Auditory Space Recalibration Following Audiovisual Experience: Sequential Effects

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Abstract

Localizing sound requires a mapping between the auditory localization cues and the corresponding position in space. This mapping is subject to successive recalibrations through sensory experience. In this work we analyzed the impact of different sequences of audiovisual stimuli on subsequent perceived sound position. Sequences of five audiovisual stimuli pairs were presented, where each pair could be matching in space or 12 deg apart. Results revealed that, on average, sound localization was shifted by a few degrees towards the position of light in audiovisual discrepant trials. When sound was presented alone, the same shift was observed, revealing a recalibration effect. Interestingly, this shift was also observed in audiovisual matching trials. The total number of discrepant trials in a sequence, how many were presented in the end, and the maximum consecutive discrepant trials, all predicted the auditory shift. In a sequence, the last audiovisual trial was the one to better predict the amount of auditory shift. These results reveal that brief audiovisual stimulation can induce auditory space recalibration, and that this is a dynamic process, subject to constant tuning, where the latest stimulation better predicts auditory localization.

Introduction

To be able to localize sounds, humans must combine several auditory cues and associate them to a perceived position in space. This association is learned through sensory experience and can be shaped by it (e.g. [1]). Audiovisual experience plays a special role in auditory space calibration. In has been shown to induce changes in auditory localization through a mechanism called the ventriloquism aftereffect [2,3,4]. In the ventriloquism effect, when a sound and a light are presented simultaneously, the subject fails to perceive the correct sound source position. Instead, the sound is perceived closer, or realigned with the visual sources. After this experience, subjects may still exhibit sifts in the localization of sounds, even in the absence of the visual cue. This effect, known as the ventriloquist aftereffect, can occur after very brief audiovisual stimulations [5,6].

The goal of the study reported here was to identify temporal aspects in the ventriloquism aftereffect. Several sequences of audiovisual stimuli, matching or mismatching in space, were presented. Differences in localization bias after exposure to each sequence type were analyzed.

Methods

Participants: 11 subjects took part in the experiment, 3 of which were female. One participant was author.

Stimuli: There was a semicircular array of speakers and LED lights. Stimuli were white noise bursts and light flashes. There were visual, auditory and audiovisual trials. There were 3 stimulus areas. Within these areas, stimuli positions are randomly selected in all trials: from -5° to +5°; from -20 to -10°; from +10 to +20°. There were two types of audiovisual trials: matching and discrepant. In matching trials sound and light positions were the same. In discrepant trials, sounds were always shifted in 12 deg. Half of the participants undertook the experiment with sounds consistently shifted to the right, and the other half to the left.

Design: There were always sequences of 5 audiovisual trials, followed by an auditory trial and by two visual trials (see Figure 1). Sequences varied in the arrangement of matching and discrepant trials. All possible sequence permutations were repeated 12 times.

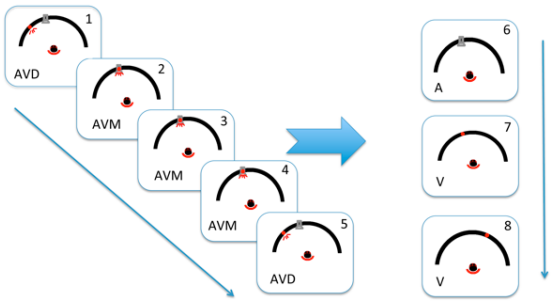

Figure 1: Example of a sequence of trials. Numbers reveal trial order. AVD: Audiovisual discrepant trial; AVM: Audiovisual matching trial; A: Auditory trial; V: Visual trial.

Each trial followed the steps: 1) Fixating yellow light at 0° for 0.8 sec; 2) Interval of varying randomly in duration, from 0.5 sec to 0.8 sec; 3) Stimulus for 350 ms; 4. Answer: subject pointed where the sound and/or the light were, in a slider interface. The experiment lasted for approximately 6 h

for each subject.

Results

Localization results are shown in Figure 2. Curves are Gaussian fittings obtained from the mean and standard deviation of the normalized responses. Data were normalized such that point zero deg in the x axis corresponds to the position of the visual stimulus. In discrepant trials (top graph), the auditory stimulus was normalized to point 12 deg. The visual stimulus was mostly perceived in the correct position, but there was greater response variability in discrepant trials.

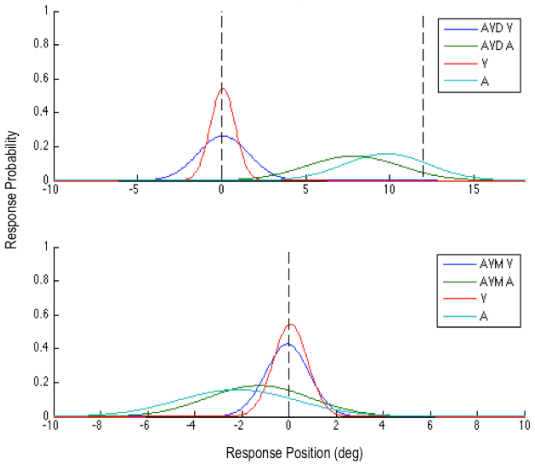

Figure 2: Average response distributions in discrepant trials (top) and matching trials (bottom). AVD V and AVD A stand fro visual and auditory responses, respectively, in audiovisual discrepant trials; AVM V and AVM A stand for visual and auditory responses, respectively, in matching trials; A stands for auditory-only trial responses; and V stands for visual-only trial responses. A and V are the same curves in both graphs.

Auditory responses had greater variability, both in unimodal and in audiovisual trials. On average, sound localization was shifted by 4.16 deg toward the position of light in audiovisual discrepant trials (Figure 2, top). Interestingly, this shift was also observed in audiovisual matching trials (1.39 deg), revealing a generalization effect (Figure 2, bottom). When the sound was presented alone, after a sequence, there was an average shift of 2.3 deg. This shift was greater than that observed in matching trials, but smaller that the shift in discrepant trials. The amount of shift, in degree, between sound source and average sound response, is considered a bias.

Table 1: Linear regressions between bias and a) total discrepant trials sequence, b) total discrepant trials at the end of sequence, c) maximum consecutive discrepant trials in sequence.

	r^2	p	slope
Sum discrepant	0.39	0.001	0.41
Sum discrepant at end	0.36	0.037	0.3
Max consecutive discrepant	0.31	0.01	0.4

To explore which sequence parameters led to greater bias in the subsequent auditory trial, three linear regressions were fitted. The coefficient of determination, significance, and slope are shown in Table 1. The total number of discrepant trials in a sequence predicted better the amount of auditory bias at the end of a sequence.

Figure 3 shows the level of bias at the end of the sequence when each sequence trial is discrepant or matching. It was found the fifth trial in a sequence had greater impact on subsequent auditory localization bias.

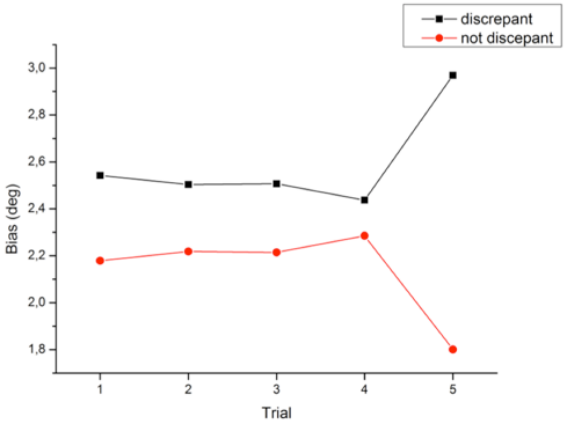

Figure 3: Bias in final auditory trial when each audiovisual trial in the sequence was discrepant (black) and matching (ref).

Conclusions

Brief audiovisual stimulation can induce auditory space recalibration. This is a dynamic process, subject to constant tuning, where the latest stimulation better predicts auditory localization.

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