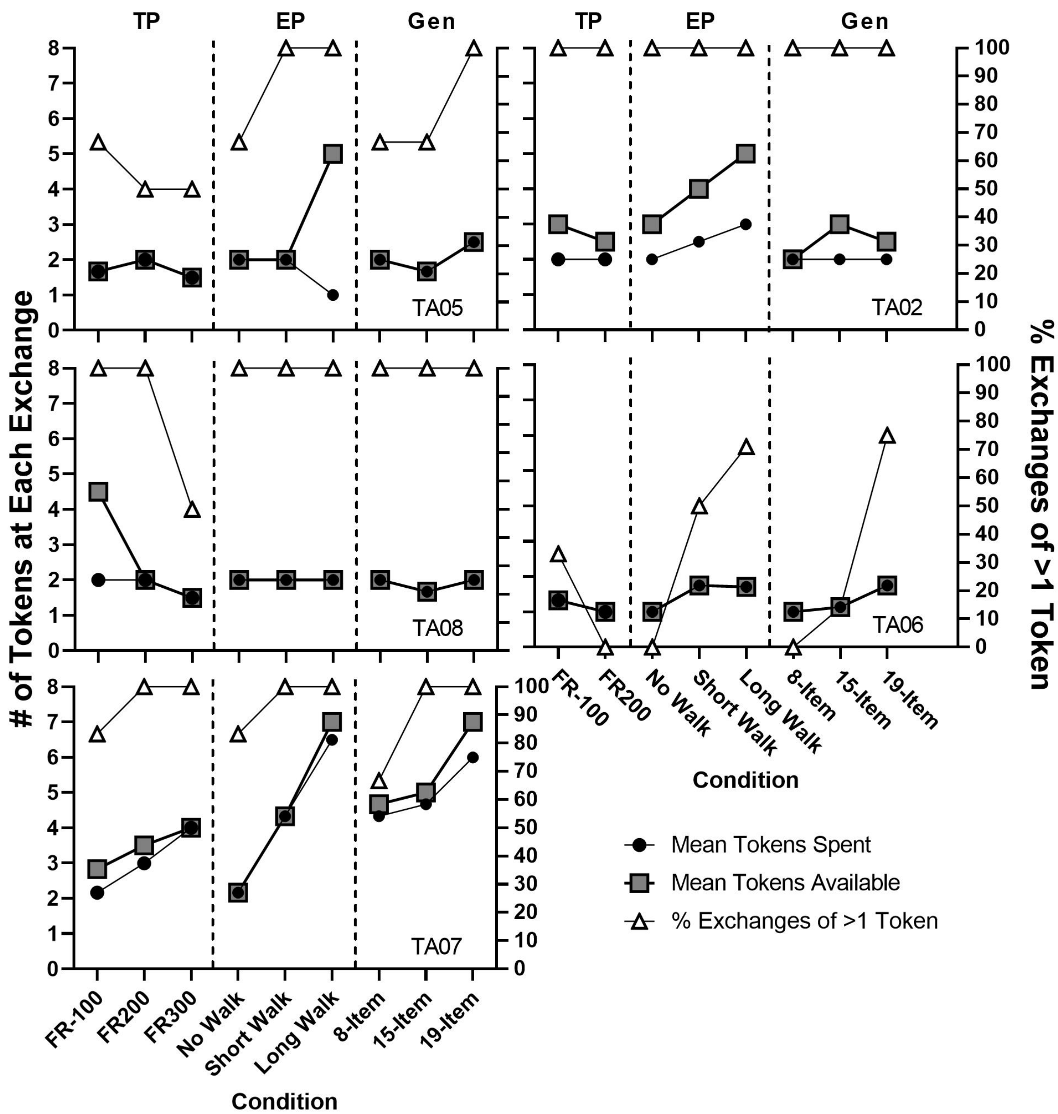
DISCUSSION

In this study, token accumulation was primarily a product of the exchange production schedule. Three of five participants had an immediate increase in accumulation when moving from the Short Walk to the Long Walk condition, while four of five participants increased their accumulation by the Long Walk condition. The effects of generalizability on accumulation were not substantial. Two participants increased their accumulation as generalizability was increased, with the largest increase in the token 19-item condition. Overall, participants' accumulation was unaffected by the token production schedule. One participant (TA08) was insensitive to all experimental contingencies.

The positive relationship between exchange production schedule and accumulation observed in this study is consistent with previous research on reinforcer accumulation (Yankelevitz et al., 2008; Killeen, 1974). The method used to manipulate the exchange production response requirement in the present study was similar to the method used by Killeen, though Killen's procedure did not incorporate tokens. In contrast, the present study and the Yankelevitz study both featured token economies, but differ-

Figure 1

Token accumulation across all conditions.



Note. Primary outcome variables for all study participants across all conditions. The left y-axis corresponds to the data paths with circle and square symbols, which represent mean tokens spent and mean tokens available for each participant, respectively. The right y-axis corresponds to the data path with triangle symbols and shows the percent of all exchanges in which more than one token was exchanged

ed in the method used for manipulating the exchange production response requirement.

The lack of relationship between token production schedule and accumulation is not consistent with prior research. Yankelevitz et al. (2008) found an orderly decrease in accumulation as the token production schedule increased from an FR-1 to an FR-10. In the present study, there were no observed accumulation trends across participants. TA06 was the only participant to have an immediate decrease in accumulation from the FR-100 (1.33/exchange) to FR-200 (1.0/exchange). In opposition to the predicted effect, a linear increase in accumulation was observed with TA07 as the production schedule increased.

A procedural difference between Yankelevitz et al. and the present study may explain the lack of token production schedule effect. Two participants did not run an FR-300 token production schedule because their accumulation had already been eliminated at the FR200 level (e.g., TA06). As a matter of efficiency, the FR300 condition was not conducted since that condition tends to reduce accumulation. Since they did not run an FR300 schedule, their low levels of tokens spent at each exchange did not contribute to the overall participant mean for the FR300. Not including these sessions likely increased the mean tokens spent and % multiple exchanges on the FR-300 schedule, which would have then been like the results on the FR-200 schedule.

Another important difference between this study and Yankelevitz et al. is that the magnitude of FR schedules used in this study were much higher. The FR-100 schedule produced low baseline accumulation, which led to a floor effect. It is possible that the parameter space within which humans would accumulate tokens on this task lies below the FR 100 response requirement. Perhaps more importantly, all token production manipulations were done with the smallest exchange production response requirement. Accumulation may be much more sensitive to token production schedule changes in the context of a larger exchange production schedule.

A possible limitation of the present study was that container size appeared to be a determinant of participants' behavior. For example, participant TA08 spent two tokens at a time during most sessions. Informal conversation with this participant indicated that the reason for this was that two tokens roughly equaled an individual-sized bag of chips. Thus, the spending of tokens may have been under the partial antecedent control of the commercial packaging of the food items on the menu. Chips were exchanged at the rate of one token for 14 grams, but this was roughly equivalent to one-half of a bag, which may have led to self-generated rules such as, "two tokens equals a bag." Further, participants observed the weighing of the food products on the scale. Such issues could easily be avoided in future studies by, for example, using larger bags of snacks rather than single serving bags. Consideration of stimulus control related to commercial packaging, and procedures designed to eliminate it should be a design consideration in future human operant studies of token systems.

A second potential limitation of this study was that the order of conditions was identical for all participants. All participants underwent each condition in the same order. This leaves open the possibility of an undetected sequence effect. For example, the No Walk condition may have served as an "anchor" for the short walk and long walk conditions (Tversky & Kahneman, 1974). A participant may have made accumulation decisions based on the magnitude of the first schedule. Counterbalancing could be used in an attempt to wash out sequence effects, but such a technique would also obscure any sequence effect rather than revealing it. The effects of condition sequencing on accumulation could be addressed in future studies by directly comparing a limited number of alternative sequences.

Research on reinforcer accumulation has significant applied value and may improve the quality of token economies as interventions. For example, in one study that used token systems to promote appropriate behavior, participants who save their tokens show performance decline over time (Winkler, 1973). In Subramaniam et al. (2017), however, the authors found that participants who held a higher balance during a therapeutic workplace intervention for adherence to naltrexone also tended to have higher rates of heroin and cocaine abstinence. Although the conclusions of these studies indicate opposite effects, they both indicate that there are conditions under which accumulation can mediate the effects of token interventions. It is thus possible that interventions that target accumulation specifically could improve overall outcomes in clinical applications of token economies. Given the robust effects of token component schedules on accumulation, these variables would be strong candidates for inclusion in future studies designed to investigate accumulation as a mediating variable in token economy interventions.

Generalized reinforcers are part of everyday human life and come in many forms ranging from verbal behavior to money (Skinner, 1953). We join Tan & Hackenberg (2015) in the view that despite the obvious translational value of generalized reinforcement studies, the literature remains limited. Generalizability of tokens did not produce a robust effect in the present study. Nevertheless, the possibility remains that generalizability may moderate the relationship between performance and accumulation. For example, the incentives used in Subramaniam et al. were paychecks, which are highly generalized reinforcers. Participants were able to save large sums of money during that study to pay for high cost bills such as rent. However, in Winkler et al. (1973) the tokens participants were working towards were restricted to privileges, meals, and beverages in an inpatient ward in which basic needs were met independent of the participants' performance. It is possible that participants were saving their tokens in that study partially because the relevant motivational operations fairly weak. This could serve to enhance the effects of the component schedules on accumulation and is also consistent with the reduction in earning responses observed in the study. Thus, a parametric analysis of the effects of token production schedule, exchange production schedule; and token generalizability on accumulation is warranted. This would constitute a systematic replication of Yankelevitz et al. (2008), with human participants and the addition of a token generalizability manipulation.

The relationship between the token exchange schedule and token accumulation also warrants further study. Yankelevitz et al. (2008) held the token exchange schedule constant at FR-1 when manipulating token production and exchange production schedules. In applied settings, the token exchange schedule is typically the number of tokens required to purchase a backup reinforcer. Increasing the token exchange schedule may promote accumulation. However, the price of the items was not experimentally manipulated in the current study. Increasing the token exchange schedule by simply increasing the cost of all backups would inflate accumulation by requiring participants to save more tokens to spend them. However, possessing a number of tokens that is greater than one but less than the minimum necessary to purchase the least costly backup item should not be conceptualized as accumulation. Although price is a common independent variable in the field of economics, the effects of the token exchange schedule on accumulation has yet to be explored in an operant framework.

The present study was the first investigation of token generalizability and accumulation with human subjects and one of the first to indicate that the relationship between generalizability and accumulation merits further inquiry. Additionally, this study provides additional support for the exchange production schedule findings from Yankelevitz et al. (2008) This finding could have translational value, especially if saving undermines the effectiveness of token-based interventions.

REFERENCES

Andrade, L. F., & Hackenberg, T. D. (2017). Substitution effects in a generalized token economy with pigeons. *Journal of the Experimental Analysis of Behavior, 107(1)*, 123–135. http://dx.doi.org.libproxy.library.wmich.edu/10.1002/jeab.231

Ayllon, T., & Azrin, N. H. (1965). The measurement and reinforcement of behavior of psychotics. *Journal of the Experimental Analysis of Behavior, 8(6)*, 357–383. http://dx.doi.org.libproxy.library.wmich.edu/10.1901/jeab.1965.8-357

Charnov, E. (1976). Optimal foraging: The marginal value theorem. *Theoretical Population Biology, 9(2)*, 129–136. https://doi.org/10.1016/0040-5809(76)90040-X

Cole, M. R. (1990). Operant hoarding: A new paradigm for the study of self-control. *Journal of the Experimental Analysis of Behavior*, *53*(2), 247-261. https://doi.org/10.1901/jeab.1990.53-247

DeLeon, I. G., Chase, J. A., Frank-Crawford, M. A., Carreau-Webster, A. B., Triggs, M. M., Bullock, C. E., & Jennett, H. K. (2014). Distributed and accumulated reinforcement arrangements: Evaluations of efficacy and preference. *Journal of Applied Behavior Analysis*, *47*(2), 293-313. https://doi.org/10.1002/jaba.116

Deslauriers, B. C., & Everett, P. B. (1977). Effects of Intermittent and Continuous Token Reinforcement on Bus Ridership. *Journal of Applied Psychology*, *62*(4), 369–375. https://doi.org/10.1037/0021-9010.62.4.369

Falligant, J. M., Pence, S. T., & Bedell, S. B. (2020). Preferences for token exchange-production schedules: Effects of task difficulty and token-production schedules. *Behavioral Interventions*, *35*(2), 234-248. https://doi.org/10.1002/bin.1706

Frank-Crawford, M., Borrero, J. C., Newcomb, E. T., Chen, T., & Schmidt, J. D. (2019). Preference for and efficacy of accumulated and distributed response–reinforcer arrangements during skill acquisition. *Journal of Behavioral Education*, *28*(2), 227-257. https://doi.org/10.1007/s10864-018-09312-7

Fulton, C. J., Tiger, J. H., Meitzen, H. M., & Effertz, H. M. (2020). A comparison of accumulated and distributed reinforcement periods with children exhibiting escape-maintained problem behavior. *Journal of Applied Behavior Analysis*, *53*(2), 782-795. https://doi.org/10.1002/jaba.622

Hackenberg, T. D. (2018). Token reinforcement: Translational research and application. *Journal of Applied Behavior Analysis*, *51*(2), 393–435. https://doi.org/10.1002/jaba.439

Kazdin, A. E. (1982). The token economy: A decade later. *Journal of Applied Behavior Analysis*, *15*(3), 431–445. https://doi.org/10.1901/jaba.1982.15-431

Kazdin, A. E., & Bootzin, R. R. (1972). The token economy: An evaluative review. *Journal of Applied Behavior Analysis*, *5*, 343–372. https://doi.org/10.1901/jaba.1972.5-343

Killeen, P.R. (1974). Psychophysical distance functions for hooded rats. *The Psychological Record*, *24*, 229–235. https://doi.org/10.1007/BF03394238

Lovaas, O. I. (1968). Some studies on the treatment of childhood schizophrenia. In J. M. Shlien (Ed.), Research in psychotherapy (pp. 103-121, Chapter vii, 615 Pages) American Psychological Association, Washington, DC. https://doi.org/10.1037/10546-005

McFarland, J. M., & Lattal, K. A. (2001). Determinants of reinforcer accumulation during an operant task. *Journal of the Experimental Analysis of Behavior*, *76*(3), 321-338. https://doi.org/10.1901/jeab.2001.76-321

Michael, J., Palmer, D. C., & Sundberg, M. L. (2011). The multiple control of verbal behavior. *The Analysis of Verbal Behavior*, *27*, 3–22. https://doi.org/10.1007/BF03393089

Phillips, E. L., Phillips, E. A., Fixsen, D. L., & Wolf, M. M. (1971). Achievement Place: modification of the behaviors of pre-delinquent boys within a token economy. *Journal of Applied Behavior Analysis*, *4*, 45–59. https://doi.org/10.1901/jaba.1971.4-45

Robinson, N., & St Peter, C.,C. (2019). Accumulated reinforcers increase academic responding and suppress problem behavior for students with Attention-Deficit hyperactivity disorder. *Journal of Applied Behavior Analysis*, *52*(4), 1076-1088. https://doi.org/10.1002/jaba.570

Skinner, B.F. (1953). Science and human behavior, New York: Macmillan. https://doi.org/10.1002/sce.37303805120

Skinner, B.F. (1957). Verbal Behavior, New York: Macmillan. https://doi.org/10.1037/11256-000

Sousa, C., & Matsuzawa, T. (2001). The use of tokens as rewards and tools by chimpanzees (Pan troglodytes). *Animal Cognition*, *4*(3-4), 213-221. https://doi.org/10.1007/s100710100104

Winkler, R. C. (1973). An experimental analysis of economic balance, savings and wages in a token economy. *Behavior Therapy*, *4*(1), 22-40. https://doi.org/10.1016/S0005-7894(73)80072-3

Yankelevitz, R. L., Bullock, C. E., & Hackenberg, T. D. (2008). Reinforcer accumulation in a token-reinforcement context with pigeons. *Journal of the Experimental Analysis of Behavior*, *90*(3), 283-99. https://doi.org/10.1901/jeab.2008.90-283