# Like Elephants Do: Sensing Bystanders During HMD Usage

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## Abstract
The introduction of consumer head mounted display (HMD) systems and mobile VR devices lead to a growing number of mixed presence situations. One problem that arises is the awareness of bystanders while using a fully immersive HMD. We aim to address a subtle, non-visual communication of (1) the recognition of people approaching the VR user, (2) the communication of intentions of the approaching people and (3) higher level non-verbal communication of surrounding people to the HMD user. We investigate ways to foster the sense of presence beyond visual representations. Based on examples from the animal kingdom, we present three concepts that use either seismic vibrations on the foot, or eclectricity or vibrations on the upperbody to increase awareness of others in mixed presence scenarios.

## Author Keywords
head mounted displays; virtual reality; awareness

## Introduction
The recent accessibility of virtual reality head mounted displays (HMD) in consumer markets raises opportunities for using VR in public environments. Mixed presence scenarios in which HMD users are surrounded by people in the real world are becoming more common. Recent research shows that this leads to negative effects on the HMD user, as the missing visual information about surrounding people

causes a feeling of insecurity and further degrades the VR experience [11]. We first give two exemplary scenarios to motivate the work and better understand the arising issues:

First, many car companies use HMDs to support car dealers with highly immersive tools (e.g. [8]). Existing car shops are too small to showcase all personalization options and functions, like crash avoidance systems. In this case, an HMD can be used to show the customer different car features. The HMD user acts in this semi-private environment, surrounded by his/ her family and strangers like the salesperson and other costumers. Due to the lack of visual connection to the real world, the user cannot differentiate the relationship between him/ her and the other persons and their intentions, even if their proximity is very close [11].

Second, the growing interest in mobile VR headsets, like the Gear VR [18] brings VR to public spaces. The possibilities to entertain or inform people with this technology are of high industrial interest and investment in this area has been continuously growing [5]. One of the visions of mobile VR is that it would be used at a bench, on a sidewalk or a cafe. In this public scenario, the user is not familiar with any of the surrounding people when starting to use the HMD. This however, may change during the usage time, for example when a friend or the waitress arrives in close proximity. Because of the blocked vision, the user's sense for identifying others and their intentions is disturbed.

Based on research in proxemics which revealed that the use of space by human beings has an impact on their behavior, communication, and social interaction [7], we believe that both scenarios discussed may lead to trust issues and can cause a feeling of insecurity. This may result in a lowered feeling of presence in VR and might even lead to the user taking off the HMD to monitor the surrounding environment. To overcome this we want to introduce concepts that enable (1) the recognition of people approaching the VR user, (2) the communication of intentions of the approaching people, and (3) higher level of non-verbal communication by surrounding people to the HMD user.

Our concept was driven by the aim to find subtle, non-visual ways of communicating the spatial relation and intentions of bystanders to the HMD user. A non-visual approach can be desirable as an avatar or a videostream of the surrounding environment might interfere with the users' experience and therefore break the involvement and feeling of presence in the virtual world [19]. We propose three concepts inspired from the non-visual sensing of others by elephants, eels and sharks and discuss how these concepts can be technically applied in HMD usage scenarios.

## Concepts

Sensing the presence of others is mainly achieved through the traditional five senses which humans possess: sight, hearing, taste, smell, and touch. However, humans possess further sensing capabilities, like acceleration, temperature, pain and kinematics of body parts. Which sense is triggered to what extent depends on the relative position between human beings and the surrounding situation. Our goal is to stimulate these senses in order to generate a subtle feeling of *somebody is there*. For example, when a person is walking through a dark alley at night and they feel, they are not alone. This feeling is naturally not based on a specific sense, but describes well a feeling we would like to create for HMD users. Another example is the ability of people to sometimes recognize people, e.g. family members, from the sounds created by their steps when walking through the house, identify the room they are located in and from that coarsely derive what the intentions of those family members are. To achieve this we want to amplify existing stimuli and adopt senses animals use to the human senses. The

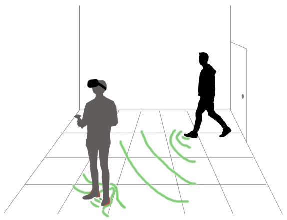

**Figure 1:** Illustrating the elephant seismic vibrations concept: A person is approaching the HMD user who feels a vibration from the floor. The amplitude of the vibration under the right foot is higher than that of the left foot giving a subtle cue of the direction from which the person is approaching.

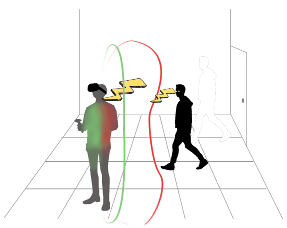

**Figure 2:** Illustrating the Electroreception concept: A person is approaching the HMD user who feels the thought magnet field bending. The flash symbolizes the approaches intention to interact with the user and is felt as electric stimuli by the HMD user.

following section details our approach to achieve this goal.

*Like Elephants Do: Using seismic vibrations*

Elephants have the ability to sense seismic vibrations from the ground [13] and are able to discriminate if the signal belongs to their own or a different group [14]. Depending on the presented seismic stimuli they change their position to either get a better sense for the seismic or auditory stimuli. With this they localize the direction and the intention of the message, such as danger or mating behavior [14]. We propose using the presence sensing mechanism of elephants to create a similar analogy for VR systems. The concept is to have a vibrating ground under the users' feet. The distance to the other person and the attributes of a person such as height or size can be encoded in the amplitude and frequency of the vibrating ground. By altering the vibrational stimuli sent to each foot of the HMD user, the relative direction to the other person can also be sensed (Figure 1). An implementation of a vibrating floor was discussed in a patent by Cooperstock et al. [4]. A disadvantage of this implementation is the immobility of the system, and the relative complexity of adding different vibrational stimuli to each food. However, the vibrational floor is instantaneously usable and does not require augmenting the user. Another implementation of this concept would be by using shoe-based stimulators embedded into the users' soles. Research in wearables has investigated this idea for use in sending navigational cues to users and achieved high accuracy and recognition compared to stimulating other parts of the body, without disturbing other senses [12]. That the detection of direction and distance of others by tactile stimuli of the upper body is possible even under high cognitive load could be shown [16, 10], however is not tested for the feet.

*A Tingling Message From the Eel: Electroreception*

Fish generally communicate by using electricity in two forms. Either by sensing electric currents produced by other fish or by sensing changes in their own magnetic field, when another object or fish enters it. Fish can further send electric stimuli explicitly to communicate their intentions. The sensory cells are directed, e.g. at the nose of the fish, or along the whole body of the fish to sense the environment [9]. Simulating this sense in humans, we propose stimulating the users' upper body to give a feeling of being surrounded by other people. When the HMD user focuses on the VR experience, a thought magnetic field is simulated around him. Without any intruders, or passersby in the vicinity of the user, nothing happens. When somebody approaches the thought magnetic field, it is bent and altered. This induces a force that will be applied to the users' upper body, depending on the relative position of the other person and their size. If the intention of approaching the HMD user is to interact, electric stimuli will be presented to the HMD user in order to communicate the intentions of the other person. Basic information about the approaching person can be communicated, such as if they are a friend or a stranger (Figure 2). To realize this concept, several industrial commercial solutions are already being developed. For example the Teslasuit [17] uses electrical muscle stimulation (EMS) of several parts of the body to to generate different sensations. Pfeiffer and Rohs investigate the different effects of EMS stimulation using wearable smart textiles [15].

*Sensing pressure like a shark*

Sharks have organs to sense changes in pressure. With the organs of their lateral line they mainly look for frequencies that tell them about possible preys. With this sense sharks can feel a touch remotely [6]. However, the pure sense of pressure does not trigger a hunting behavior. For this a second stimulus is necessary. From this we derive a system that gives a feeling of a wave stroking over the users' skin. The strength and direction of the wave sensation can depend on the relative direction between the real world person and the HMD user. The speed of the wave can also be used to communicate the approaching speed of the other person. The technical implementation of such a concept can be realized by vibrotactile stimuli on the upper body. The existing work shows the shows the big advantages of sensing direction and distance of others [16, 10], however not in a subtle way and without any additional information like the size of the other. Alternative to vibrotactile communication, stimulation to epidermal skin receptors, as used in tactile displays, should be taken into account [2].

## Discussion

Our presented three concepts, inspired from the sensing abilities of animals, pose technical and interaction challenges that we would continue to investigate in the next phase of our research. An important question our research poses is, if the proposed stimuli can indeed amplify stimuli to generate a feeling of having another person nearby, or that the user will learn to interpret the stimuli. For example, would vibrotactile wave sensations on the skin directly communicate a feeling of presence, or would they be learnt by the user as a form of output *notification*. Humans already possess presence sensing abilities like a sense for light or heat. However, due to being immersed in an HMD scenario, their regular sensing abilities are degraded. Through our concepts we aim to further enforce those degraded senses. Another open question for our proposed concepts is investigating the effect of stimulation on triggering unwanted emotional responses such as fear or surprise, which would again interfere with the original goal of keeping the user immersed in the VR environment and only subtly enhance their presence sensing abilities. Finally, our presented three concepts enable the HMD user to (1) recognize somebody approaching by their height, speed and direction. Further systems might be able to communicate the (2) intentions of the approaching person to some extent, such as the intention to walk towards the user or just to pass by. However higher order of communication, such as emotions of the approaching person, might be difficult to obtain without additional hardware (e.g. [3, 1]) and (3) non-verbal communication seems to be impossible due to the complexity.

## Conclusion and Future Work

In this work we proposed innovative concepts for using existing technology to communicate the awareness of bystanders in the real world to the HMD user. We aimed at finding subtle solutions that would not interfere with the virtual reality experience and therefore the level of presence experienced in VR. All concepts have in common that there are commercial techniques or broad scientific knowledge available on how to create different kind of stimuli to the human body. To our knowledge, there is no existing work that uses these technologies in order to create the sensation of somebody else being nearby, without giving a visual stimulus. The next step in our research is to create prototypes, and conduct user tests to test if the chosen stimuli can give the HMD user a feeling of a person (1) approaching. It is questionable whether a user might be able to learn to interpret the given stimuli quickly, whilst keeping focus on the virtual task. Further analysis is necessary on how much information the user can discriminate in order to find out how much of the approaching persons (2) intention can be communicated to the user. As we believe that there is no (3) direct communication of intentions to the user possible, user studies need to answer the question at which level of communication a switch to other senses like hearing or vision is necessary. This will define the border between subtle and direct communication between a HMD user and an approaching person.

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