# Beyond vision:
## The vertical integration of sensory substitution devices

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## 1. Introduction

The ability of blind people to navigate through unfamiliar environments cannot but make us wonder. It also leads to philosophical problems, which Descartes already captured:

> No doubt you have had the experience of walking over rough ground without a light, and finding it necessary to use a stick in order to guide yourself. You may then have been able to notice that by means of this stick, you could feel the various objects situated around you, and that you could even tell whether there were trees or rocks, or sand, or water, or grass, or mud, or any other such thing. It is true that this kind of sensation is somewhat confused and obscure in those who do not have long practice with it. But consider it in those born blind, who have made use of it all their lives: with them, you will find it is so perfect and so exact, that one might almost say that they see with their hands, or that their stick is the organ of some sixth sense given to them in place of sight (Descartes, 1637/1985, p. 153).

The development of refined conversion devices designed to compensate for blindness certainly makes Descartes' puzzle all the more actual and difficult to solve. These systems, which convert visual stimuli into tactile or auditory stimuli, give access to remote objects in a way that was not possible with white canes. Can these devices offer a genuine substitute for vision or do they merely compensate its loss through other means? The term chosen for these systems: "sensory substitution devices" (SSDs from now on) seems to have embraced the most ambitious solution considered by Descartes in his quote: SSDs enable blind people to see. These devices certainly offer at first glance a striking functional equivalence with vision: they respond to electromagnetic stimuli, they enable blind people to navigate in new environments, to detect and identify remote objects and to judge their approximate distance. Bypassing the constraints of the mechanical transfer at stake in the white cane, SSDs convey information about the surrounding objects which is *richer* than the information previously accessed through the intact sense. What's more, they can do so from a *distance*, independently of an actual contact between the device and the object. Blind people now have access to out-of-reach objects, a privilege reserved so far for the sighted. Although training remains necessary and performance uneven, Descartes'

first hypothesis seems to have been willingly embraced by most specialists in the field: users of SSDs are said to "see with their skin" (White et al., 1970) or with their ears.

While expressions such as "seeing with the skin" rightly express the strength of the intuitive assimilation of SSD-use to vision, they also reveal an underlying tension: how could blind people ever see? Claiming that they see appears to be an oxymoron: given that the definition of seeing involves proper visual processing, it is almost tautological to say that blind people, whose visual system is irreversibly damaged, cannot see. The initial idea that they "almost see" (Descartes, 1637/1985, p. 153) thanks to sensory aids might have to be taken in a non-literal way: isn't it more appropriate to say that they have gained or recovered something *like* vision, or close to it? Using a SSD provides blind people with what is often intuitively taken to be a "quasi-vision".

*Quasi-vision: visual or pseudo-visual?*

Once one agrees to take "visual" as a graded term, more difficulties arise: To what extent should we grant quasi-vision to trained users of SSDs? And more importantly: should we try to defend the quasi-vision hypothesis in our best philosophical accounts? These, in our view, are the two main questions to be raised if we want to draw philosophical lessons from SSDs. The fact that SSDs resemble vision at first sight, which we suggest to encompass as the intuitive claim that they are quasi-visual, seems to have led to two distinct philosophical theories. On a first reading, quasi has been taken to mean "same but less". The claim, shared by what is known as the "deference thesis", is that SSDs give a sense of vision, but to a lesser degree than regular vision. On a second reading, quasi only means pseudo-visual and theorists, encompassed under the "dominance thesis", want to stress that SSDs remain in the substituting modality, e.g. touch or audition depending on the device used. How comes that authors have reached such strongly opposite views? Each alternative must her be described in more details.

The first theory is nicely expressed in Heil's comment that "a person making intelligent use of a TVSS (Tactile Vision Sensory Substitution) may be said to be seeing (though perhaps only dimly) features of his environment" (Heil, 1983, p. 16). Heil implies here that SSDs differ from full-blown vision in that it provides a diminished form of it. Although this will be further clarified, this broadly means that SSD-users have a less exact or less powerful sense of vision. Trained users can indeed negotiate their way in simplified environments, with widely separated, very high-contrast objects (Collins, 1985; Jansson, 1983), but are much less successful with more complex tasks in real-world conditions, such as navigating through environments cluttered with small and low-contrast objects. They are better at recognizing simplified drawings than ordinary objects, not to mention complex scenes (Kim & Zatorre, 2008). When the "visual" acuity of blind persons perceiving information through a visual-to-tactile SSD has been quantified using a standard Ophthalmological test, acuity averaged 40/860 (Sampaio, Maris & Bach-y-Rita, 2001). These facts are sometimes forgotten when it comes to discussing the status of SSDs. They should temper any straightforward assimilation of SSD-use to classic or full-blown vision, and at least encourage the defenders of the deference thesis to follow Heil's moderate formulation.

This first philosophical interpretation of the intuitive quasi-visual status of SSDs still recognizes a difference between using a SSD and seeing. The general idea is that

visual impairments might well form a continuum, from total blindness to perfect sight, with blind-sight, color-blindness and various pathological cases in the middle, and that, by using SSDs, blind people get closer to the "sighted" side of that continuum. How close could they get to full-blown vision? Could they get closer than what is actually observed or is sensory substitution necessarily limited? This is not an easy question to address, and it certainly goes beyond currently available empirical evidence.

This has not prevented optimists from claiming that SSD-users can be, and will be one day, on an equal footing with sighted people, but most people who conceive of SSDs as being on a continuum with vision are more moderate: Heil, for instance, concedes that "it is, to an extent, misleading to describe a TVSS-user as seeing in an unqualified sense" (Heil, 1983, p. 145). Such claims make the thesis nonetheless harder to pin down. What is the "qualified" sense in which blind users of SSDs see? Could vision come in various grades or kinds? Some theorists defend indeed the idea that visual perception comes in degrees; in other words, that it is not an all-or-none state, but a skill with various degrees of mastery (Hurley & Noë, 2003; Noë, 2004; O'Regan, 2011). According to these theorists, people are more or less successful in seeing. SSD-users, although generally less successful, participate nonetheless in the same general skillful exercise of vision, along with people who rely on their eyes. Despite the difference in means (SSD vs. visual system) the two nonetheless result in access to more or less the same kind of information. The argument comes here from the way we individuate actions, by reference to their goals and independently of variations in means. We count cutting with a knife or cutting with an ax as the same kind of action; as a consequence, the case should be the same for seeing with one's eyes or through a SSD.

Such an interpretation of widespread quasi-visual intuitions comes with compromises, because it either obliges one to remain non-literal and accept a certain lack of clarity, or leads to abandon the classical definition of vision as a state. Is there a less compromising option? According to a second, more conservative interpretation, the notion of quasi-vision must be interpreted as "pseudo-vision". This intuition simply suggests that using a SSD can be *mistaken for* vision, that it looks like vision when it is not. "Seeing with the skin" or with the hand, as Descartes suggested, is considered to be only a way of speaking, not even an analogy. As Leon wrote, saying that TVSS enables sight is not persuasive:

> "It is not more persuasive than the suggestion that we would hear sounds
> and various properties by means of the eyes, simply because we observe
> an optical transformation of an aural input by using, say, an oscilloscope"
> (Leon, 1988, p. 252).

This second interpretation is more often favored by proponents of an all-or-none approach to perception, especially those who think that acquiring specific qualitative states is constitutive of vision. Using a SSD or a white cane is allegedly not like having a visual experience: it does not give characteristically visual sensations, like colors, the feeling of empty space or other modes of phenomenal presence of objects. There are different ways to extend the pseudo-visual interpretation, yet the most common is to claim that SSD-users still exert their intact sense of touch or audition, albeit in a more expert way. Audition or touch is recruited to achieve new tasks, usually performed through vision, but they do not become visual for this reason.

*A philosophical dispute*

The initial intuitions about the quasi-visual status of SSDs are vague and imprecise. This partly explains why they have led to such opposite philosophical interpretations. The representatives of the enactive tradition (e.g., Hurley & Noë, 2003; O'Regan, 2011; Noë, 2004), along with remote sympathizers of the Gibsonian notion of perception as a pick-up of information (such as Heil, 1983), claim that visually-impaired users of SSDs gain a sense of sight through learning. This can be maintained, according to them, even if the obtained compensation falls short of being perfectly similar to vision as we commonly understand it. By contrast, the pseudo-visual interpretation attracts the representationalists who put emphasis on the qualitative characters of experience. People like Block (2003) or Leon (1988), for instance, claim that the intact modality, where sensations are obtained, is dominant.

The main source of disagreement between these two theories comes down to the definition given to seeing. Is it sufficient to access the same kind of information or to respond to the same kind of stimuli for an ability to be defined as being visual? Is it possible to see without using one's eyes, or without enjoying any of the classic visual phenomenology of sighted people? These questions converge toward the more general problem of the individuation of the senses which has recently benefited from a resurgence of interest (see MacPherson, 2011, for an overview). However, this renewed interest has not spread to the field of sensory substitution, or at least it has not led to an interest in updating their philosophical and empirical understanding. On the contrary, it has rather led to the idea that SSDs are "not paradigmatic" (Gray, 2011) enough to constitute proper tests to assess the distinction between the senses. As a result, they have shifted out of the scope of recent discussions. At best, following Nudds (2004), they seem to encourage the negative conclusion that SSDs raise mostly terminological problems. As suggested by Gray (2011, p. 255), "the presence of disagreement can itself be regarded as providing some support for the anti-realist view that there is no mind-independent fact of the matter about the case" (e.g., whether TVSS-users see or not).

The aim of the present chapter is to correct this orientation. SSDs, we claim, can contribute to the debates about the senses. Our first goal is to bring the recent work about SSDs to bear on their philosophical understanding. First, we show why thinking of SSDs as more advanced white canes, or as they were in the 1970's, has led to an imperfect grasp of the quasi-visual dilemma. Recent empirical studies, detailed in section 2, show how complex and deeply integrated the use of SSDs is; making it harder, but also more crucial, to say whether or not they bring back a form of genuine vision. The next goal is to address this difficulty. The first lessons, as we show, are negative: SSDs provide good reasons to reject certain ways of distinguishing the senses, that is through an ecumenical combination of personal and sub-personal criteria (sections 3 and 4) as well as all single-criterion distinction between the senses which have been more recently attempted (section 5). This is, however, not a reason to think of SSDs as undecidable cases, or to embrace a form of anti-realism about the senses. Instead, we offer a way out of the dilemma. This comes with a third way of understanding SSDs as being "beyond vision". In the final section, we distinguish this thesis from the idea that SSD experiences could constitute a sixth sense. Although we agree with the later that the exercise of SSDs cannot be reduced to any of the existing modalities, and leads to some novel ability, our core

claim is that this novelty *emerges* from users' pre-existing sensory capacities, and does no longer align with them. The crucial challenge therefore comes from understanding the emergence or development of a new level, above the pre-existing perceptual one and its various sensory divisions.

## 2. The integration of SSDs

Understanding what the use of sensory substitution devices really gives rise to requires describing in more details what SSDs are. These devices were first developed in the late sixties to improve blind people's ability to navigate and identify objects (e.g., Bach-y-Rita et al., 1969). The principle they rest on differs from the mechanical transfer at play in white canes: they start with a series of sensors, most often a camera, which respond to certain electromagnetic signals. These stimuli usually accessed through vision are converted into sensory cues that are detectable through an intact modality. Devices such as the TVSS (Tactile Vision Sensory Substitution), the TDU (Tongue Display Unit) or the Optacon (Optical to Tactile Converter) convert these light signals into tactile stimuli, that is electromechanical or vibratory stimulation of different intensities and spatial distribution applied to the skin of a part of the body. In this case, the conversion from visual to tactile information is isomorphic. Other types of devices like the vOICe (Meijer, 1992) or the Vibe (Hanneton et al., 2010) capture the shapes of objects and their locations through a camera and convert this information into auditory signals. The conversion relies on a series of translations - for several relevant dimensions of the original signal - and follows the rule of a correspondence between the value of the original stimulus and the value in the new scale.

At first, and as was noted for instance by Leon (1988) or Ross (2001), perceiving with a SSD seems to be a form of indirect perception, analogous to the case where one indirectly sees the temperature of the stove through directly seeing its redness:

> "It may seem that use of a TVSS is a kind of vision without color. But while use of TVSS detects properties usually detected by vision - namely, spatial properties at a distance - and while its use can provide such information without reflective inference after a period of training, still its use is not a kind of vision because it is not a kind of direct perception. Rather, tactual properties are used as a basis to infer spatial properties" (Ross, 2001, p. 501).

The same interpretation could be applied to users of the vOICe *indirectly* accessing information about shapes through *directly* hearing certain sounds or patterns of sounds. However, this analysis proves to be inadequate. Many things have been encompassed under the heading of indirect perception. For the present purpose, and in line with what Ross means by the term, indirect perception is defined as a form of two-steps perception. It is supposed to be distinct from a two-step inferential process, with a first perceptual stage leading to a judgment. If one first *sees* the redness of the stove and then infers that the stove is hot, this does not qualify as indirect perception. One has to (indirectly) see the hotness of the stove *in* its color. A crucial difference with the inferred judgment comes from the fact that both the directly and indirectly accessed information are somewhat co-present in perception: one can see both color and warmth. For SSDs to be interpreted as indirect perception, users have to be able to perceive both the sounds and the shapes. This is not what is observed. Before training, people wearing the headphones of a visual-to-auditory device like the vOICe perceive noises. They later become able to perceive shapes through the

device, but then they are no longer able to perceive the sounds they first heard (unless they make a special effort to selectively attend to their auditory sensations). The initial auditory sensations disappear as users become aware of the distant shape. By contrast, people who indirectly see the temperature of the stove in its color are still able to perceive its color, independently of perceiving its temperature.

Similarly, with visual-to-tactile conversion systems, trained users no longer feel the tactile stimuli on their skin. In a much quoted report, Guarniero, a trained user of the TVSS (who was also a graduate in philosophy), explains:

> "Very soon after I had learned how to scan, the sensations no longer felt as if they were on my back, and I became *less and less* aware that vibrating pins were making contact with my skin. By this time objects had come to have a top and a bottom; a right side and a left; but no depth - they existed in an ordered two dimensional space" (Guarniero, 1974, p. 104 - quoted by Leon, 2011, p. 165; Heil, 1983; 2003, p. 228, 2011, p. 288; Peacocke, 1983, p. 15).

Capturing the exact nature of this transition is no easy matter. How does training allow users to move beyond the experience of stimulation at the site of the human-machine interface (such as the tongue or the ears) and become able to gain relevant information about the source-object? Recent studies have illuminated this transition, dubbed "integration". We think it is necessary to distinguish carefully three aspects of integration often associated in the literature. Unlike cochlear implants for instance, SSDs are worn intermittently and are not therefore fully anatomically integrated. The term "integration" is rather meant to capture the effects of familiarization with the device. It encompasses three different aspects that will subsequently be described in more detail: distal attribution, direct acquaintance and generalization.

*Distal attribution*

First, training with SSDs results in what is called "distal attribution", and what some philosophers would be happy to call "intentionality": the received information is taken to be *about* an object which appears to be independent of the perceiver. The expression, as much as the correlated philosophical notion, has to be handled carefully. Distal attribution is often considered to be synonymous with *spatial projection*. It is thought to occur when the sensations felt on the skin or in the ears are projected onto a distant perceived object, which should correspond to the one captured by the camera. Being perceived as distant in space is nonetheless not necessarily conceptually equivalent to being perceived as mind-independent (e.g. objective, see the debates around Strawson, 1959, for instance in Evans, 1980 and Burge, 2010). First, for certain SSDs, the sensor needs to be in contact with the to-be-perceived object, so that distant objects cannot be accessed. The Optacon, for instance, and its predecessor, the Optophone, functions more like a scan, as pages of written text need to be put in close contact with the sensors before being converted into tactile Braille stimuli. Note that tactile-to-tactile SSDs also start with contact sensors. Second, SSDs could be designed to compensate for the loss of a contact sense. This has actually been the case for instance with SSDs compensating for the loss of touch (e.g., see Bach-y-Rita et al., 2003) or pain (Brand & Yancey, 1993), which do not give access to remote objects.

Leaving the variety of current and possible devices aside, finally, what seems to be crucial for the most well-known visual-to-tactile and visual-to-auditory SSDs is not so

much the projection in distant space, but the transition from an egocentric representation of space to an allocentric one. In other terms locations are not just represented with respect to the users' perspective, but within a external frame of reference which is independent of their actual position. As Guarniero (1974) reported, the objects seem to the user to have "a left and a right", and not just to be felt relative to her own left and right. What distal attribution brings is first and foremost the perception of objects as being independent from the observer.

*Direct access and transparency*

Integration also involves a second transition: users become "directly aware of the distal object" (Siegle & Warren, 2010, p. 209). What this means is that the information about the independent objects *seems* to be delivered immediately, e.g. literally not through the mediation of a sensational episode. This aspect is mainly apprehended through subjective reports and remains hard to interpret further at this stage. Most often, sensations in the intact sensory modality are said to somehow be merged into a new percept, from which they become inseparable. People perceive the shapes of objects, not sounds, when they use the vOICe.

The integrated use of SSDs may count then as a form of *transparent* access: perceiving the object is no longer dissociable from what it is like to use the device, in the same way as perceiving blue is not dissociable from what it is like to see blue (Tye, 2002). There is however an alternative interpretation, under-estimated in our sense, according to which sensations remain present per se, but are less attended to (see for instance Noë, 2004).

In summary, immediacy, directness and transparency are hard to define (see Smith, 2002, for a discussion). They are also difficult to separate and assess empirically (Auvray et al., 2005, 2007-b; Siegle & Warren, 2010).

*Generalization to new objects*

The third aspect of integration comes from what is called "generalization". With training, users are able to recognize objects or to navigate in environments which differ from the ones they have been trained with. This crucially shows that their learning can be transferred to unfamiliar situations and therefore does not just reduce to memorized routines about familiar cases (Auvray et al., 2007-a; Kim & Zatorre, 2008). For instance, having learnt to recognize a plant during their training, users of the vOICe are subsequently quite fast in learning to identify another plant. Although generalization to new objects therefore remains limited, and deserves further study, it crucially rules out the hypothesis that SSD-users proceed only on the basis of associative memory: users do not only learn to associate a specific pattern of sensory stimuli (a certain sound, a certain pattern of tactile vibrations) to a specific object or kind of object. Identification goes beyond the memorized associations and, as we just said, users are able to identify another pattern of sensory stimuli as being a new object of the same kind.

The data need here to be very carefully interpreted: background knowledge certainly plays a role in the use of SSDs, as it does in everyday navigation or identification. In a recent study, Siegel & Warren (2008) have shown that people who are told to attend to proximal stimulation  do less well with a visual-to-tactile minimalist device than people who are told to directly attend to the distal source of stimulation. Having

active training noticeably helps with the generalization of learning. But, as the evidence stands, nothing rules out that conceptual knowledge and explicit rules do not provide users with other advantages, or good-enough substitutes. How much knowledge *that* and how much knowledge *how* – or practical mastery – enter in the integration of SSDs is certainly a hot topic for discussion; and above all, investigation. Anyhow, the fact that there is a form of spontaneous generalization, on the basis of previous use and not requiring as much new training, can be taken as similar to perceptual learning, where for instance people do not need training to recognize new textures or new shades of color.

As we can see, the evidence gained from the integrated use of SSDs encourages the intuitions that SSDs are quasi-visual: Gaining information in an immediate way, about new independent and possibly remote objects is almost like seeing. But is the status of SSDs thereby clarified?

## 3. In which sensory modality do SSDs get integrated?

The ambiguity remains between the "same but less than vision" theories (or deference thesis) and the "not-vision" theories (or dominance thesis). Overcoming this ambiguity requires explaining how and where to draw the line between seeing, touching and hearing. As Nudds (2011) rightly wrote, the individuation of the senses is itself an intuitive matter, calling for further clarification:

> "The distinction we make between the five senses is universal. Instead of saying in a generic way that we perceive something, we're talking about a perception in one of these well defined five modes: we see, hear, touch, smell and taste things. But what exactly is our distinction, when we identify these specific ways of perceiving things? What is, in other words, a sensory modality?" (Nudds, 2011, p. 311).

The vagaries surrounding the status of SSDs may reflect the vagaries of our concept of a sense. Instead of discouragement, this brings some hope that clarifying our theorizing about SSDs will shed some light on the distinction between the senses.

*Four criteria to distinguish among the senses*

Among the various attempts to analyze our intuitive distinction between the senses, the most famous one came from Grice. In his 1962 paper, he proposed a list of the main criteria along which this distinction could be drawn. They can synthetically be specified as ranging over characteristic phenomenology, intentional objects, kinds of stimuli and dedicated processing.

The most immediate distinction between our senses comes from experience. Seeing usually does not feel like hearing or touching. Each sense corresponds to a specific kind or family of feelings; what Grice called "special introspectible characters".

> (Phenomenological criterion). Two senses, S1 and S2, are different as far as they give rise to experiences with different kinds of subjective feelings or conscious qualitative characters.

This later criterion is reminiscent of Descartes' (1637/1985) remarks: what makes us think that blind people have a form of vision when using their canes, results from an analogy with our own phenomenology or experience. *What it is like* for us to be

moving in a room with a stick could be confused for *what it feels like to see*, and therefore, the same might be true of blind persons.

The first comparison needs of course to be taken cautiously: what does it mean to say that touching a stone with a stick feels like seeing it? On the one hand, this might be a real experience – feeling the shape of the stone through the cane. On the other hand, it might only mean that one recognizes the object explored with the cane, and when identifying it as a stone through her background knowledge, recalls the how a stone looks like. . The phenomenological criterion is not supposed to apply to this form of associated imagery. The senses are supposed to be different regarding their specific phenomenal modes of presentations, or kinds of experiences. The difficulty to apply this criterion is here illustrated by the difficulty to distinguish bewteen "feeling like seeing" and "feeling like one is acquainted with an object associated to a visual image". Considering at an abstract level what it is like to see, independently of what is seen, is a difficult task, perhaps an impossible one (Tye, 2002). The first criterion is strongly tied up with a second one, spelled out in terms of the objects or properties which are perceived. Note that these intentional objects are not necessarily identical (nor reducible) to physical objects or properties.

> (Object criterion). Two senses, S1 and S2, are different as far as they give access to different characteristic kinds of objects or properties.

This second criterion is very much reminiscent of the old Aristotelian way of drawing the distinction between the senses in terms of "proper objects". Vision can for instance be defined as the perception of colors, and hearing as the perception of sounds. It is important here to note that the distinction remains a *psychological* distinction: proper objects are intentional objects that do not necessarily correspond (or at least not exactly) to physical entities. Saying that vision's proper objects are, for instance, colors and visual shapes, does not presume of what colors and shapes are, metaphysically or physically speaking. This said, it is clear that this criterion considers sensory modalities as ways of accessing information: the question is what kind of information is *presented* to us, and how. This way of conceptualizing the senses leaves aside the fact that senses are also organs and physiological circuits; e.g., they correspond to ways in which this information is *delivered*.

Two additional criteria are needed to capture this aspect. The first one appeals to a difference in terms of range of responses. Different senses are sensitive to different changes in the environment:

> (Stimulation criterion) Two senses, S1 and S2, are different as far as they respond to different kinds of physical stimuli.

Furthermore, the different stimuli serve as inputs to different and independent kinds of processing, which can be specified in computational and neurological terms. This criterion is also sometimes put in terms of sense-organs or kinds of receptors.

> (Processing criterion) Two senses, S1 and S2, are different, as far as they correspond to independent processing and neurological channels, or to different sense-organs.

A perceptual episode, for example, is visual if it is initiated by the stimulation of the retina by light-waves, which results in the activation of the optic nerve and brain

areas V1 to V5 in the occipital lobe. Another episode is auditory if it begins with the vibration of the eardrum, generated by acoustic waves, and extends through the activation of the auditory nerve and another part of the cortex, the temporal lobe.

*Adapting Grice's distinction*

Our definitions of the four criteria depart from Grice's ones in two important respects. First, the definitions are all formulated in "as far as" conditions. This is crucial to enable a graded application, needed to account for "quasi" cases like SSDs. Absolute criteria, such as the ones that Grice used, restricts assimilation to a sensory modality to a perfect match with their specific conditions. In other terms, the phenomenology, object, stimulation and/or processing must be *perfectly* identical to what they are in sighted people, for something to count as seeing. This requirement can be criticized as being too "anthropocentric", the objection being that animal creatures might be granted a sense of vision in the absence of such perfect identity. Dogs have a sense of vision, although their experiences and neurological wiring might not be exactly similar to ours. Likewise, we argue, it is too "traditionalist" and also detrimental to the various realizations of vision (and other modalities) in human perceivers.

A second difference with Grice's view comes from the relation between the criteria. Grice's agenda was to show that the four criteria are all closely connected, although some have more importance than others (i.e., intentional objects and characteristic experiences). Here, we want to remain neutral about their connection or independence. Our concern is indeed to see whether or not they help to clarify the status of SSDs, be it in combination or in isolation.

## 4. Why SSDs challenge the ecumenical conception of the senses

As stressed by Grice, the common-sense distinction between the five senses builds on all four criteria. It encompasses broad ideas about access as well as delivery. Vision for instance is taken to involve a certain kind of experience, to be about a certain range of objects and properties, to be obtained through the visual system and to start with specific stimuli. Problems arise when one wants to articulate more precisely these different criteria.

The combination of the four criteria creates immediate problems for SSDs, as they do in other respects (for instance, in animal perception, see Matthen, 2007). A device like the vOICe for instance comes out being both visual and non-visual depending on what definition of a sense one has in mind, and which criterion is applied. *Phenomenologically* speaking, the experiences are not canonically auditory, but they are not canonically visual either. Yet the *objects* that are perceived definitively seem visual. In terms of *stimuli*, both auditory and visual ones seem to be involved in the functioning of the headphones and the camera. Yet the sense-organ (i.e., *processing* criterion) which is used is certainly not visual. This at least explains the quasi-visual intuitions as coming from the contradictory results of these criteria. In terms of access (e.g. how it feels like to access such and such proper object), a device like the vOICe can be characterized as neither visual nor auditory, but might still strongly come out as visual if one considers the object as a visual one. In terms of delivery (e.g. what kind of stimuli and processing are involved), the vOICe counts both as visual and auditory, with a common-sensical inclination for the auditory side.

If one wants to maintain the four criteria, it then seems at least necessary to accept that not all of them are equally important. But which one of the four should prevail in the definition of a sense? Several factors might encourage philosophers to privilege the criteria of intentional objects and stimuli. These two criteria are the less hazardous, because they don't rely on subjective reports (like the phenomenological criterion) or on what can seem to be still unsettled or at least fast-changing neurophysiological accounts (like the processing criterion). Moreover, widespread representationalist tendencies support the criterion of intentional objects over the other criteria, whereas the also frequent physicalist sympathies tend to stress the criterion of environmental stimuli. Note that these two criteria will make SSD-use come out as visual. If the idea is to still acknowledge that the other criteria do not go in the same direction, it is possible to put them further down the list and add some nuance to the philosophical assimilation of SSD-use to vision, like in Heil's proposal (1983).

We believe that even this nuanced assimilation of SSD-use to vision is still too rapid and needs to be further qualified. The privilege given to the criteria of intentional objects and environmental stimuli is not appropriate when dealing with SSDs. In systems such as the vOICe or the TVSS, the human-machine interface is designed to provide access to "visual objects" (e.g., objects and properties which are equivalent to objects and properties normally accessed by the sighted). The interface is also designed to start from inputs that are traditionally visual. Putting the criteria of intentional objects and stimuli first offers a trivial reformulation of the initial goal: SSDs are designed to function as visual, therefore they are visual. This reformulation does not make a distinctive contribution in defending the real visual status of SSDs. The problem is not "what are SSDs used *for?*" but rather "*how* are they used?". It is a descriptive, and not a design or functional, question. The former question remains unanswered.

## 5. SSDs challenge the single criterion approaches

If the combination of criteria raises problems, adopting a single criterion could lead to better results. Each of the four Gricean criteria has been thought, in turn, to be sufficient to draw the line between the senses - be it phenomenology (Leon, 1988; Lopes, 2000; O'Dea, 2011), stimulation (Gibson, 1966; see also Heil, 1983, 2011), objects (Roxbee Cox, 1970; Everson, 1999), or processing (see for instance Milner & Goodale, 2008, for a discussion in the domain of vision). Do single criteria perform better in clarifying the quasi-visual status of SSDs?

*The phenomenology criterion*

The application of the first criterion introduces a methodological problem: this criterion cannot be investigated from a third person perspective. It is impossible to specify what the experience of trained blind people are really like, for instance what a user of the vOICe really feels. We can only apprehend the associated phenomenology by using the device ourselves. However, even if we do so, there is no certainty that our experiences would be qualitatively similar, or even comparable to those of another user, and especially to those of a blind user. Taken at face value, the most recent studies tend to stress the inter- and intra-individual variations in the experiences enjoyed by trained users of SSDs.

One standard way to investigate other's conscious experiences is to ask them what they are like. This methodology was applied in a series of interviews in which some blind users of the vOICe surprisingly reported visual phenomenology, involving colors, but limited to certain kinds of objects (Ward & Meijer, 2010). One of them for instance describes:

> "One day I was washing dishes and without thinking I grabbed the towel, washed my hands, and looked down into the sink to make sure that the water had got out and I realized Oh! I can see down. I can see depth."

Later on, she claims:

> "Over time my brain seems to have developed, and pulled out everything it can from the soundscape and then used my memory to color everything.
> JW: But if you look at someone's sweater or pants you wouldn't necessarily know the color? It could be blue or red.
> PF: My brain would probably take a guess at that time. It would be grayish black. Something I know such as grass, tree bark, leaves, my mind just colors it in" (from Ward & Meijer, 2010, p. 496).

It is very difficult to know what to infer from these reports. The origin of the visual, color imagery is crucial for the application of the phenomenological criterion. It is important to know whether or not the visual phenomenology is truly perceptual, or just given by imagination or memory, and then simply added to a more confused set of non-visual qualities obtained when using the SSD. Another related thing to be checked is what kind of visual imagery is exactly at stake. Blind people may not be best qualified to report on this point.

In their study, Auvray et al. (2007-a) asked sighted participants what it felt like to perceive with the vOICe. The replies varied importantly. While some of the participants claimed that their experience was close to vision, some claimed it was more like audition. The idea that the phenomenology is neither exactly visual nor exactly auditory was confirmed by the fact that some thought that their experience was best described as tactile or even olfactory. Some even reported that their experiences felt more like a sonar sense. Furthermore, the phenomenology differed depending on the task that was performed: most of the participants gave different descriptions of their qualitative experience for localization tasks and recognition tasks. One of the participants for instance felt that her experience was visual when he was locating an object in space, but auditory when she was recognizing the shape of the object.

The lesson of this survey is twofold. From a methodological point of view, it questions users' ability to establish classes of similarities between their experiences, and thus to apply the phenomenological criterion in a rigorous or consistent way. For the present purpose, it shows that the phenomenological criterion is not sufficient to determine whether users of SSDs see or not. The phenomenological criterion is by itself not stable or accurate enough to go beyond the intuition that using a SSD is quasi-visual.

*The object criterion*

The object criterion proves easier to assess. Trained users of SSDs are able to navigate in new environments, and to make sometimes coarse, but still accurate

judgments about shapes and distances of remote objects. They rely on something that audition or touch cannot usually provide, and have acquired something closer to vision. But the distinction in terms of kinds of objects does not prove more helpful when it comes to move beyond this general characterization.

There are indeed limits to the application of the object criterion in isolation. Distance is accessed both by sight, audition and other distal senses. At best, therefore, if users of SSDs are able to make distal attribution, they can be said to exercise a distal sense; whether it is visual or not remains open. Shape is not the *proper object* of sight either, as it can be accessed through touch as well. None is therefore sufficient to declare SSD-use as being characteristically visual. A more promising suggestion comes from combining the two kinds of information, given that the joint access to distance and shapes seems distinctive of vision. Audition gives information about distances, but only limited and approximate information about sizes of the sources; touch provides information about shapes, but not at a distance. But in SSDs, the question remains open as to whether the two kinds of information can be accessed jointly or, as suggested by the previous experiments (Auvray et al. 2007-a), they are distributed in two distinct perceptual tasks (localisation and identification).

A second limit is that certain key visual properties are lacking in the experience of SSD-users. Their perception is limited to a smaller number of dimensions. Brightness and color, for example, are recognized as being specific to vision, yet they are not accessed through the vOICe or the TVSS. The objection, however, is still not decisive. First, this is an actual technological limit and should not be taken for a principled impossibility. Current systems could be made to code for brightness or color: the relevant sensors are available and the conversion can be performed. SSDs could theoretically give access to all the contents which are specific to vision. The main problem comes again from the joint experience of dimensions. Each dimension in the lacking modality needs to be translated into another dimension in the intact modality, and it seems this time a real impossibility to map all visual dimensions at once in modalities which have less dimensions like touch or audition.

The object criterion remains compatible with the two horns of the dilemma. It is true that SSDs give access to a lesser number of properties than regular vision. This may mean that they are on a continuum with vision, or that they remain in the intact modalities, which share access to these properties. The object criterion is finally no more conclusive than the phenomenological one.

*The stimulation criterion: starting with electromagnetic waves*

The criterion of environmental stimuli provides a clear answer, if one agrees to consider the user and the device as a single system: the stimulus to which the overall system responds is the same as vision, since the sensors detect electromagnetic differences. The difficulty in applying this criterion comes this time from the way to accommodate the non-visual, intermediate step. What counts as "stimuli" could be either the light-waves received by the captor or the auditory or tactile stimuli they get converted to by the device.

Note here that the stimulation criterion is distinct from the phenomenological one, about whether users feel auditory *sensations* when using the vOICe. The question concerns the role of the auditory *stimuli*, which undeniably occur. On the one hand, these auditory stimuli only exist because of visual stimuli: both their existence and

their nature depend on electromagnetic waves. This strict dependence on visual stimuli makes them purely parasitic and somehow dispensable in the understanding of the input-output process. To take an extreme analogy, one does not count the chemical transduction of information through sensory channels as a sign that chemical stimuli are relevant for the functioning of every sense. On the other hand, auditory stimuli are certainly *necessary* for the proper functioning of the device they are also constitutive of the way these SSDs have been designed. Switching from visual-to-auditory devices to visual-to-tactile devices for instance requires a complete new design, and training. The distinction between the senses in terms of stimuli does not deliver a single answer to the dilemma.

*The processing criterion*

The answer given by the strict application of the neurophysiological criterion is no less problematic. The distinction between the senses has sometimes been thought to be only a matter of sense organs. Following this line, Morgan (1977) pointed out the similarity between the visual system and the TVSS: in both cases, an image is formed on a bi-dimensional surface (the retina in the case of vision, the lens of the camera for the TVSS), this surface contains discrete elements (rods and cones in the eye, vibrators for the TVSS), these elements are connected to certain regions of the surface (receptive fields) that send electrical signals to the brain, the device (eye or camera). The sensor (eye or camera) can be moved, and its movements introduce changes in the image. Moreover, these two systems are similar in that the source of stimulation is remote and sensing is subject to the effects of occlusion, when an obstacle comes between the source object and the detection system. But are these structural similarities sufficient to conclude that the two are one and the same sense? The animal kingdom provides a perfect illustration of the difficulty: it is commonly said that dogs "see". These creatures are equipped with detection systems which share some similarities with the organ of vision. It is more cautious to say that perceiving through these organs, or devices, is distal and discrete. Vision, hearing and many other senses can be grouped into this category, thereby denying the possibility to decide over the visual status of SSDs on such a criterion.

Can further neurological investigations help? Recent studies have shown increased activation in visual areas in trained users of visual-to-auditory (De Volder et al., 1999; Renier et al., 2005) and visual-to-tactile conversion devices (Ptito et al., 2005). There is thus a recruitment of visual areas through brain plasticity. Applying the processing criterion suggests that blind users acquire a form of vision: if perception recruits a channel identified as visual, it counts as visual.

We must however be cautious with this sort of inference: the studies which motivate the claim that the occipital lobe is visual have been performed on sighted, and not blind, people. Interestingly, Ptito et al.'s (2005) study revealed increased activation in the visual cortex only in trained congenitally blind people, but neither in sighted ones reaching the same level of performance, nor in untrained people from both groups. We must also not forget that calling this area visual results from a functional mapping and that a common area may not be functionally similar in two groups of people, noticeably blind and visually impaired people.

Increased activity in a given brain area does not indeed prejudge of the associated function. In accordance with this conclusion, Kupers et al. (2006) used transcranial magnetic stimulation (TMS) in both blind and blindfolded sighted participants' visual

cortex before and after training with a visual-to-tactile conversion system (the Tongue Display Unit). When TMS was applied over the visual cortex before training, none of the participants reported any subjective tactile sensation. However, after training, when TMS was applied over the same brain area, some (but not all) of the blind participants (3 out of 8 early blind and 1 out of 5 late blind) reported somatopically organized tactile sensations that were referred to the tongue, whereas no such sensations were reported by sighted participants. The authors concluded from their data that the subjective experience associated with increased activity in the visual cortex after practice is tactile and not visual (see also Ptito et al., 2008, for similar results with Braille reading).

The application of the sole processing criterion does not deliver a definite answer. What is shown at best is that using a SSD is distal, which we knew already from the study of SSD integration; and that it requires some further perceptual processing, which can recruit un-solicited areas like V1 in blind people. Should we conclude that calling SSD visual or not is just arbitrary or, as suggested by Nudds (2004), a matter of pragmatic decisions, but offers no fact of the matter? This instrumentalist line, we argue, can be resisted.

## 6. When integration leads to emergence: SSDs as vertically integrated abilities

It is impossible to clearly answer the question of whether blind people "see" or "hear" when using the vOICe through any of the usual accounts, whether they rely on a combination of criteria or a single privileged one. As we reviewed these criteria, it nonetheless became clear that the integration of such devices have noticeable effects on their users. In other words, the results obtained with any of the criteria, are relevantly different between SSD-use and perception in one of the existing modalities (either the substituted or the substituting one).

The mistake comes, we claim, from not acknowledging this difference and trying to square SSD-use with one of the existing sensory modalities. The application of the criteria thus should lead to a more qualified re-description of the effects of SSDs integration:

(Phenomenological criterion). Using a SSD leads to subjective impressions that cannot easily be compared with experiences in existing modalities.

(Object criterion). A SSD can give access to a variety of objects, constrained by the initial design and the number of dimensions in the stimulated modality.

(Stimulation criterion). A SSD uses a series of inter-dependent stimuli.

(Processing criterion). Integrating a SSD requires some supplementary neurological processing.

Altogether, these criteria lead to the conclusion that SSDs introduce something new, which, albeit intimately connected to the intact modality, does not reduce to it. It also strongly depends on the otherwise lost modality – which governs the design, e.g. the selection of stimuli and kinds of conversion. What emerges is an experience which is relevantly different from both, while it can also somehow be reminiscent of either of

them, at times. The best way to capture this novelty is to think about the integrated use of a SSD being something closer to a new set of automatic recognition abilities emerging from other sensory modalities and other pre-existing capacities. Unlike other senses, whose developments occur in a parallel way, SSDs are modes of access and delivery which fundamentally emerge – technologically and cognitively – once a certain degree of development in the existing senses has been achieved.

Several recent accounts point toward the "emergence thesis". As detailed in Auvray and Myin (2009), SSDs are better thought of as mind-enhancing tools than as being visual or auditory. Following Clark's (2003) lines, such tools provide means to carry out cognitive functions in ways that would have been impossible without them, given the intrinsic or initial properties of the system. Accordingly, SSDs provide cognitive or perceptual extensions to the existing senses. Starting from a different perspective, Nagel et al. (2005) designed a SSD for entirely new intentional objects. They equipped participants with a "magnetic belt" which gave them some brand new information about changes in the magnetic field. With training, users were able to track their orientation relative to the cardinal points. The authors' main point was to establish that trained users had acquired a new "modality", e.g. a new sensorimotor skill. They nonetheless reckon that their results form a transformation of the existing spatial perception:

> "Strictly speaking, the changes in perception indicate not a genuinely new modality, but modification of the meta-modality of spatial perception. The term 'metamodality' is used to reflect the fact that normal spatial perception is fueled by visual, auditory and somatosensory information. The ability to infer spatial information from these pooled 'primary' modalities may have thwarted our objective to create a completely new sensory modality. Instead, the acquired sensorimotor contingencies lead to a transformation of this already existing meta-modality" (Nagel et al., 2005, p. 23).

The most noticeable aspects of SSDs come from their non-reducibility to the existing senses, and their dependence on them. As suggested by Nagel et al. (2005), the successful use of a SSD would not have been possible without the existing resources, in this case in terms of intentional objects (spatial orientation) and stimuli (tactile vibration). Their non-reducibility and dependence on existing senses are constitutive features of SSDs, consequently their use is best captured by the idea of an emerging ability.

This new thesis changes radically the way integration should be understood, that is not in a *horizontal way*, with SSDs fitting, so to say, among or in between the existing senses, but rather in a *vertical way*, with SSDs coming on top and depending on the pre-existing senses. It also crucially solves Descartes' puzzle. SSDs are neither less than visual, nor just pseudo-visual; and consequently the deference – dominance debate does not really make sense. To stick with the expression, the better way to conceive of SSD-use is that it goes *beyond* vision and audition (in the case of the vOICe) or touch (in the case of the TVSS).

## 7. Conclusions

We have confirmed and extended the idea that SSDs cannot be squared with our common-sense and philosophical models of the senses. The common-sense intuitions that SSDs are somehow visual lead to a dead-end. As we have shown, they result in a

philosophical dilemma which proves impossible to overcome, and this, independently of the way one chooses to define vision. Recognizing this aporia is, we contend, an important first step which clears the way for a better understanding of sensory substitution in general. Contrary to Gray (2011), we have tried to show that the impossibility to fit SSDs into the existing classification of the senses should not lead us to abandon any hope to fit them more broadly in our typologies of the mind. The emergence thesis takes us out of the initial dead-end of the visual - not-visual dilemma, by refusing its two horns and resorting to a third option.

This third option goes further than the idea of a new emerging modality. According to us, these emerging capacities brought by SSDs do not and cannot figure on the same list as the natural or existing senses. We need to open another list, *on top of the first one*, to account for SSD-use.

This new theory allows us to think about integration in a vertical and not horizontal way. It avoids philosophical confusions and offers better ways to understand and push forward and higher the philosophical and empirical investigation of sensory substitution devices.

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