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Does visual experience influence the spatial distribution of auditory attention?☆

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ABSTRACT

Sighted individuals are less accurate and slower to localize sounds coming from the peripheral space than sounds coming from the frontal space. This specific bias in favour of the frontal auditory space seems reduced in early blind individuals, who are particularly better than sighted individuals at localizing sounds coming from the peripheral space. Currently, it is not clear to what extent this bias in the auditory space is a general phenomenon or if it applies only to spatial processing (i.e. sound localization). In our approach we compared the performance of early blind participants with that of sighted subjects during a frequency discrimination task with sounds originating either from frontal or peripheral locations. Results showed that early blind participants discriminated faster than sighted subjects both peripheral and frontal sounds. In addition, sighted subjects were faster at discriminating frontal sounds than peripheral ones, whereas early blind participants showed equal discrimination speed for frontal and peripheral sounds. We conclude that the spatial bias observed in sighted subjects reflects an unbalance in the spatial distribution of auditory attention resources that is induced by visual experience.

1. Introduction

Does visual experience determine the spatial distribution of attention resources in the auditory modality? We know from animal studies that vision plays a role in calibrating the spatial representation of the auditory sense (Knudsen & Knudsen, 1985, 1989; Withington, Binns, Ingham, & Thornton, 1994). Studies in visually deprived animals also clearly demonstrated how visual experience affects performance in the auditory modality (Rauschecker, 1995). While sighted human and non-human primates localize less accurately (and more slowly) sounds coming from the peripheral space as compared to the frontal one (Oldfield & Parker, 1984; Recanzone & Beckerman, 2004; Teder-Sälejärvi, Hillyard, Röder, & Neville, 1999), such disadvantage for peripheral sounds seems reduced in congenitally blind individuals (Röder et al., 1999; Voss et al., 2004). Visually deprived animals and humans are better than sighted subjects at localizing sounds coming from the peripheral space (Chen, Zhang, & Zhou, 2006; Rauschecker & Kniepert, 1994; Röder et al., 1999; Voss et al., 2004) and from the back space (Després, Candas, & Dufour, 2005; Voss et al., 2004), whereas equal performance levels are observed for frontal sounds (Després et al., 2005; Röder et al., 1999; Voss et al., 2004; Zwiers, Van Opstal, & Cruysberg, 2001a, 2001b). Interestingly, a similar effect of the auditory experience on the spatial distribution of attention between the central and the peripheral visual fields was reported in studies in early deaf individuals (Bavelier, Dye, & Hauser, 2006; Bavelier et al., 2000; Proksch & Bavelier, 2002).

To date, no study has investigated the potential effect of sound source location on non-spatial processing either in sighted or in early blind individuals. General attention mechanisms could mediate this effect of the sound source location on the stimulus processing abilities (e.g. stimulus localization or discrimination). The present study aimed to test the effects of visual experience on auditory discrimination abilities in the frontal and the peripheral space. We hypothesized that sighted participants would be affected by an attention bias that leads them to most efficiently (i.e. more accurately and/or more rapidly) process the sounds originating from frontal locations, whereas early blind participants would have equivalent performance levels across the sound source locations.

A secondary goal was to test to what extent blind individuals are better than sighted ones when simultaneously attending to multiple potential sound sources versus only one sound source. Since blind

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individuals need to be more attentive than sighted individuals to multiple auditory stimulations from their surrounding environment, we hypothesized that they would typically perform better than sighted individuals in situations involving multiple stimulation sources than in situations involving a single one.

2. Methods

2.1. Subjects

Twelve early and totally blind individuals (EB) and 12 sighted controls (SC), matched for gender (10 men), age (EB: 38 ± 12; SC: 37.5 ± 16) and self-rated musical experience (evaluated on a “5 level” scale that took into account both expertise (how well) and musical practice amount (0: no musical notion, 1: some musical notions associated with an old or current practice of a musical instrument, 2: good musical notions associated with a regular practice of a musical instrument, 3: professional player, 4: absolute pitch, EB: 1.8 ± 1.3, SC: 1.8 ± 1.1)), took part to the experiment. The musical experience was evaluated to test its potential effect on frequency discrimination, since increased tonal processing capabilities in musicians have been reported in the literature (Micheyl, Delhommeau, Perrot, & Oxenham, 2006; Pitt, 1994). The participants were totally blind due to congenital or early (before the age of three) peripheral deficits (see Table 1 for additional details). No participant reported neurological, psychiatric illness or auditory impairment. All participants signed an informed consent. This experiment was approved by the ethics committee of the school of medicine of the Université catholique de Louvain.

2.2. Stimuli and materials

Stimuli consisted of three broadband noises of 60 dB of intensity created using “Adobe Audition” and filtered with three different bandpasses: 2500–4500 Hz for the target, 1500–3500 Hz for the distractor 1 and 500–2500 Hz for the distractor 2. The stimuli duration was 100 milliseconds (ms) including 10 ms rise and 10 ms fall. The stimuli were presented via three speakers located on a half-circle placed at a distance of 70 cm from the centre of the head (see Fig. 1(A)). The first speaker was located in front of the participant and corresponded to the frontal location. The second speaker was located at the extreme left of the participant, corresponding to −90°azimuth and the third speaker was located at the extreme right of the participant, corresponding to +90° azimuth, both being considered as peripheral locations. We used one speaker per location (i.e. frontal, peripheral right and peripheral left) instead of a set of numerous close speakers for each attended location as used in previous studies (e.g. Röder et al., 1999) since our goal was to evaluate the effect of the speaker location on frequency discrimination and not to determine the ability to finely discriminate between close spatial locations.

Table 1
Characteristics of the blind participants.

Participants	Age	Sex	Musical experience	Blindness onset	Cause of blindness
EB[a] 1	26	M[b]	4	congenital	Genetic eye disorder (abnormal retina development)
EB 2	39	F[c]	0	congenital	Retinopathy of prematurity
EB 3	60	M	2	infancy (<2 years)	Bilateral retinoblastoma
EB 4	35	M	2	congenital	Genetic eye disorder (abnormal retina development)
EB 5	31	M	2	congenital	Optic Leber neuropathy
EB 6	35	M	1	congenital	Optic Leber neuropathy
EB 7	48	M	4	congenital	Genetic eye disorder*
EB 8	52	M	1	congenital	Bilateral retinoblastoma
EB 9	27	M	2	congenital	Genetic eye disorder (abnormal retina development)
EB 10	55	M	2	congenital	Retinal degeneration
EB 11	24	M	0	infancy (<3 years)	Genetic eye disorder (abnormal retina development)
EB 12	34	F	1	congenital	Retinopathy of prematurity

Note: EB: early blind; M: male; F: female; (*) no additional details available.

2.3. Procedure

Participants were instructed to perform an auditory target detection task; they had to press a button as quickly as possible at the target presentation regardless of the speaker it originated from. Three different conditions were administered in a counterbalanced order: two experimental conditions and one control condition. In the first experimental condition, called “wide spatial distribution”, targets and distractors came sequentially and pseudo-randomly from the frontal and the peripheral (right and left) speakers. The participants had to pay attention to the three sound source locations. In the second condition, called “focused spatial distribution”, targets and distractors always came from the same speaker (either from the front, the right or the left) in each sub-condition. In this condition, the speaker location was announced to the participants at the beginning of each sub-condition, so that they could focus on it. For the two experimental conditions, a total of 1650 stimuli were presented with a ratio of 1/3 of targets, 1/3 of distractors 1 and 1/3 of distractors 2. The targets and the distractors were presented sequentially in a pseudo-random order with the only constraint that two targets were never presented consecutively (Fig. 1(B)). Different interstimulus intervals were used (ISIs: 500, 700, 900, 1100, 1300 ms). The control condition consisted in an auditory detection task during which the target appeared pseudo-randomly at one of the three locations. The subjects had to press the button as quickly as possible at the stimulus presentation. No distractor was presented during this condition. In the control condition, one hundred targets appeared pseudo-randomly either from the front, the right or the left speaker. The rest of the procedure in the control condition was identical to the experimental conditions.

The entire testing took place in a sound attenuated room. The speakers were positioned at ear level and the head was wedged with a cushion in order to maintain it in the same orientation throughout the experiment. Sighted participants were blindfolded throughout the experiment. Before the experiment, the target and the two distractors were presented to the participants. Then the participants underwent a brief familiarization session (20 trials for each condition).

Stimulations and responses recording were controlled using Matlab (Mathworks Inc. Sherborn MA, USA). Participants delivered their responses via a mouse of high temporal accuracy (Razer, model number: RZ01-0015). Breaks of few minutes were introduced every 8 min to reduce any potential decrease of attention.

3. Data analyses

For the experimental conditions, we performed two separate 2 (groups: EB vs SC) × 2 (spatial distribution of the stimuli: “wide spatial distribution” vs “focused spatial distribution”) × 2 (sound source locations: front vs periphery) analyses of variance (ANOVAs): on the reaction times (RTs) for the hits (targets correctly detected) and on the target omissions rates. In addition, simple effects were tested on the RTs using Student *t*-tests. The false alarm (FA) rates were too low (1.2% on average) in all conditions to allow discriminating between conditions and groups and were therefore not further analyzed. We carried out a Pearson correlation analysis in order to test the relation between the musical experience and RTs. The RTs and the target omissions rates of the control condition were evaluated with two separate 2 (EB vs SC) × 2 (front vs periphery) ANOVAs.