ANIMAL PERCEPTUAL LEARNING

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Definition

Perceptual learning refers to the set of processes by which experience with similar stimuli increases the ease with which they can be discriminated. In nonhuman animal this is revealed by enhanced acquisition in a task in which the critical stimuli are associated with different outcomes (and thus come to control different responses); also by a reduction in the extent to which a response trained to one of the stimuli will generalize to the other. It reflects the fact that experience with the stimuli enhances the perceptual effectiveness of features that differentiate them and/or reduces the effectiveness of features they hold in common. It can be produced not only by explicit training but also by mere exposure to the stimuli.

Theoretical Background

The ability of nonhuman animals to perform subtle discriminations is legendary; and it is confirmed by experimental study. For example, appropriately trained dogs can detect the presence of human odor on a microscope slide touched by a human finger three weeks previously; they can determine the direction of a 1-hour-old odor trail left by a human given access to only five footsteps; they can detect the difference between cancer patients and healthy controls on scent alone, given access exhaled breath samples. These examples rival (perhaps surpass) the achievements of human experts (e.g., wine tasters, tea blenders), achievements that have been taken to be prime instances of perceptual learning. Laboratory studies undertaken to reveal the nature of the mechanisms involved have been more mundane. In one procedure, widely used with rats, discrimination is required between two flavors, A and B. After training in which A is associated with experimentally induced nausea, the degree to which the aversion that is established to A will generalize to B is tested. Failure to generalize indicates that the rats can discriminate A from B. In fact such generalization commonly occurs (especially as it is customary to add a third flavor to both, making the stimuli AX and BX and thus making them more similar). Generalization is reduced, however, (i.e., discrimination is enhanced) if the rats are given prior exposure to the flavors. It is concluded that such preexposure allows perceptual leaning to occur.

A common theoretical analysis applies to all the various examples of the phenomenon. Any two stimuli can be conceived of as being composed of sets of features, some of which are unique to each individual stimulus, others of which are held in common. Similar stimuli will have a high proportion of common features. Discrimination is evidenced when an animal makes different responses to the different stimuli. In order for this to be achieved, behavior must come under the control of the unique rather than the common features. Thus, to pursue the example just outlined, generalization will occur between AX and BX to the extent that training with AX establishes an aversion to the common feature X; on the other hand, discrimination will be enhanced if the rat learns principally about the unique feature A during conditioning and/or its behavior is chiefly controlled by the unique feature B on the test. Procedures (like preexposure to the stimuli) that enhance discrimination may be assumed to do so because they promote control by the unique features. Experiments with animal subjects have been conducted to elucidate the processes by which this might occur.

Important Scientific Research and Open Questions

Much work has focussed on the role of explicit discrimination training. In such training the animal experiences presentations of the stimuli associated with different outcomes (e.g., response to AX is followed by food and response to BX is not). When differential responding is established (e.g., the animal chooses to approach AX rather than BX) we conclude that the unique features have gained control over behavior. Standard theories of associative learning are designed to explain this result; according to such theories, the predictive cues, A and B, gain associative strength at the expense of nonpredictive (X) cues, which become 'neutralized'. This learning process may be enough in itself to supply an explanation for the abilities of experts (humans and canines), as these abilities are typically established by means of (extensive) explicit discrimination training. To that extent, these skills would not strictly involve perceptual learning according to the definition offered above, as the proposed mechanism would not necessarily involve changes in the perceptual effectiveness of the stimuli.

It remains possible, however, that, in addition to the associations it establishes, discrimination training might produce a change in the perceptual effectiveness of the stimuli. This notion is central to Mackintosh's (1975) theory of animal discrimination learning, with its proposal that the ability of a stimulus feature to command attention is enhanced by training in which that feature has accurately predicted its consequences. Evidence for this form of attentional learning has been sought in transfer tests – after initial discrimination training with one set of stimuli the animal is shifted to a new task in which the same stimuli are used but which involves different response requirements, so that the associations acquired in initial training will be irrelevant. Positive transfer might thus be taken to indicate that the initial training had produced a change in the properties of the stimuli. Such transfer was demonstrated early on in the study of animal discrimination learning. It should be acknowledged, however, that alternative accounts have been offered and that the proper interpretation of such transfer tests continues to be debated (see Hall, 1991).

Perceptual learning does not require explicit training; mere exposure to the stimuli has been found to facilitate subsequent discrimination between them. An early, and influential, example was provided by Gibson and Walk (1956), who showed that the ability of rats to discriminate shapes (triangle from circle) was enhanced when the rats had been raised with these shapes displayed in the home cage. The instance mentioned above, reduced generalization in flavor-aversion conditioning after preexposure to the flavors, constitutes a modern example of the same phenomenon. This simple case has been investigated in detail in the hope of establishing learning principles that might be applied to explain perceptual learning more generally.

The best known effect of mere exposure to a stimulus is *habituation* – a form of learning that shows in a reduction of the ability of the stimulus to evoke its usual response. An habituated stimulus is effectively less salient than a novel one. This simple learning process can supply a partial explanation for the perceptual learning effect. Preexposure to the stimuli will allow habituation to occur to all their various features, but especially to the features they hold in common. Animals exposed to AX and BX experience X on every trial and thus this feature will experience twice as much habituation training as the unique features, A and B. The effective salience of A and B will thus be high relative to that of X, and behavior will be more likely to be controlled by these features, resulting in an enhanced ability to discriminate between AX and BX.

Evidence that this process cannot be the sole source of perceptual learning after mere exposure comes from experiments investigating the effects of different schedules of stimulus presentation. Symonds and Hall (1995) gave some rats alternating presentations of two compound flavors (AX/BX/AX/BX... and so on); other rats received equivalent exposure except that the flavors were presented on separate blocks of trials (AX/AX....BX/BX...). In spite of the fact that in both conditions the common element X was presented on every trial, only the first schedule produced a sizeable perceptual learning effect. This result, the superiority of the alternating over the blocked preexposure schedule, has been confirmed many times, and with a variety of species and training procedures. It has been taken to support the proposal that perceptual learning occurs best in circumstances that allow the possibility of comparison between the stimuli (the assumption being that comparison will be facilitated by a procedure in which the critical stimuli are presented in alternation).

It remains to specify the mechanisms by which the comparison process might work. One possibility is that when BX, for example, is experienced immediately after AX, habituation of the common (X) features, allows the unique feature (B, in this case) to stand out, so that this feature receives particularly efficient processing and is accurately encoded in memory. This mechanism seems plausible for procedures in which the stimuli are presented in quick succession, but the alternating schedule is effective in producing perceptual learning in rats even when stimulus presentations occur several hours apart. For this case it has been argued that associations formed among the constituent elements of the stimuli play an important role in producing the perceptual learning effect (see McLaren & Mackintosh, 2000; Hall, 2003) but there is, as yet, no consensus as to what this role might be.

The phenomena of animal perceptual learning are important for two reasons. First, standard theories of learning, based largely on studies of animal conditioning, have treated ‘the stimulus’ as something defined solely by its physical properties. The fact that the way in which a stimulus is perceived can be modified by experience means these theories need to be supplemented by an account of the learning processes responsible for such modification. Second, in human, as in nonhuman animals, discrimination will be facilitated by processes that enhance the perceptual effectiveness of unique features of the stimuli to be discriminated (and/or reduce the effectiveness of features the stimuli hold in common). Evidence from experiments on animals can help elucidate the learning mechanisms involved in perceptual learning generally.

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