TEMPORAL PROCESSING, RANGE EFFECT AND WEBER FRACTION

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Abstract

The aim of this study was to measure the impact on threshold estimates, for temporal discrimination, of the range of comparison intervals on a psychometric function. The experiment included two standard interval durations (.2 and 1 s) and compared a condition where all (8) comparison intervals were randomized within blocks with a condition where only pairs of intervals varied within blocks. The results revealed that the mode of presentation (totally randomized vs. only pairs of intervals within blocks) did not have an effect, whereas the range of comparison intervals did have one, although the effect depended on the standard intervals. With brief intervals (.2 s), using a narrower range of comparison intervals led to a smaller mean difference threshold. The results show that the parameters selected for drawing psychometric functions determine whether the Weber fraction remains constant between .2 and 1 s.

An important issue in the field of time perception is whether or not perceived duration is the product of an internal clock. Many models of time perception are based on the assumption that there is such an internal clock (Grondin, 2001), which is often described as a clock-counter device, as in the case of *Scalar Expectancy Theory* (SET: see Gibbon, 1977, 1991; Gibbon, Church & Meck, 1984). One critical property of this theory is actually the scalar one, i.e., the fact that the variability of time estimates grows as a constant fraction of the mean. In terms of psychophysics, this means that the Weber fraction should remain constant over a wide range of durations.

Assessing the validity of Weber's law for time may well depend on the data points selected for drawing the psychometric functions used to estimate sensitivity. There is some evidence in the timing literature, based mainly on bisection and temporal generalization tasks, that the range of data points actually changes the estimate of sensitivity, with larger differences between the longest and shortest intervals leading to higher estimates of sensitivity (Ferrera, Lejeune, & Wearden, 1997; Wearden & Ferrara, 1995, 1996; see also Wearden, Rogers, & Thomas, 1997).

In this experiment, we wanted to determine, on the basis of individual estimates of temporal sensitivity, the extent to which the range of comparison intervals would affect these estimates and, consequently, the verdict regarding the stability of the Weber fraction for time. Sensitivity was estimated with two sets of comparison intervals (a large and a narrow one) for two very distinct standard durations (200 and 1000 ms) where explicit counting was not expected to provide any benefits (Grondin, Meilleur-Wells & Lachance, 1999). The distance between the intervals was kept proportional in the 200 and 1000 ms durations (i.e., it was multiplied by 5). Moreover, in order to search for factors that might influence the threshold estimate, the comparison intervals were presented randomly in some sessions, while in others only one short and one long interval were used for each block and the difference between the short and long intervals was increased from one block to the other. In such conditions, one of the longest intervals of the set of comparison intervals would not be perceived as short simply by contrast with the previous interval if that interval was actually the longest of the set.

Method

Participants
Eight volunteers from Université Laval (5 women and 3 men) took part in the experiment. The average age was 27.1 years. Participants received $40 CAN for taking part in the experiment.

Apparatus and stimuli
The intervals to be discriminated were marked by two 1-kHz 20-ms auditory signals. The signals were produced by an IBM PC and presented binaurally through headphones (Sony MDR-V600). Each participant was seated at a computer in a dimly lit room and asked to respond either "short" or "long" by pressing 1 or 3 respectively on the computer keypad.

Procedure
The experiment consisted of eight experimental sessions of 20 to 30 minutes for each participant. A minimum of one hour was required between sessions. There were 8 experimental conditions: 2 Standards (200 and 1000 ms) x 2 Spreads (Large vs. Narrow) x 2 Modes of presentation (Randomized vs. Blocked).

The experiment included two standard interval durations (200 ms and 1000 ms) and eight comparison intervals. For the 200 ms standard, each comparison interval was separated by either 2 ms (ranging from 193 ms to 207 ms) in a narrow spread condition or 10 ms (ranging from 165 ms to 235 ms) in a large spread condition. For the 1000 ms standard, each comparison interval was separated by either 10 ms (ranging from 965 ms to 1035 ms) for the narrow condition or 50 ms (ranging from 825 ms to 1175 ms) for the large condition (200 ms condition multiplied by 5).

Each session consisted of four blocks of 64 trials, with a 20 s pause between blocks. In four sessions, the stimuli were presented in random order, eight times per block. In the other four sessions, each block consisted of the two comparison stimuli separated by the same duration above and below the standard (i.e., 199 ms and 201 in block one, 197 and 203 in block two, 195 and 205 in block three, 193 and 207 in block four for the 200 ms standard, idem for the 1000 ms standard), presented 32 times each. Half of the participants began with the four sessions of random presentations, and the other half began with the blocked presentations. The two standards, two comparison conditions, and random vs. blocked presentation provided a total of eight different experimental conditions, with one condition per session. Results from the four blocks were combined to trace one psychometric function per participant per condition, where each point is represented by 32 observations.

At the beginning of each session, the standard (200 or 1000 ms) was presented ten times. Participants were informed that they would have to judge whether later intervals were longer or shorter than the standard. After the presentation of the standard, the experimental trials began. Each trial consisted of one comparison interval marked by two brief tones. After the participant entered a response, the correct response was indicated on the computer screen.

Data Analysis
For each participant and for each experimental condition, an 8-point psychometric function was traced, plotting the eight comparison intervals on the x axis and the probability of responding "long" on the y axis.

The cumulative normal distribution was fitted to the resulting curves. Two indices of performance were estimated for each psychometric function, one for sensitivity and one for the perceived duration. One dependent variable is the bisection point (BP). The BP can be defined as the *x* value corresponding to the .50 probability of “long” responses on the *y* axis. Longer perceived durations are reflected by smaller bisection point values.

As an indicator of temporal sensitivity, which is the most important issue in the present experiment, estimates of the standard deviation (SD) on the psychometric function were determined. For this purpose, the difference between the *x* values corresponding to .84 and .16 probabilities of “long” responses, on the *y* axis, was divided by 2. Using one SD (or variance) is a common procedure to express temporal sensitivity (Grondin, 2008; Killeen & Weiss, 1987). From this estimate, we derived a Weber-like index of sensitivity, the coefficient of variation (CV = SD / BP).

Results

Because of some poor individual goodness-of-fit values (particularly in the narrow conditions), results of only 6 participants were kept for the final analysis. The results for participants as a whole (6 in the narrow conditions and 8 in the large conditions) are presented on Figure 1, and in general, the goodness-of-fit values are very high, especially in the large spread condition.

For the final analysis on the basis of individual data, the results of only 6 participants were used because of the poor goodness-of-fit values, particularly in some of the narrow conditions. For the coefficient of variation (CV = SD / BP), the mean results in each condition are reported in Table 1, and the difference between them was tested with a repeated-measure ANOVA (2 x 2 x 2 design). Overall, the CV was .037 in the 200-ms Standard condition, and .048 in the 1000-ms condition. This difference was not significant (p = .152; η^2 = .363). Similarly, the Spread (.041 vs. .043, p = .395) and the Mode of presentation effect (.042 vs. .043, p = .802) were not significant. However, the Standard x Spread interaction was significant, $F(1, 5) = 7.133$, $p < .05$, $\eta^2 = .588$ (see Figure 2). No other interaction effect was significant.

As for the bisection point, it was transformed into a Constant Error index (CE = BP – Standard) to allow the direct comparison of Standard conditions. The 2 x 2 x 2 repeated-measure ANOVA revealed no significant main or interaction effect.

Table 1.
Mean Coefficient of Variation in each Experimental Condition

Standard: **200 ms**		
Mode of presentation	Blocked	Randomized
Spread Narrow	.0303	.0322
Large	.0420	.0444
Standard: **1 000 ms**		
Mode of presentation	Blocked	Randomized
Spread Narrow	.0404	.0501
Large	.0479	.0417

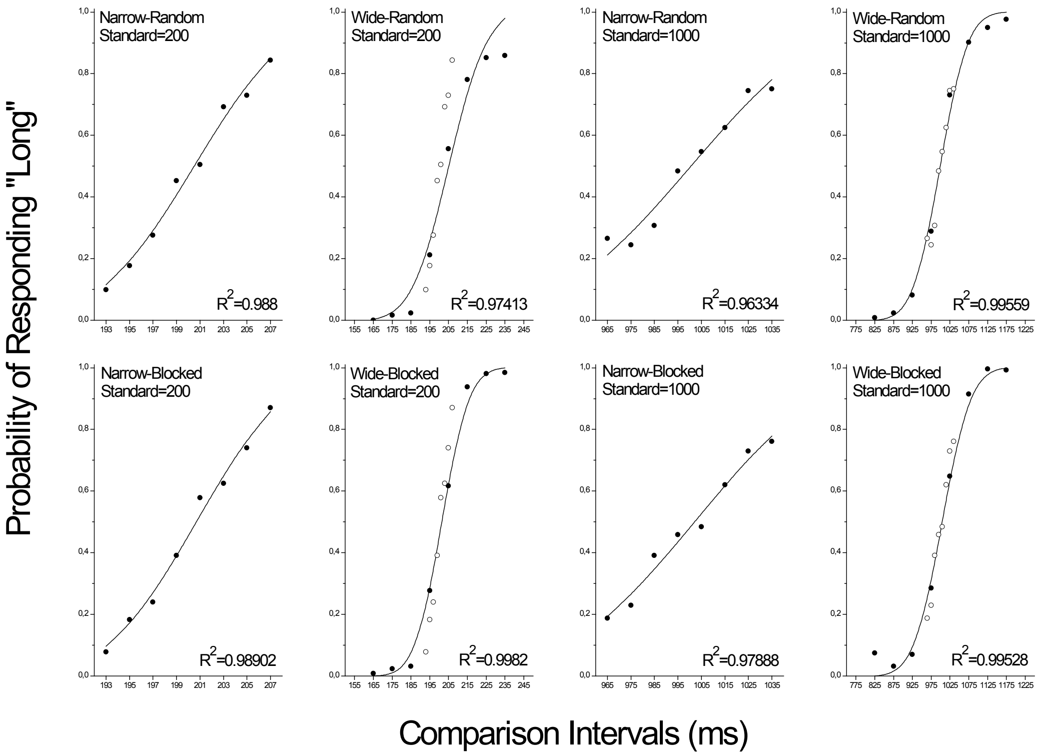

Figure 1. Psychometric function (pooled results: 6 participants in the narrow conditions and 8 participants in the large conditions) for each experimental condition. The R^2 value indicates the goodness-of-fit of filled-circle data. (empty circles are a repetition, on a "large scale", of the data points from the "Narrow condition")

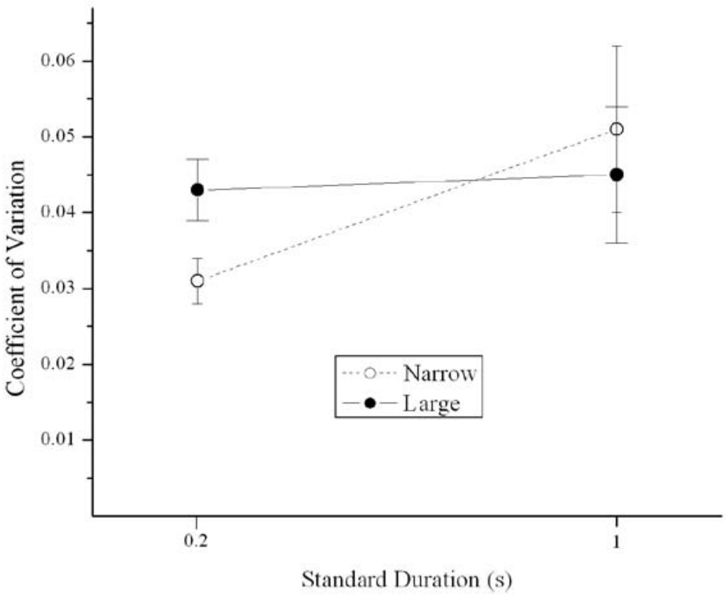

Figure 2. Mean coefficient of variation in the narrow and large spread conditions for each standard duration

Discussion

The present study confirms that the spacing of comparison intervals has an effect on estimates of temporal sensitivity. Of particular importance is the fact that this spread effect depends on the standard duration. Indeed, in the large spread condition, the coefficient of variation remained constant. This suggests that Weber's law, in its simplest form (or the basic property of SET), applies to the present temporal conditions. However, a different conclusion can be drawn from the experiment on the basis of the narrow spread condition. The coefficient was much higher in the 200-ms than in the 1000-ms standard condition. This cannot be accounted for by Weber's law, or by its generalized version, and is a violation of the scalar property of time. Although there was a huge benefit from adopting a narrow spacing of comparison intervals at 200 ms, there was no such benefit at 1000 ms. When the value of the comparison intervals in the narrow condition was kept proportional from 200 to 1000 ms, the task became too difficult.

This difference between the two standard conditions in the narrow spread condition occurred in both randomized and blocked conditions, even though the blocked conditions were expected to minimize variance. Lastly, while there was no overall effect of the blocked vs. randomized factor, the manipulation tended to impair performance the most in the narrow condition, i.e. at 1000 ms, with the coefficient of variation increasing from .04 to .05.

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