Effects of Blindfolding on Verbal and Gestural Expression of Path in Auditory Motion Events

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Abstract

Studies have claimed that blind people's spatial representations are different from sighted people, and blind people display superior auditory processing. Due to the nature of auditory and haptic information, it has been proposed that blind people have spatial representations that are more sequential than sighted people. Even the temporary loss of sight—such as through blindfolding—can affect spatial representations, but not much research has been done on this topic. We compared blindfolded and sighted people's linguistic spatial expressions and non-linguistic localization accuracy to test how blindfolding affects the representation of path in auditory motion events. We found that blindfolded people were as good as sighted people when localizing simple sounds, but they outperformed sighted people when localizing auditory motion events. Blindfolded people's path related speech also included more sequential, and less holistic elements. Our results indicate that even temporary loss of sight influences spatial representations of auditory motion events.

Keywords: blindfolding; localization; pointing; auditory motion events; spatial language

Introduction

Information provided by visual, auditory, and haptic systems work together to enhance detection, localization, and identification of objects and events in the world. Compared to auditory and haptic input, vision has the advantage of providing simultaneous, precise, and detailed information about features of objects and events that take place in close and distant space (e.g., Eimer, 2004; Thinus-Blanc & Gaunet, 1997).

Considering the qualitative differences between inputs from sensory modalities, it is interesting to ask how blindness influences conceptualization of space, and how this is reflected in the spatial language of blind individuals. Numerous studies have reported enhanced auditory spatial skills in blindness (e.g., Lessard, Paré, Lepore & Lassonde, 1998; Röder et al., 1999; Voss et al., 2004), and the spatial

language of blind individuals has been shown to be conceptually different when it is based on haptic input (Iverson, 1999; Iverson & Goldin-Meadow, 1997). The present study is the first to focus on how information acquired from the auditory modality alone affects spatial event conceptualization as expressed in both language and pointing gestures in blindfolded and sighted people.

It is claimed that blind individuals can compensate for their lack of vision through better auditory processing. Consistent with this, some studies suggest the blind even outperform their blindfolded counterparts in low-level auditory spatial tasks, such as estimating distance based on echo cues and localizing direction of a sound in the horizontal plane (e.g., Després, Candas & Dufour, 2005; Dufour, Després & Candas, 2005; Lessard et al., 1998; Röder et al., 1999; Voss et al., 2004). It is possible that blindfolding creates a temporary disadvantage for sighted individuals' spatial mapping of sounds. Only a single study compared sound localization skills of blindfolded and sighted individuals (Tabry, Zatorre, & Voss, 2013). Tabry et al. presented simple sounds on the horizontal and vertical planes and measured accuracy of pointing by hand or head laser pointer. Tabry et al. found that the absence of visual feedback decreases localization accuracy mostly for head-pointing and sounds on the vertical plane.

Other studies measuring navigation and spatial updating skills have claimed that blind individuals have impaired performance when required to process multiple pieces of information or simultaneous information, such as creating representations of large-scale environments, or inferring new spatial relations that are not directly experienced (finding the shortest way from A to B, when only experiencing A to C and B to C) (e.g., Coluccia, Mammarella & Cornoldi, 2009; Pasqualotto & Newell, 2007, Rieser, Guth & Hill, 1982; Thinus-Blanc & Gaunet, 1997). This may be because blind individuals have to rely on sensory information that is perceptually represented sequentially, thereby making it

more difficult to build holistic spatial representations of path information.

Language studies investigating speech and gesture in route description tasks have also found evidence that blind peoples' conceptualization of space has an underlying sequential representation of path for large-scale layouts; but that they can build holistic representations for small-scale layouts (Iverson, 1999; Iverson & Goldin-Meadow, 1997). Iverson and Goldin-Meadow (1997) examined sighted, blindfolded, and blind children's speech and co-speech gesture production in a task where participants had to give directions for familiar locations in their school. The results showed that blind children's speech was more segmented, with several landmark points on the path described, whereas sighted and blindfolded children linguistically represented the area in a global manner. Iverson and Goldin-Meadow did not report any difference between sighted and blindfolded children's speech but this is not surprising given the fact that blindfolded children also initially saw the scene before the description task and so, their initial encoding of the school space was based on visual input.

As a follow-up Iverson (1999) examined sighted, blindfolded, and blind children's route descriptions for small-scale scenes constructed from Lego blocks. Even though both blind and blindfolded children explored the Lego scenes haptically, while sighted children explored the Lego scenes visually, all children gave similar path expressions (in terms of landmark use). Iverson claimed that the Lego scenes could be encoded similarly by touching and seeing because the amount of available spatial information was equivalent for both modalities, which allowed blind children to build more holistic representations for small-scale scenes.

The Present Study

We investigated the effect of blindfolding on localization and verbal descriptions of auditory motion events. Having both linguistic and non-linguistic tasks performed by the same participants helps us understand whether possible differences between groups come from the processes required for linguistic packaging, or are grounded in more fundamental spatial representations, independent of the demands of speech production.

As shown by Tabry et al. (2013), blindfolding can influence sighted people's spatial mapping of sounds. To investigate this possibility further, we measured localization ability in two non-linguistic tasks for simple beep sounds and also for the first time in more complex auditory motion events. In both tasks, participants were asked to trace the path of the movement as accurately as they could by tracing a line with their finger or hand. Tabry et al. (2013) used simple sounds similar to our beep sounds, and only one condition in their study—hand pointing on the horizontal plane—was relevant to the task in the current study. In this condition, Tabry et al. did not report a difference between the blindfolded and the sighted group in the degrees of deviation from target location. Based on Tabry et al.'s findings, we expected no difference between blindfolded and sighted

participants in the localization task with beep sounds. We also examined whether these findings for simple beep sounds generalize to localization of complex auditory events. It may be the case that as the stimulus becomes more complex, there is more opportunity to see differences between sighted and blindfolded individuals.

In speech we aimed to explore path representations by measuring different manners of encoding. As we know from the blindness literature (e.g., Iverson & Goldin-Meadow, 1997; Thinus-Blanc & Gaunet, 1997), sequential representations typically encode consecutive landmarks in relation to path, but spatial relations between distant objects are not encoded explicitly. To address the distinction between sequential and holistic path representations, we coded whether speech included information about source, goal, orientation, and path verbs. Source and goal elements in speech represent sequential information because those encode discrete units of information—such as which landmark is a starting point of movement—without explicitly encoding its spatial relation to other elements. We take orientation and path verbs in speech to represent spatial relations because these encode information about direction (e.g., from left to right) and trajectory of movement (e.g., approaching). Thus, it can be argued that mentions of orientation and path verb show more holistic representation of the space. We conducted the current study in Turkish as source and goal elements are optional when describing a motion event. Therefore, Turkish enables us to compare differences in the event descriptions.

If having visual cues at encoding—such as seeing the source of a sound—enables people to build a more holistic representations of space, even temporary absence of sight may affect spatial representations and make them more akin to the representations created by the blind, i.e., make them more sequential. As such, it may be expected that, compared to sighted people, blindfolded people's event descriptions would include more sequential path information, such as more mentions of the source, but less holistic path information that encodes trajectory of motion and the relation between two different locations—such as figure and source.

Method

Participants

Twelve sighted (M = 22.27 years, SD = 2.10, 7 female) and 12 blindfolded (M = 21.83 years, SD = 2.21, 7 female) Turkish adult speakers participated in the experiment in exchange for extra credit in an introductory psychology course. The sample size was based on previous studies comparing sighted and blindfolded participants (Iverson 1999; Iverson & Goldin-Meadow, 1997; Tabry et al., 2013). Participants all had normal or corrected-to-normal vision and provided written informed consent.

Auditory Stimuli

We filmed and simultaneously recorded the sound of locomotion and non-locomotion events. Locomotion events served as the critical experimental items in the study, whereas non-locomotion events served as filler items. For the locomotion events, an actress moved in distinct manners (walk, run, and limp) with respect to a landmark object (door or elevator) along a specific path (to, from, into, and out of). Each manner was combined with each path, creating 12 different items. The sound recorder was placed next to the landmark objects, so the path direction in the events was either approaching (for *to* and *into* paths) or away from (for *from* and *out of* paths) listeners. In addition, the path azimuth was edited using Soundtrack Pro audio editing software to increase the variety of possible path motion. Five movement angles were created in a semicircular space ranging from 90° left to 90° right with 45° intervals, thus from the right to the left these are: 0° (right), 45° (right-sided), 90° (front), 135° (left-sided), and 180° (left) motions (see Figure 1). We created all 12 events with the 5 movement angles, resulting in 60 events in total. All locomotion events were exported as 5.1 surround sound.

For the non-locomotion events, the same actress performed different actions with objects (e.g., drinking water, eating chips), and the video and sound were recorded across from her. We did not examine these items further. There were 77 experimental trials in total, including 60 locomotion events and 17 non-locomotion events. Locomotion events lasted 9s (SD: 1.9) and non-locomotion events 8s (SD: 2.2) on average.
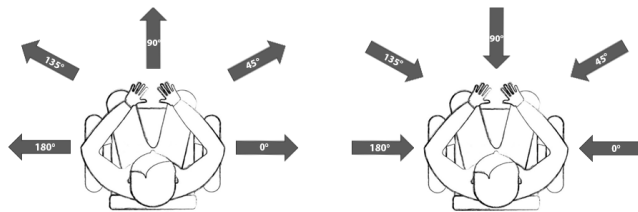

Figure 1: Path direction and angles for "from" and "out of" events (left) and "to" and "into" events (right).

In addition to the locomotion and non-locomotion events, we prepared 60 audio-clips consisting of beeps. These sounds were intended to assess people's accuracy in localizing simple dynamic stimuli, in contrast to the more complex, naturalistic locomotion events. To make a beep clip, a 1s beep sound was compounded with a 1s silence lasting 9s in total. The direction of sound movement in each clip was manipulated as described for the locomotion events (see Figure 1).

Procedure

Each participant was tested in a quiet room on Bogazici University campus in Istanbul, Turkey. The procedure of the experiment was the same for both groups, except that blindfolded participants' eyes were covered before they entered the room, and the experimenter helped them to be seated. In the room, five speakers were placed 1.34 m far from the participant's head and approximately 95 cm high from the ground in a 5+1 surround system configuration. Front left and right speakers were placed 30° off center, and rear left and right speakers were placed 110° off center. Participants sat in the middle of the speakers. The experimenter stayed in the room during the experiment to initiate the tasks and advance the trials on a laptop using Presentation Software.

There were two sorts of tasks:

(1) Event Description Task Participants listened to audio-clips of the events. Before the experiment started, there were 2 practice trials consisting of one locomotion and one non-locomotion event. In each trial, an event was presented aurally and participants were asked to describe what happened. They were told that another participant would watch their descriptions and listen to the same sounds to try and match the sound clips.

(2) Localization Task with Events vs. Beeps Participants listened to the audio-clips of 60 locomotion events and 60 audio-clips consisting of beep sounds in two separate tasks for each stimulus type. There were 4 practice trials in each task. After each audio-clip, they were asked to trace the path of the movement in the semicircular frontal space as accurately as they could by tracing a line with their finger or hand. They were instructed not to describe the audio stimuli, but only trace the paths.

Participants first performed the event description task. During this task, participants' speech was recorded with two video cameras. One camera was placed across from the participant and the other recorded the top view of the participants' frontal space so as to capture arm and hand movements. Following the event description task, participants performed either the localization task with audio events or the localization task with beeps. The order of these two tasks was counterbalanced across participants. Finally, participants were asked to fill out a demographic questionnaire on a laptop. The total duration of the experiment was around 75 minutes.

Coding

Descriptions for the motion events were transcribed and coded by a native Turkish speaker. First, the event descriptions were split into clauses. Clauses were coded as relevant or irrelevant to the target events. Second, each relevant clause for each event was coded, according to the type of information it contained: (1) the use of sequential elements—(a) source (starting point of movement), and (b) goal (the end point of the movement); and (2) holistic elements—(a) orientation (direction), and (2) path verb (trajectory of motion). An example description below encodes information about the source, the orientation, and the path verb of the movement as:

(1)

Asansör-den   sağ-a   doğru   uzak-laş-(ı)yor.
elevator-ABL right-DAT towards away-VERB-PRS.3SG
(source)   (orientation)   (path verb)

'(someone) moves away from the elevator towards the right.'
(VERB = verbal suffix)

For the localization tasks, direction and angle localization were coded by an assistant. There were 2 possible directions (approaching or going away) and 5 possible angles (from 90° left to 90° right with 45° intervals). Twenty percent of the coding was checked by the first author of the study. Interrater agreement was at least 0.80 (95% CI: 0.69, 0.91) using Kappa for both tasks.

Results

For all analyses reported in the paper, we used mixed effects regression models. All models were generated using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) in R (R Core Team, 2018). We begin by presenting the data for the simplest task—the localization task with beeps—before moving to the data of the localization task with events and the event description task.

Localization Task with Events vs. Beeps

First we investigated whether sighted and blindfolded participants differed in how they localized motion using simple beep sounds. We ran two separate glmer models to test the effects of blindfolding on binary values (correct, incorrect) for: (1) angle and (2) direction accuracy. Since localization of direction and angle was simultaneously performed by participants, we also included the accuracy of the other variable as a predictor in the models. That is, the model for direction accuracy included angle accuracy as a predictor in addition to the group factor (sighted or blindfolded). The optimal random effects structure included random intercepts of participant and item. Model 1 for angle accuracy showed that blindfolded participants did not differ in localizing the angle of beep sounds from sighted participants, and that participants became significantly more successful as direction accuracy increased (see Table 1 and Figure 2). Similarly, Model 2 for direction accuracy showed that blindfolded participants did not differ in localizing direction of beep sounds from sighted participants, and that participants became significantly more successful as angle accuracy increased (see Table 1 and Figure 2). These results showed that blindfolding did not affect localization ability when the sounds were simple, dynamic beeps, and all participants succeeded in localizing the direction of beep sounds—in fact, they were at ceiling levels.

Table 1: Accuracy models for angle and direction localization of the beep sounds.

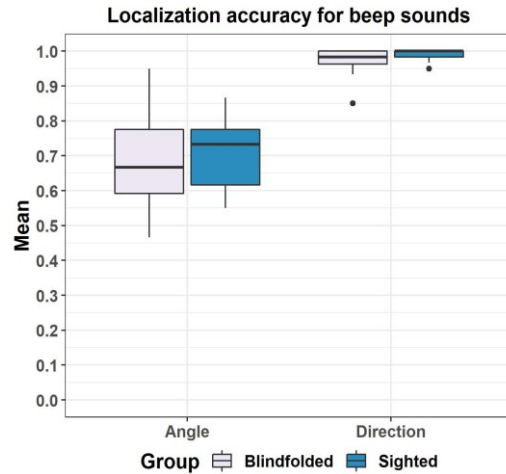|	Estimate	Std.Error	z-value	*p*-value
Model 1 for Angle				
(Intercept)	-0.5671	0.5265	-1.077	0.2814
Group	-0.0545	0.2937	-0.186	0.8527
Dir. Acc.	1.6281	0.4317	3.771	<0.001***
Model 2 for Direction				
(Intercept)	4.2448	0.6493	6.537	<0.001***
Group	-0.8279	0.6735	-1.229	0.2190
Ang. Acc.	1.4246	0.4509	3.160	0.0016**

Figure 2: Localization accuracy for beep sounds.

For the locomotion events, we again ran two separate glmer models to test the effects of blindfolding on binary values for (1) angle and (2) direction accuracy. Model 3 for angle accuracy showed that blindfolded participants performed better in localizing angle of locomotion events than sighted participants, and that participants became significantly more successful as direction accuracy increased (see Table 2 and Figure 3). Similarly, Model 4 for direction accuracy showed that blindfolded participants performed better in localizing direction of locomotion events than sighted participants, and that participants became significantly more successful as angle accuracy increased (see Table 2 and Figure 3). As with the beep sounds, all participants were almost at ceiling for identifying the direction of motion. Unlike for beeps, blindfolded participants were better able to identify the angle and direction of auditory events when sounds were meaningful, locomotion events.

Table 2: Accuracy models for angle and direction localization of the locomotion events.

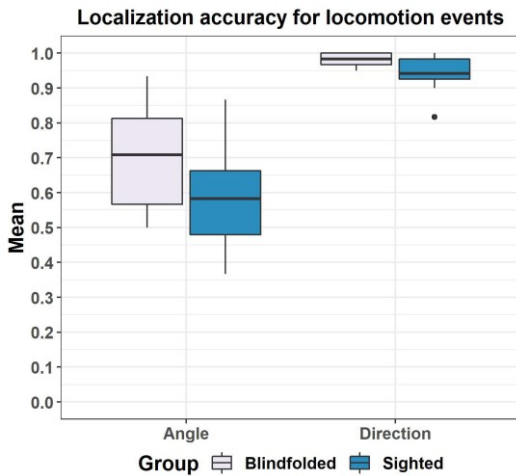|	Estimate	Std.Error	z-value	p-value
Model 3 for Angle				
(Intercept)	-0.1714	0.3603	-0.476	0.6344
Group	0.5814	0.3047	1.908	0.0564 .
Dir. Acc.	0.5998	0.3030	1.979	0.0478*
Model 4 for Direction				
(Intercept)	3.4917	0.4890	7.140	<0.001***
Group	1.5285	0.5390	2.836	0.0046**
Ang. Acc.	0.7153	0.3261	2.194	0.0283*

Figure 3: Localization accuracy for locomotion events.

Event Description Task

Finally, to investigate whether sighted and blindfolded participants differed in how they described the path of events, we calculated the ratio of sequential (source and goal) and holistic path descriptions (orientation and path verb) per relevant clause. To do this, total counts of sequential and holistic path descriptions were divided by the number of relevant clauses for each trial. So, we had a 2-level variable for the type of linguistic expression (sequential vs. holistic) and a 2-level variable for the group (blindfolded vs. sighted) as predictors.

We ran an lmer model to test the effects of blindfolding and type of linguistic expression using ratio of mention per clause as input. The optimal random effects structure included random intercepts of participant and event. The results showed that there was a significant effect of type of linguistic expression, with all participants mentioning more holistic than sequential descriptions (p < .001). This difference was not surprising because of the fact that one of the holistic elements included verbs. Due to its typology, Turkish usually expresses path of motion in the verb (Talmy, 1985). There was no effect of blindfolding in how often participants mentioned all path elements in their descriptions (p = .272). Crucially, the interaction between group and type of linguistic expression was significant (p <.001; see Table 3 for

model summary and Figure 4). Blindfolded participants gave more sequential but less holistic descriptions in their speech compared to sighted participants.

Table 3: Models for ratio of sequential and holistic path descriptions in the events.

	Estimate	Std.Error	t-value	p-value
(Intercept)	0.3187	0.0854	3.730	<0.001***
Exp.Type	0.7387	0.0333	22.208	<0.001***
Group	0.1319	0.1175	1.123	0.272
E.Type:Gr	-0.2038	0.0471	-4.307	<0.001***

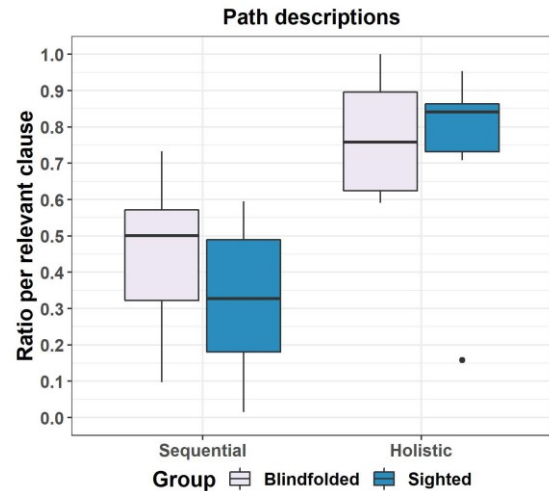Figure 4: Ratio of sequential and holistic path descriptions per relevant clauses in the events.

Discussion

In the present study, we examined the effect of blindfolding on localization and verbal descriptions of auditory motion events. In the localization task with beeps, we showed that blindfolded participants performed as well as sighted participants when localizing simple sounds. Our results are in line with Tabry et al. (2013). Similar to our localization task with beeps, Tabry et al. tested hand-pointing accuracy for simple sounds on the horizontal plane, and reported no effect of blindfolding in the deviation from target. This does not necessarily imply there are never differences in localization in response to blindfolding. Tabry et al. (2013) did find differences in other paradigms, such as head-pointing and localizing simple sounds on the vertical plane. Based on the results of our localization task, and Tabry et al.'s similar paradigm, we can conclude that blindfolded and sighted people behave similarly in the spatial mapping of simple sounds when orienting their hands toward a specific location on the horizontal plane.

In contrast to the simple auditory tones, blindfolded participants outperformed sighted participants when localizing more complex auditory locomotion events. Earlier studies investigating sound localization abilities in blindness have only ever used simple sounds as stimuli. Our result

suggests that having no visual feedback creates an advantage in localization when mapping complex sounds onto an event space. One possible explanation for this advantage could be that closing the eyes increases auditory attention and thereby leads to better performance when localizing complex sounds. Since participants are already near ceiling for simple sounds, there is no room to see this improvement in that condition. A recent study by Wöstmann, Schmitt, and Obleser (2019) found that while attending to one of two spoken streams, even in a darkened room, closing eyes modulated attention, and increased alpha power for the attended stream. Wöstmann et al. suggested that closing eyes might decrease the dominance of vision, and thus enhance attention to nonvisual input. Although they did not report behavioral enhancement with closed eyes, their participants performed the tasks in a darkened room where there was no distracting visual input. In our study, to the contrary, sighted participants could see the location of the audio-speakers, which could possibly distract them while listening to sounds and/or localizing them in space. Thus, it is possible that our paradigm is more suitable to detect a possible beneficial behavioral effect of closing eyes. Furthermore, one could hypothesize that blind people might perform even better due to their better ability to process auditory information than both blindfolded and sighted people. Future studies could examine this possibility.

We did not find an effect of blindfolding on how often participants mentioned path in their descriptions regardless of the type of linguistic expression. However, we did find that blindfolded participants gave more sequential, and less holistic descriptions for the path of auditory motion events, compared to sighted participants. This is in line with the claim that blindness leads to sequential representations and segmented speech due to the more sequential nature of the sensory information that the resulting spatial representations depend on (e.g., Iverson & Goldin-Meadow, 1997). Iverson (1999) and Iverson and Goldin-Meadow (1997) showed that landmarks on a described route were used to segment the path into several pieces. We also found that blindfolded participants in our data used more landmark information encoded as source and goal in their descriptions. Thus, our results suggest that even temporary loss of sight changes how people talk about events by possibly hindering the building of a holistic representation of space.

Conclusion

We are the first to investigate the effect of the temporary loss of sight on localization and verbal descriptions of auditory motion events. We showed that temporary loss of sight leads to more sequential and less holistic path descriptions, and better localization of auditory events as measured by pointing. These effects suggest that even the temporary loss of sight might change the sort of spatial representations people build in response to complex auditory events.

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