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## How do sighted people experience the sense of volume? A phenomenal study

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### ABSTRACT

*This study aims to provide a phenomenological description of the sense of volume in sighted people. Especially developed by non-sighted people, the sense of volume is an ability to perceive solids and voids by analysing sound reflection. Our recent works have brought it closer to the human echolocation's ability, but also to a form of spatial hearing based on the analysis of variations in the ambient sound field. In many studies, blindfolded participants were able to detect a surface positioned in front of them. However, there are no studies reporting on the experience of the sense of volume in sighted people under conditions of ecological perception. Consequently, we carried out commented walks, combined with a micro-phenomenological interview method in an urban environment. By cross-referencing participants' perceptions (wall detection at one metre, typologies' discrimination of) with feelings they share (acoustic feelings*

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*combined with synesthetic tactile feelings), we demonstrated the ability of sighted people to rapidly unveil a functional sense of volume. Several researchers have hypothesized that sighted people may use a form of automated passive echolocation. In the light of our results, we wonder whether the sense of volume might be a non-conscious factor in an urban atmosphere.*

## 1. INTRODUCTION

### 1.1. The sense of volume

The sense of volume allows non-sighted individuals to perceive solids and voids by analysing sound reflection. Our previous studies [1] have taught us that the sense of volume can be described as a combination of three echo-acoustic abilities: active or monostatic echolocation, bistatic echolocation and a kind of echo-somaesthetic perception based on the analysis of ambient sound field. Active echolocation is the ability to use self-generated sound (click of tongue, fingers, white stick) to detect and locate large objects [2]. Bistatic echolocation is the term we have suggested to call the ability to detect and locate object thanks to sounds generated by an independent, localised sound object (footstep noises of another individual and a bird's whistling reflected on a wall) [1]. The third one, described as an echo-somaesthetic perception, is the most used one. Non sighted people can sense the presence of objects by analysing variations in the ambient sound field, without emitting any sound themselves. In literature, this is called passive echolocation [3], sense of obstacle [4] or Facial vision [5].

The sense of volume has been largely neglected in literature. It was first described in the Diderot's *Letter on the blind* [6]. For a long time, however, it was unclear whether this skill was grounded in tactile or acoustic performance. The phenomenology of the sense of volume was very difficult to define. Still, many non-sighted people were convinced that their ability was based on tactile cues on the skin of their face and the sense of volume was referred as "facial vision" [7]. On the other hand, Dallenbach and colleagues argued in favour of the acoustic origin of the sense of volume [8] [5] [9]. The sense of volume was then related to human echolocation, compared to bat sonar.

However, we showed in our previous work [1] that the study of the sense of volume in ecological outdoor conditions in which participants are navigating goes beyond active echolocation. Volume sensations arise as participants walk, most often in the absence of self-generated sound. Non-sighted participants are able to detect spatial variations, the presence of walls, material variations, and certain façade's textures (e.g. a balcony, a staircase).

### 1.2. The sighted people's experience

The sense of volume and echolocation are specifically used by non-sighted people but it has been shown in early studies that sighted people could access this ability when they were blindfolded [10] [5]. Since then, most studies have been carried out with sighted participants [11] [12] [13] [14] [15] [16].

Ammons and his colleagues [10] studied blindfolded sighted people's perception of obstacles into outdoor condition. In a first experiment, blindfolded participants were trained to walk straight toward a board positioned at a variable distance, without touching it. The results showed that they had a high success rate. They were also able to detect when there was actually no board. The average distance at which they reported their first awareness of the obstacle was 6.02 ft, and the average distance at which they reported that they were as close as possible before touching it was 3.34 ft (102 cm). Their performance decreased when they were deafened. This suggests that echo-acoustic cues were the most reliable ones to detect obstacles. The same experiment was performed but under nocturnal conditions to assess the impact of a climatic cues and of the reduction of background noises. It was found

that the performance increased significantly. This study shows that sighted and hearing people can quickly learn to detect the presence of an obstacle positioned in front of them. It highlights the dominance of acoustic cues for perceiving obstacles. Finally, limiting background noises seems to enhance perception. More recently, in their study, Calleri and colleagues [17] investigated the discrimination of urban typology by the reverberation of sound. Participants were asked to listen to a recording of a night-time walk in the city of Turin, in which the person walking emitted a noise every two seconds using a clapper-board. They were then asked either to associate the sounds to images of different spatial variations (street widths, squares sizes and covered or uncovered square) or to perform a two-alternative forced choice. The results showed that the participants were able to perceive differences in the reverberation of the sound without being able to identify the corresponding spatial representation, with the exception of the sequence street-square.

While other studies about active echolocation showed sighted people's ability to gather information about shapes, sizes, positions and materials of several objects (for a review, see [2]), they were all carried out using laboratory-generated sounds, into in-vitro experimental conditions. It is likely that these abilities manifest themselves differently in-situ. In some studies, for example, researchers immobilized the participants' heads [12]. Yet we know that body movement [18] [19] and head movement [20] can increase active echolocation performance. These phenomena have not been tested for the sense of volume but are likely to be observed in the natural motion of in-situ walking.

About passive echolocation, Ashmead and Wall [21] studied sighted people's ability to perceive a wall, using the variation of the ambient sound field. Participants had to listen to tracks simulating a wall located at several distances (from 25 cm to 200 cm to the listener). Modifying some acoustic features (e. g. the simulated motion of the listener), researches obtained different perception thresholds: 48, 59 and 34 cm for the three experiments. The average of obtained thresholds is around 47 cm. This distance would be the one in which sighted people would be able to perceive a wall, analysing only the ambient sound field.

In addition, Kritly and his colleagues [3] also showed that sighted people could use the variation of the ambient sound field to discriminate different wall textures (a broad wall, a circular convex wall, a wall with an aperture, a concave parabolic wall, a crenelated wall and a staircase), with two distances (81 cm and 500 cm from the participants). Results show that the flat wall and the circular wall are the most difficult textures to discriminate (reaching detection rates of 68%). The crenelated and the parabolic wall follow (73% and 75% respectively). The wall with aperture and the staircase are the most distinguishable textures (81% and 84%).

### **1.3. Comments and target**

The studies previously described allow us to assume that blindfolded people could feel the presence of obstacles in front of them, the major variations in typology, the presence of a wall less than 50 cm away and certain high-contrast facade textures.

In addition, several studies report a powerful synesthetic phenomenon in the phenomenology of echolocation [7] [22]. Thus, tactile feelings can be experienced by listeners, even though the information is captured by ears. Furthermore, as we have seen, participants can combine echo-acoustic, climatic and olfactory cues to analyse the presence of an obstacle [10]. The phenomenology of the sense of volume could be translated into acoustic or tactile feelings, and through the diverted use of climatic or olfactory cues.

The objectives of this study were two-fold. Firstly, we wanted to replicate earlier findings showing that blindfolded sighted participants can experience a sense of volume in an urban environment. Secondly, we wanted to systematically investigate the phenomenology of their spatial experience. To do so, we used an interpretative analysis on the basis of the commented walk and micro-phenomenological interviews. We hypothesized that sighted

people would be able to access cues used for the sense of volume, and that they will be able to experience a large part of its complex phenomenology.

## 2. METHODS

### 2.1. Participants

Participants were students from the University of Nantes, the National School of Architecture and the Central School of Nantes. They were 18, with 12 men and 5 women, aged from 20 to 32 (Average = 24.45). All reported having normal sight and hearing. They also certified that they had not taken any psychoactive substances during the eighteen last hours. They gave a free informed written consent before the experiment start.

Participant 17 was removed because though he reported experiencing a sense of volume, the analysis revealed that his reports were systematically the opposite of physical reality. We assumed that this was a misinterpretation of his feelings, as had occurred in the study of de Vos and Hornikx [12].

### 2.2. Materials

All walks were filmed and recorded using a portable camera mounted on a selfie stick.

Participants were blindfolded with a totally occulting blindfold in which they could open their eyes without perceiving light.

### 2.3. Procedure

Participants were recruited via a link allowing them to choose a time slot. The walk took place in the city center of Nantes, between 5 and 6 am, or between 6 and 7 am. This choice of schedule limited the unpredictable variations in human activity, intense background noise that could reduce performance, and random variations in solar radiation [10].

The experiment was based on Thibaud's commented walk method [23] [24]. The aim of this method is to gather the situated and moving experience of participants. One uses it to conduct experiments in outdoor environments, specifically urban spaces.

Participants were invited to meet the experimenter a hundred meters from the starting point. They were instructed to express everything they felt, concentrating on their feelings rather than on interpreting them. Once the participant was blindfolded, the experimenter started the video recording and began to guide him or her. The experimenter deliberately took a detour to disorientate the participant before arriving at the starting point.

The walk had been defined according to the diversity of typology it offered: three different pedestrian streets widths, two vehicular streets, an avenue with a wide central pedestrian area, a half-disc square and a covered passageway. At several points, the experimenter brought the participant close to a wall, observing his or her reaction. The walk lasted 20 minutes and was made twice, as a round-trip (i.e. 40 minutes of experimentation). The participant was unaware of this subterfuge, which increased the validity of his or her comments. At the end of the walk, all participants declared that they had been disoriented since the beginning, and none of them noticed that they had passed the same spot twice.

During the walk, the experimenter used an interview method inspired by the micro-phenomenological interview, which aims to describe the pre-reflexive lived-experience of a person [25]. She asked questions such as: "What do you feel here?", "How would you describe your feelings?", "Where is it located?", "What could you compare it to?" She had to formulate carefully her questions in a non-inductive way, so as not to influence the participant's analysis. Finally, a debriefing session was scheduled.

This study conforms to the Declaration of Ethical and Methodological Principles of Helsinki, first signed in 1964, and last amended in 2013.

### 3. RESULTS

#### 3.1. Analysis

Each walk was transcribed into verbatim. Information about participant location and participant's motor reaction were added from videos. We then applied an interpretative phenomenological analysis method (IPA), which is well suited for acquiring introspective data [26] [27].

We made a systematic quotation by unit of meaning for each verbatims [28]. The units of meaning were sorted according to their occurrence in all verbatims. For a small group of participants, it is recommended to remove units of meanings present in less than 50% of the verbatims. In this study, we focused on the units of meaning's sensitivity, in order to enhance the accuracy of the report. The sensitivity of the units of meaning involves a reduction in the general number of occurrences: if the categories are more precise, then they apply to fewer comments. Consequently, we have removed the units of meaning present in less than 30% of verbatims, i.e. in less than 5 verbatims.

Following the IPA method, the most popular units of meaning were used to formulate the headings of the main themes: (i) the sense of warning, (ii) the sense of presence, (iii) the sense of location, (iv) the sense of open space, (v) the sense of closed space, and (vi) comparative awareness. Some units of meaning feed into the main themes, while others did not and corresponded to the experience of temporary blindness. We grouped them in a seventh category called "Miscellaneous". Thus, there were seven main themes in which 92 units of meaning were distributed (average/theme = 13,1 ; Min = 8 ; Max = 17).

The following sections present the results into a discursive form, introducing pieces of verbatim (see [27] for more details about IPA).

#### 3.2. The sense of warning

The sense of presence of a solid was expressed in several cases by a motor reaction. Participants showed surprise or turned their faces towards a wall several times before expressing their feelings. They reported an impression of proximity of an obstacle.

*P8 - "I feel ... oh yes, there must be a wall nearby on the left. [...] I believe I have a sixth sense; I have a magic power".*

For the participants, their sensation worked like a warning signal: something was telling them to go no further, to keep their arm close to them.

*P7 - "It just stretched my body a little bit. I stretched my arm as if I had to... Like when you're careful, when you're going to hit something. Little feeling of "I'm warning you"".*

*P3 - « Yes, that's it, there is a huge dark presence in front of me, who is saying "No, you are not going there"".*

They reacted to this alarm signal by introverting, tucking their heads into their shoulders, to protect themselves.

While walking, they described how their experience was constantly updated, using sentences like "the wall has gone" or "the wall has come back" as if the environment were moving around them. When there was a volume nearby, they have this feeling of approach associated with a feeling of attentional arousal.

*P7 - "It alerts the area of your body where you hear it. It wakes up the area behind you, it wakes up your left arm. It's like you had to pay attention to protect yourself".*

#### 3.3. The sense of presence

According to the participants, buildings and walls created a feeling of presence when they were near them.

*P6 - « Well, I still feel a presence on the left, a big wall".*

They found it hard to describe precisely what they experienced, whether it was an auditory, a tactile or a visual feeling (despite the fact that they were blindfolded).

When participants experienced tactile feelings, they described it as a feeling of reverberated heat on their skin.

*P3 – “No, I would say it's my heat. But... it's like, yeah, the object was giving it back to me to say “well, I'm here”.*

They also compared their tactile experience to a feeling of brushing, caressing or of light pressure.

*P6 – “What did I feel? Like before. An almost caress on my right side, or maybe, I don't know, you know, a bristling hair feeling”.*

In closed spaces, they could report feeling crushed. They pointed out that this was different from actual tactile contact; it could be more like an anticipatory tactile awareness.

*P4 - Well, I feel like it's more my protective layer that's in contact with certain things... It's too weird because usually, we always refer to touch, I thought, to perceive things, whereas actually I realize that you can feel them before touching them”.*

*P16 – “You feel something on the side. A kind of touch. You feel like something's entering your... It's like there's a circle around you. A small area. And you feel that there's something penetrating that area”*

Participants located these feelings on their head, their face, their shoulders or their arms, according to the building or wall position in relation to their body. They noticed that the feelings were more intense when solids entered into an area surrounding their body.

*P4 – “Well, I feel like I perceive things much better when ... You see, it's like I had a first hyperdense layer of these kind of things, and so when I'm close to objects I feel them directly. But when things become a little more scattered, it takes a little more time to analyse them to feel them better”.*

Participants also reported auditory feelings create a slight pressure's effect on or in participants' ears. This is linked to a feeling of acoustic void (an acoustic shadow). Sounds seem muffled when they are close to buildings.

*P2 – “On the right side, I feel the wind blowing by. On the other side, I feel it's a little more...padded. [...] It feels like a small ball in the middle of my ear.*

Visual awareness was also impacted. Participants described mental images of shapes in black and white, with blurred outlines. Feeling presence corresponded to a shape, darker or lighter than the background.

*P7 – “It's like the whole universe was white. And objects were just black passing by”.*

In most cases, several feelings were combined, and participants could have a tactile feeling in the same time as an auditory feeling.

*P7 – “Because, indeed, there was the echo of my voice, which was very muffled. But I also feel like that, with the breeze, with the proximity of the object, the body felt it”.*

### **3.4. The sense of location**

Participants were able to locate volumes in egocentric coordinates, to their right or left, in front, or above them.

*P13 – “There's something over there, I'd say [points to his left] and not much over there [points to his right]”.*

The localization of volumes was grounded on the localization of the sensations that the participants experienced. For instance, they would feel sensations on the right side of their body, from which they would infer where the volume is. They sometimes moved their head to feel better.

*P4 – “On the left I feel something [...] with my shoulder. And it's not very high. I feel like that it's limited and when I lift my head I don't have it anymore. [...] But yeah, I'd say there's a thing or a tree that's not very high or I don't know, or not as high as before [right perception]”.*

Their spatial ability worked both for solids and for voids. Solids were essentially walls of enclosures or buildings, a covered passageway's ceiling, or narrow elements such as trees or posts. Voids were delimited spaces, surrounded by solids, such as streets or clearances.

### 3.5. The sense of open space

When facing an open space, participants reported a feeling of enlargement followed by a feeling of emptiness, on the basis on which they experienced the space as being open with no physical boundaries.

*P13 – "It's a really big void. It's infinite. This place is huge".*

More specifically, they described the distance and panoramic distribution of sound sources, the increase in wind speed and its random orientation. They interpreted all these cues as the absence of surrounding elements.

*P11 – "Here it's mainly the wind, the difference is that suddenly, I feel a lot of wind, And I'm starting to hear traffic. [...] I can actually hear machines further. But hearing things coming from a little further away, it also has a wider effect".*

They speak about sound as something in motion, saying "sound is escaping", "sound is going into all direction" or "sound is not coming back". The sense of open space is associated with a sense of freedom (they could go where they wanted) but also of insecurity in the absence of fixed landmarks.

### 3.6. The sense of close space

Participants described the sense of a space closing as a feeling of tightness followed by a feeling of envelopment. In the smallest space, they reported feeling surrounded, as if in a cocoon. They imagined an arch or a dome above them, so intense could their feeling of envelopment be.

*P15 – "I think there's a close envelopment that makes you feel like you're enveloped, it's because you have a close thing that makes you feel like you're in a little cocoon and that protects yourself a little bit"*

Participants used the resonance, the echo of their own voice, the absence and isolation of sound, and the absence of wind to infer that the space is closed.

*P16 – "First, a bit quieter, we don't hear cars as much, and about voice, this is less diffused in all directions". [...] And then, same thing, still breeze, there's less... No wind".*

They also described during our walk in the early morning a refreshing feeling, probably linked to the moisture of stones at this time of the day. Sometimes, they intentionally produced a sound with their voice or clapped their hands or fingers to feel better.

Participants explained that closed spaces gave them a security feeling, because they felt that the environment was well defined and they felt serene when the atmosphere was calm.

### 3.7. Comparative awareness

As in every perceptual processes, discrimination between spaces requires contrast.

*P11 – "I feel quite enveloped right now. But mainly, there's a contrasting effect because I feel like, just before, I was crossing something much wider".*

Participants were frequently surprised by typology transitions.

*P11 – "It's... Suddenly, there's... It's hard to explain. It's a feeling of openness".*

They proceeded by comparing their feelings to deduce the type of space they were experiencing. These comparisons are based on their assessment of dimensions: height, width (or distance from walls), opening of the volume.

*P12 – "Compared to earlier, when we started, we felt more enveloped, whereas now it's more open. But less than in the middle".*

Participants often perceived a modification in sound reflection, unknowing why.

*P14 – "It's a bit... It's different. It's more... The echo is more evenly distributed, I think".*



Participants could easily identify a typology of street or covered passage. Covered passages offered intense sensations comparable to being in a tunnel. Sometimes, the narrowest streets could be mistaken for an arch: participants felt they had something over their heads. Depending on their location in the street, they could sense that one of the two walls was closer (only possible on pedestrian streets). Square typologies were identified by deduction of the following type: in the absence of solid, and knowing the possibilities offered by the urban environment, this might be a square.

### **3.8. Miscellaneous**

The experimental situation put participants into a new situation of blindness. This specific context made them insecure. They were worried about car noises, they felt disoriented, they were focused on finding where they were. Their attention was drawn to the tactile feelings beneath their feet, and they often expressed fear of stumbling. They also explained that it seemed like there were always walls in front of them. These feelings made them walking slowly at the beginning of the experiment. After a few minutes, they felt more comfortable and they could focus on other feelings.

For all participants, feelings of volume appear during the first walk's part, before turning. Some people experience them within the first few metres, while others identify them after 10 minutes, when they seem to trust their new perceptual condition.

## **4. DISCUSSION**

As a reminder, the aim of this study was to investigate the sense of volume experienced by sighted people on the basis of the interpretative phenomenological analysis of 17 commented walks.

The first question we had was whether sighted participants would be able to experience a sense of volume. Arias [7] suggested that sighted people use passive echolocation mechanisms in a non-conscious and automatic way in their daily lives. Here we showed that it could reach the threshold of consciousness. In line with previous studies [10] [5], our study confirmed that sighted participants can describe volumes and voids on the basis of acoustic signals but unlike most research in the domain, we have favoured a more ecological and embodied approach in which participants navigated in an urban environment. We hypothesized that their active involvement could improve their performance. Furthermore, by being outdoors, participants had access not only to familiar natural ambient sounds but also to other cues that they could use. Our study thus shows that the sense of volume does not depend on neural plasticity following blindness but that it should rather be considered as a perceptual skill that can be naturally acquired by any individual.

Our second objective was to explore in more details how sighted participants experienced variations in spatiality. Given the rudimentary nature of the sense of volume experience, one should acknowledge that the sense of volume is a primary sense of presence: it tells us that something is out there [29]. More specifically, non-sighted individuals describe the sense of volume as the ability to perceive solids and voids. To help better understand what is meant by void, one can refer to Calleri and colleagues' [17] distinction between content and container, which involves boundaries. Our results show that when sighted participants described voids on the basis of feelings, they mean streets, clearings and covered passageways, which all involve boundaries, and which can be conceived as urban containers. In larger environments, such as a square in the city, the detection range of the sense of volume is too short to experience any boundaries. However, although squares have no perceptible boundaries, the transitions between streets and squares create a contrast between delimited container and limitless spaces. Volumes take shape on the body scale in motion. The term "volume" can, therefore, be used to describe both solids, essentially represented by buildings, and voids. Sighted participants were able to discriminate them.

Here we propose to interpret the sense of volume as a special phenomenological consequence of peripersonal space mechanisms. It has been shown that the immediate surroundings of one's body is processed in a specific manner both at the sensory and at the motor levels, by contrast with far space [30]. In particular, it has been shown that auditory stimuli in close spaces can enhance tactile processing [31]. One of the major functions of peripersonal space mechanism is “to maintain a margin of safety around the body and to coordinate actions that defend the body surface” [32]. One may suggest that the sense of volume is a related phenomenon. Like peripersonal space, it involves tactile feelings and like peripersonal space, it plays the role of an alarm signal. Tactile feelings have appeared in the literature since the first studies [33] [34]. In our studies, the participants interpreted what they felt on their skin as alerting them of the presence of volumes. They further described the feeling of an area surrounding their body. Their sense of presence was increased when the buildings reached or crossed the boundaries of this area. Though peripersonal space is typically not consciously experienced as such, one can conceive that in case of temporary or permanent sight deprivation, it can reach the threshold of consciousness. Other cases have been described in which participants in a virtual reality environment experienced faint feelings of illusory touch with the side walls that were actually located at 40 cm away from the participants. They did not have this effect when the walls were further away (175 cm) [35]. Moreover, this was the distance at which participants in Ashmead and Wall [21] were able to perceive the presence of a wall. Thus, we propose that the illusory tactile feelings of the sense of volume are linked to an alert reaction when an architectural element enters into an individual's peripersonal space.

The space experienced in the sense of volume seems to be similar to the notion of lived space, which Griffero [36] describes as the atmosphere in which the lived body evolves. The sense of volume seems to summon the body in its sensitive and affective dimensions. It is often linked to feelings of protection, envelopment or, conversely, invasion or crushing. There seems to be a permeability between feelings of presence, affect and action in which the body is stopped or guided in correlation with the felt architectural elements. One might then say that the sense of volume provides a primitive, pre-reflexive atmospheric experience in sighted people.

The study of the sense of volume in-situ reveals relationships between sensitivity, spatio-corporeal relationships and affects, which can be discussed regarding literature on peri-personal space and urban atmospheres. However, the hypothesis about involvement of these two notions in the sense of volume's experience will have to be investigated in order to know, on one hand, whether the appearance of illusory tactile feelings is linked to the entry of an architectural element into an individual's peripersonal space and, on the other hand, whether the sense of volume is indeed a non-conscious generator of atmosphere in sighted people.

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