ABOUT THE DIFFICULTY TO TRANSFER TEMPORAL LEARNING ACROSS SENSORY MODALITIES

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Abstract

This article analyzes the possibility to improve the discrimination of brief intervals marked by two brief visual signals with training in the auditory mode, or with training involving a simultaneous presentation of both auditory and visual signals. In two experiments, it was not possible to show improvement of the visual temporal processing after training.

One hotly debated question in the field of timing is that of the communality of mechanisms for interval discrimination and production (Ivry & Hazeltine, 1995), or of the sensory motor basis of timing (Jantzen, Steinberg, & Kelso, 2005). The hypothesis of a common temporal basis for these tasks has neurological support, and also received support in an experiment where learning auditory interval discrimination was shown to transfer to the production of intervals of the same range (Meegan, Aslin, & Jacobs, 2000). 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 phenomena experienced by some persons for whom, for instance, numbers and colors, or colors and forms, are strongly associated (Dixon, Smilek, Wagar & Merikle, 2004); or like the phenomenal impression of visual changes induced by auditory sounds (Shams, Mamitani & Shimojo, 2002).

In the field of time perception, there are within-modality transfers, for specific durations, in the auditory mode (across-marker frequencies: Karmarkar & Buonomano, 2003) and the tactile mode (across-skin location: Nagarajan et al., 1998). In animal learning literature, there are evidences for the cross-modal transfer of duration (Roberts, 1982). More recently, results with humans have tended to show that visual temporal processing gains benefits from auditory training (Grondin, 2005; Grondin, Gamache, Roussel, Pouliot, & Plourde, 2005). However, a systematic test of this hypothesis remains to be completed.

The purpose of the experiments presented here is to see if it is possible to improve the discrimination of time intervals marked by brief visual signals in a type of training involving multiple presentations of auditory markers.

Experiment 1

Method

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.

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 70dB. 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 $.57^{o}$.

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.

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. 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.

Data analysis

For each participant and for each of the eight conditions, a 6-point psychometric function was traced, plotting the eight 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 sensitivity (Grondin, 2005; Killeen & Weiss, 1987). 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 for the comparison intervals are reflected by smaller PSE values.

Results

A psychometric function was traced for each individual and for each experimental condition. The mean SD in each experimental condition is illustrated in Figure 1 (left panel). The differences between the three visual conditions are significant, $F(1.62,17.78) = 6.82$, $p < .01$, but those between the auditory conditions are not, $F(1.98,21.78) = 1.90$, $p = .18$. The mean of

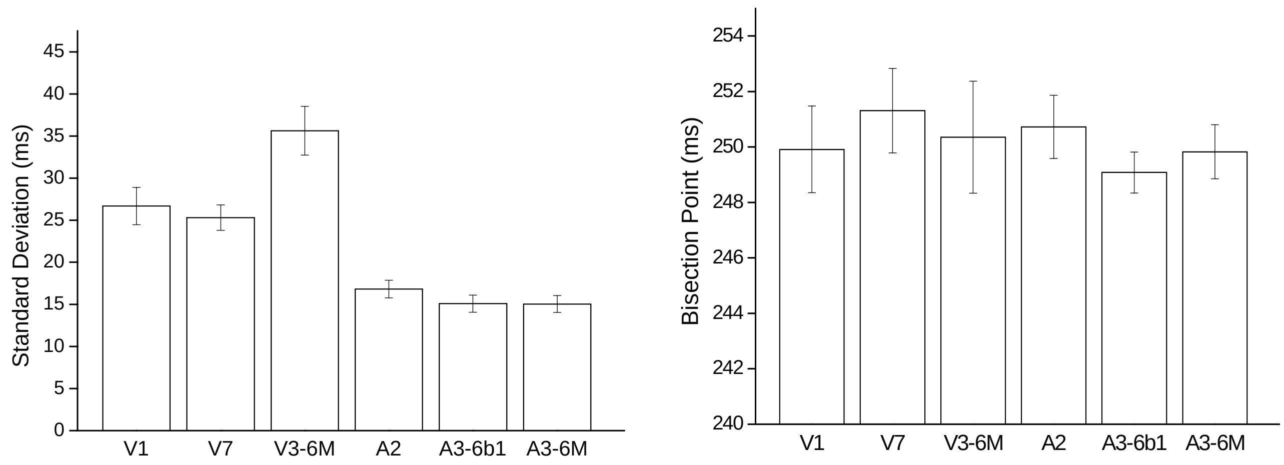

Figure 1. Mean standard deviation and bisection point (± SE) for each experimental condition of Experiment 1 (V=Visual condition; A=Auditory condition; M=Mixed condition; numbers indicate Sessions; b1 is Block 1)

the auditory conditions is significantly lower than the mean of the visual conditions, $t(11) = 7.46$, $p < .01$.

The BP in each condition is illustrated in Figure 1 (right panel). There is no significant difference between the three visual conditions, $p = .79$, between the auditory conditions, $p = .36$, or between the mean of the auditory conditions and the mean of the visual conditions, $t(11) = .43$, $p = .68$.

Experiment 2

In Experiment 2, we again tried to improve performance in the visual condition on the basis of training, mainly auditory, but we reduced the number of short and long intervals to one of each type. It was also planned to add a final session with tactile markers, to test whether the training effect—if any—would be extended to this modality.

Method

Participants

Twenty-four Laval University students, 16 females and 8 males (Mean age = 23.4), took part in the experiment. They received CAN$20 for their participation.

Apparatus and Stimuli

The material was essentially the same as in Experiment 1. However, in the last session, intervals were marked with electro-tactile stimulations on the forearm of the participant. Moreover, the auditory signals were delivered binaurally through headphones (Sony MDR-V600) at an intensity of about 70dB.

Procedure

Each observer was seated in a dimly lit room and asked to respond whether the empty interval between the signals was short (238 ms) or long (262 ms) by pressing “1” or “3” on the computer keyboard, respectively.

The participants were assigned to one of three experimental groups: visual training, auditory training, and simultaneous (A+V) training. For each participant, there were 8 experimental sessions lasting 10 to 15 minutes. Participants of each group were presented the V-V condition in Sessions 1 and 7 and the T-T condition in Session 8. The group conditions differed during the 5 identical training sessions (Sessions 2-6). Group 1 was trained in the V-V condition (same as in Sessions 1 and 7); Group 2 received training in the auditory modality (A-A); and for Group 3, both visual and auditory markers were delivered simultaneously (AV-AV). There were four blocks of 50 trials (25 short and 25 long intervals, randomly presented) in each session. The first session was preceded by a 10-trial block with feedback.

Data analysis

The statistical analysis of data is based on the parameters of the Signal Detection Theory (SDT). There are two dependent variables of interest, sensitivity and the decisional criterion, estimated with *d´* and *c*. For each difficulty level in each experimental condition, *d´* and *c* were computed on the basis of two assumptions: the distributions for the short and long intervals were normal and had equal variances. Indeed, the short and long distributions for each difficulty level are the noise and signal + noise distributions in the SDT. In the present experiment, a hit was responding “long” when the last interval of the sequence was long, and a false alarm was responding “long” when the last interval was short. The *d´* and *c* were computed with the computer program reported by Macmillan and Creelman (1991, Appendix 6) on the basis of the presentation of 100 short and 100 long intervals for the condition corresponding to Sessions 1, 7 and 8; and on 400 short and 400 long intervals for the condition corresponding, for each group, to Sessions 2 to 6 combined.

Results

Figure 2 shows the mean *d´* in each experimental condition. Sessions 1 and 7 (visual markers) were compared within a 2 (repeated measures) x 3 (groups) ANOVA design. No effect was significant. As well, Sessions 7 and 8 (visual vs. tactile conditions after training) were compared on the basis of the same design. Performance was significantly higher in the visual (M = .57) than in the tactile (M = .39) condition, $F(1,21) = 7.02$, $p < .05$. The other effects were not significant. Finally, the mean performance in Sessions 2 to 6 in each training condition was compared on the basis of a one-way ANOVA. The analysis revealed a significant effect, F(2,

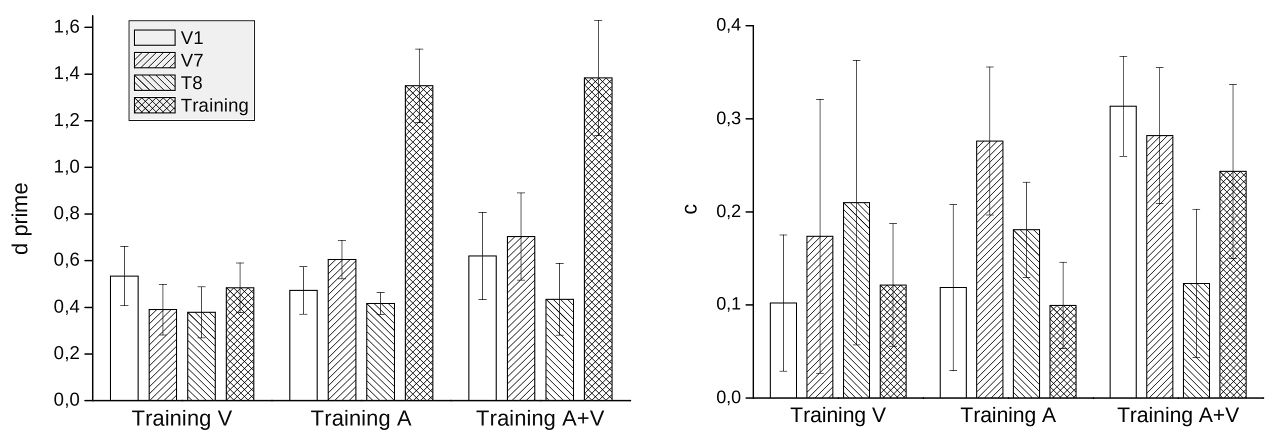

Figure 2. Mean *d´* and *c* values (± SE) for each experimental condition of Experiment 2 (V=Visual condition; A=Auditory condition; T=Tactile condition; numbers indicate Sessions)

21) = 8.05, $p < .01$, with the post hoc test revealing that in both conditions involving auditory signals, the *d´* were higher than in the condition involving only visual signals.

The same analyses were performed on the *c* index. The only significant difference was related to the comparison of Sessions 7 and 8, $F(1,21) = 7.57$, $p < .05$, with the *c* value being higher in the visual ($M = .244$) than in the tactile ($M = .163$) condition.

Conclusions

The purpose of these experiments was to show that it is possible to improve the discrimination of visually marked intervals after, or in the context of, multiple presentations of auditory intervals. In general, no such improvement was observed. Neither training in the auditory mode (Experiment 2) nor the association of auditory and visual signals (Experiments 1 and 2) led to better discrimination. These results are consistent with a previous failure in our laboratory to observe a cross-modality transfer with auditory and visual signals (Théroux, 2003).

Of course, the failure to show a training or transfer effect does not mean that visual temporal discrimination cannot gain benefit from auditory temporal training. It might simply be a matter of the extent of training. In the field of duration discrimination, it is known that moderate practice might exert a moderate effect on performance (Rammsayer, 1994), but extensive practice has a powerful effect (Kristofferson, 1980). In the present experiments, the training was probably not intensive enough to generate a potential cross-modality transfer of the duration learning effect. This is surprising considering that the transfer to interval production from training in auditory interval discrimination reported by Meegan et al. (2000) did not require such extensive training. This might imply a specific auditory-motor timing connection or a specific difficulty to transfer temporal learning across sensory modalities. Indeed, this difficulty might be caused by the characteristics of the visual system. Clearly, more research is needed to sort out modality issues (auditory, visual or tactile) in temporal learning.

It is interesting to note that, in Experiment 1, the discrimination level 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 interfered with the ability to process visually marked intervals. Also noteworthy is the fact that, in the mixed condition, there was no difference between auditory and visual conditions for perceived duration, a finding consistent with Grondin (2005), who also used empty intervals, but inconsistent with other findings on the issue.

Finally, the results of Experiment 2 also provide a rare opportunity to compare the tactile mode with other modalities for duration discrimination. The slightly better discrimination reported with the visual signals than the tactile signals is consistent with previous reports involving the same range of duration (see Grondin, 2003).

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