

Hermann von Helmholtz (1821–1894)

Helmholtz developed two major theories in psychophysiology regarding the transduction of physical stimuli into nervous impulses and how qualitative, stimulus information is coded into neural signals. His two theories are the *trichromatic theory* of color vision and the *place theory* of audition (Levine and Shefner, 1981). While it is Helmholtz's theory of perception that is our focus here, these two theories of transduction and sensory coding are central to understanding his theory of perception.

The Trichromatic Theory

In early research into color vision it was found that when the primary light waves of red, green, and blue were mixed it resulted in the subjective experience of any color of the perceivable spectrum. Thomas Young, and later Helmholtz, attempted to account for the law of three primaries. They reasoned that there must be, in the eye, receptor cells that are maximally sensitive to one of the three primaries. The subjective experience of the non-primary colors was due to the mixing of different combinations of the wavelengths of red, green, and blue light.

The Place Theory

Drawing upon his knowledge of the physiology of the inner ear, in particular the basilar membrane, Helmholtz put forward a version of *place theory* known as the *resonance theory* or the *piano theory* (Sahakian, 1975). The theory proposes that different regions of the basilar membrane are tuned (like the strings of a piano) to a particular frequency of sound. When that sound frequency is present at the basilar membrane, certain portions that are attuned to it resonate (the continuance of the sound through the sympathetic vibration of some other object). It is this resonant response of particular regions of the basilar membrane that takes up the sound wave and transduces it into a neural signal which is relayed to the brain. Specific nerve groups were invigorated or stimulated depending upon which region of the basilar membrane was particularly resonant. The particular nerve cells, aligned along the basilar membrane, that are stimulated by the resonating, serve as the signal for the quality of the pitch of a sound.

The Theory of Perception

The Problem

It has long been known that humans, in their perceptual experiences, are susceptible to illusions. Aristotle had noted the illusion of a stick appearing to be bent when half submerged in water. Locke had reported on the "illusion of the basins," wherein one hand in hot water and the other in cold water are transferred to the same basin of lukewarm water. The sensation in one hand is of cold water (transferred from the hot basin) and in the other the sensation was of hot water (transferred from the cold basin), even though the stimulus was the same basin of lukewarm water. Even the false experiences that were the basis of the "doctrine of specific nerve energies," e.g., a blow to the ear producing a ringing experience, seemed to suggest that whatever is acting upon the sensory receptors need not result in an

experience that is consistent with it. As McLaughlin (1998) put it, “the senses are fallible” (p. 294).

The fact of illusion, thus, to some people at least, made it quite apparent that, no matter what one perceived, there is always the possibility that one’s perception is in error. Given such findings, Helmholtz argued, according to Boring (1929), that perception might involve experiential data that are not represented in the immediate stimulus (hence the false percept). Further, he proposed, those elements that are not represented in the immediate stimulus must be additions that are the result of past experiences. Unconscious processes interpret the current stimulus upon the basis of prior experience and that interpretation is the perception. Helmholtz reasoned that while our sensations are the result of the objective conditions of the world beyond the senses, we do not have direct access to those conditions and we are therefore left in the position of having to deduce what the cause of those sensations may be (Gibson, 1966). We are imprisoned by our sensory limitations. As Turner (2000) expressed the problem, there is a radical difference between the sensations produced by the stimulation of sensory organs and those external objects that are posited to exist beyond the sensory organs as the causes of stimulation.

On the Perception of Depth

How is it that, from the two-dimensional retinal image, humans are capable of perceiving depth? The classical, empiricist perspective on the perception of depth is that the *proximal stimulus*, that which acts upon the receptors immediately, is impoverished as a source of information (Hershenson, 1999). Something else must, therefore, be added to the inadequate information provided by the senses.

As was the case with the classical, empiricist understanding of perception, Helmholtz believed that the *distal stimulus* was not what the sensory system was giving a report of. The sensory system responded to the *proximal stimulus*, i.e., the physical stimulus acting upon the receptors. In the case of vision, light is reflected off of the distal stimulus (objects in the world beyond the senses) and that is what the photoreceptors respond to. The information provided by the proximal stimulus and reported on by the receptors, as was said, was impoverished. Nonetheless, it was the object world that perception was purported to be about. Given that, and given the impoverished nature of the retinal image, the perceptual process must take up the information from the retina and interpret it somehow in order to produce a perception of the world beyond the senses. This is, in some ways, comparable to Kant’s account of subjective experience. We do not have access to the world of things but things act upon the senses. The sensory report is then taken by mind and organized by the categories in order to produce what is subjectively experienced.

The categories, as Kant conceived of them, were innate and, hence, Kant was a nativist. Helmholtz, too, believed that processes in the brain interpreted the sensory report before one has subjective experience. Helmholtz was not a nativist but an empiricist. Whatever organizing and interpreting processes existed would have to be accounted for upon the basis of prior experience rather than inborn mechanisms. This, in effect, was what Berkeley had been suggesting. As a consequence of his empiricist leanings, and in an attempt to account for the perception of three dimensions in vision, Helmholtz proposed *unconscious inference theory*.

Unconscious Inference Theory

Helmholtz, in his *Treatise on Physiological Optics* (Helmholtz, 1867, in Southall, 1925/2000), introduced what has become the classical, and standard, theory of perception—

unconscious inference theory, a *constructionist, representationalist, indirect realist* theory. In developing it, Helmholtz was influenced by two findings. First, the retina, which is a two-dimensional structure, could only indicate where an object was horizontally and vertically in the visual field; it could not be the basis for an explanation of three-dimensional visual perception. Something had to be added to the retinal sensations, to embellish them. Second, Müller's *doctrine of specific nerve energies* suggested a lack of correspondence between sensory input and subjective experience. Thus, no matter how they were stimulated, each sensory nerve, as was just mentioned, only gave a report specific to it. "It can be shown very easily," Helmholtz would later propose, "that there is no similarity whatsoever, either in kind or in degree, between the qualities of sensations and the qualities of external agents exciting and being portrayed by them" (Helmholtz, 1869/1971, p. 241). The sensory report was inadequate to represent the external world. More than that, what one perceived was not consistent with sensory stimulation. The percept therefore required mediation from within, between it and the sensory presentation, some sort of subsequent processing of the sensory input before it was delivered to consciousness as the completed percept. These mediating mechanisms, for Helmholtz, would be derived from accumulating experience and would come to serve as signs of external agents and events.

According to Helmholtz, the different nerve fibers coming from the different sensory receptors provide signs about the nature of the stimulating agent (Boring, 1929). They symbolize what is inaccessible: "the sensations have been described as being simply *symbols* for the relations in the external world. They have been denied every kind of similarity or equivalence to the things they denote" (Helmholtz, 1867, in Southall, 1925/2000, p. 18). At first, given that the perceiver is without prior experience, these sensory experiences, which will symbolize the object world, are without any objective meaning but, from birth, patterns of sensory experience are being ceaselessly taken up (Turner, 2000). With accumulating experience, the mind—a physiological, or brain process—builds up a store of experiences and, as a consequence, expectations are built up. One such expectation could be the possibility that the recurrence of a previously experienced sensory collage is most likely due to the same stimulating object producing those same impressions.

It is upon the basis of these expectations that an *imagined* world of objects (not a known world) is constructed. Consistent with his predecessor Locke, the objects of experience to Helmholtz were simply an accumulation of sensations (Sahakian, 1975). In the final analysis, all that we ever have knowledge of are our sensations and whatever expectations that we may build up refer to those sensations and not to the objects that produce them.

The psychic activities that lead us to infer that there in front of us at a certain place there is a certain object of a certain character, are generally not conscious activities, but unconscious ones. In their result they are equivalent to a *conclusion*, to the extent that the observed action on our senses enables us to form an idea as to the possible cause of this action; although, as a matter of fact, it is invariably simply the nervous stimulations that are perceived directly, that is, the actions, but never the external objects themselves. But what seems to differentiate them from a conclusion, in the ordinary sense of that word, is that a conclusion is an act of conscious thought . . . Still it may be permissible to speak of the psychic acts of ordinary perception as *unconscious conclusions*, thereby making a distinction of some sort between them and the common so-called conscious conclusions. (Helmholtz, 1867, in Southall, 1925/2000, p. 4, emphasis in original)

Our ideas of things *cannot* be anything but symbols, natural signs for things which we learn how to use in order to regulate our movements and actions. Having learned

correctly how to read those symbols, we are enabled by their help to adjust our actions so as to bring about the desired result; that is, so that the expected new sensations will arise. (Helmholtz, 1867, in Southall, 1925/2000, p. 19, emphasis in original)

Through the means of sensory experience, we act in an inaccessible world and regulate and modify those actions upon the basis of subsequent sensory feedback.

So, as a result of prior experience and unconscious association processes, incoming sensory signs or clues are automatically processed at a level that does not require conscious involvement, and which result in one's conscious experience or perception (Boring, 1929). What one perceives is thus, according to Helmholtz, due to unconscious inferences about what must have produced the present pattern of sensations. Helmholtz made his point by explaining what one's idea of a table is and to what it refers:

The idea of a single individual table which I carry in my mind is correct and exact, provided I can deduce from it correctly the precise sensations I shall have when my eye and my hand are brought into this or that definite relation with respect to the table. Any other sort of similarity between such an idea and the body about which the idea exists, I do not know how to conceive. One is the mental symbol of the other. The kind of symbol was not chosen by me arbitrarily, but was forced on me by the nature of my organ of sense and of my mind. (Helmholtz, 1867, in Southall, 1925/2000, p. 23)

In that regard, such unconscious inferences are, in their results, inductive and comparable to conscious inferences that are made upon the basis of analogy. The idea that a person has of external things is nothing other than symbols that one has learned to use in regulating one's actions in the world—a world that one has no access to or knowledge of, beyond unconscious conjecture.

In dealing with these processes of unconscious inference Helmholtz made three positive claims (Boring, 1929). Such inferences are, first, formed through experience. They begin as conscious inferences that through association and repetition develop into unconscious inferences. Conscious states, through repetition and by what Helmholtz called the "law of habit", are reduced until the process cannot be accessed through introspection; they sink beneath the level of consciousness. Boring called this "conscious decay under habituation," which we would today refer to as *automaticity*. His second point was that, due to their being unconscious, such processes are normally very difficult to resist. The associations that have been well established were practically inevitable (although they could be unlearned with further experience). The operation of such unconscious inferences is evident when one is confronted with some unfamiliar or ambiguous sensory pattern; one experiences the mind generating alternate perceptions. That is the case with a Necker cube—a two-dimensional drawing of a three-dimensional box frame. Without any conscious attempt on one's part, the perceived orientation of the frame switches and each orientation is as compelling and irresistible as the other. Optical illusions such as that, to Helmholtz, were evidence in favor of his theory. His final point, which was taken into consideration previously, was that unconscious inferences resembled conscious inferences from analogy in being inductive—an inference, indeed, but not a conscious one.

On the negative side, unconscious inferences could be wrong; we suffer illusions (McLaughlin, 1998). The fact of illusions is taken as evidence that perception is fallible. There is nothing to guarantee us that our perceptions are veridical. At the level of the receptors after all we are provided with evidence that is insufficient for the task of perceiving depth or three dimensions. Perception of three dimensions, as Anderson (2000) expressed it,

is nothing more than an educated guess. We do not know the world. We do not have direct access to it. What we do know we know only through the medium of the senses, and the medium of inferences, and, hence, perception is indirect; the world as it is will not be made available to us.

References

- Anderson, B. L. (2000). Depth perception. In A. E. Kazdin (Ed.), *Encyclopedia of Psychology*, Vol. 2 (pp. 476–480). Washington, DC: Oxford University Press.
- Boring, E. G. (1929). *A history of experimental psychology*. New York: Appleton-Century-Crofts.
- Gibson, J. J. (1966). *The senses considered as perceptual systems*. Boston: Houghton Mifflin Company.
- Helmholtz, H. von (1971). The aim and progress of physical science. In R. Kahl (Ed.), *Selected writings of Hermann von Helmholtz* (pp. 223–245). Middletown, CT: Wesleyan University Press. (Originally published 1869.)
- Hershenson, M. (1999). *Visual space perception: A primer*. Cambridge, MA: The MIT Press.
- Levine, M. W. and Shefner, J. M. (1981). *Fundamentals of sensation and perception*. Reading, MA: Addison Wesley.
- McLaughlin, B. P. (1998). Perception, epistemic issues in. In E. Craig (Ed.), *Routledge encyclopedia of philosophy Vol. 7* (pp. 293–299). London: Routledge.
- Sahakian, W. S. (1975). *History and systems of psychology*. New York: John Wiley & Sons.
- Southall, J. P. C. (2000). *Helmholtz's treatise on physiological optics. Vol. III: The perceptions of vision* (edited by J. P. C. Southall). Sterling, VI: Thoemmes Press. (Original edition printed in 1925 from Helmholtz 1867.)
- Turner, R. S. (2000). Helmholtz, Herman von. In A. E. Kazdin (Ed.), *Encyclopedia of Psychology*, Vol. 4 (pp. 109–111). Washington, DC: Oxford University Press.