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Primacy of Vision over Touch: A Brief Study of the Tactile Performance of the Blind in Contrast to the Sighted

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ABSTRACT

One of the issues in perception research that continues to be a matter of intrigue and moot point for both philosophy of perception and its neurophysiology is how vision can play an active role in the haptic adeptness of the visually deprived, especially the congenitally blind and the early blind, if it is granted that visual and tactile modalities follow two different routes of processing of information in the brain. Traditionally, philosophers adhering to the empiricist tradition, such as Berkeley and Locke have maintained that although visual and tactual modalities share one thing in common in that they can process the same object property like figure, spatial properties like distance and motion, the mode of visually grasping any of these properties is at variance with that of haptically perceiving them. This view offers one alternative to a locus classicus in this field of study — the oft-cited Molyneux's dilemma over whether a long-time blind person familiar with object shapes through touch would also be able to identify the shape for the first time if he ever recovers his visual sensory capacity. In this brief study evidence has been collated, examined and analyzed in support of another alternative to Molyneux's question. In this alternative, a case has been made for a robust visuo-tactile interplay. Another question this study addresses is whether the skillfulness perceived in vision-mediated tactile performance sparked by loss of vision or forced visual deprivation is an outcome of compensatory but de novo neural restructuring or indicates an integral, latent capacity for neuroplasticity that harnesses visual or spatial imagery so as to help the visually deprived sail through tactile identification and discrimination activities.

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Introduction

People with minimal or zero vision are known to be many times efficient recognizers of their environment in greater detail than the sighted mainly through the reliance of touch. In a significant number of cases it has been observed that they do not just navigate along the road, identify patterns and discriminate textures with skillfulness on a par with the sighted, they also prove themselves remarkably good performers of other high-level cognitive tasks, such as reproduction of semantic expressions by retaining non-visual memory of verbal language. As the body of such evidence of the blind performing vision-dependent tasks with high level of accuracy grows, the question that starts plaguing the mind is whether these skills are predominantly learning-dependent, or the deprivation of visual inputs into the neural pathways of the blind tweak the brain into drawing up a different blueprint so that non-visual inputs can be made visually effective. Confining our investigation to the tactile sensitivity of the blind for work that would otherwise largely depend upon visual cues, we would in this short paper try to shore up the latter hypothesis by gathering evidence that the brain of the blind person is not bogged down by the non-availability of visual information, but rather tries to compensate for it by activating regions of the brain that would otherwise have processed sensory inputs travelling from the optic nerves. One would, however, not believed in this phenomenon now widely referred to in the neurophysiologists' parlance as "cross-modal plasticity", if one were to stick to the view as philosopher Berkeley did, that "sight and touch make two species entirely distinct and heterogeneous"(Berkeley, 1710[1972], pp. 84-85). In his *An Essay towards a New Theory of Vision*, we find Berkeley repeatedly trying to drive home the idea that the ideas of sight and touch are so opposed to one another that the two cannot be imagined to overlap. This can of course be accepted as a naïve assertion insofar as we know that the object of sight is light and colour and these two cannot be the object of apprehension. But Berkeley's suggestion seems to go beyond this when we hear him say that the visual judgment of a particular shape of an object as "round" and the tactual judgment of "round", if used equivocally would make no sense; that would be an ambiguous use of the term. What Berkeley appears to point out here is that visual extension is radically different from tactile extension, which means the term "round" cannot be used to describe a *seen* shape in the same way as would be applied to describe a *touched* shape. Thus, his answer to the epoch-making question Irish philosopher and scientist William Molyneux posed to Locke in 1688 about the possibility of a blind person, whose vision was restored, recognizing a sphere or a cube which he had all this while known only via touch is an emphatic no. If there is no shared connection between vision-based knowledge of shapes of objects and knowledge of the same gathered by touch, then there is no reason to suppose why the blind person after gaining sight would immediately visualize a shape of which he has hitherto received only tactile output. Berkeley therefore does not take much pain to propose that the visual

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information of the shape of an object and the tactile information of the same shape lie in two never-overlapping regions— a *seen* shape is as different from a *touched* shape as chalk and cheese.

One might here of course offer to account for the inability of the blind person in recognizing a sphere or a cube by pointing out the lack of visual exposure. If this were a generic solution to the paradox of the previously blind but now sighted person not being able to identify shape without touching it, then we could have easily countered the view of Berkeley. He then had to concede by the exigencies of his own position that although the *seen* shape might still be radically different from a *touched* shape, experience could at least help teach the blind that the visually perceived pattern serves as "prognostics" of the same perceived by tactile modality. As he himself admitted:

"… visible ideas are the Language whereby the Governing Spirit on whom we depend informs us what tangible ideas he is about to imprint upon us, in case we excite this or that motion in our own bodies."(ibid., p. 85)

However, the absence of visual accompaniment to tactile sensation may not provide us with a ceteris paribus ground for the paradox for one should be on guard not to rule out other incapacities of the blind person which may not necessarily be related to his visual deprivation, as William James cites instances of blind persons who in the same condition could tell a shape right away. This James points out serves as an a fortiori evidence that "…the analogy of inner nature between the retinal and tactile sensations goes beyond mere extensity" (James, p. 211) and instead of citing the lack of visual exposure as a generic reason for the inability, degrees of difference in individual cognitive adeptness needs also to be admitted to explain why some blind people may not be able to recognize a shape by vision at first sight. However, a more scathing objection can be brought against Berkeley's contention. The main reason why Berkeley's answer to Molyneux's question is negative is he believes that the visual sensation and tactile sensation of a shape are mutually exclusive, which results in the verbal reference to the shape perceived on one hand by vision and touch on the other having two different meanings, and the same term cannot be used for denoting the two modality without landing in ambiguity. One might here contend that whether the term "round" or "square" actually is employed with such exclusive meaning, one for visual "round" and another for tactile "round". G. J. Warnock, one of the interpreters of Berkeley's philosophy argues:

"… there are two conjoined criteria for its use— how things look and and how they feel. If an object felt round but looked square, or felt square and looked round, we would never say that it was round 'in one sense', but not in another; we would not know what to say about its shape at all. The normal conditions in which we use the word 'round' would simply have broken down; and the plain fact that in this case we would be utterly baffled, and would not at once speak of its being round 'in one sense of the term', shows that there is no *ambiguity* about it. There are *two ways* of telling what shape an object is; but this does not mean, as Berkeley suggests, that there are *two shapes*, one visible and the other tangible." (Warnock, 1969, p. 41)

A significant number of studies in contemporary times however tend to disconfirm Berkeley's belief as the results from these studies point to a vision-touch interlocked processing in the blind triggered supposedly by sensory differentiations explaining why the blind are as good as and sometimes even better than the sighted in discriminating spatial object properties.

2. Is there an internal visual language involved in aiding tactile recognition? : An empirical investigation

The main question with which this section will be devoted is whether the neural functions involved in visual information processing come to mediate active tactile afferent demand in the absence of vision especially where the person is required to haptically identify objects or make discrimination among objects based solely on their haptic properties. Questions should also be raised regarding whether such transmodal interplay is a need-based adaptive change effected by the brain (through cortical remodelling) as a spur-of-the moment activity resulting from visual deprivation or is part of a normal physiological process that usually remains latent. The internal visual language hypothesis would be bolstered if evidence for the latter turns out to be stronger. With the result of a great deal of neurological studies (fMRI and PET studies) showing evidence for tactile tasks such as letter identification or word-number discrimination through Braille reading and tactile property- related discrimination (such as distinguishing objects in terms of width or texture) being mediated by brain regions that are known to interpret information from visual modality in the sighted, the internal visual language for tactile information interpretation hypothesis seemingly gets a firm footing. In what follows, we would discuss and analyze the data from these studies.

The primary visual cortex, variously known as V1 and striate cortex are known to be activated in the sighted in response to afferent visual impulses. A number of neurological studies have been done since the nineties driven by the question whether the visibly unhindered haptic performance by the blind is made possible by any innate visual imagery. As researchers conducting PET on both the blind and the sighted while engaging them in active tactile tasks[1] as well as auditory and semantic tasks found that the primary visual cortex was distinctively activated in the blind, this 'crossmodal plasticity' opened a new horizon for answering Molyneux's puzzle: nature indeed makes possible visuo-tactile intermodal exchange. What remains to be explored is whether this recruitment of visual cortices in ameliorating everyday tactile identification tasks is a result of the brain's dismantling old neural organization and generating malleable and adaptive neural connections or resurrecting hitherto untapped neural connection potent with such cross-modal interchange in the event of loss of vision. In a study conducted by Sadato et al 14 early blind participants (8 of them being Braille-proficient and 8 being non-braille) were assigned tactile discrimination tasks such as telling which English letter made up of raised dots from a set are identical and whether two Braille symbols have the same width. Alongside, a passive tactile task was also given to the subjects where they had to only sweep their index finger over a rough surface without having to respond as to the felt haptic properties. The regional cerebral blood flow corresponding to the active tactile task displayed heightened activity in the V1 area of all the blind participants while for the same task performed by the sighted a mitigated pattern of regional cerebral blood flow was recorded in the V1. In contrast, no activation in the said region was found in either group. Sadato et al reasoned that the fact that the region

[1]Throughout the paper wherever reference is made to tactile tasks, by an active tactile task would be meant those tasks where the subjects are required to distinguish one touch-based stimuli from another in terms texture, shape, width or suchlike spatial properties or identify whether any two given stimuli are identical in terms of some specified spatial properties. In contrast, a passive tactile task is one in which no response from the subjects on the basis of discrimination is required.

of the brain earmarked for visual information processing for the sighted happens to be activated by active tactile experience can be accounted for by postulating the idea of spatial imagery (and not visual imagery) in the early and congenitally blind which is further developed by 'active touch' experience (Sadato 96, p. 527). This postulation is supported by the data of the maximum increase in the percentage of regional cerebral blood flow in the Braille-reading subject-group during the Braille-reading task (vide Table 2, loc. cit.). In the Braille-reading task the Braille-proficient blind subjects were asked to distinguish between words and non-words as they moved their fingers along the surface of Braille-letter strings. Although Sadato et al attributed this heightened activation to factors such as "fast presentation of the stimuli, increased complexity of the task, or lexical processing" (op. cit., p. 527), it seems that an early haptic exposure to learning words and numbers which exert a demand on the sensory modality of the blind to form a spatial imagery, pave the way for a crossmodal plasticity indicated by the activation of primary visual cortex in the blind in response to tactile discrimination activities.

Again in one of the fMRI studies carried out by Amedi et al (2002) a distinctive region within the lateral occipital cortex which processes information related to object shape was unearthed which was found to be devoted to process the same information from both visual and tactile stimuli. Aptly labeled LOtv (lateral occipital tactile-visual) region by Amedi et al, the region showed activation patterns for both visual and tactile stimuli and notably the tactile inputs which were all commonly haptically identifiable in day-to-day experience such as man-made hand devices, animal toys and models of mode of transport in contrast with faces and houses which are not usually recognizable with the use of touch sent the said region into an overdrive as indicated by BOLD reports. Furthermore, this bimodal pattern was found to be bilateral and occur in the ventral visual or what-pathway. This according to the investigators offered a strong ground to suggest that "… vision and touch indeed share the same shape representation, and we suggest here that LOtv is the cortical region mediating this bimodal integration…" (Amedi et al 2002, p. 1209).

Some researchers in this field have suggested that this crossmodal plasticity is something in-built awaiting to be worked up only by a suitable situation: in this case a visual deafferentation. Pascual-Leone et al, for instance, propose that the superior or at par ability of the vision-deprived to handle and comprehend haptically-obtained information that would otherwise have been facilitated by visual cues is to be accounted for by crossmodal plasticity which is an "intrinsic property of the human brain and represents evolution's invention to enable the nervous system to escape the restrictions of its own genome and thus adapt to environmental pressures, physiologic changes, and experiences (Pascual-Leone 2005, p. 377). They suggest that this crossmodal plasticity, i.e. the tactile functions taken over by the visual fields in the brain is not a result of de novo changes spurred by visual deprivation. This neuroplasticity that underlies the vision-mediated comprehension and discrimination of tactile stimuli is rather a manifestation of an intrinsic feature of the neural network normally lying dormant when vision is functional, coming out at the forefront triggered mainly by loss of vision and supplemented by factors such as continued haptic exploration and identification of objects such as Braille-learning. As Pascual-Leone puts it:

… plasticity is an intrinsic property of the nervous system retained throughout a lifespan…. The brain, as the source of human behavior, is by design molded by environmental changes and pressures, physiologic modifications, and experiences. This is the mechanism for learning and for growth and development…. Therefore, plasticity is not an occasional state of the nervous system; instead, it is the normal ongoing state of the nervous system…we should think of the nervous system as a continuously changing structure of which plasticity is an integral property and the obligatory consequence of each sensory input, motor act, association, reward signal, action plan, or awareness. (Pascual-Leone 2005, pp. 378-79)

If the supposition about this intrinsic character of neuroplasticity is sound, this would imply that a mere compensatory mechanism is not at play; the potency for the visual cortex to be stimulated by and to interpret haptically perceived objects, especially lexical characters was already there. Researchers endorsing this hypothesis however do not suggest that early blind people form a visual imagery to discriminate between haptically perceived object features. Burton (2003), for instance, argue that the possible explanation of why Braille-reading evokes heightened activation of the visual cortex especially in the early blind could be that for them this haptic task involves semantic processing that is mediated by the visual cortex. Burton selected 9 congenitally blind and 7 late blind subjects for his study and assigned them the task of producing a verb corresponding to a noun that they read via Braille. His study showed that both groups exhibited activation in V1, V2, V3 and other visual fields, predominantly in the left hemisphere for the early blind and in the right hemisphere for the late blind. In the case of early blind subjects, activation was even greater in the ventral visual areas or the 'what' pathway. No activation in these areas was displayed by the sighted for the same task. As a putative explanation for this result Burton suggests the idea that since Braille identification of words and production words are haptic and semantic tasks interlinked together, the haptic perception of words leads to semantic processing in the visual cortex that acts a as a lexical processor in the blind (op. cit., p. 4008).

Now findings of congenital and early blind subjects showing better efficiency in haptic discrimination tasks than the sighted and late blind might still pose a challenge to the in-built neuroplasticity hypothesis. Subjects who have been exposed to systematic haptic tasks that draw on their semantic modules in the brain appear to have an edge over the sighted and the late-onset blind subjects in terms of prior experience and motivated learning. So against this internal visual language hypothesis it might be argued that even if it is granted that sensory differentiation triggers a compensatory cross-modal interchange of sensory information, unmasking of new cortical organization is not a direct and immediate outcome; an extensive exposure to haptic activities aiming at acquiring tactile adeptness is required as a supplement. One route to find *a fortiori* evidence for the idea that this visuo-tactile interchange of sensory data is an in-built capacity of the cortices is to turn the attention to the haptic performance of the sighted who have been blindfolded and put through intensive haptic training at a stretch. Driven by the question whether "behavioral compensations in the blind are dependent upon irreversible sensory deprivation occurring during a specific developmental period or if under certain experimentally induced in normal, adult subjects (Thėoret et al 2004, pp. 223-4)", Thėoret et al compared the performance of the sighted-blindfolded to that of the sighted non-blindfolded in a Braille character discrimination task. They sought to find out whether an induced absence of vision in the sighted-blindfolded would precipitate a cortical remodeling, unraveling capacity for vision-mediated haptic identification/discrimination of objects.

In order to find out whether an artificial visual deprivation can cause cross-modal connections to build up, they selected 24 sighted subjects dividing them into 4 groups— blindfolded-stimulated, blindfolded-non-stimulated, non-blindfolded-stimulated and non-blindfolded-non-stimulated. The blindfolded-stimulated and the sighted-stimulated groups alone were put through Braille character identification and other active haptic tasks for 5 days, devoting time to the training sessions for more than 6 hours each day. The blindfolded- non-stimulated group on the other hand did not receive any training in Braille; however they were motivated to increasingly rely upon haptic activities for identification of objects, navigating etc. for this five-day period. After the completion of the training period, all the four groups were asked to tell one pair of Braille character from another. The findings favoured the hypothesis Thėoret et al formulated (see Figure 1) — the two blindfolded groups were able to identify and discriminate between Braille characters with less error compared to the non-blindfolded group. Of course the blindfolded-non-stimulated group did not achieve the accuracy level as much as the blindfolded-stimulated group did. However, even the better performance of this group than the sighted, provided an indication according to the investigators that "tactile differences between blind and sighted subjects do not entirely depend on prior experience and the learning of perceptual skills" (ibid., p. 224) — it is primarily the onset of visual deprivation that acts as a catalyst of cortical reorganization enabling vision-touch exchange of data.

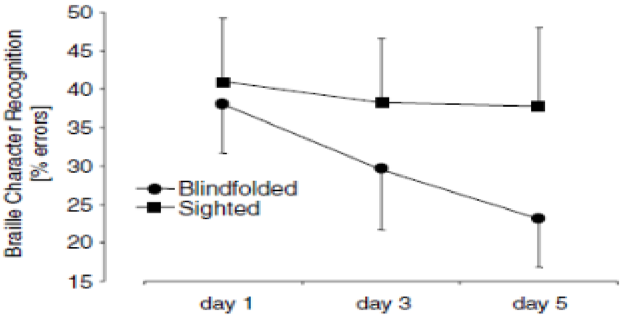

Figure 1. The improved performance of the blindfolded-sighted on Braille character identification tasks than that of the sighted-non-blindfolded (adapted from Thėoret et al 2004, p. 224)

In a further attempt to substantiate the claim of visuo-tactile cross modal plasticity claim, whose emergence does not in particular rely upon any critical developmental period and long-term learning, but can resurface at any time on the occasion of visual deficit, Sadato et al (2004) conducted an fMRI study on two late-onset blind subjects in comparison to 19 sighted subjects. Both groups were presented with pairs of Braille characters, half different and half identical. The subjects were required to press a button with their index finger if the pairs they felt were identical and with their middle finger if they were different. In conformity with the hypothesis formulated by Sadato et al, the late blind subjects showed 53.3% accuracy in the task set before them (a performance indicator that was not statistically different from that of the sighted) with activation in the superior occipital gyrus and bilateral fusiform gyrus whereas these areas remained inactive in the sighted group.

Neuroplasticity and subsequent functional overlapping of visual and tactile regions of the brain occasioned by natural or induced visual deprivation are not the only supporting evidence for the in-built visual language hypothesis. Some researchers have carried out studies demonstrating the involvement of visual cortex even under normal circumstances (i.e. without the presence of any optic disorder) during tactile object orientation discrimination and recognition tasks. Zangaladze et al (1999) applied transcranial magnetic stimulation (TMS), known to disrupt the function of extrastriate visual cortex, in 14 sighted subjects while asking them to respond whether a plastic, steel-backed grating was placed along or across the surface of their index finger pad. TMS was applied at 10 ms, 180 ms and 400 ms after the administration of the stimulus. It was found that subjects had a dropping rate of accuracy in recognizing the exact orientation at 180 ms of the administering of the TMS even if not at the start, i.e. at 10 ms. In contrast, the same disruption during what Zangaladze et al termed as the spacing task, where participants had to distinguish a wide groove of the grating from a narrow one, did not cause any performance error. This specific involvement of the visual cortex in object orientation identification even when there is no loss of sight in the usual sense may provide strong indication of an underlying visuo-tactile interplay where vision guides tactile tasks. The investigators further suggest that the functional mediation of the visual cortex holds good when it comes to discrimination of macro geometric features such as shape and orientation; however, visual cortex seems less active when haptic discrimination is related to micro geometric features such as texture (ibid., p. 589). Empirical report such as these seem to provide a positive response to the dilemma constituted by the question posed by Molyneux that whether a blind person would be able to visually identify an object after recovering sight. Although differences of opinion exist as to whether this visual mediation of non-visual including tactile object feature discrimination tasks rests on the formation of visual imagery or spatial imagery, a number of researchers exploring the role of visual cortex in mediating non-visual tasks buttress the idea on the basis of the foregoing studies that visual deafferentation only recharges the visual regions to carry out some functions lying dormant that would help the non-visual tracts of the brain to adapt to the new but difficult terrain. As Sathian put it in the context of the heightened activities demonstrated in the event of short-term induced visual deprivation: cross-modal activation of visual cortex does not necessarily require the formation of new connections, but could operate on preexisting connectivity between areas representing individual sensory modalities. Thus, visual deprivation might amplify the range of cross-modal recruitment that has been demonstrated under conditions of normal vision. (Sathian 2005, p. 284)

Evidence for the role of vision in influencing tactile stimuli detection does not alone emerge from the literature focusing on the haptic skills of the visually deprived versus sighted. Tipper et al (2001) for instance, sought to determine the pure role of vision in detecting and localizing tactile stimuli applied to limbs irrespective of the aid of proprioceptive orientation of eye and head in this respect. Proprioceptive movement of eye and head has an evolutionary history of benefitting humans in pinpointing the place of touch in the body. But proprioception is so bound up with vision that the indispensability of vision in achieving the said goal is not clear. In order to determine this, Tipper et al applied stimulation to the face and the neck of the subjects of their study because the face and the neck are not susceptible to direct proprioceptive movement. However, the face is within the reach of vision via indirect perception through mirror and to some extent the neck although very minimally, in the case of men women having long hair. Now Tipper et al had the hunch that even though the face and the neck are debarred from direct viewing and out of bounds for proprioceptive calibration, tactile stimuli placed at these two body sites especially the face would be accurately localized through the mediation of vision. Subjects in this study were shown real time images of the face and the neck in a video camera in two different trials while simultaneously tactile objects were being applied to the face and the neck respectively. In contrast to this condition, subjects were shown in a different condition the real-time view of the face while tactile object was being applied to the neck and vice versa. The result showed that the response time of the subjects in localizing tactile object on the face and the neck with accuracy was much more less in the condition where the image of the limb shown and the site of the application of the tactile stimuli were the same than in the condition where there was a mismatch between the image and the site of tactile stimulus. The investigators suggested that prior experience of coordination between vision and touch was very likely to effectuate this result. However, they admitted that "these cross modal interactions are produced at body sites that can never be directly viewed" (op. cit., p. 163).

Conclusion

In this short piece of work we began with the project of assessing a skeptical doubt hovering perennially in some philosophers' mind: whether a property of object like shape that is susceptible to both visual and tactile perception have the same dimension and if so whether an object can be identified on the basis of that property in the presence either of the sensory capacity. While framing this question philosophers like Berkeley, Molyneux and Locke had this supposition working in their mind that a visually perceived shape is radically different form a touched shape and not just that macro geometric features of objects such as shape perceived by vision preempt those perceived haptically which is probably why a blind person would have a slim chance of recognizing a geometric feature of an object using his sense of vision if he ever gets it back. In this paper a cue has been taken from this predominance of vision and main thrust of the argument consisted in showing that vision not just predominates but facilitates tactile identification through a converging and mutually beneficial process technically known as cortical plasticity when there is loss of vision, either natural or artificially induced for an extended period, reinforcing the idea that there may already exist neural connection brimming with the possibility for this vision-mediated visuo-haptic interchange of information helping the visual cortex of the brain to rapidly adapt and compensate in the event of visual deprivation. The studies discussed seem to provide a favouring evidence as they recurrently show that disruptions to the activities of the striate or extrastriate cortex stand in the way of haptically identifying and discriminating Braille characters, shape and orientation. Although a pressing argument in the literature concerned is that exposure to systematic haptic learning and Braille reading help the brain engage the occipital cortex as is evident from the level of Braille efficiency acquired by the early blind as compared to the late blind. Without dismissing the role of experience, it may still be suggested, as other studies discussed have shown (the ones showing the activity of occipital cortex in active haptic tasks in the blindfolded), vision naturally possesses the capacity for enacting a plastic change that has enormous adaptive benefits for the blind. This intrinsic capacity hypothesis should not be disregarded. As Amedi et al suggest: … it is possible that the occipital cortex inherently possesses the computational machinery necessary for the processing of nonvisual information…. the occipital cortex might be viewed as an ''operator'' of a given function based on the best-suited input available. When sight is present, visual input may be deemed as ideal for the operation of the occipital cortex, to the point of suppressing or masking inputs from other senses. In the absence of visual input, the occipital cortex may employ nonvisual inputs for its operation. (Amedi et al 2005, p. 310)

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