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About hemispheric differences in the processing of temporal intervals☆

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Abstract

The purpose of the present study was to identify differences between cerebral hemispheres for processing temporal intervals ranging from .9 to 1.4 s. The intervals to be judged were marked by series of brief visual signals located in the left or the right visual field. Series of three (two standards and one comparison) or five intervals (four standards and one comparison), marked by sequences of 4 or 6 signals, were compared. While discrimination, as estimated by d', was significantly better in the 4-standard than in the 2-standard condition when stimuli were presented in the left visual field (LVF), this number-of-standard effect on discrimination varied with the difficulty levels when the signals were presented in the LVF. Moreover, the discrimination levels were constant for the different base durations with stimuli presented in the LVF, but not with stimuli presented in the right visual field. This article discusses the implication of these findings for the study of hemispheric dominance for temporal processing and for a single-clock hypothesis.

1. Introduction

Whether in speech or music, or in the simple fact of waiting for an event to occur, processing time is required. The purpose of the present experiment was to further elucidate the mechanisms involved in the processing of temporal information. It is proposed to study these temporal mechanisms with a classical timing task, the discrimination of short time intervals. More specifically, it is the discrimination of intervals presented in sequences that is going to be used.

There is a wide variety of models developed to account for temporal processing. However, many contemporary researchers in the field of time perception recognize the scientific usefulness of the single, internal-clock hypothesis for explaining temporal judgments (see Grondin, 2001a, 2001b; Helfrich, 2003; or Meck, 1996). Such a central clock is most often described as a pacemaker–counter device (Killeen & Weiss, 1987). The pacemaker emits pulses that are accumulated in a counter, and the number of pulses counted determines the perceived length of an interval. The efficiency of this accumulation is often attributed to attentional mechanisms, more attention being paid to time resulting in an increase of pulse accumulation. The pacemaker–counter view is often embedded within an information-processing perspective and is often referred to as the *Scalar expectancy theory* (SET: Gibbon, Church, & Meck, 1984). Within this view, the variability of temporal judgments are reported to depend not only on the processes located at the clock level, but also on those associated with memory and decision.

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A central feature of most models based on a pacemaker–counter device is that the variability in a series of time judgments should increase linearly as a function of time. This property is referred to in psychophysics as the Weber law but in the field of timing, it is often called the scalar property: when reported on the same relative scale, the variability obtained for different duration ranges should be the same. Indeed, not only is the amount of variability the same but the functions should superimpose. However, the ideas that there is one central timekeeping mechanism, and that this mechanism would have a scalar property could be challenged by two independent types of results. Both are issued from the rhythm literature, more specifically from experiments where sequences of intervals are presented. Challenges come in one case from the possibility that each cerebral hemisphere offers a specific way for processing temporal information; and, in the second case, from a violation of the scalar property (see Ferrandez et al., 2003; Meck, 2003; Meck & Malapani, 2004; Pfeuty, Ragot, & Pouthas, 2003).

The involvement and efficiency of each cerebral hemisphere for processing temporal information remains an open question. It is known that the left cerebral hemisphere has an advantage over the right in temporal processing when temporal tasks involve judgments relative to the temporal order of two sensory events (Efron, 1990; Nicholls, 1996). However, it is more difficult to draw the same conclusion when temporal processing involves explicit judgments about time, i.e., about the relative length of two time intervals. Some recent findings, mostly found in the neuroscience or neuropsychology literature, argue for the existence of a right-hemisphere advantage, or for a specific role of the right hemisphere, for processing temporal information (Funnell, Corballis, & Gazzaniga, 2003; Handy, Gazzaniga, & Ivry, 2003; Harrington, Haaland, & Knight, 1998; Kagerer, Wittmann, Szelag, & Steinbüchel, 2002; Milner, 1962; Monfort, Pouthas, & Ragot, 2000; Pouthas, Garnero, Ferrandez, & Renault, 2000; Smith, Taylor, Lidzba, & Rubia, 2003). Other hypotheses have also been considered. For instance, Polzella, DaPolito, and Hinsman (1977) reported some evidence that a timer for very brief intervals might be located in the left cerebral hemisphere, without excluding the possibility that another mode for processing time might be used by the right hemisphere.

Most relevant for the present study is the method used by Ben-Dov and Carmon (1984). These authors presented a series of brief flashes marking 200- or 400-ms intervals to both cerebral hemispheres, and a second sequence, either the same as or different from the first, to only one hemisphere. The participants had to say whether the sequences were the same or different. Based on reaction time data and an analysis of errors, Ben-Dov and Carmon reported that the relative efficiency of the two cerebral hemispheres depended on the number of intervals presented. Cerebral dominance shifted from the left hemisphere to the right as the number of intervals increased (in this case, from 1 to 4). The hypothesis that cerebral dominance depends on the number of intervals presented was also shown to be viable for temporal processing in the auditory mode (Alpherts et al., 2002).

The second challenge is related to the scalar property. There are multiple reports in the rhythm literature involving the duration discrimination of interval sequences, but the conclusions concerning the variability to time ratio are mixed. These reports involve in most cases series of auditory signals. Some of these reports support the scalar property, i.e., the Weber's law model (Halpern & Darwin, 1982; see Friberg & Sundberg, 1995). However, there are some cases where the scalar property does not hold. For instance, for brief intervals (<400 ms), the difference threshold remains constant (Schulze, 1989; ten Hoopen et al., 1995). In Drake and Botte (1993), the scalar property holds for intervals ranging from 300 to 800 ms but when intervals to be discriminated last 1.5 instead of 1 s, the variability to time ratio is much higher.

1.1. The present experiment

The purpose of the present experiment was to verify, with a range of durations (from .9 to 1.4 s) different from the one used by Ben-Dov and Carmon (1984), if the location of the visual source—in the left vs. right visual fields—influences the discrimination of intervals marked by sequences of brief signals. Based on these authors' findings, this influence should depend on the length of the sequence, i.e., on the number of intervals defined by the series of signals. This potential interaction effect between the number of intervals presented and the location of signals will be tested with different difficulty levels. Moreover, the experiment provides an occasion to address another fundamental issue about temporal processing: will the discrimination levels at various base durations remain constant as would predict SET? Considering the findings of Drake and Botte (1993) and the range of duration under investigation, the discrimination level might vary as a function of time rather than staying constant. The present experiment addresses this issue and will test if the answer to the question depends or not on the location of the visual marker in the left vs. right visual field, and on the length of the sequences.

2. Method

2.1. Participants

Twelve Laval University students, 9 females and 3 males, aged 20–32 (mean = 24.5) and right-handers