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Discrimination of the auditory distance of two virtual sources, relative to the listener or to a third source

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ABSTRACT

This study aimed at assessing in which conditions auditory distance discrimination is reliably performed, in particular to determine if listeners were able to discriminate the distance of two sources relative to a third source, as opposed to relative to the listener as auditory distance is usually evaluated. This latter task was also involved here for comparison. Auditory stimuli simulating speech sources at various distances in a room were presented to 24 participants, using headphones. Two tasks required to identify the closest source either to the listener for the 2-source task, or to a third noise source for the 3-source task. Diotic versions of the stimuli were also tested by considering the signals arriving only to the left/right ear to test whether the listeners could perform the tasks when perceived externalization is reduced (diotic listening). High performance scores were observed in the 2-source task while they were just above chance level in the 3-source task. Performance improved when the source was simulated within one meter of the listener rather than further away, consistent with more, or more salient, distance cues being available close to the listener. Likewise, performance improved when interaural cues were available in dichotic listening compared to diotic listening.

Keywords: *auditory distance, virtual sources, binaural hearing.*

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1. INTRODUCTION

The study of the underlying mechanisms of spatial localization in audition is crucial as this ability is essential in our perception of the environment, particularly when it comes to estimating the danger of a sound source [1], navigating complex auditory scenes and separating sources in a complex auditory environment [2]. This study was based on the general hypothesis that auditory localization involves representations of the body in space and thus depends on factors such as the frame of reference used to discriminate auditory distances, the intrusiveness of a source, and the listener's relationship to the perceptual content.

In this context, participants were exposed to auditory stimuli that simulate a sound source at a given distance through headphones to evaluate the conditions in which a listener is capable of discriminating the distance of sources relative to themselves (2-source task) or to another sound source (3-source task) as a change in reference frame [3]. Specifically, it sought to measure the influence of the listening mode (dichotic or diotic), which notably affects the perceived degree of externalization [4], and the spatial relationship between the sources and the body through the distinction between the peripersonal space (as a defensive or exploratory space, [5]) and the extrapersonal space.

Under this hypothesis, it was expected that externally perceived percepts (dichotic) that directly engage the representation of the body's position in space (2-source task) would be processed more easily compared to internally perceived percepts (diotic) and to those that rely on a reference other than the body to discriminate source positions (3-source task). Similarly, percepts within one meter of the body (peripersonal space) would be easier to discriminate than distant percepts (extrapersonal space).

2. METHODS

Twenty-four participants were recruited. The inclusion criteria were the absence of known hearing disorders and the absence of neurological history or disorders. Having a disyllabic first name was necessary to participate in the experiment. A nickname (disyllabic) could be used if it was more relevant to the participant than their own first name.

Binaural Room Impulse Responses (BRIRs) were recorded using a log sweep technique [6] in a room for the following distances: 20 cm, 30 cm, 40 cm, 60 cm, and 80 cm for the peripersonal space, and 2 m, 3 m, 4 m, 6 m, and 8 m for the extrapersonal space.

The auditory stimuli consisted of the participant's own name, four other uncommon French names (“Felix”, “Justin”, “Charlie”, “Nora”), and a 500 ms stationary noise.

Participants had to perform two distance discrimination tasks: a 2-source task in which they had to determine which of the two presented names, simulated at different distances in a space, was closer to themselves, or a 3-source task in which they had to determine which of the two names was closer to a reference sound presented before the pair of names (all three sounds simulated at different distances from each other). The pair of names consisted of either the participant's own name and another name (referred to as the "own name" pairs), or two different names (referred to as the "other name" pairs).

The experimental factors included the task (2-source, 3-source), the listening mode (dichotic right/left, diotic left/right), the spatial context (peripersonal, extrapersonal), and the type of pair (own name, other name). Each participant was presented with a total of 400 pairs for each task.

The raw response data (inputs and reaction times) for each trial were extracted using the Neurobehavioral Systems Presentation software employed for the experimental procedure. Python scripts (version 3.9) were written to process the raw data and compute performances. Performances were calculated by comparing the participant's response to the expected response. For the 2-source task, the expected response was the simulated source at the shortest distance. For the 3-source task, the expected response corresponded to the source for which the ratio between the distances separating the listener from the source and the source from the reference was the smallest. This calculation method aligns with the experimentally verified hypothesis that perceived distance varies proportionally to the logarithm of the actual/simulated distance, meaning that perceived distance is a power function of the actual/simulated distance [7]. As such, 160 trials across participants were not included in the 3-source task data, as they corresponded to situations where this ratio was the same for both names.

3. RESULTS

Results are still being processed. They will be duly presented during the conference.

4. CONCLUSION

No study seems to have specifically investigated the role of body representations in the perception of distance through audition. However, acoustic cues that influence distance perception have been extensively studied in the field of psychoacoustics, while concurrently, the hypothesis of a specific brain pathway to process these cues has emerged in neuroscience [8]. There appears to be a missing link in understanding how acoustic cues elicit specific brain processes, while considering the embodied aspect of their integration. This study aimed to lay the groundwork for a behavioral investigation of auditory distance perception using factors that are likely to interact with body representations.

4. ACKNOWLEDGMENTS

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REFERENCES

[1] Baumgartner, R., Reed, D. K., Tóth, B., Best, V., Majdak, P., Colburn, H. S., & ShinnCunningham, B. (2017). Asymmetries in behavioral and neural responses to spectral cues demonstrate the generality of auditory looming bias. Proceedings of the National Academy of Sciences, 114(36), pp. 9743-9748. https://doi.org/10.1073/pnas.1703247114

[2] Shinn-Cunningham, B. G., Schickler, J., Kopčo, N., & Litovsky, R. (2001). Spatial unmasking of nearby speech sources in a simulated anechoic environment. The Journal of the Acoustical Society of America, 110(2), pp. 1118-1129. https://doi.org/10.1121/1.1386633

[3] Klatzky, R. L. (1998). Allocentric and Egocentric Spatial Representations : Definitions, Distinctions, and Interconnections.

In C. Freksa, C. Habel, & K. F. Wender (Éds.), Spatial Cognition (Vol. 1404, pp. 1-17). Springer Berlin Heidelberg. https://doi.org/10.1007/3-540-69342-4_1

[4] Best V, Baumgartner R, Lavandier M, Majdak P, Kopčo N. (2020). Sound Externalization: A Review of Recent Research. Trends in Hearing, 24. doi:10.1177/2331216520948390

[5] De Vignemont, F., & Iannetti, G. D. (2015). How many peripersonal spaces? Neuropsychologia, 70, pp. 327-334. https://doi.org/10.1016/j.neuropsychologia.2014.11.018

[6] Farina, A. (2000). "Simultaneous measurement of impulse response and distortion with a swept-sine technique" in AES 108th Convention, preprint 5093 (D-4), Audio Engineering Society.

[7] Zahorik, P. (2005). Auditory Distance Perception in Humans : A Summary of Past and Present Research. Acta Acustica United With Acustica, 91, 13.

[8] Alain, C., Arnott, S. R., Hevenor, S., Graham, S., & Grady, C. L. (2001). "What" and "where" in the human auditory system. Proceedings of the National Academy of Sciences, 98(21), pp. 12301-12306. https://doi.org/10.1073/pnas.211209098