What If... Humans Had a Sense for Electroreception?

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Abstract
Unlike many animal species, humans do not have a sense for perceiving electric fields. For millions of years though, sharks have been guided by their sense for electric fields to navigate and recognize their prey. Weakly electric fish can not only perceive, but also emit electric fields as a medium for communication with their counterparts. As with many communication modalities in nature, dominance and gender is conveyed with this behavior, indicated by the frequency of emitted pulses. Drawing parallels from animals species bears an interesting question: What if humans had a sense for electroreception?

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Introduction
Some aquatic animal species like sharks, rays, and eels have developed a sense for electroreception. They mostly use it to spatially perceive the surrounding, navigate and communicate with other animals. Animals using passive electroreception purely measure the electric-field in their surrounding, while animals with active electroreception emit

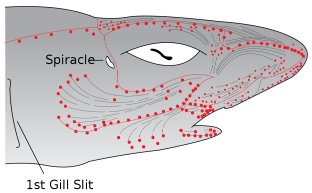

Figure 1: Ampullae of Lorenzi (red) distributed in a shark's head enable the animal to spatially perceive electric fields with high sensitivity. Photo: Chris_huh on Wikipedia.

and measure an electric field. Perceiving this electric field requires specialized organs like ampullary electroreceptors, a jelly-like structure under the skin of sharks [4] which is shown in Figure 1.

Weakly electric fish have developed electroreceptive capabilities due to missing sunlight, which prevented them from locating their prey under water [3]. The duck-billed platypus is one of the few mammals with electroreceptive capabilities—in total 41% of electroreceptive species are amphibians and another 41% are catfishes [3]. The platypus uses its electroreceptive sense to locate animals by generating an electric-field with its muscles [10], other species like eel have specialized organs for generating fields.

Weakly electric fish, such as the *eigenmannia virescens* from South America, use their electroreceptors to characterize the environment by measuring distortions of an electric field built up between their head and tail, also known as active electrolocation [1]. Such type of fish emit electric fields with frequencies ranging from 1 Hz to 10 KHz. When two fish with similar emitting frequencies come into perception range, they will even change their frequency to avoid jamming [16]. The dominant and male animals usually communicate with lower frequencies than their female counterparts.

Depending on a few human genes, it has been shown that electric fields can result in re-orientation of human cells [9]. However, an overarching sense for electric fields does not exist for humans and most terrestrial animals. Imagining a world in which humans could exploit this additional sense is within reach due to advances in wearable sensing and actuation technology.

The Electroreceptive Human

Animals with ampullary electroreceptors detect an electric potential difference between a pore of their skin and their inner body [4]. Having such electroreceptors would enable us humans to perceive the ambient electric potential with respect to our own human body potential—when either of both potentials changes, we would be able to perceive it. In the following, I will distinguish between (1) *body-centric perception* relating to perceiving one's own human-body electric potential and (2) *environment-centric perception* relating to the ambient electric potential.

Body-Centric Perception

Human activities, such as gait, modify the human-body electric potential due to changes in electric coupling to the environment. The human body is also able to accumulate and loose electric charge due to the tribo-electric effect, or contact charging, which contributes to the body electric potential. Additionally, our body's potential is influenced by local electric potential differences caused by muscular contractions, such as a beating heart. There are exciting parallels between imagining what we might perceive with this new sense and HCI and UbiComp research:

1. Due to the change of body-voltage when taking a step, we would have a much better sense for our gait and movements [2]. For example, we would be able to recognize when our shoes are in proximity to the ground [14, 6].
2. We would be very surprised how different shoes affect our electro-receptive capabilities. Shoes with thick soles would enable us to reach higher perceptual ranges due to the high static body electric potential. Walking barefoot would feel like we have lost much of our sense for body-centric perception [5].

3. Based on the change of our body electric potential, we could recognize what type of material we are walking on, e.g. whether we walk on carpet, wood, or on the street [5].

Environment-Centric Perception

The ambient electric field in our environment is a superposition of many individual electric field sources. These include electro-magnetic devices in our vicinity or the electric power line. Similarly to the body-centric perception, the ambient electric field is also affected by other humans. Moreover, electric charges that persist from human interactions with objects result in tiny electric fields covering our whole surrounding. Research in HCI and UbiComp has already contributed to the following possible sensorial impressions:

1. Indoors, we would feel the omnipresent phase and amplitude of the power line electric field. This would help us to determine our position within a room and we wouldn't need to rely on light in known dark indoor environments [15, 13].
2. Being close to a resting person, we could sense heartbeats in distances of many centimeters [12].
3. We could feel people approaching from the back, which would contribute to a more sophisticated sense for situations that are not within our field of view [6]. We would even be able to identify known people by their characteristic change in body electric potential while walking [5].
4. We would be able to feel electro-magnetic activity emitted by consumer devices and we could identify them [7].

Conclusion

Similar to the sense of hearing, many environments would often feel extremely noisy to us, especially if we weren't able to ignore electric fields on common power line frequencies. Like humans wear glasses, humans with electroreceptive capabilities might choose to wear specific footwear which raises their body electric potential. The amplitudes of the electric field sources are also very different, ranging from a few hundred milli-Volts for electro-physiological signals to a couple of kilo-Volts for the static human body electric potential accumulated when walking.

There are many technical difficulties on the way to provide a human with an additional sense for electroreception. However, with current advances in embedded technologies and the corresponding low-power sensors [2, 5], it is realistic to build such a device. Mateevitsi et al. [8] use a comparable approach by distributing ultrasound sensors over the human body and map distance to pressure. Other output modalities can include electric muscle stimulation, as presented by Pfeiffer et al. [11]. However, this would produce an electric field that is very hard to shield and would probably affect the electroreceptive capabilities of a device. We could imagine equipping a human with many tiny electroreceptors that are applied on skin - very much like a sticker. As ampullary receptors in animals reach deep into the body, it will be challenging for such a compact device to sense a difference in electric potential between the environment and the human body [2]. However, overcoming these challenges could result in tiny electro-receptive devices which convert the perceived electric field to a different modality, like electric muscle stimulation or mechanical vibrations. As the human intuition and understanding of electric fields is currently very limited, a real whole-body experience could stimulate new research ideas and lead to new discoveries.

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