THE EFFECTS OF GLOBAL TEMPORAL CONTEXT ON CHOICE IN CONCURRENT CHAIN SCHEDULES OF REINFORCEMENT

A Thesis

Presented

to the Faculty of

California State University, Chico

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Psychology

Option in Psychological Science

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by

Alyssa J. Cozine

Fall 2012

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ACKNOWLEDGEMENTS

First and foremost, I'd like to acknowledge Dr. Paul Romanowich, without whom this project wouldn't exist. His guidance over the last two years of my graduate career has been invaluable, and I'm forever grateful. I'm also indebted to Dr. Daniel Worthen, whose Learning & Memory course introduced me to many of the concepts discussed in this thesis, and who hired me as an Animal Care Technician, setting in motion my years long preoccupation with pigeons. Lastly, I'd like to thank my husband, Ben Whiteley, and my parents, Robert and Dixie Cozine, who were unlucky enough to be given the task of talking me down from the edge during the 24th straight week of daily, early morning data collection.

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ABSTRACT

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Eleven pigeons responded on a concurrent chain schedule of reinforcement in order to examine the effects of global temporal context on initial link choice proportion. Each bird was exposed to alternating blocks of concurrent chain schedules and either response dependent or response independent schedules representing the global context. Global context effects were found. Mean choice proportion during the initial links decreased as the duration of the context conditions increased. The results indicate that the temporal length of the context condition, and, to a lesser extent, response dependent or independent requirements, influence initial link choice proportion during a concurrent chains procedure. These global context effects are not accounted for in any of the three main quantitative models of choice. However, the global temporal context effect is consistent with each model's assertion that initial link choice proportion is decreased as the local temporal context duration is increased.

CHAPTER I

INTRODUCTION

Choice is inescapable in daily human life. You're faced with almost constant choice scenarios from the moment you wake up to the moment you go to sleep. "Do I allow myself to succumb to the temptation of the snooze button? Should I bring my own lunch to work or go out to eat? Paper of plastic?" In essence, choice is an almost universal human experience. Not surprisingly, this has made it a popular topic of study in the field of psychology, particularly the subfield of behavior analysis.

Concurrent chain schedules of reinforcement were first developed by Autor (1969) in an attempt to address a problem with using concurrent schedules to study choice. In traditional concurrent schedules, there is no way to separate choice from response rate. For example, if given the choice between a variable ratio (VR) (the number of responses required for reinforcement varies by trial) and a variable interval schedule (VI)(a response is reinforced after an *n*th amount of time), the subject is likely to direct the majority of its responses to the VR schedule. This is because a VR schedule requires a specific number of responses to be made while a VI schedule only requires one response to obtain reinforcement. It is in the interest of the subject responding on a VR schedule to respond at a high rate to increase the overall rate of reinforcement. As a result, the inflated response rate on the VR schedule compared to that of the VI schedule makes it impossible to reliably measure subject preference without the confound of response rate.

In a concurrent chains procedure, the subject is presented with two initial link stimuli that represent two identical, independent VI schedules of reinforcement. This represents the choice phase. Responding to either schedule leads to the termination of both initial link schedules and the presentation of one of the terminal link schedules. Once the terminal link schedule has been selected, the alternate initial link schedule is blacked out and won't be accessible again until reinforcement is obtained. This represents the outcome phase. The terminal schedule ends with primary reinforcement. Choice is measured by the distribution of responses during the initial link phase. If the subject responds more on one initial link schedule compared to the other, it is suggested that it prefers the terminal link schedule associated with that initial link schedule.

A number of theories have been proposed to describe response allocation on concurrent chain schedules of reinforcement. The matching law (Herrstein, 1961) was first proposed to accommodate data from traditional concurrent schedules. It states that a subject's relative response rate should be proportional to the relative rate of reinforcement. Fantino (1969) asserted that the matching law could accurately predict response rates only when the VI 1-minute schedule was being utilized in a simple concurrent schedule. It became inadequate when dealing with schedules with much bigger or smaller VIs or concurrent chain schedules. In other words, it does not take initial and terminal link duration into account. The matching law implies that response distribution during the initial links should not be affected by the time is takes to reach the terminal schedule. This notion is problematic, as an organism should inherently prefer a stimulus that is associated with a shorter required time to obtain reinforcement to one that requires a longer time. If matching law could still accurately predict response rates in schedules with variable lengths of initial and terminal links, there would be no need for a new model. However, a new equation must be formulated if it cannot. In order to address the problems with the matching law**,** Fantino (1969) formulated a mathematical equation derived from the matching law that sought to predict response rates in concurrent chain schedules. The new formula, which would come to be known as Delay Reduction Theory (DRT), accounts for a wider variety of temporal contexts. It states the value of a terminal link stimulus is directly related to the reduction in time before primary reinforcement is obtained (Fantino, 1969). For example, a subject is more likely to prefer a terminal link that signifies a greater reduction in the delay to food. The major component of the DRT formula is the average overall time to primary reinforcement from the beginning of the initial links.

Grace (1994) developed the Contextual Choice Model, which generalizes to the matching law and also incorporates context effects into terminal link sensitivity. In this instance, terminal link sensitivity refers to the change in response rates when the mean terminal link duration is manipulated. Similar to DRT, CCM is largely derived from the matching law, but presents a more complex view of choice and response allocation. It assumes that both initial link and terminal link schedules can affect choice responses.

Most recently, Mazur (2001) developed the Hyperbolic Value-Added model (HVA). HVA states that a reinforcer is devalued as it is increasingly delayed, and makes a few key assumptions when applied to concurrent chains procedures: the values of a both terminal and initial links are dependent on the amount of time from the onset of the links to reinforcement, and that choice proportions are based on the increase in value when a terminal link is entered. HVA also states that preference increases when the value of the terminal links is increased; likewise, when the value of the initial links is decreased, preference decreases.

Currently, none of the three models account for a possible global context effect, leading researchers to ask, “But what happens *outside* the schedule?” In this case, global context refers to anything that happens outside of the concurrent chains procedure, while local context refers to anything that happens within the confines of the concurrent chains procedure (either in the initial inks or terminal links). For example, say you want to have pasta for dinner. The first restaurant you find does not serve pasta. Do you continue looking for a new restaurant? In order to answer this question, a person approaching the problem from the global perspective would ask, “Well, what did you have for lunch?” Goldshmidt, Lattal, and Fantino (1998) attempted to address the issue of global context by manipulating external variables (i.e., presenting a stimulus during the ITI) to determine whether a global or local contextual view would be a more appropriate approach to concurrent chains. They ultimately found support for the local view, and not for the global view. However, the study only examined response dependent food presentations. Unpublished preliminary data suggests that, given a reasonable sample size, global context effects on choice may exist. The present study attempts to determine whether or not global temporal effects exist for choice within a concurrent chains procedure, where choice is the dependent variable and temporal context is the independent variable.

An experimental design was implemented to determine whether or not global context is capable of influencing choice proportion during the initial links of a concurrent chains procedure. Twelve Carneux pigeons were placed in standard operant chambers and exposed to alternating blocks of concurrent chain schedules and either fixed interval or fixed time schedules, depending on assigned condition. A concurrent chain schedule began with the presentation of two keylights that represent two identical, VI 60 s schedules. The subjects responded to these stimuli by pecking (or “choosing”) one keylight. This triggered the presentation of a terminal link. Depending on the initial link chosen, the terminal link represents either a VI 15 s schedule or VI 45 s schedule. Each terminal link was also represented by a colored keylight and results in primary food reinforcement. In this instance, a block consisted of four trials ending in reinforcement. Both fixed interval and fixed time schedule had three possible values: 20 s, 60 s, and 180 s. Fixed interval (FI) subject were required to respond on fixed schedules in order to receive reinforcement (response dependent), while fixed time (FT) subject did not (response independent). For example, in an FI 60 s schedule, the first peck after the 60 s interval expires will result in reinforcement. In an FT 60 s schedule, reinforcement will be delivered regardless of response. Schedule values for FI and FT blocks did not change until stability of choice proportion in the initial links of the concurrent chain schedules was achieved. Each schedule condition (two baselines, two 20 s FI/FTs, two 60 s FI/FTs, and two 180 s FI/FTs) was run for a minimum of 20 sessions and a maximum of 40 sessions.

Wilcoxon signed-rank tests were used to compare the population mean ranks of the choice proportions for each FI/FT context, as well as the population mean ranks for the three temporal contexts. Wilcoxon tests were used as an alternative to the standard t-test because normal distribution couldn't be assumed due to the small sample population.

Pearson correlations were used to examine the relationships between response rate in the context and choice proportion in the initial links, as well as the relationship between response rate in the context and response rate in the initial links. In addition to the various group analyses, an individual analysis was also conducted to identify any possible choice patterns when the FI or FT context was added.

I hypothesized that initial link response rates and choice proportions would vary by response requirement and temporal duration in the added contexts. Preliminary data suggested that response rates for the initial and terminal links would be higher for subject in the FI (response dependent) condition and that choice proportions become more extreme as a result of response dependent reinforcement in the context.

CHAPTER II

LITERATURE REVIEW

Concurrent Schedules and the Matching Law

Choice typically involves two or more concurrently available options. Because living things make countless choices throughout their lives, choice has been a popular topic of study in psychology. Skinner and Ferster (1957) first presented concurrent schedules of reinforcement as a possible way to test choice in *Schedules of Reinforcement.* In a concurrent schedule, the subject is simultaneously presented with two independent reinforcement schedules. Each schedule is represented by a specific stimulus, usually a keylight in the case of pigeons. Reinforcement is delivered once the subject completes the response requirement of one of the two schedules.

In 1961, Herrnstein proposed the matching law, which quantifies the distribution of choice in concurrent reinforcement schedules. The matching law was derived from the belief that choice distribution is not random. Every choice is ultimately influenced by the interaction between behavior and environment (Poling, Edwards, Weeden & Foster, 2011). Specifically, Herrnstein proposed that choice is determined by the relative reinforcement rate. Hence, a subject presented with two independent reinforcement schedules should respond more to the schedule associated with the higher reinforcement rate. The matching law can be expressed mathematically as:

$$\frac{B_1}{B_1 + B_2} = \frac{R_1}{R_1 + R_2}$$

where B_1 and B_2 are the response rates to each schedule of reinforcement, and R_1 and R_2 are the number of reinforcers received from each schedule.

Herrnstein's development of the matching law was a milestone in the history of the quantitative analysis of behavior. However, it failed to account for certain key variables. In traditional concurrent reinforcement schedules, there is no way to separate choice from response rate. For example, if given the choice between a variable ratio (VR) schedule, where the number of responses required for reinforcement varies from trial to trial, and a variable interval (VI) schedule, where a response is reinforced after a variable amount of time elapses, the subject is likely to direct the majority of its responses to the VR schedule (Vyse & Belke, 1992). It is in the interest of the subject responding on a VR schedule to respond at a high rate to increase the rate of reinforcement. As a result, the inflated response rate on the VR schedule compared to that of the VI schedule makes it impossible to reliably measure subject preference without the confound of response rate.

Concurrent Chain Schedules

Autor (1960, 1969) developed a concurrent chain schedule of reinforcement in an attempt to quantify choice independently of response rate. In a typical concurrent chains procedure, the subject is presented with two initial link stimuli that represent two identical, independent VI reinforcement schedules. This represents the choice phase. Responding to either schedule leads to the termination of both initial link schedules and the presentation of one of the terminal link schedules. The terminal link represents the outcome phase, and ends with primary reinforcement. Choice is measured by the distribution of responses during the initial link phase. If the subject responds more to one initial link schedule compared with the other, we can infer preference for the terminal link schedule associated with that initial link schedule.

The matching law initially appeared to account well for choice in concurrent chains procedures (Chung & Herrnstein, 1967). That is, choice during the initial link phase was determined by the rate of reinforcement during the terminal link. However, the matching law was insufficient for determining choice in concurrent chains procedures in the wake of Fantino's (1969) research with local temporal context. Fantino showed that manipulating the length of both the initial and terminal link phases could influence initial link choice proportion. The matching law did not account for these local context effects.

Delay Reduction Theory

Fantino (1969) proposed Delay Reduction Theory (DRT), the first quantitative model derived from the matching law that attempted to specifically address choice in concurrent chains procedures. DRT can be expressed mathematically as:

$$\frac{R_L}{R_L+R_R} = \frac{T-t_{2L}}{(T-t_{2L})(T-t_{2R})}$$

where R_L and R_R represent the number of responses directed towards each terminal link, T represents the average time it takes to receive primary reinforcement after the onset of the initial link phase, and t_{2L} and t_{2R} represent the average amount of time spent in each of the terminal links. DRT proposes that the initial link stimulus that indicates the greatest reduction in time to the delivery of reinforcement should be the more attractive option. That is, a subject is more likely to prefer a terminal link that signifies a greater reduction in the delay to food.

The major component of DRT is the average overall time to primary reinforcement from the beginning of the initial links. Fantino (1969) illustrated this by providing an example of a concurrent chains procedure where the initial links granted access to the terminal links after a mean interval of 600 s for each key:

> “Thus, the expected time required to reach each a terminal link is 300 s. The expected times to reinforcement for the left and right terminal links… are 30 s and 90 s, respectively. Since the left and right terminal links are equiprobable, in this example… the expected time to reinforcement is: 300 s + [(1/2) x (30 s) + (1/2) x 90 s)] = 360 s. Thus, when the left terminal link is obtained, the organism is 360-30 = 330 s *close*r to reinforcement than it had been at the outset; when the right terminal link is obtained, the organism is only 360-90 = 270 s closer (Fantino, 1969, p. 724).”

DRT predicts that the left initial link alternative should be the more preferred option, because it indicates a greater reduction in the delay to reinforcement, relative to the right initial link. Inclusion of these temporal context effects was a major conceptual step forward for quantifying choice.

Davison's Quantitative Comparison

A number of alternative models for concurrent chains performance emerged in the wake of DRT. Davison (1987) published a comparison of three of the more prominent models: Squires and Fantino's (1971) updated version of DRT, which accounted for unequal initial link values, a model by Killeen (1982) which included a parameter that represented exponential rate of decay, and a model by Davison & Temple (1973), which, like Killeen's, included a parameter that accounted for potential bias. Davison (1987) chose to focus on these three models because they had either no free parameters or required parameters that could be fixed.

Davison applied the three models to ten sets of data from previous experiments dealing with either fixed or variable delays during the terminal links of concurrent chain schedules. Each experiment also used concurrent VI initial links. Overall, each model underperformed in regards to the amount of variance accounted for. Davison (1987) ultimately determined that "overall variances accounted for less than 70% and standard errors of 0.14 are poor, though each model seemed to have its area of competence " (p. 234). These findings indicated that the standards by which the quantitative models were accepted were too lenient.

The Contextual Choice Model

Although Davison's findings seemed bleak, research on choice continued. Grace (1994) proposed the Contextual Choice Model (CCM) as a quantitative model of concurrent chains performance. CCM can be expressed mathematically as:

$$\frac{B_L}{B_R} = b\left(\frac{r_{i1}}{r_{i2}}\right)^{a1}\left(\frac{r_{t2}}{r_{t2}}\right)^{a2\left(\frac{Tt}{Ti}\right)}$$

where B_L and B_R represent response rates in each initial link, *b* represents a bias term, r_{i1}/r_{i2} represents the ratio for the rates of reinforcement in the initial links, r_{t1}/r_{t2} represents that ratio for the rates of reinforcement in the terminal links, *a1* and *a2* represent sensitivity to reinforcement in the initial and terminal links, and *Tt* and *Ti* represent the average terminal link and initial link duration respectively.

Similar to DRT, CCM is largely derived from the matching law, and presents a more complex view of choice. Like DRT, CCM assumes that both initial link and terminal link schedules can affect choice proportions. However, CCM goes beyond DRT by incorporating context effects into terminal link sensitivity. In this instance, terminal link sensitivity refers to the change in response rates when the mean terminal link duration is manipulated. CCM also differs from DRT by separating the concept of value from the concept of choice asserting that "the delay-reduction hypothesis states that values of stimuli as conditioned reinforcers are determined by context… CCM states that values of stimuli are determined independently of context, but that differential effectiveness of the stimuli is context dependent" (Grace, 1994, p. 119). Grace believes this is important because context can influence variables other than terminal-link delay, as previous research has shown (Ito, 1985; Ito & Asaki, 1982; Navarick & Fantino, 1976; White & Pipe, 1987).

Grace (1994) assessed the adequacy of CCM by applying it to a number of existing data sets, and ultimately found that CCM accounted for roughly 91% of total variance, which was much higher than the models proposed by Davison & Temple (1973), Squires and Fantino (1971), and Killeen (1982), which all hovered around 50-60%. However, Grace was quick to point out that CCM was expected to account for a higher variance because it included a larger number of free parameters compared to the other models.

Hyperbolic Value Added

More recently, Mazur (2001) developed the Hyperbolic Value Added (HVA) model. Like DRT and CCM, HVA is derived from the matching law. However, it differs from DRT and CCM by incorporating a hyperbolic function, which serves to describe the tendency of a reinforcer's value to decrease the more it's delayed. HVA can be expressed mathematically as:

$$\frac{B_L}{B_R} = b\left(\frac{r_{i1}}{r_{i2}}\right)^{a1}\left(\frac{V_{t1}-a_tV_i}{V_{t2}-V_i}\right)^{a1} \qquad V_{t1} > a_iV_i,\quad V_{t2} > a_tV_i$$

The first half of this expression is identical to CCM. The second half then incorporates the hyperbolic value function. V_{t1} and V_{t2} represent the value of the two terminal link options, while V_i represents the value of the initial links. These values are calculated by utilizing the hyperbolic delay equation:

$$V = \frac{A}{(1 + KD)}$$

where V represents the value of the reinforcer after a delay, A represents the value if the reinforcer were delivered instantly, D represents the delay, and K represents a constant parameter that determines how rapidly the value will decrease with increasing delay.

HVA makes the following key assumptions when applied to concurrent chains procedures: 1) the value of both terminal and initial links are dependent on the amount of time from the onset of the links to reinforcement, 2) choice proportions are based on the increase in value when a terminal link is entered, and preference increases when the value of the terminal links is increased; likewise, when the value of the initial links is decreased, preference decreases (Mazur, 2001).

Mazur (2001) also conducted a quantitative comparison of DRT, CCM, and HVA. The three models were applied to the same data sets used by Grace (1994), but Mazur added a number of free parameters to each model in an attempt to control for the larger amount of variance accounted for by CCM. Each model accounted for a similar percentage of variance: CCM for 90.8%, HVA for 89.6%, and DRT for 83.0%. Mazur pointed out that even though DRT accounted for slightly less variance than the other two models, this finding could be the result of adding free parameters to each model, and not a true reflection of the accuracy of DRT.

<u>Similarities and Differences</u>

Although all three models share many similarities, they also make different assumptions about the psychological concept of choice, which justifies the existence of three separate models. At their core, each model shares the same goal: to quantitatively describe response allocation in concurrent chain schedules of reinforcement. Each model also states that the perceived value of an initial link stimulus is at least partially influenced by the terminal link schedule associated with that initial link stimulus. That is, a subject should prefer an initial link stimulus paired with a shorter terminal link schedule than one paired with longer terminal link schedule. Each model also reduces to matching law when the terminal links are removed.

Even though the differences between the three models may be understated, they do exist. Both the DRT and the HVA assume that value is determined largely as a result of delay to reinforcement, but HVA doesn't take average value into consideration. In this respect, it's more similar to CCM, even though CCM makes no mention of relative delays to reinforcement at all.

Instead, CCM is primarily concerned with the ratio of the average amount of time spent in both the initial and terminal links, as well as the rate of reinforcement in both. CCM and DRT are also at odds when it comes to the role of the initial links. CCM states that the rate of reinforcement and average time spent in the initial links influences the value of the terminal links. DRT believes the initial links are only notable for influencing the overall time to primary reinforcement from the beginning to the end of the procedure. This implies they have no direct effect on the overall choice proportion. HVA is more similar to CCM in this regard, in that it assumes the initial links have a direct influence on choice independent of the terminal links. HVA also differs from DRT by excluding the overall time to reinforcement from the beginning of the initial links to the end of the terminal links. Instead, more focus is put on the initial and terminal links as individual phases.

The Global Context Effect

Despite their accuracy, none of the three models account for a possible global context effect. In this case, global context refers to anything that happens outside of the concurrent chains procedure. By contrast, a local context would be anything that happens within the confines of the procedure (i.e., manipulating the delay to primary reinforcement). Goldshmidt, Lattal, and Fantino (1998) attempted to address this issue by manipulating external variables (i.e., presenting a stimulus during the ITI) to determine whether a global or local contextual view would be a more appropriate approach to concurrent chains. They ultimately found support for the local view. However, this study only examined response independent food presentations and inter-trial interval duration manipulations. Unpublished preliminary data suggests that the global context may affect choice, given the addition of response dependent manipulations.

Research Questions and Hypotheses

The present study examined the effects of incorporating either a response-dependent or a response independent global temporal context into a traditional concurrent chains reinforcement procedure. The response-dependent global context consisted of a fixed interval (FI) reinforcement schedule, whereas the response-independent global context consisted of a fixed time (FT) reinforcement schedule. If a significant effect exists for global context, the current models of concurrent chains performance may need to be revised.

This study attempts to determine whether or not global temporal effects exist for choice within a concurrent chains procedure, where choice is the dependent variable and global temporal context is the independent variable. The study is primarily concerned with three questions: 1) Does the introduction of a schedule of reinforcement representing a global context have a significant effect on choice allocation in the initial links of a concurrent chains schedule? 2) Does the specific type of global context (FI or FT) schedule influence choice allocation? And 3) Does the specific temporal value of each global context condition produce a recognizable pattern of choice allocation?

CHAPTER III

METHODOLOGY

Subjects

Twelve white Carneux Pigeons (*Columba livia*) were used as subjects. The birds were previously used as subjects in an upper division Learning and Behavior course and had extensive operant experience. Subjects were kept at roughly 80% of their free feeding weight for the duration of the experiment. The subjects were weighed daily to monitor their health and food intake. They were withheld from testing if they exceeded 85% of their free feeding weight or dropped below 75% of their free feeding weight. They were given supplemental feeding if they had not reached 80% of their free feeding weight by the time they had finished that day's session. All subjects were kept on a 14:10 light/dark cycle and had free access to both water and health grit. Approval for animal research by Chico State's Animal Care and Use Committee (ACUC) was obtained prior to experimentation. All animals were cared for according to the standards laid out in California State University's Animal Welfare Policy.

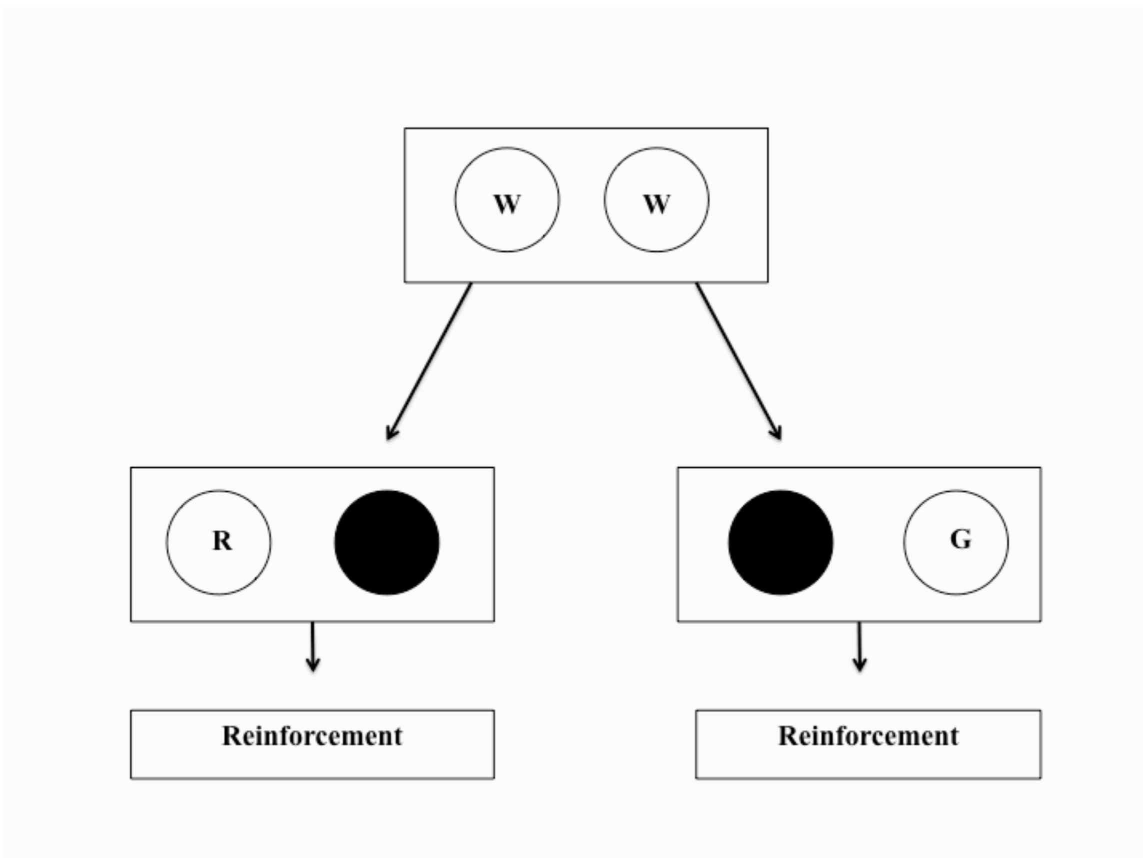
Materials

Twelve operant chambers (BRS-LVE model SEC 9381-D) were used to conduct the experiment. All chambers were equipped with a single houselight and three visual stimuli projectors, which could project 12 different colors and shapes onto the keylights. Pecking the keylight with a force of approximately .15 N led to the delivery of food.

Twelve Windows based PCs controlled the procedural parameters and recorded response data. Microsoft® Excel® 2011 and IBM® SPSS® Statistics Version 20 were used to analyze the data.

<u>Concurrent Chain Schedule</u>

Figure 1 represents a schematic of the concurrent chain schedule used in this procedure.



The initial link began with the presentation of two white keylights on the left and right keys that represent identical, VI 60 s schedules of reinforcement. The pigeons responded to these stimuli by pecking the keylights. The first response to a given keylight after the interval had elapsed triggered the presentation of the terminal link associated with that initial link. Once a terminal link had been activated, the alternative initial link keylight was blacked out and was not accessible again until the terminal link phase was completed. Depending on the initial link chosen, the terminal link was either a VI 15s or VI 45s schedule. Terminal link schedules were represented by red and green keylights. The left/right color orientation for each individual chamber was determined randomly before the condition began, with half the chambers displaying a red keylight on the right side and the other half displaying a red keylight on the left side. Completion of the terminal link schedule resulted in reinforcement, which was access to food for two seconds. A given initial link signaled either a rich or poor terminal link schedule. The rich terminal link schedule was characterized by a shorter time to reinforcement compared to the poor schedule (i.e., VI 15 s vs. VI 45 s). The left/right orientation of the rich schedule was counterbalanced for each condition. For example, if a subject was exposed to a right-sided rich schedule with a fixed time (FT) 180s global context condition, the rich schedule was switched to the left side for the fixed interval (FI) 180s global context condition. A changeover delay of 2 s was used during the choice phase of each procedure, in an attempt to ensure that the subjects didn't quickly switch back and forth between the two initial link alternatives. Each subject was required to spend at least 2s responding on a specific initial link before a response could result in a transition to the terminal link schedule.

Global Context Schedules

Two types of schedules represented the global context: FI and FT. Both FI and FT schedules had three possible temporal values: 20s, 60s, and 180s. This ensured a wide range of independent variables, so any effect of a global context on response allocation was more likely to be found, if it existed. FI schedules required at least one response by the subject to produce reinforcement (response dependent), while FT schedules produced reinforcement independent of responding. For example, a subject operating on an FI 60s schedule of reinforcement had to respond once after the 60s had elapsed in order to gain access to food. Subjects operating on an FT 60s schedule received reinforcement regardless of responding after the 60s had elapsed. FI schedules were signaled by a yellow keylight illuminated on the center key, while FT schedules were signaled by a keylight depicting a white triangle on the center key. These stimuli were chosen to avoid any possible confusion with initial and terminal link stimuli.

Procedure

A within-subjects design was used, whereby each subject completed all experimental conditions. Procedures began daily at 7:30 AM. Each session began with a block of global context schedules followed by a block of concurrent chain schedules. Each block consisted of either four consecutive concurrent chains schedules, or four global consecutive context schedules, each ending in food reinforcement. These blocks alternated for approximately one hour. The number of food reinforcements varied depending on the global context. Subjects operating on a 180s global context schedule completed a total of 24 trials per session, while those operating on a 60s or 20s global context schedule completed a total of 32 and 48 trials per session respectively. This was done to ensure that each subject remained in the chamber for approximately the same amount of time. Baseline conditions contained no global context and were conducted for a total of 32 trials. Once the subjects were removed from the chambers, they were weighed and given supplemental food as needed.

Each subject completed eight phases: two baselines and six global context conditions. The order of these phases was randomized prior to experimentation for each subject. The two baseline conditions appeared at the beginning and end of the experiment. Six of the birds began the experiment with a baseline condition, while the other six birds ended the experiment with a baseline condition. If a subject began with a baseline condition, the second baseline condition would be completed within the last three experimental phases. If a subject ended the experiment with a baseline condition, the first baseline condition would appear within the first three experimental phases.

Stability Criterion

In order to calculate stability, it was first necessary to determine the choice proportion for that individual condition once a minimum number of trials had been completed. This was done by dividing the total number of responses in the initial links by the total number of responses to the rich schedule (i.e., VI 15 s). Once this had been determined three requirements needed to be met before the subject's behavior was considered stable: 1) the mean choice proportion for the last five sessions of the procedure could not be the highest or lowest for that condition, 2) the mean choice proportion was within 10% for each of the five sessions, and 3) each condition was run for a minimum of 20 days or a maximum of 40 days. If a subject had not reached stability by 40 days, they were moved on to the next condition.

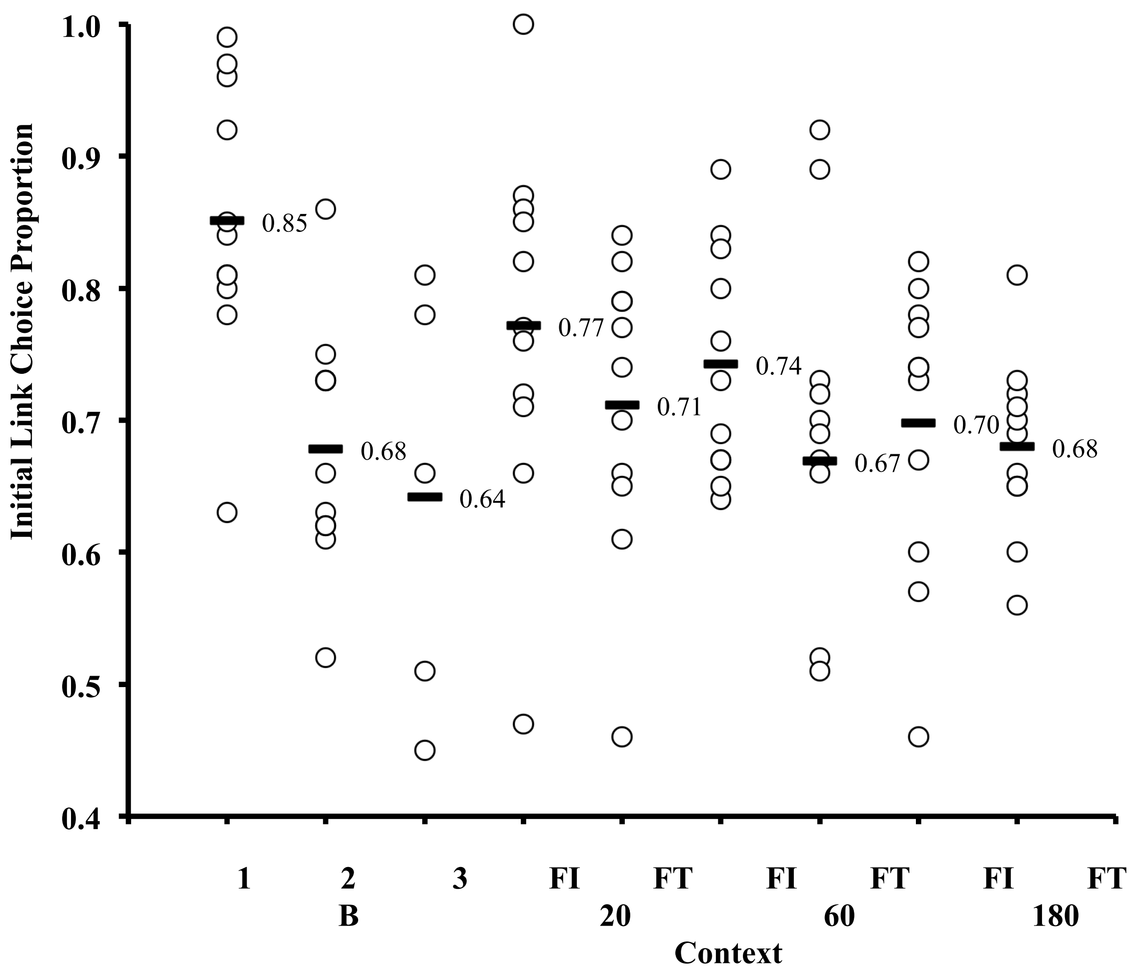
Data Analysis

All the data included in the analysis represents the mean calculated from the last five sessions of each condition. One subject (KD963) of the original twelve subjects was excluded from analysis due to chamber malfunction.

CHAPTER IV

FINDINGS AND RESULTS

Figure 2 shows the mean choice proportion for each context and baseline condition across all subjects.



Wilcoxon Signed-Rank Tests

Wilcoxon tests were conducted to evaluate whether subjects would display higher initial link choice proportions with the addition of the FI global contexts, relative to the addition of the FT global contexts, as well as higher choice proportions with the addition of shorter global temporal contexts relative to longer global temporal contexts. This non-parametric test was used because a normal distribution could not be assumed due to the small sample size. The results indicated a significant difference between initial link choice proportions during the 20s global temporal contexts relative to initial link choice proportions during the 180s global temporal contexts, $z = -1.913$, $p = .05$. The mean in the ranks of initial link choice proportion during the 20s global contexts was 10.08, while the mean of the ranks of initial link choice proportion during the 180s contexts was 11.37. Wilcoxon tests showed no significant difference in initial link choice proportions between FI and FT global context conditions, 60s and 20s contexts, or 60s and 180s contexts.

Group Analysis

There are two recognizable initial link choice proportion patterns across global context conditions at the group level. First, the initial link choice proportions during the FI conditions appear to be higher than the initial link choice proportions during the FT conditions. Second, initial link choice proportions steadily decrease as the length of the FT or FI global context is increased. However, these patterns are more variable for individual subjects. This variability is shown in Figure 3. In addition, Table 1 shows the mean initial link choice proportion for each subject across all conditions:

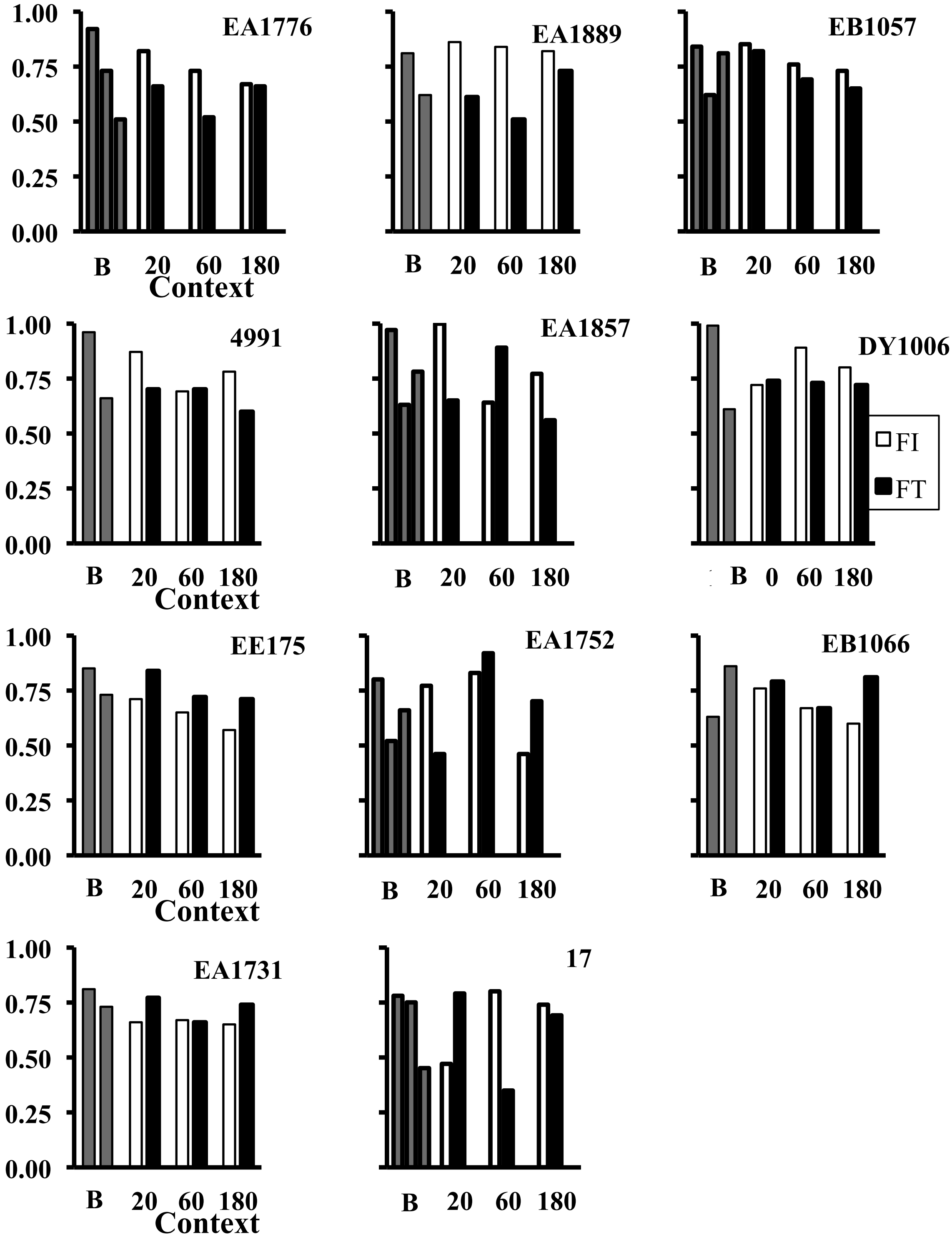
Pigeon	Context	VI 15s TL	Trials	IL choice	IL total responses (left)	IL total responses (right)	IL total time (sec)	IL response rate (min)	Context response rate (per minute)	Total time in context
EA1776	Baseline	L	20	0.92	1313.00	108.80	1411.80	60.42		
	FI 60	R	24	0.73	254.60	671.00	544.20	102.05	67.80	968.20
	FT 180	L	22	0.66	460.20	240.60	413.80	101.61	0.00	2160.00
	FI 180	R	20	0.67	234.80	517.00	347.00	129.90	56.00	2176.70
	FT 20	L	24	0.66	768.40	386.20	836.42	82.82	0.00	480.00
	FI 20	R	20	0.82	248.20	865.32	752.16	88.82	86.60	493.48
	FT 60	L	20	0.52	571.00	522.80	532.32	123.29	0.60	960.00
	Baseline	R	20	0.73	496.20	1349.80	1102.94	100.42		
	Baseline	L	20	0.51	892.60	852.00	1056.06	99.12		
EA 1889	FT 180	R	24	0.73	77.20	219.00	503.40	35.30	0.00	2160.00
	Baseline	L	20	0.81	787.40	169.20	1279.90	44.84		
	FT 60	R	25	0.51	230.80	246.00	560.20	51.07	0.00	960.00
	FI 180	L	20	0.82	297.40	66.40	437.20	49.93	44.10	2240.00
	FT 20	R	23	0.61	211.40	321.20	786.98	40.61	0.00	480.00
	FI 20	L	23	0.86	427.40	69.00	918.52	32.43	98.14	485.38
	FI 60	L	20	0.84	393.00	75.20	644.64	43.58	57.86	970.90
	Baseline	R	20	0.62	291.60	483.80	1179.10	30.46		
EB 1057	FI 20	R	20	0.85	1070.40	186.40	872.50	86.43	42.80	494.30
	Baseline	L	21	0.84	1507.00	272.80	1097.90	97.27		
	FI 180	L	20	0.73	558.60	202.00	418.10	109.15	57.40	2173.20
	FT 60	R	22	0.69	237.60	527.80	531.50	86.40	9.20	960.00
	FT 20	L	21	0.82	1097.60	261.00	807.50	100.50	1.30	480.00
	FT 180	R	22	0.65	248.60	433.80	420.68	97.33	7.86	2160.00
	FI 60	L	25	0.76	508.00	158.00	4897.98	8.16	49.68	969.44
	Baseline	R	20	0.62	567.80	933.40	1134.50	79.39		
	Baseline	L	22	0.81	1071.20	253.00	1110.00	71.58		
4991	Baseline	R	20	0.96	53.80	1443.60	1621.88	55.39		
	FT 180	L	23	0.60	292.00	199.40	417.60	70.60	17.80	2160.00
	FI 20	R	23	0.87	61.00	419.60	2015.70	14.30	19.70	762.10
	FT 20	L	20	0.70	644.60	275.60	830.90	66.44	30.20	480.00
	FI 180	R	21	0.78	155.20	544.80	400.36	105.00	35.70	2169.30
	FI 60	L	22	0.69	513.25	228.00	559.38	80.00	47.83	965.73
	Baseline	L	20	0.66	953.00	493.20	1027.78	84.41		
	FT 60	R	21	0.70	271.40	626.20	603.70	89.00	20.70	960.00

Pigeon	Context	VI 15s TL	Trials	IL choice	IL total responses (left)	IL total responses (right)	IL total time (sec)	IL response rate (min)	Context response rate (per minute)	Total time in context
	FI 20	L	20	1.00	1244.60	0.60	1454.10	51.38	60.90	509.10
	FT 20	R	21	0.65	251.60	471.40	789.10	54.97	49.10	480.00
	Baseline	L	20	0.97	1639.00	62.40	1520.10	67.16		
EA1857	FT 180	R	22	0.56	201.00	246.00	375.00	71.52	1.20	2160.00
	FI 60	R	20	0.64	243.40	427.60	558.50	72.09	68.00	966.80
	FI 180	L	24	0.77	346.00	105.60	395.34	68.54	49.96	2166.80
	FT 60	L	24	0.89	574.60	70.20	637.90	60.65	21.80	960.00
	Baseline	R	20	0.63	421.40	720.60	1060.68	64.60		
	Baseline	L	20	0.78	921.60	258.00	1165.00	60.75		
	Baseline	R	20	0.99	12.00	1340.60	1811.10	44.81		
	FI 20	L	20	0.72	608.40	239.20	849.70	59.85	118.20	487.50
	FI 60	R	24	0.89	78.40	649.20	584.80	74.65	65.00	966.80
DY1006	FT 60	L	21	0.73	539.00	197.40	558.10	79.17	0.30	960.00
	FI 180	R	20	0.80	93.20	399.60	351.10	84.22	45.30	2170.30
	Baseline	L	20	0.61	792.80	500.00	1007.60	76.98		
	FT 20	R	20	0.74	253.00	713.00	825.40	70.22	0.00	480.00
	FT 180	L	27	0.72	351.60	136.40	399.80	73.24	0.30	2160.00
	FT 20	L	20	0.84	713.60	133.60	880.30	57.74	128.30	480.00
	Baseline	R	35	0.85	290.10	1547.80	1035.50	106.49		
	FI 60	L	20	0.65	626.80	339.40	616.80	93.99	104.20	971.80
EE 175	FI 20	R	20	0.71	288.20	701.20	764.40	77.66	37.50	496.40
	FT 180	L	20	0.71	396.60	199.20	349.10	102.40	0.12	2160.00
	FT 60	R	27	0.72	229.80	593.00	590.78	83.56	0.96	960.00
	FI 180	R	20	0.57	182.00	241.80	410.64	61.92	38.18	2178.20
	Baseline	L	20	0.73	885.20	319.40	1031.60	70.06		
	FT 60	L	20	0.92	513.20	43.00	671.10	49.73	4.90	960.00
	Baseline	R	20	0.80	267.60	1087.60	1200.10	67.75		
	FI 180	L	25	0.46	247.80	296.20	381.30	85.60	36.20	2230.40
EA 1752	FI 20	R	20	0.77	282.80	931.20	802.20	90.80	47.30	493.10
	FI 60	R	20	0.83	172.00	841.00	577.60	105.23	30.70	972.00
	FT 20	L	20	0.46	666.20	777.40	787.38	110.01	45.78	480.00
	FT 180	R	20	0.70	202.00	462.80	347.82	114.68	2.62	2160.00
	Baseline	L	20	0.52	805.40	895.60	1080.50	94.46		
	Baseline	R	21	0.66	696.00	1352.60	1074.14	114.43		

Pigeon	Context	VI 15s TL	Trials	IL choice	IL total responses (left)	IL total responses (right)	IL total time (sec)	IL response rate (min)	Context response rate (per minute)	Total time in context
	FT 20	R	20	0.79	123.00	466.60	859.60	41.15	0.80	480.00
	FT 60	L	23	0.67	527.60	253.60	532.20	88.07	2.10	960.00
	Baseline	R	22	0.63	633.60	1081.80	1017.10	101.19		
EB 1066	FT 180	L	21	0.81	794.40	188.00	444.90	132.49	3.70	2160.00
	FI 60	R	29	0.67	450.80	924.60	606.04	136.17	65.10	963.58
	FI 20	L	23	0.76	1354.00	438.00	801.88	134.08	98.96	484.28
	FI 180	R	26	0.60	350.20	537.00	388.34	137.08	45.22	2171.40
	Baseline	L	23	0.86	1830.00	280.60	1087.08	116.49		
	Baseline	R	20	0.81	188.60	825.40	1068.10	56.96		
	FI 20	L	20	0.66	448.40	233.40	844.90	48.42	61.70	491.80
	FI 60	R	23	0.67	195.20	404.20	511.10	70.37	47.00	969.30
EA 1731	FT 180	L	24	0.65	331.00	175.80	313.20	97.09	1.00	2160.00
	FI 180	R	28	0.74	146.60	414.80	399.18	84.38	34.70	2169.80
	FT 60	L	22	0.66	498.80	261.40	527.28	86.50	0.04	960.00
	Baseline	L	20	0.73	779.00	358.60	1059.50	64.42		
	FT 20	R	23	0.77	239.40	810.80	810.96	77.70	1.02	480.00
	Baseline	L	20	0.78	1266.60	374.00	1157.40	85.05		
	FT 180	R	20	0.69	148.80	331.80	383.80	75.13	0.30	2160.00
	FI 20	L	23	0.47	489.40	537.20	814.50	75.62	91.60	489.00
17	FI 180	R	20	0.74	387.40	133.00	425.10	73.45	68.60	2399.30
	FT 20	R	22	0.79	195.80	714.20	811.90	67.25	145.10	480.00
	FT 60	L	20	0.35	174.00	324.60	491.64	60.85	10.02	960.00
	FI 60	R	22	0.80	103.00	309.08	548.14	45.11	52.64	970.54
	Baseline	R	20	0.75	266.80	793.00	1141.42	55.71		
	Baseline	L	22	0.45	343.67	423.33	1014.10	45.38		

Individual Analysis

In addition to group analysis, individual analysis was done in order to provide a more well rounded view of the data. Figure 3 shows the mean initial link choice proportion across all context conditions for each individual subject.


EA1776
EA1889
EB1057
4991
EA1857
DY1006
EE175
EA1752
EB1066
EA1731
17
FI
FT
1.00
0.75
0.50
0.25
0.00
B 20 60 180
Context

Analyzing subject data individually led to a few identifiable choice patterns when the FI or FT global context was added. Six birds (EA1776, EA1889, EB1057, 4991, EA1857, DY1006) displayed more extreme initial link choice proportions with the addition of the FI global contexts, relative to the FT global contexts during at least two of the three conditions. Because this pattern involved over half of the subjects, this pattern was similar to the mean initial link choice proportions show in in Figure 2. From these six subjects, three (EA1776, EA1889, and EB1057) had more extreme initial link choice proportions with the addition of the FI global context relative to the FT global context during all three conditions.

By contrast, birds EE175 and EA1752 exhibited larger initial link choice proportions with the addition of the FT global contexts, relative to the addition of the FI global contexts. EE175 exhibited this pattern across all three global contexts, whereas EA1752 had higher initial link choice proportions during the FT 60s schedule (.67) relative to the FI 60 s schedule (.83), and the FT 180s schedule (.70), relative to the FI 180s schedule (.46). However, this was not the case with the FT 20s schedule (.46), relative to the FI 20s schedule (.77).

Two birds (EB1066 and EA1731) had initial link choice proportions that did not appear to be systematically influenced by the added global contexts. Pigeon EB1066 showed initial link choice proportions similar to EE175, whereby the initial link choice proportions tended to be higher during the added FT global contexts relative to the added FI global contexts. However, EB 1066 also showed more extreme initial link choice proportions during the FT 180 condition (.81) relative to the other subjects. By comparison, the mean initial link choice proportion for all subjects during the FT 180s condition was .68. Additionally, the initial link choice proportions during the added 20 s (.76 vs. .79) and 60 s (.67 vs. .67) global contexts were similar, making the extreme initial link choice proportions during the added 180s global contexts (.60 vs. 81) stand out even more.

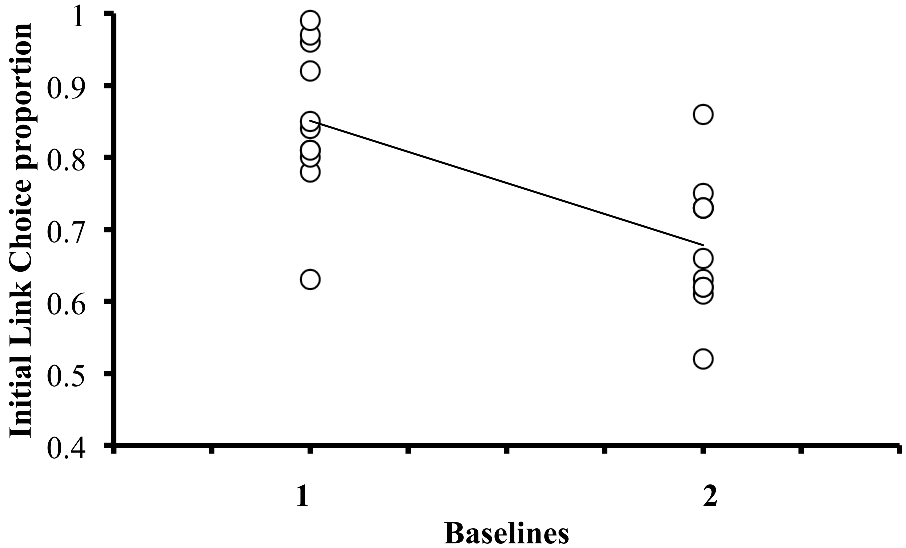
Lastly, Bird 17's initial link choice proportions showed evidence of a side bias. Initial link preference was skewed towards responses on the right key, irrespective of whether the right key was the rich schedule. Thus, there was no systematic change in initial link choice proportions as a function of the added global contexts.

<u>Pearson Correlations</u>

Pearson correlation coefficients were calculated to determine what, if any, relationship existed between initial link choice proportions and response rate during the FI global contexts. FT global contexts were excluded from analysis due to their low response rates. No significant relationship was found. Pearson correlation coefficients were also used to examine the relationship between overall response rate during the global context and overall response rate during the initial links. No significant relationship was found.

<u>Baseline Discrepancy</u>

There was a general trend for less extreme initial link choice proportions during the baseline conditions as the experiment progressed, $r(20)= -.676$, $p = .001$ (Fig. 4).



A paired-samples t-test indicated a statistically significant difference between the initial link choice proportion between the first baseline condition (*M* = .85, *SD* = .10) and the second baseline condition (*M* = .68, *SD* = .09), *t*(10), = 3.33, *p* < .05, *d* = .27. The six global context conditions were also analyzed to check for any order effects observed during the baselines. The initial link choice proportions during the global contexts were compared by splitting them into three phases according to the order each subject completed them: the first and second global contexts (*M*= .73), the third and fourth global contexts (*M* = .72), and the fifth and sixth global contexts (*M* = .71). While there was a slight trend towards less extreme initial link choice proportions as the experiment progressed, a paired-samples t-test test showed no significant difference between the means of each group.

Five subjects were run in a third baseline condition in an attempt to control for possible side biases. However, there was no statistically significant difference between the second (*M* = .69, *SD* = .08) and third (*M* = .64, *SD* = .16) baseline determinations, suggesting that the overall initial link choice proportion during the baseline phase was between .64 and .69.

CHAPTER V

Discussion

The results show that initial link choice proportion can be decreased by increasing the temporal duration of a global context condition. This is consistent with the findings of the three main quantitative models of choice concerning local context effects. As the duration of the initial or terminal links increases, choice proportion becomes less extreme (Fantino, 1969; Fantino, Preston, & Dunn, 1993; Grace, 1994; Mazur, 2001; Squire & Fantino, 1971). The results of the current experiment imply that global context affects initial link choice in a similar direction as local context.

The current findings are not consistent with the findings of Goldschmidt, Latall, & Fantino (1998), who only examined response independent reinforcement. The current data showed a slightly diminished range of initial link choice proportions during the FT conditions as compared to the FI conditions. In addition, no positive correlation was found between response rate during the global context and choice proportion during the initial links, implying that the global context effects may indeed be response independent. Furthermore, the significant global effects observed tended to be smaller relative to the local context effects from previously published experiments (Fantino, 1969; Fantino, Preston, & Dunn, 1993; Grace, 1994; Mazur, 2001; Squire & Fantino, 1971). This may explain why previous research has not found support for the global contextual view for choice with concurrent chain reinforcement schedules (Goldschmidt, Lattal, & Fantino, 1998; Williams & Fantino, 1996).

As a result of the global contexts' functional similarity to the local context effects, each of the three quantitative choice models could easily be expanded to account for global contextual effects on choice. What follows is a description of the term in each quantitative choice equation that represents the local context effects, and how it might be modified to incorporate global contextual factors.

In DRT (Fantino, 1969; Squire & Fantino, 1971; Fantino, Preston, & Dunn, 1993), *T*, which currently represents the average time to primary reinforcement from the onset of the initial links, could be modified to represent the average time to primary reinforcement from the onset of the associated global context. Thus, T would still include the value of the delay to reinforcement in the actual concurrent chains procedure, in addition to global reinforcement context. For example, if the average time to primary reinforcement from the onset of the initial links in a concurrent chain schedule of reinforcement was 120 seconds, and also included a global context with a fixed-interval, 60 s context, then *T* could be split into two separate terms: the average duration of the global context, $T_{G,}$ and the average time to reinforcement from the onset of the initial links, T_L. Thus, *T* would be the product of T_G and T_L, and would equal a total of 180 seconds.

Both CCM (Grace, 1994) and HVA (Mazur, 2001) have equations that lack a term that encapsulates the average temporal duration from the beginning of the initial links until the delivery of primary reinforcement. In a way, CCM splits DRT's *T* term into two separate terms: *Tt* and *Ti*, which represent the average terminal link and initial link duration, respectively. Thus, a third term could be incorporated which represents the total global context duration (i.e., T_g). Additionally, terms representing the rate of reinforcement and sensitivity to reinforcement in the context must be included to coincide with the new T value.

HVA doesn't include any terms for temporal duration. Instead, HVA uses the construct of value to affect choice. Therefore, to incorporate global context effects into HVA, one must determine the value of the context schedule. This can be achieved by using the hyperbolic delay equation: the value of the reinforcer during the global context if it were delivered instantly, divided by the product of the delay to reinforcement and the constant parameter that indicates how quickly the value will decrease as the delay increases, plus one. Or:

$$V = \frac{A}{(1 + KD)}$$

In each case, the key to modifying the existing quantitative models of choice is simple. Each equation currently incorporates values that represent the local context. In order to account for the effects seen in the present experiment, these values must be identified and expanded to incorporate the global context.

A potential confound may have been an order effect, as shown by the shifting baselines observed throughout the experiment (see Figure 4). While statistical analyses showed a significant difference between initial link choice proportions during the first and second baseline conditions (see Figure 4), the fluctuating initial link choice proportions during the baselines should not have affected the overall results of the experiment so long as the conditions were balanced to control for an order effect.

Because the mean initial link choice proportions with the added global context conditions uncovered no significant differences, this implies that the difference in initial links choice proportions during the baselines did significantly influence the results for the global context conditions. That is, the balancing procedure was sufficient to prevent a shifting baseline from disrupting the overall results.

This brings us to the crux of the findings: why were the global context effects so small? We believe the answer lies somewhere in the procedural variables. The most obvious variable is the blocking procedure used to alternate context and concurrent chain schedules within a single session. Each block consisted of four concurrent chain schedules ending in primary reinforcement followed by four global context schedules ending in primary reinforcement. Concerns about the blocking procedure could potentially be investigated in future research. For example, it would be simple to investigate the effects of increasing or decreasing the number of consecutive trials per block on initial link choice proportion. Factors such as the total number of global context presentations may be also be responsible for the relatively small change in choice proportions. However, this is an empirical question that demands further inquiry.

Another avenue for future research could address the pigeons that didn't show a recognizable pattern of initial link choice proportions during the concurrent chains procedure and appeared to be insensitive to changes in the global context. It would be interesting to test whether these birds' initial link choice proportions can be influenced by changes in initial and terminal link durations. If this manipulation results in more extreme initial link choice proportions for the initial link schedule associated with the richer terminal link schedule, it would be safe to say the birds are only influenced by local context manipulations, and not the global context manipulations. If the manipulation results in no significant change in initial link choice proportion, this would suggest that these birds' initial link choice proportions are not influenced by any context manipulation, local or global, and instead appear insensitive to time manipulations.

In summary, the present experiment attempted to investigate the possible effects of global temporal context on initial link choice proportions in concurrent chain schedules of reinforcement. We believe the results obtained provide sufficient evidence for a global contextual view of choice. Although the study itself is limited in scope, we believe it should be viewed less as a limitation and more as an opportunity for future research to uncover these underlying mechanisms of global context on choice.

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