

ACOUSTICAL LETTER

Categorization of brief temporal intervals: An auditory processing context may impair visual performances

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1. Introduction

One hotly debated question in the field of timing is that of the communality of mechanisms for interval discrimination and production [1], or of the sensory motor basis of timing [2]. The hypothesis of a common temporal basis for these tasks has received support in an experiment where learning auditory interval discrimination was shown to transfer to the production of intervals of the same range [3]. If transfer is possible from a perceptual task to a production task because timing is based on a central mechanism, transferring temporal learning should be possible from one perception task to another. Indeed, a very hot topic in the field of perception in general is that of intermodal relations. These relations take different forms, like synaesthesia, a phenomenon experienced by some persons for whom, for instance, numbers and colors, or colors and forms, are strongly associated [4]; or like the phenomenal impression of visual changes induced by auditory sounds [5].

In the field of time perception, there are within-modality transfers, for specific durations, in the auditory mode (across-marker frequencies [6]) and the tactile mode (across-skin location: [7]. In animal learning literature, there are evidences for the cross-modal transfer of duration [8]. More recently, results with humans have tended to show that visual temporal processing gains benefits from a context involving the categorization of auditory intervals [9,10]. However, a more systematic test of this hypothesis remains to be completed.

It is known that the sensitivity for processing temporal intervals is much better when signals marking time are auditory rather than visual [9,10]. The purpose of the present experiment is to see if it is possible to improve the categorization of time intervals marked by brief visual signals in a context involving multiple presentations of intervals marked by auditory signals.

2. Method

2.1. Participants

Twelve volunteer Laval University students, 10 females and 2 males, participated in this experiment ($M = 21.4$ years old). All were paid $35 Canadian for their participation.

2.2. Apparatus and stimuli

The intervals to be discriminated were silent durations between 20-ms auditory or visual stimuli. The auditory stimuli were 1-kHz pure sinusoidal sounds generated by an IBM Pentium IV micro-computer running E-Prime software (version 1.1.4.1-SP3). The computer was equipped with an SB Audigy 2 sound card, and the sounds were delivered through a Logitech Z-640 loudspeaker at an intensity of about 70 dB SPL. The visual stimuli were produced by a circular red-light-emitting diode (LED; Radio-Shack #276-088) placed about 1 m in front of the participant and subtending a visual angle of about 0.57°.

Each observer was seated in a dimly lit room and asked to respond whether the interval presented between the brief signals belonged to the short or to the long category by pressing "1" or "3" on the computer keyboard, respectively.

2.3. Procedure

There were seven experimental sessions lasting about 30 minutes, with five blocks of 72 trials. There were 20 seconds between the blocks. Before the each session, there were 12 practice trials. Within each block, there were 12 presentations, in a random order, of each of the six intervals: the short group (200, 220, and 240 ms) and the long group (260, 280 and 300 ms). Once the participant responded, 200 ms later a visual feedback indicated for 1.7 s whether the interval was short or long. There was a 1-s pause between the feedback and the presentation of the next signals marking the interval.

In Sessions 1 and 7, all signals marking intervals were visual. In Session 2, all signals marking intervals were auditory. During Sessions 3 to 6, all signals marking intervals during the practice trials and Block 1 were auditory; during Blocks 2 to 5, 75% of the intervals were marked auditorily, and 25% visually (Mixed condition). These auditory and visual intervals were presented in a random order, with equal probabilities of occurrence of each of the six interval lengths for auditory and visual intervals.

3. Results

For each participant and for each of the six conditions, a 6-point psychometric function was traced, plotting the six empty intervals on the x-axis and the probability of responding "long" on the y-axis.

The *cumulative normal distribution* (CND) was fitted to the resulting curves. Two indices of performance were estimated from each psychometric function, one for sensitivity and one for the perceived duration. As an indicator of temporal sensitivity, estimates of one standard deviation (SD) on the psychometric function were determined. Using one SD (or variance) is a common procedure to express temporal

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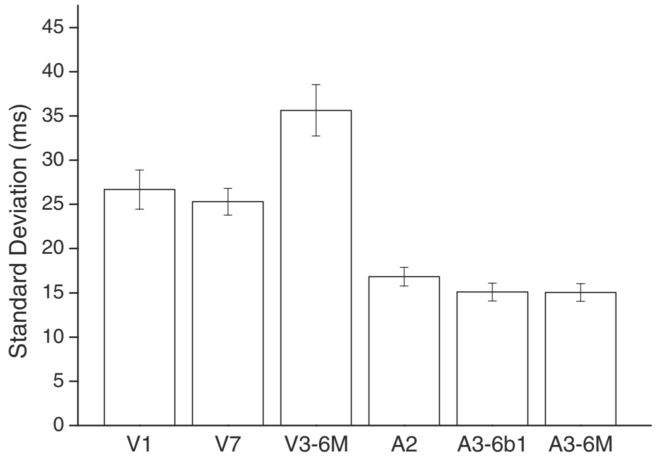

Fig. 1 Mean standard deviation (± SE) for each experimental condition (V = Visual condition; A = Auditory condition; M = Mixed condition; numbers indicate Sessions; b1 is Block 1).

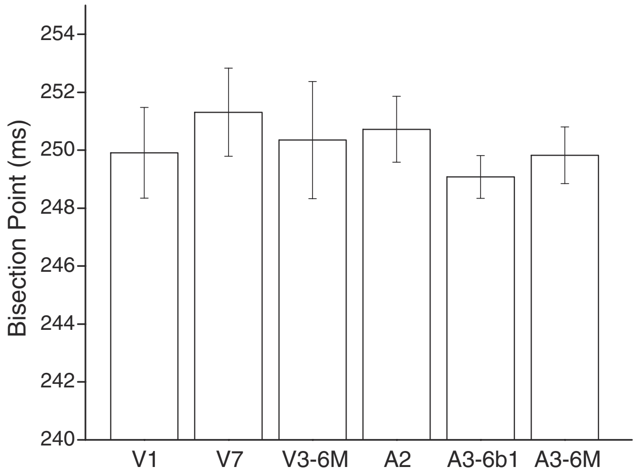

Fig. 2 Mean bisection point (± SE) for each experimental condition (V = Visual condition; A = Auditory condition; M = Mixed condition; numbers indicate Sessions; b1 is Block 1).

sensitivity [9–11]. The other dependent variable was the bisection point (BP). The BP can be defined as the x value corresponding to the 0.50 probability of "long" responses on the y-axis. Longer perceived durations are reflected by smaller PSE values.

A psychometric function was traced for each individual and for each experimental condition. The mean SD in each experimental condition is illustrated in Fig. 1. The figure shows the results in the visual condition in Session 1, Session 7 and Sessions 2–6 (Blocks 2–5); and in the auditory condition in Session 2, Sessions 3–6 (Block 1) and Sessions 3–6 (Blocks 2–5). Two repeated-measure ANOVAs, one for each modality condition, were conducted. One ANOVA revealed that the differences between the three visual conditions are significant, $F(2, 22) = 6.82$, $p < 0.01$, $\eta^2 = 0.38$. The other ANOVA revealed no significant differences between the auditory conditions, $F(2, 22) = 1.90$, $p = 0.18$, $\eta^2 = 0.15$. In the visual condition, the SD is significantly lower in Session 1 or 7 than in Sessions 3–6 (see the first three conditions on the left side of Fig. 1). Finally, a t test revealed that the mean of the auditory conditions is significantly lower than the mean of the visual conditions, $t(11) = 7.46$, $p < 0.01$.

The BP in each condition is illustrated in Fig. 2. Two repeated-measure ANOVAs, one for each modality condition, were conducted on the BP. There is no significant difference between the three visual conditions, $p = 0.79$; and between the three auditory conditions, $p = 0.36$. As well, a t test revealed that there is no difference between the mean of the auditory conditions and the mean of the visual conditions, $p = 0.68$.

4. Discussion

The purpose of this experiment was to show that it is possible to improve the categorization of visually marked intervals in a context where multiple intervals marked by auditory signals are presented. No such improvement was observed. This result is consistent with a previous failure in our laboratory to observe a cross-modality transfer of temporal processing learning with auditory and visual signals [12].

The failure to show a training, transfer or association effect does not necessarily mean that visual temporal processing cannot gain benefit from temporal processing training in the auditory mode. It might simply be a matter of the extent of training. In the field of duration discrimination, it was shown that moderate practice might exert a moderate effect on performance [13], but extensive practice has a powerful effect [14]. The transfer to interval production from training in auditory interval discrimination reported by Meegan *et al.* (2000) did not require such extensive training though. This finding, and the present unsuccessful attempt to improve visual performance, might imply that there is either a specific auditory-motor timing connection, or a specific difficulty to transfer temporal learning across sensory modalities. Clearly, more research is needed to sort out modality issues in temporal learning, and more extensive training in the auditory mode will probably be required.

Indeed, in the present study, the auditory context rather impaired the performance with intervals marked visually, which is not consistent with what previous findings tended to show in interval categorization experiments where visual and auditory signals were randomized within blocks [9,10]. The performance levels remained constant in the different experimental conditions in the auditory condition (Weber fraction around 6%), but not with visual signals, where the Weber fraction was slightly above 10% in sessions involving only visual stimuli, but close to 15% when auditory signals were also presented. Instead of helping discrimination, the auditory context (Session 2, Block 1 in each of Sessions 3–6, and 75% of trials in Blocks 2–5 of Sessions 3–6) interfered with the ability to process visually marked intervals, in spite of the fact that the participants knew that they should keep paying attention to the visual signals in the mixed-modality blocks. On the other hand, the difference between the performance levels in the auditory and visual conditions is consistent with the literature on this issue [see 15].

Finally, in the mixed condition, there was no difference between auditory and visual conditions for perceived duration. This finding is consistent with previous results [9] where empty intervals were also used, but inconsistent with other findings on this issue [see 16].

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