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Loss of a sense: Effect on others, psychological

The experience of deaf or blind individuals is so drastically different from what is deemed 'normal' experience that, throughout the ages, blind and deaf individuals alike have been treated by societies as having skills that are out of the ordinary – sometimes for the better, but also for the worse. Recent advances in brain science are starting to unveil how blind individuals and deaf people perceive the world differently, and what that means for the way they think and interact with their environment.

Loss of a sense – Generalized deficiency or across sense enhancement?

Loss of a sense dramatically alters the type of experience that individuals can rely on as they navigate their world. Some have argued that this is likely to have a negative impact on the sensory-deprived individual. Such a view holds that normal development requires integration of information from the different senses, such as when one connects what is being said (audition) with the shape formed by the lips of the speaker (vision). In the absence of such integration, some have argued that development of the remaining senses is compromised and cognitive functioning as a whole is challenged.

Studies of animals and humans show, however, that the loss of one sense is often met by an enhancement of the remaining senses; a phenomenon called cross-modal plasticity. For example, cats blinded early in life are better at localizing the source of a sound. They also show enhanced growth of facial whiskers resulting in larger areas of somatosensory cortex dedicated to tactile exploration. Such compensatory mechanisms

often result in deprived individuals outperforming their non-deprived peers on tasks involving their remaining senses. As outlined below, enhanced performance is not systematic. Rather, enhancements in the remaining modalities are most marked under conditions of attention, when the task requires selecting a target from among distractors, or when the time and place of occurrence of the target are unknown. The consequences of these changes for how individuals perceive, remember and think are being worked out.

The work discussed here only applies to those individuals who have completely lost access to one of their senses early in life, have no associated brain damage, and who have been given the opportunity to develop adequate social and communication skills. These selection criteria are necessary to study the effect of sensory loss itself, not confounded by effects of brain disorder or atypical social development. Thus, most research focuses on blindness due to early vision loss in both eyes or on deafness due to profound hearing loss in both cochlea. Although this restricts the relevance of the work to only a small subpopulation of deaf or blind individuals, the focus on early and total deprivation is not arbitrary. It is necessary because brain changes after early deprivation are more widespread. Similarly, brain changes after total sensory loss are more profound and of a different nature to those observed after partial sensory loss. As research matures, it is encompassing the situation of a greater number of individuals, documenting which mechanisms of brain plasticity are shared by different amounts and onsets of deprivation and which ones may be specific to early and total loss.

Effects of blindness on audition, touch and cognition

A review of over 200 famous blind people from the past few centuries reveals that almost a third of them were professionals or artists in a field related to music. While such

an observation may suggest that blind people have a talent for music, caution is warranted. The prevalence of musicians in the blind population may not be due to loss of vision itself. Rather, exposure to music and musical activities may be more likely among blind individuals, indirectly fostering musical ability. This not a mere academic distinction. The view that blind individuals have better musical skills because of their sensory loss holds that sighted individuals will not be able to catch up to the level of blind musicians even if they are given an equivalent amount of music training. In other words, the removal of a sense is necessary for the compensation seen in the remaining senses. On the contrary, the exposure view holds that sighted and blind individuals do not differ in their musical skills and given similar exposure to music, sighted individuals would show the same musical skills as blind individuals. The literature on music skills in the blind is unfortunately rather sparse, leaving this question unanswered. Intriguingly, it appears that perfect pitch is more likely in musicians who lost their sight within the first few years of life than in sighted musicians or blind musicians who lost their sight later in life.

Better documented is the remarkable compensatory skills that blind individuals display when tested on various auditory and tactile tasks. For example, they are better able to determine where sounds originate from, and they have an easier time distinguishing amongst complex textures by touch. These changes are more systematically observed in attention-demanding tasks, such as monitoring a stream of sounds for a target sound. Little changes are observed in sensory thresholds, such as the audiogram which measures the amount of loudness needed to hear different sound frequencies. Enhancements are not restricted to the remaining senses, but are surprisingly

widespread. There are reports of blind individuals outperforming sighted counterparts when asked to recall a list of words several days after presentation, or in the study time needed to memorize a long list of words in its exact order of presentation. These enhanced verbal memory skills demonstrate that sensory loss can also lead to cognitive compensatory adjustments.

The performance enhancement in blind individuals goes hand-in-hand with a reorganization of their primary visual cortex (V1). Remember that blindness in these individuals is not due to cortical damage, but rather to binocular visual loss. As a result, the visual cortex is being denied visual input. Interestingly, recruitment of V1 in blind individuals correlate with performance on tasks as varied as sound localization, tactile discrimination, Braille reading and verbal memory. In addition, temporary disruption of V1 results in transient impairments of Braille reading in blind individuals, but not in sighted controls. Thus, a brain area typically dedicated to visual analysis has been reorganized to sustain several other abilities as a result of sensory loss. A radical thought emerging from this work is that what was once considered to be visual cortex may be cortex that receives inputs from multiple senses. Such multi-modal connections are believed to be latent even in area V1 of sighted individuals. Upon visual loss they would get unmasked, revealing widespread plastic brain changes in this area. Greater plasticity in early than in late blind individuals is to be expected as redundant connectivity across senses is a landmark of early development. As the individual matures, pruning occurs with only specific neural pathways and local neuronal circuitry being maintained, reducing the multi-modal plastic potentialities of the visual cortex by adulthood.

Effects of deafness on vision and language processing

There are several studies reporting deficient visual skills in deaf individuals. Yet, when confounds are removed and only the effects of auditory loss are studied, a different pattern of results emerges. Deaf individuals do not have better vision than hearing individuals in the sense that they need prescription lenses less often, but for some aspects of vision, such as peripheral visual attention, their skills are heightened. For example, deaf individuals are better than their hearing peers at localizing a peripheral target in a cluttered visual scene. A real-life example would be the ability to detect a deer on the side of the highway while driving. Conversely, when focusing on a central task - such as reading or doing math - their attention is more likely to be pulled away by peripheral events. This behavior has often been described in the literature as increased distractibility, and has led many to argue that deaf individuals lack the ability to focus visual attention. Recent studies have established, however, that this distraction effect is not the sign of a deficient focusing of visual attention in the deaf population, but rather of a greater awareness of their surroundings.

There is also recent evidence that tactile processing is enhanced in individuals born with profound hearing losses. Again the changes appear to be attentional rather than perceptual. Deaf individuals cannot distinguish between the frequencies of a pair vibrating rods any better than hearing individuals, but they are better at monitoring a vibrating rod for a change in frequency whose time of onset is unknown. Thus, as noted in the blind literature, the changes in visual and tactile processing noted in deaf individuals are also best revealed under conditions of attention.

The neural correlates of these behavioral effects have been linked to a reorganization of posterior parietal cortex (PPC) and of the posterior superior temporal gyrus (posterior STG). Importantly, these regions are known to be key brain centers for visual attention and zones of convergence for the different senses. Thus, attentional and multi-sensory associative cortex reorganizes in the face of missing auditory input. This result is similar to that documented in the animal literature, and is well accounted for by a competitive, Hebbian-like mechanism, where neurons that fire synchronously are more likely to maintain their connectivity. When there is no auditory input to these associative areas those neural connections die away, and connections from the remaining modalities take over.

Contrary to the case of blindness, where changes to area V1 have been observed, changes in primary auditory cortex (A1) have been harder to observe following the loss of audition. It may only be a question of time before such changes are found, or it may be that the connectivity that would allow A1 to reorganize and be taken over by the remaining modalities is lacking. This issue is still being worked out by researchers, but the discrepancy illustrates one of the major challenges in the field of brain plasticity – plastic changes are highly specific in their effects. Although the same neural mechanisms for plasticity appear to be at play across different types of altered experience, the consequence of a given change in experience will be determined by the state of the existing neural connectivity between sensory and associative cortices as well as local neural organization at the time of sensory loss, leading to highly specific patterns of changes as a function of the type and timing of that sensory loss.

Cross-modal plasticity, implants and sensory restitution

The loss of a sense in early childhood is often perceived as a devastating event by parents and peers. Blind individuals are often thought by the sighted to be overwhelmed by darkness. Deaf individuals, because of the language barrier it introduces with the hearing world, have been labeled ‘deaf and dumb’. Even though recent movies like “Children of a Lesser God” have raised awareness of what it means to live as a deaf person, it is still perceived by many in the hearing world as an extremely debilitating condition. Assuming that individuals who are blind or deaf would welcome becoming sighted or hearing, and leaving cultural issues aside, our understanding of brain plasticity calls for caution. The main determinants of how likely restitutive technologies such as cochlear implants are to be of help are (i) age of onset of sensory loss and (ii) age of implantation. Early loss will impact the development of the brain and result in specific cortical reorganization. Indeed, during development the brain learns to tune itself to the type of information it receives. The reorganization will be all the more extensive when that loss occurs early and is maintained throughout development. The resulting organization will not be easily undone if the missing modality is suddenly re-introduced in adulthood. By that time, the brain lacks much of the plastic potentiality that would allow it to make use of the added sense. This phenomenon is probably best exemplified by the few reports of early blind and early deaf individuals whose sense has been restored in adulthood. After an initial period of amazement at being able to feel light or sound, these individuals typically report extraordinary difficulties in making sense of the signal provided by their new implant. Many choose to turn off their implant after a few months of struggles.

Implants, however, have had fantastic clinical utility for individuals who suffer from sensory loss in their adulthood. They also have significant restitutive potential for those children who are implanted at a very early age. For example, there is much interest in the conditions that would favor oral language development in deaf children that have received a cochlear implant. An active research effort is on-going to understand the effects of implantation in babies and toddlers on both the stimulation and recruitment of sensory cortices and as well as the proper functioning of higher cognitive processes.

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See also:

Attention: Physiological

Audition: Disorders

Cochlear implants: Technology

Cortical reorganization

Experience-dependent plasticity

Loss of a sense: Effect of others, physiological

Multi-modal interactions

Visual disorders: Blindness

Visual prostheses

Further Readings

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