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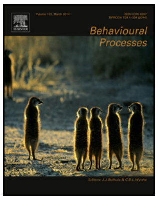

Reprint of "Acquisition of choice in concurrent chains: Assessing the cumulative decision model"☆

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ABSTRACT

Concurrent chains is widely used to study pigeons' choice between terminal links that can vary in delay, magnitude, or probability of reinforcement. We review research on the acquisition of choice in this procedure. Acquisition has been studied with a variety of research designs, and some studies have incorporated no-food trials to allow for timing and choice to be observed concurrently. Results show that: Choice can be acquired rapidly within sessions when terminal links change unpredictably; under steady-state conditions, acquisition depends on both initial- and terminal-link schedules; and initial-link responding is mediated by learning about the terminal-link stimulus-reinforcer relations. The cumulative decision model (CDM) proposed by Christensen and Grace (2010) and Grace and McLean (2006, 2015) provides a good description of within-session acquisition, and correctly predicts the effects of initial and terminal-link schedules in steady-state designs (Grace, 2002a). Questions for future research include how abrupt shifts in preference within individual sessions and temporal control of terminal-link responding can be modeled.

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The concurrent-chains procedure is widely used in the study of choice behavior. In a typical version of the task, shown in Fig. 1, pigeons respond during a choice phase or 'initial link' to produce access to one of two mutually-exclusive outcome schedules or terminal links that are signalled by distinctive stimuli. After reinforcement in a terminal link, the initial links are reinstated. Because the terminal links can differ in terms of the delay, magnitude, or probability of food, concurrent chains is useful for studying choice between complex outcomes.

Most prior studies have used steady-state designs in which subjects receive many sessions of training with the same contingencies until initial-link choice has stabilized. The contingencies are then

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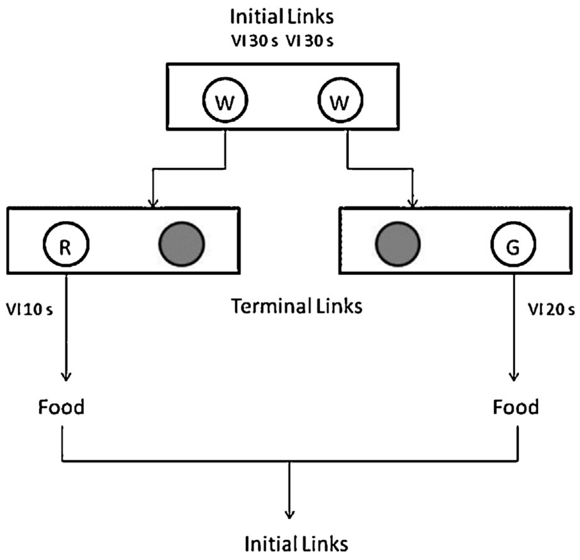

Fig. 1. Diagram of concurrent-chains procedure.

changed and training begins in the next condition (see Grace and Hucks, 2013; for review). Results from these studies have been well described by models such as the contextual choice model (CCM; Grace, 1994) and hyperbolic value-added model (HVA; Mazur, 2001), which share the assumption that choice in the initial links depends on the relative value of the terminal links. This assumption is based on the matching law (Baum, 1974; Baum and Rachlin, 1969; Grace, 2002a, 2002b; Killeen, 1972), and resembles revealed preference theory in economics, where consumer demand for goods across prices is used to infer a utility function (Richter, 1966; Samuelson, 1938). The value assumption has been useful for steady-state models, and recently allowed concurrent chains to be applied to delay and probability discounting (Grace et al., 2012; Grace and McLean, 2015). From a comparative perspective, understanding how nonhumans make tradeoff choice between multiple reinforcer dimensions, like those in discounting studies, may ultimately provide insight into the processes underlying human decision making.

To accomplish this requires a move beyond steady-state models to characterize the acquisition of choice (or choice in transition) in concurrent chains: How initial-link responding changes when the terminal-link contingencies are altered. A successful acquisition model should also be able to describe steady-state choice. Grace and colleagues have worked towards this goal by proposing a 'cumulative decision model' (CDM) based on acquisition studies with fixed-interval (FI) schedules (Grace and McLean, 2006). The model was later extended to predict steady-state choice with both FI and variable-interval (VI) terminal links (Christensen and Grace, 2008, 2009a, 2009b, 2010), and most recently, with terminal links that differ in magnitude and probability of reinforcement (Grace and McLean, 2015). Here we summarize known results on choice in transition in concurrent chains, and ask whether the CDM is able to account for them. In particular, we wanted to identify any shortcomings in the model which could indicate areas for future development.

1. 'Rapid acquisition' and the cumulative decision model (CDM)

The CDM was originally developed to explain results from studies in which terminal-link schedules changed unpredictably from session to session. This procedure can be described as 'rapid acquisition' because the development of preference is studied within individual sessions. In Grace et al.'s (2003) Experiment 1, the left terminal link was always FI 8 s but the right terminal link was either FI 4 s or FI 16 s, as determined by a 31-step pseudorandom binary series (PRBS; Schofield and Davison, 1997). Three PRBS replications were completed (93 sessions in total). Fig. 2 shows results for one pigeon. Choice was initially undifferentiated, but near the end of the first PRBS consistently favored the alternative associated with the shorter delay, and this trend continued to strengthen over the second and third replications. How preference developed within sessions is shown in Fig. 3, which plots the generalized-matching sensitivity to the log terminal-link immediacy ratio (i.e., reciprocal of delay) at six points across sessions. Sensitivity increased across blocks, reaching an asymptote of about 1.30 at midsession. Thus pigeons developed a strong preference (overmatching) for the shorter delay within individual sessions. However, because only two delays were used for the right terminal link, it is unclear whether this preference reflects sensitivity to the immediacy ratio, or that pigeons simply learned to choose the shorter delay.

In Grace et al.'s (2003) Experiment 2, the same pigeons were tested with a different delay in each session for the variable terminal link. At issue was whether sensitivity to the immediacy ratio would be reduced compared to Experiment 1. Surprisingly, it was

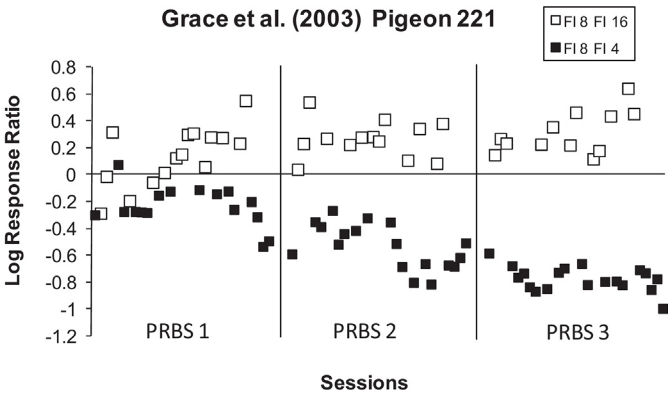

Fig. 2. Data from a representative pigeon from Grace et al.' (2003) Experiment 1. Shown are log response ratios over successive sessions of training which comprised three replications of a pseudorandom binary series (PRBS). Data from sessions in which terminal links were FI 8 s FI 16 s are indicated with unfilled squares; data from sessions with FI 8 s FI 4 s terminal links are shown with filled squares.

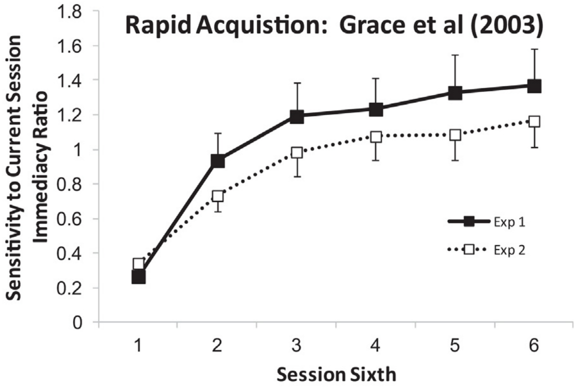

Fig. 3. Generalized-matching sensitivity to the current-session immediacy ratio by session sixth, averaged across pigeons, from Grace et al., 2003 Experiment 1 (filled symbols) and Experiment 2 (unfilled symbols). In Experiment 1, the variable delay was either 4 s or 16 s. In Experiment 2, the variable delay varied between 2 s and 32 s pseudorandomly, such that the left/right location of the shorter value varied according to the PRBS and the average (log) immediacy ratio was 2:1 or 1:2 for sessions in which the shorter value was associated with the left or right alternative, respectively. Bars indicate one standard error.