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Comparison of Scalar Expectancy Theory (SET) and the Learning-to-Time (LeT) model in a successive temporal bisection task

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Abstract

The present research tested the generality of the "context effect" previously reported in experiments using temporal double bisection tasks [e.g., Arantes, J., Machado, A. Context effects in a temporal discrimination task: Further tests of the Scalar Expectancy Theory and Learning-to-Time models. J. Exp. Anal. Behav., in press]. Pigeons learned two temporal discriminations in which all the stimuli appear successively: 1 s (red) vs. 4 s (green) and 4 s (blue) vs. 16 s (yellow). Then, two tests were conducted to compare predictions of two timing models, Scalar Expectancy Theory (SET) and the Learning-to-Time (LeT) model. In one test, two psychometric functions were obtained by presenting pigeons with intermediate signal durations (1–4 s and 4–16 s). Results were mixed. In the critical test, pigeons were exposed to signals ranging from 1 to 16 s and followed by the green or the blue key. Whereas SET predicted that the relative response rate to each of these keys should be independent of the signal duration, LeT predicted that the relative response rate to the green key (compared with the blue key) should increase with the signal duration. Results were consistent with LeT's predictions, showing that the context effect is obtained even when subjects do not need to make a choice between two keys presented simultaneously.

Keywords: Context effect; Bisection; Successive discrimination; Key peck; Temporal discrimination; Timing models; Pigeon

1. Introduction

Research on the temporal control of human and nonhuman organisms' behavior has made considerable progress in the last few decades. One of the most well-known procedures used to study timing is the temporal bisection task. This procedure was first used with animals (Catania, 1970; Stubbs, 1968), and later adapted for humans (Allan and Gibbon, 1991; Wearden, 1991).

In a typical temporal bisection task, one of two signal durations might be presented to the subject at the start of a trial: a "short" (e.g., 1 s) or a "long" (e.g., 4 s) signal duration. After the signal duration has elapsed (e.g., houselight on during 1 s or 4 s), the subject chooses between two different keys presented simultaneously (e.g., a red key and a green key) and obtains a reinforcer (e.g., food) if it makes a correct choice. The choice of the red key is rewarded if the preceding signal duration was 1 s, and the choice of the green key is rewarded if the preceding duration was 4 s. After this discrimination is learned, the experimenter introduces intermediate signal durations (ranging from 1 to 4 s), and records the preference for the green key. The curve plotting the proportion of green key choices against the signal duration is called a psychometric function.

This function has three main characteristics. First, as the signal duration increases, the proportion of green key choices increases from about 0 to about 1. Second, the point at which the psychometric function equals 0.5 (i.e., the bisection point, indifference point, or point of subjective equality) tends to occur close to the geometric mean of the two training signal durations for animal subjects (Catania, 1970; Platt and Davis, 1983), and close to the arithmetic mean of the two training signal durations for human subjects (Allan and Gibbon, 1991; Wearden and Ferrara, 1995). Third, the functions obtained with different pairs of "short" and "long" signal durations, but with their ratio held constant, superpose when plotted in relative time. To illustrate, imagine that the same subject that learned to discriminate 1 s from 4 s, subsequently learns to discriminate 2 s from 8 s. To plot on the same axis the two psychometric functions (one obtained with signal durations ranging from 1 to 4 s and the other with signal durations ranging from 2 to 8 s), one would rescale the

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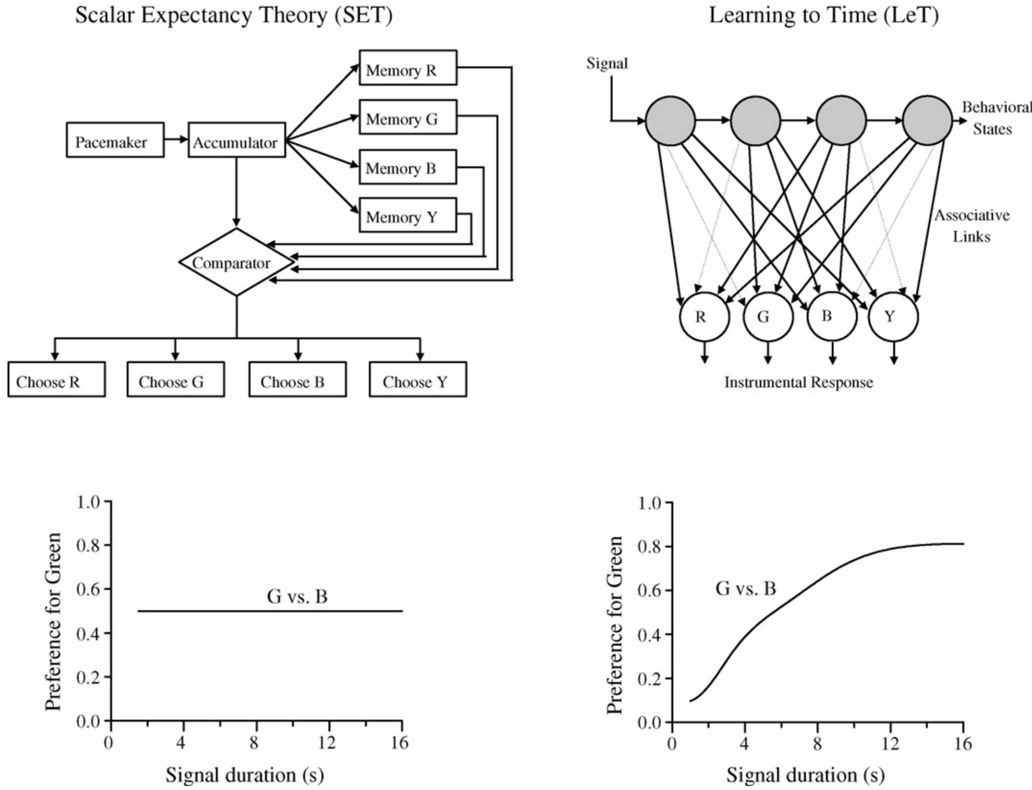

Fig. 1. Scalar Expectancy Theory (SET) and the Learning-to-Time (LeT) model for the bisection procedure, and respective predictions for the critical test when, following signals ranging from 1 to 16 s, the experimenter presents the green or the blue key, both associated with the same 4-s signal durations. R = red key; G = green key; B = blue key; and Y = yellow key.

durations from the 2 s vs. 8 s set by dividing them by 2. The two functions would then superimpose. Superimposition suggests a property similar to Weber's law for temporal discrimination in the sense that equal ratios yield equal discriminabilities.

In 1999, Machado and Keen modified this basic temporal bisection task. In their experiment, pigeons learned not one, but two temporal discriminations within the same session. The most important feature of their procedure was that the "long" signal duration in one discrimination was the same as the "short" signal duration in the other discrimination (both signals had the duration of 4 s). Specifically, in Machado and Keen's experiment, pigeons learned to discriminate 1 s vs. 4 s during Type 1 trials and 4 s vs. 16 s during Type 2 trials. On Type 1 trials, two keys were presented simultaneously, one red and one green: the choice of the red key was rewarded if the preceding signal duration was 1 s, and the choice of the green key was rewarded if the preceding signal duration was 4 s. On Type 2 trials, two other keys were presented simultaneously, one blue and the other yellow: the choice of the blue key was rewarded if the preceding signal duration was 4 s, and the choice of the yellow key was rewarded if the preceding signal duration was 16 s. It is important to note that the signal was the same in both types of trials (houselight) and that it only changed in duration (1 s, 4 s, or 16 s). Critically, the green and the blue keys were both associated with the same signal duration of 4 s. They called this procedure a double temporal bisection task.

Machado and Keen's (1999) major purpose was to compare two models of timing, Scalar Expectancy Theory (SET) and the Learning-to-Time (LeT) model. The fundamental question, for which these models make different predictions, was: What would a bird do if, following a signal duration *t* seconds long (with *t* varying from 1 to 16 s), it was presented with the green and the blue keys, the keys associated with 4-s signal durations and never before experienced simultaneously?

SET is an information-processing model developed by Gibbon and his collaborators (Gibbon, 1977, 1991; Gibbon et al., 1984). It assumes an internal clock with a pacemaker that generates pulses at a high rate, an accumulator that counts the pulses emitted during the interval to be timed and, in a double bisection task, four long-term memory stores that save the counts obtained at the end of each trial (see Fig. 1, top left panel). To decide which of the two keys to choose at the end of a signal duration, the animal compares the number that is in the accumulator when the signal duration ends with two samples, each extracted from the memory store associated with the corresponding key. When the choice is between the green and the blue keys, the just-experienced test duration would be compared with two samples that came from identical distributions. Therefore, regardless of the signal duration, the animal should be indifferent between these two keys. This prediction is illustrated by the horizontal line in the bottom left panel of Fig. 1.

LeT is a behavioral model developed by Machado (1997) based on earlier work by Killeen and Fetterman (1988). In the double bisection task, LeT assumes a serial organization of behavioral states, a vector of associative links connecting the behavioral states to the four instrumental responses, and the