Perceptual Learning

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Synonyms

Sensitization; habituation; perceptual adaptation

Definition

Perceptual learning consists of long-lasting changes to an organism's perceptual system that improve its ability to respond to its environment in specific ways. These changes persist over time; more ephemeral perceptual changes are typically considered to be adaptation, attentional processes, or strategy shifts, rather than perceptual learning. These changes are due to environmental inputs; perceptual changes not coupled to the environment are considered maturation, rather than learning. Perceptual learning benefits an organism by tailoring the processes that gather information to the organism's needs for and uses of information.

Theoretical Background

Perceptual learning is psychologically important both because it is *perceptual* and because it is *learning*. Because the changes are perceptual they affect all cognitive processes that occur downstream in the flow of information processing. Accordingly, it makes sense for perceptual systems to change slowly and conservatively. However, because these changes constitute learning, the payoffs for perceptual flexibility are too large to forego completely. They allow an organism to respond quickly, efficiently, and effectively to stimuli without dedicating on-line attentional resources. Instead of strategically determining how to use unbiased perceptual representations to fit one's needs, it is often easier to work with task-relevant representations created directly by perceptual processes. Many sophisticated cognitive tasks can be solved by converting originally demanding, strategic operations into learned, automatically executed perceptual processes.

An initial suggestion that our experiences and tasks influence perception comes from a consideration of the differences between novices and experts. Experts in many domains, including radiologists, wine tasters, and Olympic judges, develop specialized perceptual tools for analyzing objects within their domains of expertise. Much of training and expertise involves not only developing a database of cases or explicit strategies for dealing with the world, but also tailoring perceptual processes to represent the world more efficiently (Gibson, 1991). There is evidence that perceptual learning occurs early in both neurological and functional senses.

Neurological evidence for perceptual learning. Several sources of evidence point to the influence of expertise occurring at a relatively early stage of perceptual processing. First, electrophysiological recordings of dog and bird experts show enhanced electrical activity at 164 milliseconds after the presentation of dog or bird pictures, but only when the experts categorized objects within their domain of expertise (Gauthier, Tarr, & Bubb, 2010). Likewise, practice in discriminating small motions in different directions significantly alters electrical brain potentials occurring within 100 milliseconds of the stimulus onset, in an area centered over the primary visual cortex. These neurophysiological responses implicate relatively early influences of expertise. Expertise for visual stimuli as eclectic as butterflies, cars, chess positions, dogs, and birds has been associated with an area of the temporal lobe known as the fusiform face area. The identification of a common brain area implicated in visual expertise for many domains suggests the promise of developing general theories and models of perceptual learning.

Prolonged practice with a subtle line discrimination task results in much improved discrimination, but the improvements are highly specific to the orientation of the lines shown during training (Jacobs, in press). Such high specificity of training effects is typically associated with changes to early visual cortex. There is also evidence for early effects of experience on tactile perception, where “early” is operationalized neurologically in terms of a relatively small number of intervening synapses connecting a critical brain region to input from the external world. Monkeys trained to discriminate between slightly different sound frequencies develop larger somatosensory cortex representations for the presented frequencies than do control monkeys (Recanzone, Schreiner, & Merzenich, 1993). Similarly, monkeys learning to make a tactile discrimination with one hand develop a larger cortical representation for that hand than for the other hand. Expert violinists show greater activity in their sensory cortex when their left rather than right hand is lightly touched, consistent with the observation that violinists use their left hand fingers considerably more than their right hand fingers.

Functional evidence for Perceptual Learning. Experience often exerts an influence before other putatively early perceptual processes have been completed. The organization of the mental representation of a scene into figure and ground is influenced by the visual familiarity of the contours. A shape is more likely to be interpreted as the figure in an ambiguous scene if it is familiar rather than unfamiliar. Furthermore, object fragments that are not naturally grouped together can nonetheless be perceptually joined if participants have been familiarized with an object that unifies the fragments. Two complementary functional processes of perceptual learning are unitization and differentiation.

Via unitization, a single functional unit is constructed that combines many stimulus components useful for a task (Goldstone, 1998). One source of evidence for unitization is the absence of complexity effects. People can identify a long word almost as quickly as a short word, if the words are equated for familiarity. Shape components of often-presented stimuli become processed as a single functional unit with practice, resulting in highly efficient identification of the unit being identified even in a field of similar distractors. Unitization tends to occur when a set of components to be unitized frequently co-occurs and their co-occurrence is diagnostic for an important task.

New perceptual representations can be created by chunking together elements that were previously psychologically separated, but the converse process of differentiation also occurs. Perceptual dimensions that were originally psychologically fused together can become separated and isolated. Wine experts can learn to isolate the tannin content in wine. Color experts (vision scientists and artists) are better able than non-experts to selectively attend to dimensions (e.g. hue, chroma, and value) that comprise color. There is developmental evidence that dimensions that are easily isolated by adults, such as the brightness and size of a square, are treated as psychologically fused by four-year old children. Differentiation of objects into psychologically separated elements tends to occur when the elements appear approximately independently of each other, and when the elements are differentially relevant for an important task.

Important Scientific Research and Open Questions

One of the theoretical and empirical challenges underlying our opening definition is to distinguish between perceptual learning and higher-level, cognitive learning. In fact, Hall (1991) has persuasively argued that many results that have been explained in terms of perceptual learning are more parsimoniously described as strengthening and weakening of associations. Several strategies have been proposed for differentiating perceptual changes from higher-level changes. Under the assumption that perception involves the early stages of information processing, one can look for evidence that experience influences early processes, exactly the goal of the aforementioned neurological and functional research.

Mechanisms of perceptual learning. Perceptual learning is not a unitary process. Psychophysicists have distinguished between relatively peripheral, specific adaptations and more general, strategic ones, and between quick and slow perceptual learning processes. Cognitive scientists have distinguished between training mechanisms driven by feedback (supervised training) and those that require no feedback, instead operating on the statistical structure inherent in the environmentally-supplied stimuli (unsupervised training). Identifying the major mechanisms by which perceptual learning occurs is helpful for organizing empirical results as well as informing formal models of learning. In addition to unitization and differentiation, another major mechanism is attention weighting. By this mechanism, perception becomes adapted to tasks and environments by increasing attention to perceptual dimensions and features that are important, and/or by decreasing attention to irrelevant dimensions and features. Attention weighting, however, is not always properly considered perceptual because attention can be selectively directed toward important stimulus aspects at several different stages in information processing, not only at the early stages.

A phenomenon of particular interest for attentional accounts of perceptual learning is categorical perception. According to this phenomenon, people are better able to distinguish between physically different stimuli when the stimuli come from different categories than when they come from the same category. This effect was originally documented for speech sounds. Observers listened to three sounds -- A followed by B followed by X - and indicated whether X was identical to A or B. Subjects performed the task more accurately when syllables A and B belonged to different phonemic categories than when they were variants of the same phoneme, even when physical differences were equated. Perceptual learning is implicated because the categorical perception effects that are found depend on the listener's language. A sound difference that crosses a boundary between phonemes in a language will be more discriminable to speakers of that language than to speakers of a language in which the sound difference does not cross a phonemic boundary. Furthermore, laboratory training on the sound categories of a language can produce categorical perception among speakers of a language that does not have these categories. Categorical perception is an important phenomenon because it involves the interplay between higher-level conceptual systems and lower-level perceptual systems. Traditional information flow diagrams in cognitive science typically draw a clean division between perceptual and conceptual systems, with information moving only from perception to the conceptual system. The frequency of categorical perception effects indicates permeability and bidirectional influence between these systems. We do not simply base our categories on the outputs of perceptual systems independent of feedback. Instead, our perceptual systems become customized to the useful categories that we acquire.

<u>Perceptual Learning and Education.</u> A perceptual learning perspective can inform scientifically grounded educational reform. A credible and worthy hope for education is to teach students to re-task for new purposes their long-tuned, but still inherently dynamic perceptual systems. Systematically training perception is a highly effective method to facilitate sophisticated reasoning. Developing expertise in most scientific

domains involves perceptual learning. Biology students learn to identify cell structures, geology students learn to identify rock samples, and chemistry students learn to recognize chemical compounds by their molecular structures. In mathematics, successful solution of a problem is often a matter of changing one's way of looking at it. Progress in the teaching of these fields will be well served by understanding the mechanisms by which perceptual and conceptual representations inform and influence one another.

One of the reasons why wisdom cannot be simply told, but rather must be lived, is that wisdom is frequently perceptual and thus must be built into one’s neurological wiring. Doctors with years of clinical experience frequently experience are often surprised to find that their verbal descriptions have little value to second-year residents. The lecturer knows what she means by “spiky” tumors or “aggravated” tissue, but the meanings of these words are not communicable in the same way that “isosceles” can be given a simple verbal gloss of “a triangle having two sides of equal length.” The doctor’s terminology is not easily communicated because the words are just the tip of the iceberg. The iceberg below the surface is the years of experience needed to connect perceptual information to the words. Understanding the words is largely a matter of acquiring the perceptual skills of segmentation, highlighting, categorical perception, differentiation, and unitization. While the doctor’s terminology takes years to master because its perceptual basis must also be learned, the final result of this mastery is that the newly forged expert sees a new world. Philosophers of science have described how scientists, exposed to a novel theoretical paradigm, can come to see physical phenomena in new ways. A similar transformative experience accompanies students acquiring expertise and justifies the hard and long work necessary to establish this “see change” in perception.

Scientific and mathematical reasoning depend on thinking analytically, making novel and creative associations between dissimilar domains, and developing deep construals of phenomena that seem to run counter to untutored perceptions. However, an appreciation of the adaptability of perception can lead us to reevaluate the traditional position that abstract reasoning is opposed to, and must overcome, potentially misleading perceptual resemblances. The results reviewed here suggest an alternative position that even seemingly abstract cognitive tasks can be accomplished by educating perceptual processes. Sophisticated understandings do not merely trump perception. Sophisticated understandings shape perception, and vice versa.

Cross-References

Adaptation and learning; Animal perceptual learning; Discrimination learning model; Expertise; Neuropsychology of Learning; Perceptual similarity (and learning); Routinization of learning; Sensorimotor adaptation; Simultaneous discrimination learning; Visual perception learning.

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