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Concerns Regarding Sensory Substitution: Overload and Conflict

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ABSTRACT

Sensory Substitution is a means of using one sensory modality to gain external information to be used by another sensory modality. However, throughout this process, unintentional effects may occur due to various external reasons. When a substituted sense interferes an original sense, or when the brain experiences unexpected and unfamiliar signals, many malfunctions may appear, affecting the sensory substitution process. In this paper, we introduce the basis of sensory substitution found in perception and neuroplasticity, then analyze the possible complications that may occur throughout the sensory substitution process; in particular, we investigate the implications of sensory conflict and sensory overload in substitution.

Keywords: *neuroplasticity, sensory substitution, sensory overload, sensory conflict*

1. INTRODUCTION

To those who are impaired, Sensory substitution is an exciting opportunity to regain the lost information by redirecting the stimuli to a different sense. Without even the requirement of surgery, the visually impaired are able to experience sight like every other; the auditory impaired are able to experience sound like every other.

However, sensory substitution comes with many complications in its implementation. Both sensory overload and sensory conflict has clear implications for sensory substitution device and therefore must be carefully considered when designing a sensory substitution device.

2. SENSATION AND PERCEPTION

Sensation is purely the detection of any basic environmental stimuli, while perception is brain's interpretation of such stimuli. Therefore, to perceive, the brain relies heavily upon both sensory information and the brain's processing. In particular application to the perception of spatial orientation, the brain also further relies on proprioception. Any abnormality among these three factors lead to unusual reactions and behaviors.

2.1Room Tilt Illusion (RTI)

A transient attack resulting in the upside-down reversal of the visual field is called the room tilt illusion (RTI). RTI is a scarce clinical syndrome; people with RTI often have irregular percept often with 90 degrees or 180 degrees forward rotation of vision without any alternation of size and color. Previous reports and research ascribe the underlying reasons of RTI to the peripheral vestibular system, neurological system disorders and so on [1]. RTI is a manifestation of an unusual perception caused by abnormalities among sensory information, prorioception, and the brain's interpretation of such information, more specifically, information from the vestibular system [2]. On this basis, we question how conflicting sensory stimuli that emerges from sensory substitution can affect perception.

Figure 1 RTI

3. SENSORY SUBSTITUTION

To better understand this idea, a neurological fundamental principal of sensory substitution is needed. Sensory substitution refers to the translation of one type of sensory stimuli that typically would be undetected due to deficient receptors in the subject to another type of stimuli, allowing for detection by another proficient sense [3], usually occurring through various biotechnological devices. Sensory information is sent to a specific region of the cerebral cortex as action potentials. These nerve impulses' spatial patterns serve as the basis for our sensory experience. Such coding of information as nerve impulses forms the basic idea of perception in physiology and psychology [4]. For example, visual information is transduced into the form of a nerve impulse, and the afferent impulse is sent to the visual cortex of the brain along the optic nerves. The visual cortex then decodes and interprets the input spikes as a visual "image". This process is the basis for our sensing and behaviors.

3.1Neuroplasticity

People who are visually deprived also show few overt impairments in their natural behaviors because they are able to take advantage of another senses, such as auditory sensation, to spatial localization and any other behaviors in their daily life. Josef Rauschecke found that a cat, whose eyes had been sewed up at the time the cat was born, still were able to behave normally and naturally with no affects from the loss optic sense. And the cortex of visual sense of the cat are occupied by other sensation.

Interestingly, for people who are impaired, the relevant cortical region is not idle, as though the brain did not want to waste any cortical real 'estate' and has found a way to rewire itself [5]. The brain possesses an ability to reorganize itself and compensate the sensory loss under the guidance of sensory-motor feedback that enables remaining adjacent cortical areas to recruit the cortex that are normally associated with the lost sensation [6]. This process of adaptation is called neuroplasticity, and the function of sensory substitution is determined by the availability of compensatory plasticity in this process. Neuroplasticity is likely the neural basis for sensory substitution and is the most remarkable capability of the brain for sensory substitution. With the advent of computerized measuring techniques, electric or magnetic surface potentials recorded from the human brain in response to sensory stimuli can now also be localized much more precisely.[6] Two common examples of neuroplasticity are braille and sign language: braille is a tactile writing system, through which the blind can read similarly to how we read words through tactile perception; sign language can take advantage of visuals to express meaning for the purpose of compensating for the loss of hearing. Both of these are made possible by neuroplasticity, where an area of the brain normally unassociated with the sense in question provides the individual with much needed information interpreted through the two mediums, also reveals a profound reorganization and integration of language areas in the cortex of people with lost senses.

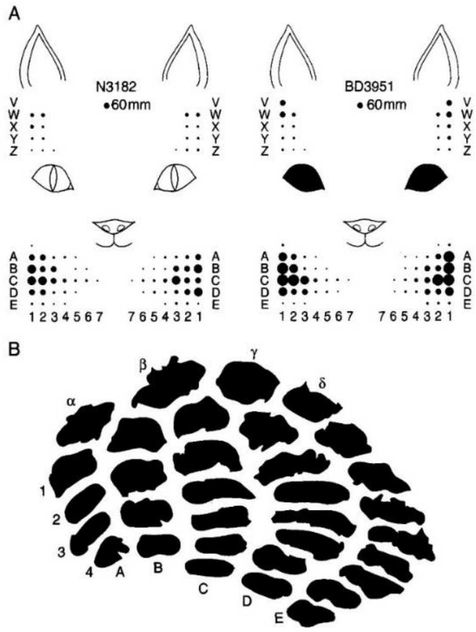

Figure 2 Signs of somatosensory compensation in visually deprived animals' brain

3.2Examples of Sensory Substitution

With the advent with computerized technology, various sensory substitution devices (SSDs) have been developed. These appliances collect information and signals from an external environment that would normally be collected by the lost sense through receptors. And then the human-machine interface (HMI) will transmit and couple that information to a different sense for the brain to interpret.

Figure 3 TVSS

For instance, for people with vision deprived, the TVSS (tactile-visual sensory substitution) technique may transform a video camera picture to a tactile image, then distribute it to the tactile human-machine interface, also called The Tongue Display Unit (TDU) [7]. Newer systems and utilities based on the TVSS with wider-ranging receptors are able to help the blind by conveying distance, orientation, and even facial expression [8].

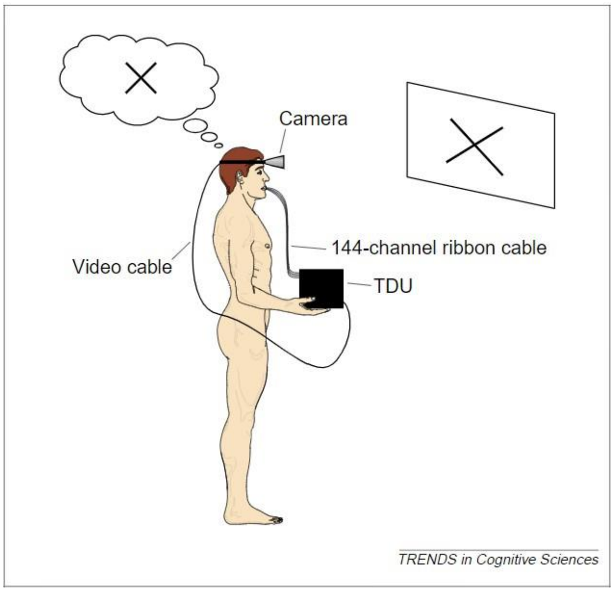

Figure 4 Schematic drawing of TVSS

In another project, the visual-to-auditory devices can convert information to a space sound. Additionally, by correlating height with pitch and brightness with loudness in any video frame's left-to-right scan, the blind may see [7].

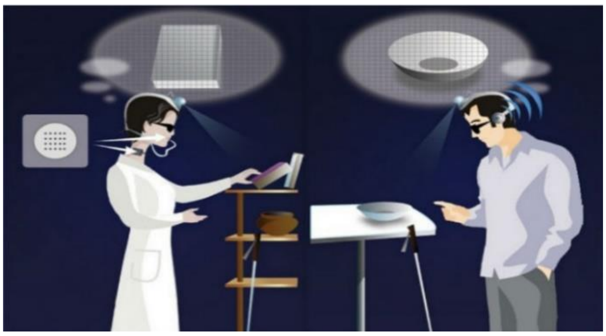

Figure 5 visual-to-auditory SSD

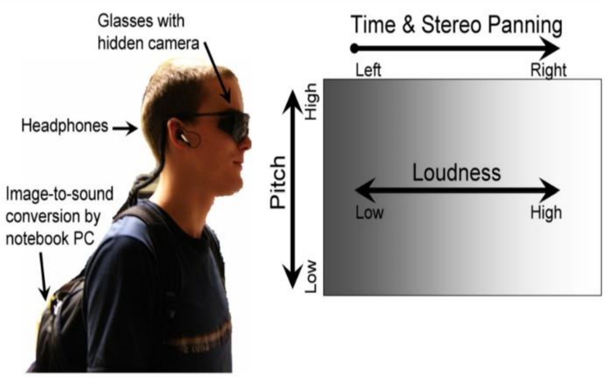

Figure 6 transit info to brain through existing sense. An illustration of SSD and its compensation process

Besides, for bilateral vestibular damage (BVD) patients who experience functional difficulties that include postural 'wobbling', unstable gait and oscillopsia. Using vestibular substitution devices produces a strong balance on head and body coordination. People with BVD can adapt to new environment immediately. Also, other study show that these didn't occur at extremes of motion, which would suggest they are triggered by proprioceptive mechanisms. [9]

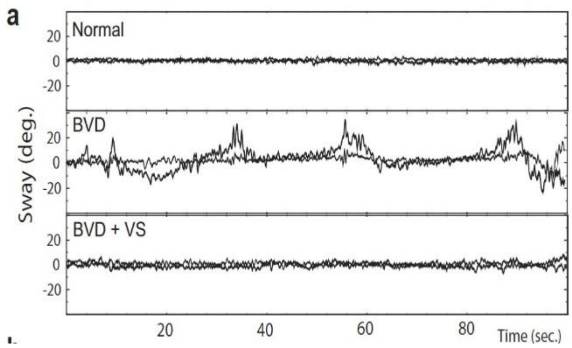

Figure 7 Graph of head displacment in both anterior/posterior(A/P) and media-lateral direction for an adult subject with eyes closed and sitting upright without back support

As seen in the above examples, substitutive sensory devices play an important part in helping people restore their impaired sensation by perceiving sensory information and transcribing the signals to a functional sensory modality.

4. CONCERNS IN SENSORY SUBSTITUTION

The major concern with sensory substitution is whether or not the apparatus would become problematic for the patient to use. As such, ambiguities and clashes surrounding senses are most relevant when discussing this topic. Therefore, one must have a sufficient understanding of sensory overload and sensory conflict to understand the effects of using a sensory substitution device.

4.1Sensory Overload

The brain is only able to process limited amounts of information that is received by the senses. The restrictive nature of the attentional capacity causes much information to be filtered out. An observer cannot notice the intricacies and details in a visual scene while making rapid eye movements [10]. This idea applies similarly to audition and haptic perception. Such constraints have obvious implications for the design of sensory substitution devices [11].

A substituted sense should not interfere with the original sense. For instance, sounds from headphones that substitute vision should not affect the comprehension of actual sounds coming from the environment. Sensory overload will result in a wide variety of symptoms and responses both mentally and bodily.

Figure 8 bodily responses caused by sensory overload

For instance, self-harm, making poor eye contact and muscle tension. Besides, substitution devices can strain attentional resources, distracting from other key information of the environment. Therefore, when designing substitution devices, one critical aspect to consider is that the device requires minimal attention to implement. Only key information should be conveyed, while redundant and extraneous information should be avoided [11], to protect users from detrimental responses.

4.2Sensory Conflict

To discuss sensory conflict, while the most intuitive explanation of sensory conflict would be an inconsistency in different sensory inputs resulting from direct comparison, such an explanation is inadequate because whether or not two senses are consistent must rely on previous sensory experiences and context, particularly concerning the visual, proprioceptive, somatosensory, and vestibular senses [12]. Therefore, sensory conflict is more probable to concern predicted inputs and actual sensory inputs. As humans perform motor commands, the brain continuously predicts the future positions of the body, and any misalignment between this tracing of movements and sensory input results in sensory conflict. This idea aligns with the previous explanation because the prediction of movements in the body are indeed based upon previous sensory experiences and context [13].

Whenever the brain experiences unexpected or unfamiliar sensory signals with reference to previous experiences, in other words sensory conflict, for an extended period of time, "sensory rearrangement" occurs, redefining the contexts that would determine whether a sensory input is "normal"; such a process typically results in motion sickness or nausea [12].

In application to sensory substitution, one would generally assume that the process of integrating the substituted sense into the actual sensory representations the brain builds would also in some form involve sensory rearrangement since the medium in which the substituted sense is delivered is indeed unexpected and unfamiliar. However, no research has yet to be conducted that concludes a definitive relationship between sensory substitution and sensory rearrangement.

5. CONCLUSION

Sensory substitution is definitely a pronounced occasion for the sensory impaired. However, in its implementation, we must be very careful about whether each aspect of a device is really necessary for the subject requiring substitution. One must carefully consider the implications of sensory overload and sensory conflict while designing a sensory substitution device: the last thing a substitution device should do is further confuse the subject.

REFERENCES

[1] Sierra-Hidalgo, F., de Pablo-Fern´andez, E., Herrero-San Mart´ın, A., Correas-Callero, E., Herreros-Rodr´ıguez, J., Romero-Mun˜oz, J. P., & Mart´ın-Gil, L. (2012). Clinical and imaging features of the room tilt illusion. *Journal of neurology, 259*(12), 2555-2564

[2] Malis, D. D., & Guyot, J. P. (2003). Room tilt

illusion as a manifestation of peripheral vestibular disorders. *Annals of Otology, Rhinology & Laryngology, 112*(7), 600-605.

[3] Bach-y-Rita, P., Collins, C. C., Saunders, F. A., White, B., & Scadden, L. (1969). Vision substitution by tactile image projection. *Nature*, 221(5184), 963-964.

[4] Bach-y-Rita, P. (1972). *Brain mechanisms in sensory substitution.* academic Press.

[5] Hubel, D. H., & Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *The Journal of physiology, 160*(1), 106-154.

[6] Rauschecker, J. P. (1995). Compensatory plasticity and sensory substitution in the cerebral cortex. *Trends in neurosciences, 18*(1), 36-43.

[7] Bach-y-Rita, P., & Kercel, S. W. (2003). Sensory substitution and the human–machine interface. *Trends in cognitive sciences, 7*(12), 541-546.

[8] Cassinelli, A., Reynolds, C., & Ishikawa, M. (2006). Haptic radar/extended skin project. In *ACM SIGGRAPH 2006 Sketches* (pp. 34-es).

[9] Mitchell tyler, Yuri Danilov and Paul bach-y-rita(2003). Closing an open loop control system: vestibular substitution through the tongue. *Journalof Integrative Neuroscience, Vol.2, No.2 (2003)159{164}.*

[10] Grimes, J. (1996). On the failure to detect changes in scenes across saccades. *Perception, 5*, 89-110.

[11] Kristj´ansson, A., Moldoveanu, A., J´ohannesson,´ O. I., Balan, O., Spagnol, S., Valgeirsd´ottir,´ V. V., & Unnthorsson, R. (2016). Designing sensory-substitution devices: Principles, pitfalls and potential 1. *Restorative neurology and neuroscience, 34*(5), 769-787.

[12] Reason, J. T. (1978). Motion sickness adaptation: a neural mismatch model. *Journal of the Royal Society of Medicine, 71*(11), 819-829.

[13] Oman, C. M. (1991). Sensory conflict in motion sickness: an observer theory approach. *Pictorial communication in virtual and real environments*, 362-376.