

# Hearing the city without vision: An exploratory study



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## Abstract

This exploratory study explored what sounds people with varying amounts of auditory experience perceive hearing in city soundscapes without vision, and also how these sounds are ranked in order of importance by those with the most auditory experience. Auditory experienced and auditory inexperienced participants without vision participated. The auditory experienced mentioned 2 to 3 times more sounds than the auditory inexperienced; they perceived hearing several aspects of each sound and ranked identity the most important and location the second most important aspect. The auditory inexperienced typically mentioned one aspect per sound, either identifying or imitating them, rarely and only in general terms their location. These results warrant further research on auditory awareness, both when vision is lost at birth and later in life, and also on the process of developing from auditory inexperienced to auditory experienced without vision, especially in the field of orientation and mobility.

## Keywords

Auditory experience, blind, hearing, orientation and mobility, soundscape

## Introduction

This exploratory study focused on hearing the city without vision. Using auditory information from the environment effectively is an essential skill for safe, confident, and independent travelling when vision is significantly impaired: sounds help people who are blind identify the where and when of objects, people, and actions; directions and movements; places and locations (Saerberg, 2010). Still, previous research and practice in the field of orientation and mobility have mainly concentrated on using and adapting long cane techniques, technologies (e.g., GPS Navigation), and built environments (i.e., inclusive design and accessibility) (Blake, 2021; Emerson & McCarthy, 2014). Thus, for the first time, this two-part exploratory study explored the awareness of sounds in city environments in people with various amounts of auditory experience without vision.

Previous research in laboratory settings has found differences in auditory attention, discrimination, memory, perception, recognition, and target detection: indeed, a structural and functional

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reorganisation of the brain, in people who are blind compared with those who are fully sighted (e.g., Anurova et al., 2019; Lubinus et al., 2021; Musz et al., 2022; Pascual-Leone et al., 2005; Sabourine et al., 2022). However, only a handful of studies have investigated what sounds people with visual impairment hear in natural soundscapes, typically anchored in the work by R. Murray Schafer.<sup>1</sup>

The term ‘soundscape’ was first introduced in a scientific study by Michael Southworth in 1969 and, later, popularised by composer R. Murray Schafer in his World Soundscape Project, published from 1973 onwards (Axelson, 2020). Schafer (1994) identified four categories of soundscape sounds: keynotes, signals, soundmarks, and archetypical. Keynote and archetypical sounds are both background sounds and they are most often heard unconsciously; for example, the sea in a maritime community and the ventilation system in an office building. In contrast, signals and soundmarks are foreground sounds, heard consciously. Soundmarks are unique to specific communities while signals attract attention. An example of soundmarks is church bells, and an example of a signal is sirens on an emergency vehicle. However, Schafer (1994) emphasised that all sounds can be upgraded from background to foreground sounds simply by listening consciously to them.

There is, in fact, some evidence that people who are visually impaired often upgrade keynote sounds to soundmarks or signals (Herzsens et al., 2011). For example, the sound of trembling poplars as a cue for turning right (soundmark) and of traffic as a warning to not cross the street (signal). It also seems they deliberately intervene in or shape the soundscapes more than the fully sighted, for example, by snapping their fingers (Herzsens et al., 2011). However, this research was conducted to explore the role of haptic touch rather than of hearing; the data on audition were volunteered by the participants. Moreover, people who are visually impaired describe soundscapes with more terminologies, and in a different order, than the fully sighted (e.g., eventfulness; pleasantness; danger; direction; space; nature vs. pleasantness; eventfulness; dynamic) (Mediastika et al., 2019a, 2019b, 2020a, 2020b). Then again, these terminologies describe the emotional perceptions associated with soundscapes instead of individual sounds appearing in them. In addition, all this research was conducted with a heterogeneous sample regarding both visual acuity and time of onset of visual impairment: in turn causing uncertainties about the sample’s amount of auditory experience without vision. To this end, Southworth (1969) found that fully sighted people mention more frequently and make closer observations of sounds when they are blindfolded than when not. However, Southworth’s (1969) research did not include participants who were blind and, thus, had ample auditory experience with no vision.

Certainly, it remains unclear what sounds people with various amounts of auditory experience without vision are aware of in city environments. This two-part exploratory study was, therefore, designed to explore the following research questions:

- (Part one) What sounds do people who are experienced and inexperienced in using hearing without any vision perceive hearing in city soundscapes?
- (Part two) How do people who are experienced in using hearing without any vision rank the sounds they perceive hearing in city soundscapes in order of importance?

## **Part one**

### *Method*

*Design.* Structured interviews, with open-ended questions, were conducted with participants who had varying amounts of auditory experience without any vision, to explore what sounds they

perceived hearing in city soundscapes. The Social Sciences and Humanities Interdivisional Research Ethics Committee, University of Oxford, provided approval for this exploratory study (Ref. No. R58049/RE001).

**Sampling approach.** To keep visual acuity, time of onset of visual impairment, and amount of auditory experience with no vision under control as much as possible, Part one recruited participants who were blind with no conscious memory of seeing and (fully sighted) blindfolded (Stevens & Weaver, 2009; WHO, 2024a). The amount of auditory experience with no vision was operationalised as (auditory experienced) relying, and (auditory inexperienced) not relying on hearing for spatial information. Hence, the participants who were blind were treated as auditory experienced and the blindfolded as auditory inexperienced without vision. They were matched in pairs on visual acuity (blind; blindfolded), time of onset of blindness (early; recently), and auditory experience (experienced; inexperienced) (WHO, 2024a).

Because the population of people who are blind with no conscious memory of seeing is low-frequency, a purposeful sampling technique was used for these participants; keeping the sample size to a bare minimum and instead increasing the number of interviews per participant (Gill, 2020; Rahimi & Khatooni, 2024; Stevens & Weaver, 2009; WHO, 2024a, 2024b, 2024c). Information-rich participants with no hearing difficulties, comorbidities, and/or cognitive delay or impairment were selected (Argyropoulos & Gentle, 2019; Gill, 2020; Ozturk et al., 2016; Rahimi & Khatooni, 2024). Saturation was reached, and thus the recruiting process stopped, when the participants' answers clustered around certain themes across all interviews (Rahimi & Khatooni, 2024).

Volunteered sampling was used for the blindfolded participants (Gill, 2020). Only individuals who confirmed having no conscious memory of using hearing without vision and with no hearing difficulties, comorbidities, and/or cognitive delay or impairment were included.

**Pilot study.** A pilot study was conducted with two participants: one was auditory experienced and one was auditory inexperienced without vision (WHO, 2024a). Both were experienced in playing musical instruments (Wan et al., 2010). The pilot study was performed to trial the materials, interview guide, procedure, and scoring of data. As in Southworth's (1969) research, which is the only study that has asked people to mention the sounds they perceive hearing in city soundscapes without vision, five soundscapes lasting for about an hour were included. This proved to be exhausting for the auditory inexperienced participant, but not for the auditory experienced. Following this initial trial, recording equipment (to ensure all participants heard the same soundscapes, as they typically changed throughout the day and in different weather conditions) and modifications of the scoring of data were deemed necessary and, thus, a second pilot study was conducted. This time, both participants were auditory experienced without vision: one had participated in the first pilot study and one had no musical experience (Wan, 2010; WHO, 2024a).

**Participants.** There were four participants in total (20–65 years old; one male). In Pair A, one participant was (auditory experienced) born blind with light perception and one was (auditory inexperienced) fully sighted (WHO, 2024b). They had no experience of playing musical instruments (Wan et al., 2010). Both had a PhD. In Pair B, one participant (auditory experienced) had been totally blind from the age of 2 years in one eye and 5.5 in the other and one was (auditory inexperienced) fully sighted (WHO, 2024b). Both had over 15 years of experience playing musical instruments and now studied music (keyboard; percussion; song) at university (Wan et al., 2010).

**Materials.** Six city soundscapes were chosen by people who rely on sound for spatial information, work with or study music, or both. The soundscapes were recorded using a Soundfield St450MkII microphone and Zoom F6 recorder and included

- walking along narrow and wide streets (quiet and busy; 8.12 min)
- walking on a narrow lane (quiet; 4.39 min)
- sitting outside in a café (busy; 6.23 min)
- walking through a shopping centre (busy; 4.19 min)
- walking in a pedestrianised street (busy; 5.42 min)
- walking into and standing still in a park (quiet; 10.07 min)<sup>2</sup>

All soundscapes were presented to the participants in a sound studio with Reaper DAW, Blue Ripple Plugins, 8-Channel Speaker array, and WAVES NX Binauralizer and Head-tracker. The participants' responses were recorded via Reaper DAW using a Shure SM58 microphone.

*Interview guide.* The interview guide asked the participants the following questions: (1) 'Please describe/name the sounds you're hearing', and (2) 'Please give examples of sounds that attract your attention'. These questions were asked for all soundscapes.

*Procedure.* First, the head tracker was calibrated so that a virtual reality scenario of the soundscapes surrounding the participants could be presented. The fully sighted participants put on a blindfold. Next, all participants were asked to describe/name the sounds they heard while the soundscapes were playing. The soundscapes were then played and all of the participants' responses were audio-recorded. After each soundscape, the participants were asked what sounds had attracted their attention. The participants were not given any feedback. All participants were interviewed separately for 25–30 min. Pair A received Soundscapes 1–3 and Pair B Soundscapes 4–6.

*Scoring.* The audio recordings were scored in two steps. Because Southworth (1969) is the only one who has asked people to mention the sounds they perceive hearing in city soundscapes without vision, Step 1 was to code the participants' described/named sounds as Southworth's (1969, p. 57) 'mentions', however with the following modifications: mentions describing maritime communities and subways were removed, as these were not relevant to this exploratory study. Some mentions were merged, that is, 'long whistle', 'police whistle', and 'whistling' and 'motorcycle' and 'plane'. Mentions of older technologies were removed and new ones were added. Also, people's reasons for choosing these soundscapes were added (see Note 2). Because the participants perceived all the soundscapes in a sound studio, they could not deliberately intervene in or shape them and, thus, no mentions describing intentional altering of the soundscapes were included (Herssens et al., 2011). In addition, because this exploratory study asked what sounds people perceive hearing, it did not include any terminologies describing emotional perceptions associated with the soundscapes (Mediastika et al., 2019a, 2019b, 2020a, 2020b). In Step 2, clarifications and added comments were written down (in exact wording) in a think-aloud protocol (Aanstoos, 1983).

*Analysis.* The data were analysed using Template Analysis (King, 2012; Landridge, 2007). Step 1 was composed of two parts: (a) listen, and (b) listen again to the participants' answers. In Step 2, new mentions were discovered and added to the *a priori* mentions, or themes. Step 3 was to merge related themes, for example, 'clacking of shoes', 'footsteps', 'high heels', 'people walking/running', and 'tramping of feet', and delete redundant ones, namely, 'paper crinkling', 'metal clank', 'bouncing ball', 'horse clopping', 'screech of mailbox', and 'squeal of rugs on window' (Southworth, 1969). In Step 4, the participants' answers were listened to again, pursuing clarifications and added comments, that is, rich data. Finally, coded themes and rich data were unified to identify templates of what sounds people who are auditory experienced and

auditory inexperienced without vision perceive hearing in city soundscapes (King, 2012; Landridge, 2007).

## Results

*Pair A.* The participant who was auditory experienced provided nearly 3 times more mentions than the auditory inexperienced one (486 and 164, respectively). The most striking difference was in the mentioning of location (178 vs. 1) and people/footsteps (44 vs. 8), followed by motion (42 vs. 14) and people's breathing/voice (37 vs. 17). Equally striking was the difference in mentions of overall sound and onomatopoeia, with the auditory inexperienced participant mentioning them 25 and 20 times, respectively, and the auditory experienced nine and zero. The participant who was auditory experienced mentioned music 10 times and the auditory inexperienced seven times (see Table 1).

Regarding the overall sound, the think-aloud protocol revealed that the auditory inexperienced participant mentioned, for example, 'Busy', 'Crowded', and 'Traffic', and most often together with 'Loud' (volume). The participant who was auditory experienced described spaces opening up and closing in. For example, 'The space is opening up in front of me' and, indeed, even navigating in them: 'Listening to the steps, I feel like I'm going in a zig-zag between people'. Furthermore, instead of imitating sounds without identifying them, for example, 'Click clacking' and 'Swish-swish', the auditory experienced participant typically identified 'Clacking high heels' and 'Swish-swish sound of clothes'. A similar example is the auditory inexperienced participant saying 'Dragging sound' and the auditory experienced participant 'Walking, dragging their feet a bit'.

According to the think-aloud protocol, the auditory experienced participant provided several mentions for each sound, typically, first identity and then either location or motion. For example, 'Car starting and passing on my right . . . going away from me', 'Someone talking almost straight at me, almost as if they were talking to me', and 'Some person with a clacking shoe on the doorstep, with one foot . . . and . . . then stopped'. Moreover, they regularly checked in on sounds to hear if they were still there or had changed, for example, a screaming child: 'Child is not leaving, he's at about two o'clock from me'. They also predicted how sounds moved and then checked in on them:

Engine sound in front of me. It's gonna come in front of me . . . There was a pavement-thing tilting to my left. Now the engine . . . There it goes in front of me. (Auditory experienced participant)

The think-aloud protocol also revealed that the auditory inexperienced participant provided one mention per sound, often not identifying them, but instead interpreting the situation. For example, 'Lots of competing sounds here' and 'Walking very purposefully'. Similar examples are when they referred to the 'Rather annoying music' and the 'Low hum of conversations. . . . An area where people are sitting down to eat and drink'. The participants did not often place the sounds in space and, when they did, they were not always accurate: 'Bus very close. . . . I think it just ran me over' (which was a car driving parallel to them on their right-hand side). They checked the overall sound when it changed the ambiance of the soundscape, for example, from noisy to quiet:

Now there is no traffic noise, we just get this nice sense of people chatting and . . . relaxing . . . and then this very purposeful person walking along the pavement. (Auditory inexperienced participant)

The sounds that attracted the attention of the auditory experienced participant were those that could be used for navigation, for example, the 'Wall coming towards me', 'Hammering of the bayonet when preparing coffee', and 'Traffic behind me', that is, 'So I had a reference point'. Also sounds

**Table 1.** Pair A's mentions in city soundscapes.

Mentions	Number of mentions per city soundscape when auditory experienced and auditory inexperienced					
	(1) Quiet and busy city soundscape		(2) Quiet city soundscape		(3) Busy city soundscape	
	Exp.	Inexp.	Exp.	Inexp.	Exp.	Inexp.
<b>Bike/bicycle/cycling</b>	8		6	5	6	1
<b>Bird</b> (e.g., crow; duck; pigeon)	2	4				
<b>Breaks</b> (i.e., from car or bus)	1					
<b>Building/wall/arch/cover</b>	5		3			
<b>Car/bus/motorbike/plane/vehicle</b>	15	6	3	2	1	1
<b>Church bells</b>	1	1	1			
<b>Coffee making sound</b>					4	
<b>Construction work</b>	4		1			
<b>Crockery and cutlery</b>					7	7
<b>Dog</b> (e.g., collar; harness; walking)	5		1			
<b>Door/gate</b> (i.e., opening or closing)			3	1	4	2
<b>Dragging/dropping/moving sound</b>	1				11	3
<b>Echo</b>	1	1	2			
<b>ICT/technology/telecom sound</b>	2					
<b>Intercom/speaker announcement</b>						
<b>Location</b> (e.g., above; behind; left)	72		43	1	63	
<b>Machinery/motor/engine</b>		2	1		10	2
<b>Motion</b> (e.g., across; distance; passing)	20	5	12	5	10	4
<b>Music/instrument/singing/whistling</b>	2	2			8	5
<b>Onomatopoeia</b>		8		4		8
<b>Overall sound</b> (e.g., busy; open; traffic)	8	12	1	7		6
<b>People</b> (i.e., sum of activity)	9	6	4	4	1	6
<b>People/footsteps</b> (e.g., walking)	18	5	13	3	13	
<b>People's breathing/voice</b>	21	8	6	5	10	4
<b>Plastic/shopping bag/bag of crisps</b>	1					
<b>Sirens/alarm</b>			2	2		1
<b>Size</b> (e.g., big; heavy; medium; large)	6	5	2	1		
<b>Soft/hard/sharp/dull/clear/dry/wet</b>	3		4	1	2	1
<b>Speed</b>		1			1	
<b>Stick</b>	3		2			
<b>Tile/lid/slab tilting</b>	4				4	
<b>Trolley/case on wheels/pram</b>	3	1			4	
<b>Volume/pitch</b>		5			1	
<b>Wind</b> (e.g., in trees)			1			
<b>Total number of mentions</b>	<b>215</b>	<b>72</b>	<b>111</b>	<b>41</b>	<b>160</b>	<b>51</b>

**Table 2.** Sounds attracting Pair A's attention in city soundscapes.

Participants	Sounds attracting attention per city soundscape		
	(1) <i>Quiet and busy city soundscape</i>	(2) <i>Quiet city soundscape</i>	(3) <i>Busy city soundscape</i>
<b>Auditory experienced without any vision</b>	The: 'wall coming towards me' 'opening up in to . . .' 'child throwing a tantrum and motorbike'	The: 'traffic behind me, so I had a reference point' 'sirens' 'shifts in footsteps from clacking to squishy soft sound' 'going under the arch'.	The: 'hammering of the bayonet when preparing coffee' 'backing car and shutting of car doors'
<b>Auditory inexperienced without any vision</b>	The: 'traffic noise, especially when it was very loud' 'children screaming loud'	The: 'siren'	The: 'slamming of doors' (i.e., car doors) 'different conversations of people'

that warned them of danger attracted their attention, like 'The sirens' and 'The backing car and shutting of car doors' and the changes in individual sounds, like 'Shifts in footsteps from clacking to squishy soft sound'. Fewer sounds attracted the attention of the auditory inexperienced participant and the ones that did were loud and/or warning them of danger, for example, 'Loud traffic', 'Loud screaming', 'Sirens', and 'Slamming doors' (see Table 2):

It depends on whether you can identify them, doesn't it, because once you have identified it, then you go on hearing it. (Auditory inexperienced participant)

*Pair B.* The participant who was auditory experienced provided twice as many mentions as the auditory inexperienced participant did (354 and 175, respectively). Similar to Pair A, the most striking difference was the number of mentions regarding location (116 vs. 0); however, unlike in Pair A, this was followed by overall sound (29 vs. 7), and then motion (39 vs. 24). As in Pair A, also the difference in mentions of onomatopoeia was striking, with the auditory inexperienced participant imitating sounds 12 times and the auditory experienced participant only once. Both participants mentioned music 16 times (see Table 3).

Notably, the think-aloud protocol revealed the same striking difference between these participants as those in Pair A regarding both overall sound and onomatopoeia. The participant who was auditory inexperienced described the ambiance of the soundscapes and the auditory experienced participant changes in openness and closeness. For example, the auditory inexperienced participant said 'Noisy', 'Quiet', and 'Traffic'; the one who was auditory experienced identified 'Another opening on the left, maybe a side street', 'The sound starts to close off in front of me as we reach the wall on the other side', and 'A lot of echoes again, so I think we've gone into another high sealing area'. Furthermore, while the auditory inexperienced participant imitated sounds, for example, 'Hunk', 'Sludging', and 'Tinkle' without identifying them, the auditory experienced participant typically said 'Car horn', 'Moist', and 'Glass tinkle'. Only once did they imitate the sound without identifying it, 'Some kind of a little rattly thing in front of me', but then added 'Not sure what that is'. Indeed, the auditory inexperienced participant also said once: 'Little drone in the background. . . . I don't really know what it is'.

**Table 3.** Pair B's mentions in city soundscapes.

Mentions	Number of mentions per city soundscape when auditory experienced and auditory inexperienced					
	(4) <i>Busy city soundscape</i>		(5) <i>Busy city soundscape</i>		(6) <i>Quiet city soundscape</i>	
	<i>Exp.</i>	<i>Inexp.</i>	<i>Exp.</i>	<i>Inexp.</i>	<i>Exp.</i>	<i>Inexp.</i>
<b>Bike/bicycle/cycling</b>					1	
<b>Bird</b> (e.g., crow; duck; pigeon)					9	7
<b>Breaks</b> (i.e., from car or bus)			3	2	1	
<b>Building/wall/arch/cover</b>			1		2	
<b>Car/bus/motorbike/plane/vehicle</b>	2	3	7	4	3	6
<b>Church bells</b>			1	2		
<b>Coffee making sound</b>						
<b>Construction work</b>					4	1
<b>Crockery and cutlery</b>	2	1				
<b>Dog</b> (e.g., collar; harness; walking)	1		1		4	
<b>Door / gate</b> (i.e., opening or closing)					1	1
<b>Dragging/dropping/moving sound</b>						
<b>Echo</b>	2					
<b>ICT/technology/telecom sound</b>	1		7	2		
<b>Intercom/speaker announcement</b>	2	1				
<b>Location</b> (e.g., above; behind; left)	25		51		40	
<b>Machinery / motor / engine</b>				1	1	
<b>Motion</b> (e.g., across; distance; passing)	4	7	15	5	20	12
<b>Music/instrument/singing/whistling</b>	8	8	8	8		
<b>Onomatopoeia</b>	1	3		2		7
<b>Overall sound</b> (e.g., busy; open; traffic)	6	1	15	2	8	4
<b>People</b> (i.e., sum of activity)	3	1	9	4	2	2
<b>People/footsteps</b> (e.g., walking)	6	3	6	3	8	10
<b>People's breathing / voice</b>	3	4	6	12	9	9
<b>Plastic/shopping bag / bag of crisps</b>			1	1	1	
<b>Sirens/alarm</b>	1	1				
<b>Size</b> (e.g., big; heavy; medium; large)	4	5	8	11	10	8
<b>Soft/hard/sharp/dull/clear/dry/wet</b>	1	1			4	3
<b>Speed</b>					1	
<b>Stick</b>	1					
<b>Tile/lid/slab tilting</b>			1			
<b>Trolley/case on wheels/pram</b>			3	1		
<b>Volume/pitch</b>		1	1	2	7	3
<b>Wind</b> (e.g., in trees)					1	
<b>Total number of mentions</b>	<b>73</b>	<b>40</b>	<b>144</b>	<b>62</b>	<b>137</b>	<b>73</b>

Continuing as in Pair A, according to the think-aloud protocol for Pair B, the auditory experienced participant provided several mentions for each sound but, in contrast to in Pair A, sometimes before, sometimes after, and sometimes both before and after identifying the sound. For example, ‘A runner is coming up from behind. I can hear their breathing and their steps’, ‘Behind me, I can hear the wind in the trees’, and ‘From left to right’ and they regularly checked in on sounds too:

I can hear the traffic going away behind me. Crunchy sound of gravel. Yeah, all the traffic noise is behind me now. . . . Kids still playing over to the right. Can really faintly hear the traffic noise in the distance behind us. (Auditory experienced participant)

The auditory inexperienced participant, also like in Pair A, provided one mention per sound, most often without identifying them, and then interpreted the situation. For example, ‘Sludging’, ‘The music makes it sound like a high-class restaurant’, and ‘Oh, the bird is responding to the first bird . . . Oh, responding again’. When they mentioned motion, they typically said, for example, foot-steps, moving, or walking ‘Across’. This participant checked the overall sound when it changed the ambiance of the soundscape, for example, from busy to quiet, and revisited situations they struggled to interpret:

Why is somebody counting? It’s very quiet. There’s no kind of background vehicle humming. She’s still counting. Oh, birds. This girl is still counting. . . . Oh, I didn’t realise the girl had stopped counting, but I don’t know what she was counting for. Real loudly. There’s barely anybody. It’s really nice. (Auditory inexperienced participant)

According to the think-aloud protocol, both participants mentioned sounds in the background, for example, ‘I can hear some people talking in the background, far away, quite loudly’, ‘I hear some distant piano music in the background again’, and ‘I can hear some engines running in the background, but there doesn’t seem to be too many cars’.

Again, like in Pair A, the sounds that attracted the attention of the auditory experienced participant in Pair B were those that could be used for navigation. For example, ‘The percussionist’, that warned them of danger such as ‘The alarm or siren’, or that somebody possibly approached them; the ‘. . . thank you’ said by somebody in front of them, and/or the sounds that did not belong in ‘That natural environment’. Also as in Pair A, fewer sounds attracted the attention of the auditory inexperienced participant in Pair B, and the ones that did were those that set their mood, they did not understand, and/or changed the overall ambiance of the soundscape (see Table 4).

*Templates of what sounds people perceive hearing without vision in city soundscapes.* The participants who were auditory experienced perceived hearing several aspects of each sound, typically their identity, location, and/or motion. They regularly checked in on individual sounds to hear if they were still there or had changed. The sounds that attracted their attention were those that could be used for navigation, warned them of danger or somebody possibly approaching them, and/or did not naturally belong in the soundscape. They stayed attentive to sounds until the situation had ended, for example, to a reversing car until hearing the sound of car doors being shut.

The auditory inexperienced participants typically perceived hearing one aspect of each sound, either identifying or imitating them. Only occasionally – and in general terms – did they perceive hearing their location and/or motion. These participants rather interpreted the situation instead. They checked the overall sound when it changed the ambiance of the soundscape and revisited situations they struggled to interpret. The sounds that attracted their attention were loud, warned

**Table 4.** Sounds attracting Pair B's attention in city soundscapes.

Participants	Sounds attracting attention per city soundscapes		
	(4) <i>Busy city soundscape</i>	(5) <i>Busy city soundscape</i>	(6) <i>Quiet city soundscape</i>
<b>Auditory experienced without any vision</b>	The: 'alarm or siren' 'percussionist' 'thank you' (i.e., said by a passersby) 'intercom announcement' 'piano' 'car in front of me . . .'	The 'bell' 'buskers' 'cashpoint' 'traffic at the end of the road, because that's when I have to stop'	The: 'car horn' 'child counting' 'ducks' traffic and construction work: 'Even though it's far away and quite quiet, the traffic noise and the sound of construction work as well – because they sort of fall out of that natural environment'
<b>Auditory inexperienced without any vision</b>	The: 'distinct music and sirens. They gave me a feeling of urgency' "“thank you”, that somebody said' 'intercom saying there is now free wi-fi in the shopping mall'	The: 'church bells at the beginning. I recognise the tune' 'piano music in the middle. It sets the mood'	The: 'child at the very beginning' 'abrupt change into quieter' 'girl counting. I don't know what that's all about'

them of danger, set their mood, were not understood, and/or changed the ambiance of the soundscape.

## Part two

### Method

**Design.** Structured interviews, with open-ended questions, were conducted with participants who were experienced in using hearing without any vision, to explore how they rank the sounds they perceive hearing in city soundscapes in order of importance. The Social Sciences and Humanities Interdivisional Research Ethics Committee, University of Oxford, provided approval for this exploratory study (Ref. No. R58049/RE001).

**Sampling approach.** As in Part one, Part two recruited participants who were blind with no conscious memory of seeing and, thus, were among the most auditory experienced without any vision (Stevens & Weaver, 2009; Wan, 2010; WHO, 2024a). A maximum variation (auditory experience), purposeful sampling (visual acuity) technique was used for these participants; again, as in Part one, keeping the sample size to a bare minimum and increasing the number of interviews per participant (Gill, 2020; Rahimi & Khatooni, 2024; Stevens & Weaver, 2009; WHO, 2024a, 2024b, 2024c). Information-rich participants who either (1) relied on sound for spatial information, or (2) in addition to relying on sound for spatial information, played musical instruments; with no hearing difficulties, comorbidities, and/or cognitive delay or impairment were selected (Argyropoulos & Gentle, 2019; Gill, 2020; Ozturk et al., 2016; Rahimi & Khatooni, 2024; Wan et al., 2010; WHO, 2024a, 2024b, 2024c). Finally, as in Part one, saturation was reached, and thus the recruiting

process stopped, when the participants' answers clustered around certain themes across all interviews (Rahimi & Khatooni, 2024).

**Participants.** There were two participants (20 and 44 years old; one female); one had light perception and one was totally blind (WHO, 2024a). Participant 1 had 15 years of musical experience (keyboard; percussion), currently studying music at university (Wan et al., 2010).

**Materials.** Six city soundscapes were chosen and recorded as in Part one. They included

- queuing for a table, inside or outside, in a café (busy; 5.08 min)
- sitting in a café on the mezzanine level (quiet; 5.13 min)
- standing in a pedestrianised square with ongoing restoration work (busy; 4.55 min)
- walking around in a church (quiet; 5.51 min)
- walking around in a museum (quiet and busy; 6.55 min)
- walking through a narrow passage (quiet; 2.15 min)<sup>3</sup>

**Interview guide.** The participants were asked to 'Please describe/name the sounds you're hearing'. This question was repeated for all soundscapes.

**Procedure.** The procedure in Part two was the same as in Part one. Both participants received all six soundscapes in a random order, and the interviews lasted for 35–40 min.

**Scoring.** The participants' description/naming of individual sounds were scored as identity, location, and/or motion, with the order they were mentioned in as their rank in importance (Graven, 2015, 2016a, 2016b, 2018). For example, if the participant said, 'Car starting and passing on my right . . . going away from me' (see Part one) their answer was scored as 'identity' (car) ranked first, 'motion' (passing) ranked second, and 'location' (on my right) ranked third. Had they said, 'Passing car on my right' instead, then their answer would be scored as 'moving' (passing) ranked first, 'identity' (car) ranked second, and 'location' (on my right) ranked third. Onomatopoeia or imitation of sounds and overall sound were scored as 'identity' (see Part one).

**Analysis.** All scored mentions were counted as the number of first-mentions, second-mentions, and third-mentions. Because of the risk of data inflation when aggregating results from repeated measures in small samples, descriptive statistics were employed to explore how people who are experienced in using hearing without vision rank the sounds they perceive hearing in city soundscapes in order of importance.

## Results

### Participant 1

- 283 first-mentions; identity counted 238 times, location 13 times, and motion 32 times – identity 84.1% of all first-mentions, and 5.3 times more than location and motion combined. Identity had the highest count on first-mentions in all six soundscapes
- 236 second-mentions: identity counted 35 times, location 163 times, and motion 38 times – location 69.1% of all second-mentions, and 2.2 times more than identity and motion combined. Location had the highest count on second-mentions in all six soundscapes
- 43 third-mentions: identity counted 1 time, location 35 times, and motion 7 times – location 81.4% of all third-mentions, and 4.4 times more than identity and motion combined. Location had the highest count on third-mentions in five of six soundscapes, and there were no third-mentions in one soundscape (see Table 5)

**Table 5.** Ranking of sounds in order of importance.

City soundscape	Rank in importance	Participant 1			Participant 2				
		Rank in importance			Total	Rank in importance			Total
		1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>		1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	
<b>(1) Busy</b>	<i>Identity</i>	34	10		<b>44</b>	28	16		<b>44</b>
	<i>Location</i>	3	19	9	<b>31</b>		12	19	<b>31</b>
	<i>Motion</i>	8	6	1	<b>15</b>	17	8		<b>25</b>
<b>(2) Quiet</b>	<i>Identity</i>	25	1		<b>26</b>	56	1		<b>57</b>
	<i>Location</i>	1	19		<b>20</b>		40	2	<b>42</b>
	<i>Motion</i>		3		<b>3</b>	1	2		<b>3</b>
<b>(3) Busy</b>	<i>Identity</i>	35	5		<b>40</b>	38	20		<b>58</b>
	<i>Location</i>	2	28	8	<b>38</b>		24	9	<b>33</b>
	<i>Motion</i>	4	8	1	<b>13</b>	23	6	1	<b>30</b>
<b>(4) Quiet</b>	<i>Identity</i>	53	11	1	<b>65</b>	43	3	1	<b>47</b>
	<i>Location</i>	4	34	10	<b>48</b>		30	6	<b>36</b>
	<i>Motion</i>	11	8		<b>19</b>	11	6	2	<b>19</b>
<b>(5) Quiet and busy</b>	<i>Identity</i>	63	7		<b>70</b>	52	6		<b>58</b>
	<i>Location</i>	2	46	4	<b>52</b>		24	7	<b>31</b>
	<i>Motion</i>	9	3	3	<b>15</b>	13	8	5	<b>26</b>
<b>(6) Quiet</b>	<i>Identity</i>	28	1		<b>29</b>	20	2		<b>22</b>
	<i>Location</i>	1	17	4	<b>22</b>	1	8	2	<b>11</b>
	<i>Motion</i>		10	2	<b>12</b>	3	4	1	<b>8</b>
<b>Overall ranking of sounds in order of importance</b>		<b>283</b>	<b>236</b>	<b>43</b>	<b>562</b>	<b>306</b>	<b>220</b>	<b>55</b>	<b>581</b>

### Participant 2

- 306 first-mentions; identity counted 237 times, location 1 time, and motion 68 times – identity 77.5% of all first-mentions, and 3.4 times more than location and motion combined. Identity had the highest count on first-mentions in all six soundscapes
- 220 second-mentions; identity counted 48 times, location 138 times, and motion 34 times – location 62.7% of all second-mentions, and 1.7 times more than identity and motion combined. Location had the highest count on second-mentions in five and identity in one of six soundscapes
- 55 third-mentions: identity counted 1 time, location 45 times, and motion 9 times – location 81.8% of all third-mentions, and 4.5 times more than identity and motion combined. Location had the highest count on third-mentions in all six soundscapes (see Table 5)

*Ranking of sounds in order of importance without vision.* The auditory experienced participants ranked identity as the most important and location as both the second and the third most important aspect of sounds in city soundscapes.

## Discussion

This two-part exploratory study explored what sounds people who are auditory experienced and auditory inexperienced without vision perceive hearing in city soundscapes, and also how the

auditory experienced rank sounds in order of importance. The auditory experienced mentioned 2 to 3 times more sounds than the auditory inexperienced; they perceived hearing several aspects of each sound and ranked identity the most important and location the second most important aspect. The auditory inexperienced typically mentioned one aspect per sound, either identifying or imitating them, rarely and only in general terms their location.

This finding, that the auditory experienced participants mentioned more sounds than the auditory inexperienced, suggests according to Schafer's (1994) work that they listened more consciously to the soundscapes than the less experienced. Also, when taken together with the finding that they checked in on sounds if and when necessary, it seems they constantly upgraded and downgraded sounds, or in other words, shifted the focus of their attention from one sound to another (Kaya & Elhilali, 2016; Noyce et al., 2021; Price & Moncrieff, 2021; Schafer, 1994). Further research is needed to investigate whether people who are auditory experienced without vision downgrade signal sounds and soundmarks they will check in on later all the way to keynote or archetypical sounds or if they store them in an in-between position, for the quickest possible next upgrade.

Moreover, although fewer sounds attracted the attention of the auditory inexperienced participants than of the auditory experienced, they seem more widespread (see Tables 2 and 4). In line with Schafer's (1994) categorisation of soundscape sounds, it seems the auditory inexperienced participants were in a state of high alert regarding signal sounds and soundmarks and that the auditory experienced had learned which sounds truly required their attention. Hence, the auditory experienced participants would have been quicker than the auditory inexperienced to downgrade the sounds that were not true signals or soundmarks to keynote or archetypical sounds and, thus, ready to pick up more sounds in the soundscape (Schafer, 1994). It seems the auditory inexperienced participants needed to focus their attention more on each signal sound and soundmark before perceiving them and then deciding whether or not to downgrade them, as one of them clarified: '... once you have identified it, then you go on hearing it'. However, theories on top-down and bottom-up attention offer an alternative explanation, namely that the auditory experienced participants had a mixture of top-down and bottom-up attention (see Kaya & Elhilali, 2016; Noyce et al., 2021; Price & Moncrieff, 2021 for reviews). For example, their attention was drawn bottom-up to an 'Alarm or siren' warning them of danger and, at the same time, focused top-down to the 'Hammering of the bayonet when preparing coffee' . . . 'So I had a reference point'. It seems they scan their environment with top-down, focused attention, and that they stop focusing when the sounds they are searching for pop out, bottom-up (Lavie, 1995; Lavie & Tsai, 1994; Treisman et al., 1992; Wolfe & Robertson, 2012). The attention of the auditory inexperienced participants seems to have been drawn bottom-up, for example, to sounds that were loud, but it is not clear from this exploratory study whether it was also drawn top-down. Further research is needed to investigate bottom-up and top-down attention in people with varying amounts of auditory experience without vision in natural surroundings, and also on whether and if so when they start ranking sounds in order of importance as a strategy for reducing any perceptual and/or attentional load (Graven, 2015, 2016a, 2016b, 2018).

In a similar vein, when the participants in this exploratory study mentioned sounds in the background, the think-aloud protocol revealed that they regardless of their prior auditory experience related it, not to attention as Schafer (1994) did, but to distance and volume.

Finally, this exploratory study raises the question of whether there is a mismatch between brain plasticity and how people use sounds after losing vision (Pascual-Leone et al., 2005). Does the brain adapt immediately to only receiving auditory cues, but need time to firmly establish new ways of using them, as 'old habits die hard'? Indeed, as fully sighted (blindfolded) individuals, the auditory inexperienced participants in this exploratory study would have been used to turning to

see what and where the signal sounds and/or soundmarks were and using visual cues to decide whether to act on or to downgrade them (Schafer, 1994; Scholl, 1986). Those being (blind) auditory experienced would have been used to basing their decisions solely on auditory cues (Scholl, 1986). Furthermore, the auditory inexperienced participants would also have been used to using an external frame of reference to determine where the sounds were located and moving in space; those who were auditory experienced used to using their internal frame of reference (Millar, 2008; Scholl, 1986). For example, if still using an external frame of reference, the auditory inexperienced participants would only be able to mention footsteps, moving, or walking 'Across' as they did not receive any visual cues about the sound, where it came from, and/or how it moved. The participants who were auditory experienced identified location and motion according to themselves, for example, 'Behind me' and moving 'From left to right' (Millar, 2008). Further research is needed to investigate how people with varying amounts of auditory experience without vision perceive, process, and navigate through sound in various natural surroundings.

### **Limitations**

This exploratory study was conducted with a limited number of participations and soundscapes and, thus, cannot be used to generalise about what and how people perceive hearing sounds in their natural surroundings without vision. It can, however, be used to phrase more precise research questions and hypotheses as well as to design research for larger samples and with more defined soundscapes.

### **Conclusion**

This exploratory study warrants further research on auditory awareness, both when vision is lost at birth and when it is lost later in life, and also on the process of developing from auditory inexperienced to auditory experienced without vision. Moreover, despite its limitations, this exploratory study suggests that Orientation and Mobility training should start with an assessment of auditory awareness; that is, what sounds people perceive hearing in their natural surroundings and how they rank these sounds in order of importance, if at all. Further research is again needed.

Research on auditory awareness and the process of becoming auditory experienced without vision is essential to the furthering of auditory techniques for safe, confident, and independent travelling when vision is significantly impaired, whether used alone or together with any residual vision, long cane, guide dog, technologies (e.g., GPS Navigation), or all of the above (see Blake, 2021; Emerson & McCarthy, 2014; Saerberg, 2010). At the same time, research on hearing natural surroundings without vision is vital to the development of cities that are truly accessible and enjoyable for all.

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**Notes**

## 1. Database search.

A database search in Scopus and Web of Science retrieved 40 hits in total, using the keywords ‘soundscape’ and ‘blind’. Of these, 25 hits did not include blind or blindfolded participants, natural soundscapes, and/or participants’ descriptions/naming/mentions of soundscape sounds; 10 hits were concerned with sensory substitution, and one hit presented a review of previous research.

*Scopus*

- Advanced search – Soundscape AND blind
- Material type: Articles. Peer review journals
- Language: English
- Subject: Humanities, Life Science, Social Science, Soundscapes, Auditory perception, Blindness, Sound, Soundscape

*Web of Science*

- TS=(Soundscape AND blind)
- Document type: Article and review article
- Language: English

## 2. An edited version of these soundscapes can be found in The Oxford Sound Album; Episodes 9, 2, 10, 5, 6, and 8.

## 3. An edited version of Soundscapes 2 and 4 can be found in The Oxford Sound Album; Episodes 7 and 4.

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