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Case Study

Non-optic vision: Beyond synesthesia?

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ABSTRACT

Patient NS is a 28 year-old female who went blind in her early twenties as a result of S-cone syndrome, a degenerative retinal disorder. A few years after losing her vision, she started experiencing visual perceptions of her hands as she moved them and objects that came into contact with her hands. Over the course of a year, these cross-modal sensations evolved to become veridical visual experiences accurately representative of her hands, objects she touched, and to some degree, objects she could infer from her immediate surroundings. We argue that these experiences are distinct from mental imagery as they occurred automatically, remained consistent over time, and were proprioceptively mediated by her head position much like normal optical vision. Moreover, she could neither consciously force these visual experiences to occur without sensory inference nor prevent them from happening when haptically exploring an object. Her previous visual experiences contributed to a strong influence of top-down processing in her perceptions. Though individuals have previously been able to develop limited veridical acquired synesthesia following extensive practice over many years with the use of a special sensory device, none reported experiencing the richness of complexity or degree of top-down processing exhibited by NS. Thus, we posit that NS's case may represent a phenomenon beyond synesthesia altogether.

1. Introduction

Psychological fascination with cross-modal perception dates back to John Locke in the 17th century, predating formal scientific documentation of such phenomena by two centuries (Jewanski, Day, & Ward, 2009). Locke's analogy of a blind person attempting to describe the color scarlet in terms of the sounds of a trumpet tackles the question of how one modality can be understood in terms of another (Locke, 1690). For individuals with synesthesia, this analogy becomes a reality as stimulation in one sensory modality activates additional perceptions usually associated with another modality (Cytowic, 1997; Pearce, 2007). Synesthetes may report that seeing the color red may produce an experience of a sweet taste, for example. While several different manifestations of synesthesia have been documented, most synesthetes report that their cross-modal sensory experiences have been present throughout their whole life (Simner, 2012). Nevertheless, in the case of sensory deprivation, there are numerous accounts of "acquired synesthesia" that developed after an individual lost his or her vision (for reviews, see Afra, Funke, & Matsuo, 2009; Proulx & Stoerig, 2006). In each of these cases, the extent of the synesthetic experience has been limited to simple flashes of light or color known as phosphenes following auditory or tactile stimulation (Afra et al., 2009; Proulx & Stoerig, 2006). In contrast to these examples of simple cross modal perceptual experiences, a few rare cases of blind individuals with more complex acquired synesthesia have occurred, but only with the aid of a sensory substitution device (SSD). Such a device translates incoming visual information from a camera to another sensory modality (e.g. auditory, tactile) that the user can experience. In a few cases, after blind individuals practiced receiving real-time tactile information from such a device, they sometimes reported a visual experience of "seeing" the objects that they had been inferring from tactile stimuli alone (for reviews, see Bach-y-Rita, 2004). If the brain is capable of generating accurate visual percepts, without optical input, through the use of an SSD, could this occur without such intervention?

1.1. Case history

NS (not true initials) was a 28 year-old right handed woman whom we evaluated after she presented to a behavioral neurology clinic for evaluation of new visual perceptual experiences. Born

Abbreviations: SSD, sensory substitution device; MRI, magnetic resonance imaging; EEG, electroencephalogram; fMRI, functional magnetic resonance imaging; PET, positron emission tomography; BOLD, blood oxygenated level dependent; MEG, magnetoencephalography; ERP, event related potential.

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sighted, as a teenager she had gradual progressive loss of vision. She was diagnosed with pigmentary retinopathy secondary to enhanced S-cone syndrome. At the time of our evaluation, she had no functioning visual capacity for several years, and was dependent on reading with Braille and walking with a long cane ("white" cane or Hoover cane). She could see crude aspects of motion if a hand was waved immediately in front of her eyes, but could not identify whether or not it was a hand. She could say if a room was lighted or not. She had occasional infrequent sensations of a point of light lasting briefly, usually blue in color, consistent with phosphenes. She had no history of any other sensory disturbance, and had never had synesthesia-like experiences before this point. She was intellectually well preserved, had done well in college, and was pursuing a doctoral degree. She had no previous history of psychiatric or psychological trouble. Thorough neurological history and physical examination were normal, as was a structural brain magnetic resonance imaging (MRI) scan. Importantly, no thinning or volume loss was evident in the sensorimotor or visual cortices (See supplementary materials, Fig. 1). During an electroencephalogram (EEG), photic stimulation produced no occipital cortical responses, and the study was otherwise normal without focal or generalized cortical slowing nor epileptiform diathesis.

1.2. Reported phenomenology

Beginning a few months before we met her, NS had changes in her visual experiences. Previously, she had infrequently experienced brief and tiny points of blue light. For a few months, she gradually started to perceive seeing more blue light occurring in broader spatial expanse throughout her visual field. This experience became nearly continuous, with the light seeming to shimmer or flash in response to changes in emotion, activity, or music. As these experiences evolved, she began to see a "Technicolor" quality with an apparent full spectrum of colors spread across these perceptions. The experience was distracting to her and disrupted her ability to function in school for a while. Over time, as these experiences seemed to wax and wane but persist continuously, she was less distracted by them and could function more normally. If she was sleep deprived or more stressed than normal, the visualizations became more intense and distracting.

After a few months of these changes, she began to perceive seeing formed images of the objects that she interacted with using her other senses. For example, she reported that she could "see" her hand as she moved it in front of her eyes, but not if she moved it behind her head or if she moved it in other locations where, had she been sighted, it would not have been visible. When she "saw" her hand, it was still imbued with the Technicolor qualities that she had already been experiencing, and was not the true color of her hand. If she moved her hand, she perceived seeing the movement of her fingers and her hand as a whole. The fingers looked correct in number, size, shape, and moved consistent with her proprioceptive feedback. If she closed her eyes, she still perceived seeing her hand as she did this. She had similar vision of other body parts such as her legs and feet, as long as her head position was oriented in the correct direction. As we wanted to focus on her tactile perception, we did not further explore NS's experience of perceiving her other body parts beyond her hands in the present report.

In addition to the perception of seeing her body parts, she reported that she could see objects she held or manipulated with her hands. For example, she reported that when she held onto a coffee cup, she could see the cup, the whole cup, and the vision corresponded to the cup's true shape. The vision she experienced was that of the correct diameter of the opening, the height and thickness of the cup's wall, and the handle in its actual shape. If she placed the cup on a table, and let go, she still experienced a vision of the cup on the table. But, if she turned her head so that the cup would not have been within the field of view for a sighted person, the cup then disappeared. Sometimes, if she moved her head position back toward the cup again, it would seem to reappear. The color of the cup did not correspond to its actual color, even if she had been told what this was, and instead was of the Technicolor quality that had come to dominate her visual experiences. She was clear that these phenomena felt like the true experience of vision, and not the experience of imagery.

For many years, she had been skilled in being able to walk with a long cane, sweeping it left and right as she moved, tapping it in front of her to guide ambulation. As with many blind individuals who can walk in this way, she learned to infer what objects or structures were around her by using echoes from the sound of the cane's tip as it hit things, and the feeling of the cane in her hand as she moved it over textures and contours. She also had become skilled in inferring details about her surroundings by listening to the sounds she heard or even by noting the feeling of wind, such as when she passed through open or closed-in spaces, or when doors moved back and forth. However, as she began to develop the visual experiences described above, she also began to "see" some of her surroundings as she walked, visually experiencing the details that previously she could otherwise only infer or sense in non-visual ways. For example, if she rounded a street corner, by the methods above she knew that a building was in front of her. Now, however, she began to experience a vision of the building. This vision was often incomplete, limited to those aspects that other sensations had informed her were present. For example, she perceived seeing the lower level of a tall building, but even though she knew that the building in question was taller, she could not "see" above the first floor. Moreover, the building appeared rather crude and generic looking, bereft of architectural or structural details about which her other senses had not informed her.

It was clear that NS was not actually "seeing" objects from light transduced in her retina. For example, when a piece of paper was placed without her knowledge in between her hands and her eyes, this did not affect her sense of visual perception. When prompted to use her hands to explore novel objects haptically, NS reported that her visual perception would automatically "fill in" as her fingers swept over an object. Interestingly, she described recognizing an object by its visual characteristics, but only for objects that she had a visual memory of before losing her vision. As such, her existing visual memories played a role in her synesthetic-like phenomena. In contrast, for objects (e.g. a stud-finder or furniture slider) for which she had no previous visual memory, she could only experience seeing details that her fingers could provide such as shape and texture. Nevertheless, these unknown objects still produced visual percepts for her. Texture also provided its own dimension to her visual experiences, as smooth or glossy surfaces looked "shinier and more vibrant," while rough or textured surfaces produced more muted visual experiences. When asked why this was, she stated that she knew that textured surfaces like fabric or foam did not reflect light the same way that something smooth or shiny did. We also examined her visual memory by handing her 5 random but common household objects (tennis ball, water bottle, etc.) sequentially over the course of 10 min and asking her to place them on the table in front of her. As a distraction, we engaged her in normal conversation during this time. At the end of the ten minutes, we asked her to report what she could see on the table. Though she reported knowing where all 5 objects were spatially and could pick them all up without searching, she could only report seeing the last two objects she had placed on the table. Verbal consent was provided by the patient for all testing as a part of her clinical assessment.