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A Comparison of Variable Ratio and Fixed Ratio Schedules of Token Reinforcement

A Thesis Presented

by

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The Department of Counseling and Applied Educational Psychology

In partial fulfillment of the requirement for the degree of

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Submitted in partial fulfillment of the requirements for the degree of Master of Science in
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Abstract

Previous research has shown the effects that different schedules of reinforcement have on behavior. Much of this research was applied to production schedules of token reinforcement, meaning how many responses an individual needs to emit before receiving a token, which can later be exchanged for preferred items. Little research has focused on behavior changes under different schedules of token exchange, that is, how many tokens need to be earned before the opportunity to exchange is presented. The present study sought to examine whether behavior change under different schedules of token exchange is similar to that under simple schedules of reinforcement. Two individuals with developmental disabilities participated in the study. In the fixed ratio (FR) condition, the participant received a token for every instance of target touching, and was presented with the opportunity to exchange those tokens for a preferred edible after receiving 10 tokens. In the variable ratio (VR) condition, the participant received a token for every instance of target touching, but the opportunity to exchange the tokens varied from 1-18 tokens, averaging 10 tokens across the session. The schedules produced show a lower response rate during the VR condition for one individual, and no difference in responding between the two conditions for another individual. The practical implications of this study suggest that a fixed ratio token schedule may be more beneficial for both practitioners and students.

Keywords: conditioned reinforcement, schedules of reinforcement, token economy

A Comparison of Variable Ratio and Fixed Ratio Schedules of Token Reinforcement

Both basic and applied research has shown the effects schedules of reinforcement have on behavior. It is well documented that an organism's rate and pattern of responding alter depending on the schedule in effect. For example, fixed schedules often produce a post-reinforcement pause, in which the organism will cease responding for a short time following the delivery of a reinforcer. This is often followed by an increase in the rate of target behavior until the requirements for reinforcement are once again met. On the other hand, variable schedules, in which the requirement to contact reinforcement changes for each delivery, produce higher and steadier rates of responding (Ferster & Skinner, 1957).

Token reinforcement is a type of conditioned reinforcement, and has been shown to be an effective behavior modification strategy across many different populations (Kazdin, 1978; Hackenberg, 2009). A token is "an object or symbol that can be exchanged for goods or services" (Hackenberg, p. 257) and has many benefits, including ease of delivery, immediacy of reinforcement, the absence of reinforcer satiation, and the availability of choice for the individual. Tokens themselves have no value originally and only obtain their value through their pairings with other stimuli. Tokens, therefore, can serve many roles, including as reinforcers, punishers, eliciting stimuli, or discriminative stimuli (Hackenberg).

Tokens have been demonstrated to be as effective as unconditioned reinforcers for many individuals. Wolfe (1936) demonstrated the effectiveness of conditioned reinforcers with chimpanzees that were token trained. Token training consisted of the experimenter modeling the token exchange (depositing it into a vending machine type device) and immediately reinforcing exchange with a variety of primary reinforcers (grapes, water, etc). Once the chimpanzees were token trained, they were then trained to use a weight-lifting device in order to earn tokens. Out

of four token-trained chimps, three of them showed no differences in response rates when behavior was reinforced with tokens as compared to grapes. Results also showed that similar response efforts could be maintained by both tokens and unconditioned reinforcers. This was demonstrated by altering the weight of the bar the chimpanzees needed to maneuver in order to earn tokens or primary reinforcers. Three of the four subjects showed no difference in how much weight they would lift in order to have access to tokens as compared to direct food reinforcement.

Cowles (1937) demonstrated the effects tokens can have on skill acquisition. Also using chimpanzees, he presented a two stimulus array in order to train discrimination. Tokens were used as reinforcers for choosing the correct stimulus. The results showed that for two out of the three subjects, discrimination was established quickly with tokens. Cowles also later used a five choice array to compare the acquisition of discrimination under tokens and direct edibles. Results of this study showed that four of the five subjects showed discrimination just as quickly with tokens as they did with direct edibles.

However, Kelleher (1956) was the first person to investigate how token schedules are similar or distinct from simple schedules of reinforcement. In a token economy, there are three different components to the schedule of reinforcement. The first component is called the token-production schedule, which is the schedule that determines when the individual receives tokens for emitting the target behavior. For example, if the token-production schedule is FR 5, the individual must emit the target behavior five times in order to earn one token. The second component is called the exchange-production schedule, which determines when the opportunity to exchange tokens for preferred reinforcers is available. For example, if the exchange-production schedule is FR 5, the individual may begin exchanging tokens after five tokens have

been accumulated. The final component is called the token-exchange schedule, which is the schedule that determines when tokens can be exchanged for other reinforcers. For example, if the token-exchange schedule is FR 5, the individual must exchange five tokens for one reinforcer (Hackenberg, 2009). For the purpose of the current study, there will be two components to the schedule of reinforcement: the production schedule which determines how many responses must be emitted in order to receive one token, and the exchange schedule which determines how many tokens are required to exchange those tokens for a preferred item. The schedules will be denoted by “exchange schedule (production schedule).” For example, an FR 10 (FR 1) schedule would indicate that the participant would earn a token for every one correct response, and exchange for a preferred reinforcer after receiving ten tokens.

Previous research has shown that behavior is related to each of the components separately and in combination (Hackenberg, 2009). Kelleher (1958) demonstrated this effect in his experiment involving chimpanzees. In this study, Kelleher compared different values of fixed ratio schedules of conditioned reinforcement. Two chimpanzees received tokens on an FR 50 schedule of token production for pressing a telephone key. This requirement was then gradually increased to an FR 125 schedule of reinforcement, though the exchange schedule remained at FR 50 across all sessions. Results of this study showed that there were much longer pauses in responding followed by higher response rates as the production schedule increased. This is consistent with what one would find with simple schedules of reinforcement.

Kelleher (1956) also compared different types of schedules of reinforcement (i.e., ratio vs. interval schedules). He trained chimpanzees to press a lever in order to receive tokens on both a fixed ratio schedule and a fixed interval schedule. He found that responding under both the FR and FI token schedules were similar to what one would expect under FR and FI simple

schedules of reinforcement: a break-run pattern and a scallop effect were observed in the FR schedules and the FI schedules respectively.

The results of Kelleher's (1956) study were replicated by Waddell, Leander, Webbe, and Malagodi (1972) with rats as subjects. In this study, the rats were on an FR 1 (FR 20) schedule of reinforcement for lever pressing. Following the FR 1 (FR 20) schedule, lever pressing was reinforced on an FR 2 (FR 20) and finally an FR 3 (FR 20) schedule. After the FR schedules, the rats were placed on an FI schedule of token exchange, ranging from 1.5 to 9 minute intervals. Waddell et al. noticed similar effects as Kelleher when comparing FR and FI schedules. In addition, they found that pauses in responding increased as the exchange schedule increased, demonstrating that responding is dependent on both the production and the exchange schedules of reinforcement and that these changes in responding are similar to simple schedules of reinforcement.

Malagodi (1967) examined variable schedules of conditioned reinforcement as compared to fixed schedules. In Malagodi's study, the token-production schedules alternated between variable interval and fixed ratio schedules. Malagodi found that FR token-production schedules produced a high steady rate of responding with pre-ratio pausing, while the VI token-production schedule produced a lower steady rate, much like responding under simple schedules.

Webbe and Malagodi (1978) published an early article that compared fixed-ratio and variable-ratio exchange schedules of token reinforcement. In their experiment, rats were trained to press a lever and received a marble for every 20 responses (FR 20: TOKEN). During baseline, the rats were provided an opportunity to exchange their marbles after six completions of the schedule (FR 6: EXCHANGE) and each marble produced a food pellet (FR 1: FOOD). After the response rate was stable, the exchange schedule was changed from a fixed-ratio

schedule to a variable-ratio schedule (VR 6: EXCHANGE), and the number of marbles delivered until reinforcement varied from 1-14. A reversal to FR 6: EXCHANGE was implemented after response rate was stable. There were higher rates of responding under the VR condition as compared to the FR condition. There was also less variability in rate of responding between sessions under the VR schedule. Finally, post-reinforcement pausing after token delivery was much shorter in the VR condition as compared to the FR condition, and pausing in the second FR condition was much longer than the first FR condition, suggesting that exposure to a VR schedule increased pausing in the FR schedule.

In 2001, Foster, Hackenberg, and Vaidya replicated these effects by measuring key pecking in pigeons. Responses on the right side key were reinforced with an illuminated token. Exchange periods were made available when the red center key was illuminated. During this time, a peck on the exchange key produced access to food. In their first experiment, Foster et al. alternated the exchange-production schedule between fixed-ratio and variable-ratio schedules with the exchange period becoming available after 1-8 responses. For the higher ratio requirements (e.g. FR 8 or VR 8), the variable-ratio schedules had produced higher response rates. More importantly, as ratio requirements increased, responding decreased under the fixed-ratio schedule and the variable-ratio schedule remained unaffected. Finally, for most pigeons, preratio pausing was shorter under a variable-ratio exchange schedule when compared to a fixed-ratio exchange schedule of the same value. In their second experiment, Foster et al. manipulated both the token-production schedule and the exchange-production schedule. The exchange- and token-production schedules were either a FR production schedule with a VR exchange schedule, or a VR production schedule with a FR exchange schedule. The token-production requirement was always 50 (either an average of 50 responses when it was a VR exchange condition, or a

fixed requirement of 50 responses when it was an FR exchange condition). The exchange schedule requirement varied from 1-8 tokens. Results of the second experiment supported results from the first experiment. When the exchange schedule was fixed-ratio, rate of responding decreased as the token-production ratio schedule increased (e.g. from VR 4 to VR 8). However, when the exchange schedule was variable-ratio, response rates were unaffected as the token-production schedule increased (e.g. from FR 4 to FR 8). In addition, more pausing occurred when the FR token-production schedule was increased than when the VR token-production schedule was increased. Rate of responding was steady throughout the session in the VR schedule, meaning that after reaching an exchange opportunity, response rate in the next token-production segment was similar to the previous one. However, responding increased throughout the session in the FR schedule, meaning that after receiving reaching an exchange opportunity, response rate in the next token-production segment was higher than the previous one. Foster et al. demonstrated that responding under schedules of conditioned reinforcement is similar to responding under simple schedules of reinforcement.

The purpose of the current study was to examine if schedules of conditioned reinforcement is similar or distinct from simple schedules of reinforcement. In particular, the current study examined if fixed vs. variable ratio exchange schedules of token reinforcement will produce behavior similar to what is found under fixed and variable ratio simple schedules of reinforcement.

Method

Participants and setting

Participants were two children, age 6 and 12. Both were diagnosed with an Autism Spectrum Disorder (ASD) and attended a residential school specializing in ASD. Each of the

students' parent/guardian had agreed to participation and signed an informed consent outlining the method and benefits of the experiment. Sessions were discontinued if the participant at any point asked to be finished, attempted to leave, or showed discomfort. All sessions took place in students' individual workplaces in their regular classroom, and lasted between 2.5 and 10 min in duration.

Materials

A round tap light, approximately 15 cm in diameter, was used as the target. The tap light would illuminate if touched with the correct amount of pressure, and would switch off in the same manner if illuminated. Two rectangular pieces of construction paper (21.5 cm x 27.9 cm) were laminated and used as token boards. The token board for the FR condition was green, and red for the VR condition. Two strips of Velcro® were added to each token board, approximately 25.4 cm in length each, and spaced 3 cm apart from each other. Each token board could fit approximately 20 tokens. White Bicycle® poker chips were used as tokens, with small pieces of Velcro® on the back to adhere to the token boards. In addition, preferred edibles were used as back-up reinforcers and were determined by a mini preference prior to each session. The preferred edibles used were Starburst®, Twizzlers®, jelly beans, Fruit Loops®, lollipops, Mike & Ikes®, Rice Krispie Treats®, Baked Lays® potato chips, Laffy Taffy®, fennel seeds, Parmesan cheese, feta cheese, Skittles® and Airheads®. A camera was used to videotape all sessions for scoring and interobserver agreement purposes.

Response definition and measurement

The target response was target touching, defined as the participant making contact with the tap light in such a way as to turn it on or off, and the light remained that way after the participant discontinued contact with it. Therefore, if the participant touched the light and it

turned on, but once his/her hand was withdrawn, the light turned back off, this was not scored as a response. Responses were measured in responses/minute, calculated by dividing the frequency of responses by the total number of minutes in the session. Interobserver agreement was collected across 33% of sessions and was calculated by dividing the smaller number of scored responses by the larger number of scored responses and multiplying by 100. In addition, for Elizabeth, the number of exchanges per session was also recorded to determine the actual ratio schedule in place. The number of exchanges across sessions ranged from 11 exchanges (in the VR condition) to 58 exchanges (in the reversal to the VR condition).

FR exchange condition

The first condition in the experiment was the FR condition, in which the participant received a token for each instance of the target behavior, and exchanged the tokens for a preferred edible after receiving 10 tokens, and was therefore on an FR 10 (FR 1) schedule of reinforcement. Once 10 tokens were placed on the board, the experimenter removed the tap light and waited for the participant to hand the experimenter the token board with all 10 tokens on it. Once this occurred, the session timer was paused and a preferred edible was delivered. Once the participant placed all of the edible in his/her mouth, the tap light was returned to its place in front of the participant, and the session timer was re-started. Therefore, consumption time was not included in the session. Only when the tap light was in front of the participant did the timer start again and the session continued. Session time varied in duration for each participant from 5 min to 10 min, with actual time including consumption time ranging from 5'44" to 22'58". Sessions were sometimes stopped due to student behavior and were therefore shorter than 5 or 10 minutes. This occurred in 15/64 sessions. Those data were still analyzed, converted to response rate, and included in the study. Criterion to switch conditions was based on visual analysis.

VR exchange condition

Following stable responding in the FR condition, a VR 10 (FR 1) schedule of reinforcement was implemented. In this condition, the participant received a token for every instance of the target behavior, but received edibles on an average of 10 responses. The number of responses required for reinforcement was predetermined to ensure the average was 10 responses. The response requirement after each exchange ranged from 1 to 18 responses. The ratio requirement for each trade-in and the order in which it was presented was based on the Excel macro described in Bancroft and Bourret (2008).

FR and VR Reversal

A return to the FR condition was conducted after responding was stable in the VR condition, followed by a reversal to the VR condition after responding was stable in the FR condition in order to replicate treatment effects.

Results

Results of the current study were inconsistent across participants. For one participant, the FR condition produced more rapid responding. Responding was stable across both the FR and VR conditions for this participant. For the second participant, there was no noticeable difference in the level or variability of responding across conditions.

Figure 1 depicts the results for Elizabeth. In the first condition of the study, her responding slowly increased until it stabilized at about 115 responses/min. When the VR condition was implemented, responding was immediately stable, but dropped to around 85 responses/min. As soon as the FR condition was re-implemented, the level of responding immediately increased to the level it was before the VR condition was implemented, around 110

responses/min. The next reversal to the VR condition resulted in a sharp and immediate decrease in responding to a level similar to the first VR condition.

Figure 2 shows the results for David. Similar to Elizabeth, his responding in the FR condition gradually increased until it stabilized at around 45 responses/min. David's responding remained variable under the FR condition, but did not appear to have a specific increasing or decreasing trend. Therefore, the condition was changed to the VR condition. Under the VR condition, David's responding was immediately stable, but unlike Elizabeth it remained at the same level as the FR condition, with 4 of the 5 sessions producing between 44.2 and 45.4 responses per minute. A reversal to the FR condition again produced variable responding. The level of responding in this condition was slightly higher than in the two previous conditions, though not consistently. A reversal to the VR condition produced variable responding at a level similar to the previous conditions.

Discussion

For Elizabeth, the FR schedule produced a higher response rate than the VR schedule. Stable responding was achieved in all conditions for this participant as well, which indicates the VR condition did not produce more stable responding. For David, no reliable difference in responding occurred. Responding was variable across all conditions, and response rate remained similar across all conditions as well. These findings are contrary to previous research regarding schedules of conditioned reinforcement, which indicate a VR schedule should produce higher and more stable responding than an FR schedule (Hackenberg, 2009; Webbe & Malagodi, 1978; Foster et al., 2001). There are a few potential reasons for the difference.

The response may have had such a low response effort that no difference in responding was necessary to obtain maximum reinforcement, meaning that the response effort was so low

that the individual would continue responding until reinforcement was obtained, regardless of the schedule of reinforcement. Future research should choose responses of various difficulties to see if responding changes across conditions.

Additionally, the low ratio requirement for reinforcement may have produced different results than earlier studies with animal subjects. Earlier studies have shown that VR schedules produce higher and more stable responding than FR schedules. However, differences were observed only at higher ratio requirements. At low ratios, responding remained the same across different schedules of reinforcement (Foster et al., 2001). Future research should try increasing the ratio until a difference is noticed across conditions.

It is also important to note that the reinforcement for the target behavior was inconsistent. Throughout the sessions, oftentimes the individual would respond so quickly that reinforcing every response was impossible, so the token production schedule could not consistently be an FR1 schedule. The results of the study could have been affected by this inconsistency. Future research should focus on reinforcing every correct response by either choosing a longer response so an FR1 schedule is possible, or by using an automated delivery of reinforcement that could ensure every response is reinforced.

Results of the current study displayed a pattern of responding different from what has been shown to occur under simple schedules of reinforcement. This seems to suggest exchange schedules of token reinforcement are independent from simple schedules of reinforcement. For one participant, the VR schedule produced a lower rate of responding than the FR schedule. For the other participant, there was no clear difference in responding across VR and FR exchange schedules of token reinforcement. These data suggest there are more factors involved than simply the schedule of reinforcement in effect for token exchange.

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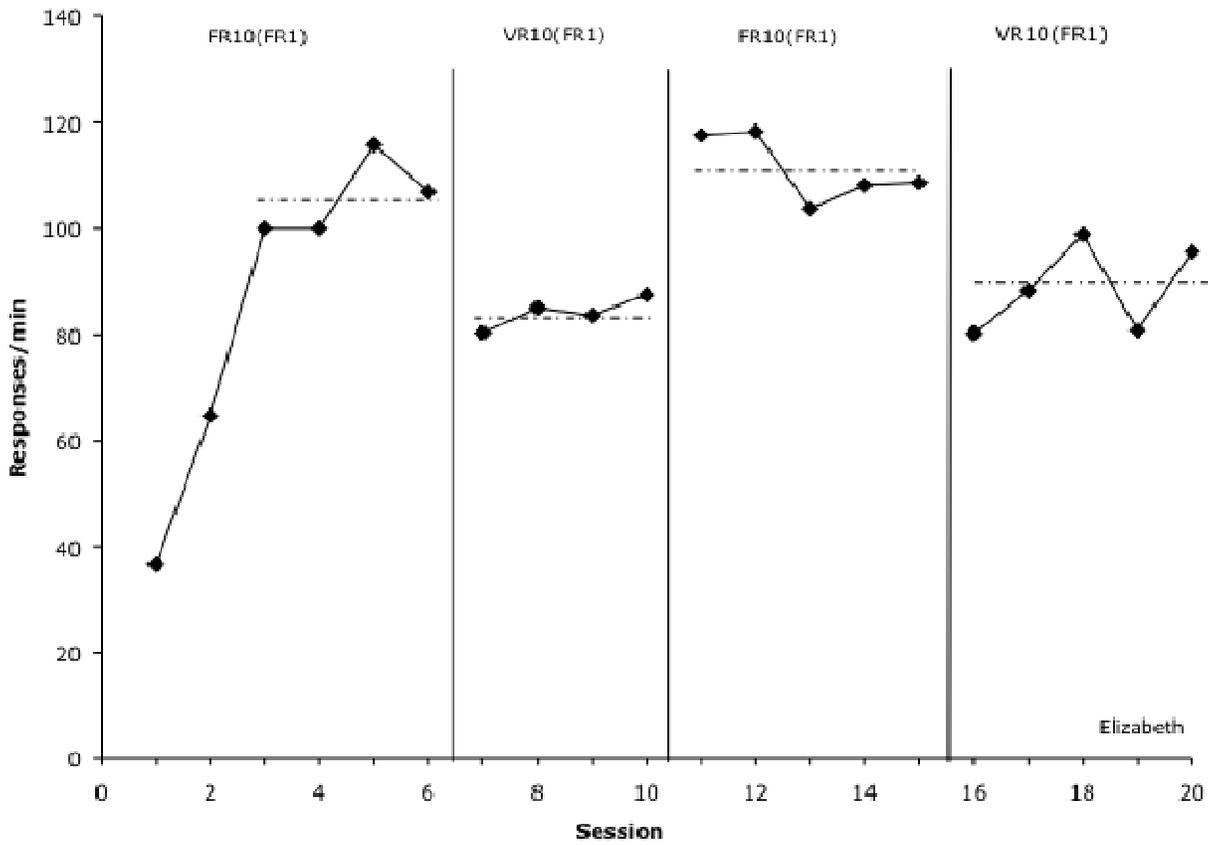


Figure 1. Response rates under FR and VR exchange schedules for Elizabeth.

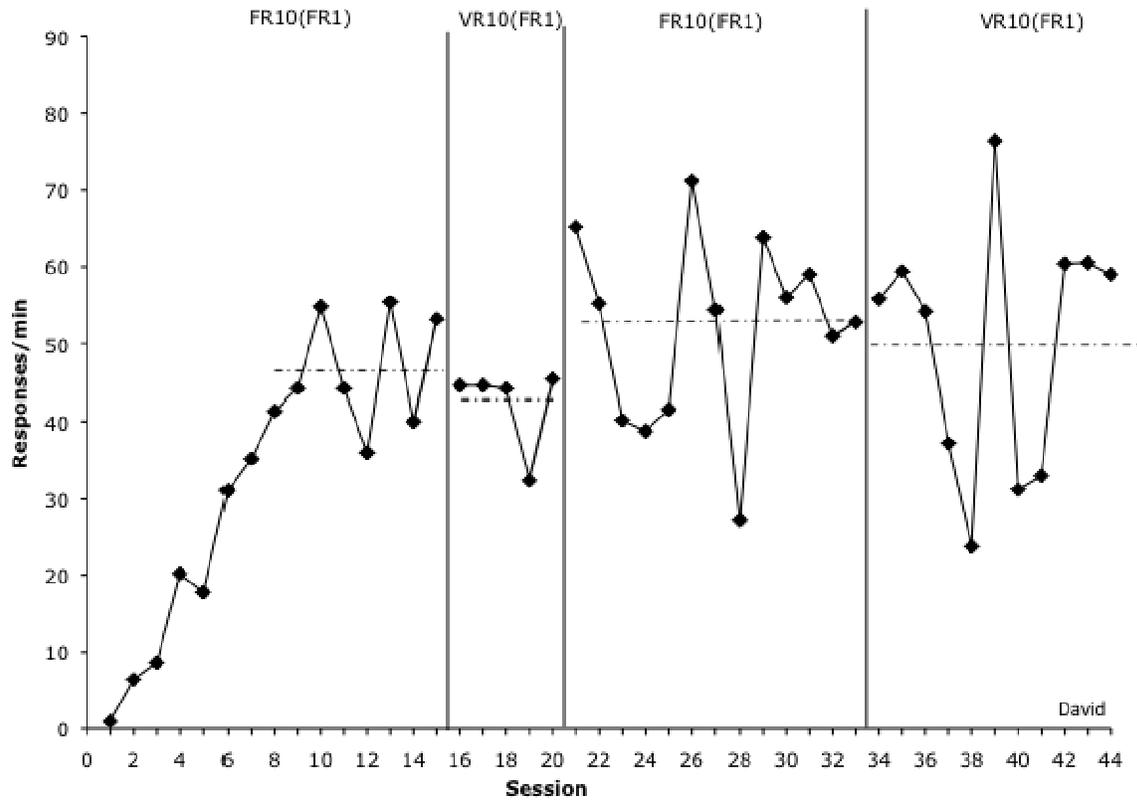


Figure 2. Response rates under FR and VR exchange schedules for David.