Chem. Senses 30 (suppl 1): i238–i239, 2005 doi:10.1093/chemse/bjh202

Persistence of Acquired Changes in the Properties of Odors and Flavors for Both Humans and Rats

R.A. Boakes

University of Sydney, Sydney, NSW 2006, Australia

Correspondence to be sent to: Professor R.A. Boakes, e-mail: bobb@psych.usyd.edu.au

Key words: extinction, flavor; learning, odor, persistence, preference, taste

How pleasant or unpleasant we find an odor depends on our past experience. Similarly, the perceptual properties of an odor and how similar it seems to other odors are also subject to change. The ways in which liking for an odor and its perceptual properties can be altered have been examined in two main kinds of experiment. One involves what we refer to as odor–odor learning. Participants are asked to sniff some mixtures, each containing two odors and later to rate the individual component odors in various ways. Thus, two mixtures can be represented as AX and BY, where A and B are unfamiliar odors that participants find difficult to identify, whereas X and Y are more familiar and more easily identified. Sniffing the mixtures, AX and BY, a number of times changes the way in which the odors are subsequently rated. Thus, A is perceived as being more X-like and B as more Y-like. For example, after sniffing a mixture of champignol (mushroom-smelling) and citral (lemon-smelling), participants rate champignol as more lemonlike than participants who had sniffed a mixture of champignol and cherry. Furthermore, when asked to rate the similarity of pairs of odors, A is rated as more similar to X than it is to Y and B more similar to Y than to X. Thus, odors can acquire new properties simply as a result of being experienced in a mixture with another odor (e.g. Stevenson *et al.*, 2003).

The second way to change the properties of odors involves odor–taste learning. In a typical experiment participants are first given a sniffing pre-test in which they rate a series of odors in terms, for example, of intensity, sweetness, sourness and liking. Within this set of odors is a target odor (CS+, e.g. lychee) and a control odor (CS–, e.g. water chestnut). The subsequent training phase consists of a series of trials on each of which participants drink a small amount of a solution and then make some judgment about the sample; for example, how pleasant or how strong it tastes. Some of these samples consist of a 10% sucrose solution to which the target odor has been added as a flavorant and others consist of water to which the control odor has been added as a flavorant. Following the training phase a sniffing post-test is given that is identical to the pre-test. The consistent outcome from such experiments is that the target odor is rated as sweeter in the post-test than it was in the pre-test. We refer to this acquisition of taste-like properties by an odor as the 'tasty-odor effect'. It is not limited to sweetness. An odor can smell more sour after it has been drunk in combination with citric acid or more bitter after being drunk in combination with a quinine solution (Stevenson *et al.*, 1998, 2000; Yeomans *et al.*, 2004).

Related experiments have been carried out in the context of human evaluative learning (De Houwer *et al.*, 2001). Drinking a mixture of a flavor and unpleasant taste can reduce liking for the flavor. However, drinking a mixture of a flavor and sucrose solution does not consistently increase liking for a flavor. Very recently Yeomans *et al.* (2004) have found that this outcome depends on individual differences in liking for sweet tastes. When the odor–taste procedure described above is used, only those participants who rate a 10% sucrose solution as very pleasant show increased liking for the target odor that had been added to the sucrose solution during training.

An animal that shows much more consistent liking for sucrose solutions than adult humans is the laboratory rat. After a few occasions on which a rat has drunk a sucrose solution containing a target flavor, it will subsequently display a preference for this flavor when given a choice between water containing the target flavor and plain water (e.g. Harris *et al.*, 2004). To drink a flavored, but non-sweet, solution rats need to be motivated. Usually this is achieved by maintaining a fluid deprivation schedule and by giving trials only once or twice a day. Human participants can simply be asked to drink a number of small samples within a session. Apart from these motivational considerations, the experimental procedures can be unusually similar.

In addition to the procedural similarities, some of the properties of odor–taste learning in rats are remarkably similar to those found for human odor–odor and odor–taste learning. Following odor–odor learning we have attempted to reduce the change that exposure to a two-odor mixture has produced in various ways. The simplest is to use the equivalent of an extinction procedure following classical conditioning. Thus, after participants have been given the two-odor mixtures, AX and BY, in the training phase, they are then exposed to A and X separately. Even when the number of such post-acquisition (i.e. 'extinction') trials has far exceeded the number of times in which AX were initially presented as a mixture, we have failed to detect any reduction in the acquired similarity—or 'acquired equivalence'—produced by the initial odor–odor training (Stevenson *et al.*, 2003).

Subsequently, we have used a potentially more powerful interference treatment following acquisition. In these experiments training on AX and BY is followed by an interference phase in which the target odors—A and X, say—are now mixed with other odors, i.e. CX and AZ. This resembles a classic retroactive interference design of the kind that can produce substantial forgetting in human memory experiments. However, when applied to odor–odor learning it had no effect: the acquired similarity between A and X was unaffected by this form of interference (R.J. Stevenson, T. Case and R.A. Boakes, submitted).

Odor–taste learning shows similar persistence. As already noted, an odor mixed with citric acid solution will acquire some 'sourness', as rated in a sniffing post-test. In two experiments we compared such a control odor with one that had been treated in an identical way during the acquisition phase, namely, presented in a citric acid solution on eight separate trials, but had then been presented in water alone for a further 12 trials (extinction procedure). This treatment produced no detectable decrease in the odor's sourness, relative to the control odor that had not been given an extinction treatment (Stevenson *et al.*, 2000).

Exactly the same persistence in seen in flavor preferences acquired by rats. In a typical experiment two groups of rats are given identical training consisting of a number of sessions in which they drink a tasteless odor—for example, almond—added to a 10% sucrose solution. An initial two-bottle choice test is then given to confirm a greater preference for almond over water—typically ~70%—compared to control groups not exposed to the almond–sucrose mixture, these having typically a neutral preference score, i.e. ~50%. One group is now given almond alone for many sessions, while its matched group is given only water on these sessions. They are then given a second two-bottle test. A consistent result is that both groups still show the same high level of preference for almond. Thus, the extinction treatment of giving almond without sucrose has had no impact on the acquired preference (R.A. Boakes and L. Albertella, in preparation).

A possible explanation for the failure to detect any interference effect is that the procedure was not powerful enough or the data too variable. To check on this, added controls were included in some human experiments. Thus, in Stevenson *et al.* (2000) participants were trained on color–taste combinations as well as on odor–taste mixtures; the extinction procedure was found to reduce participants' ability to retrieve a color–taste association, while leaving unaffected the similarly treated odor–taste effect. Similarly, in Stevenson *et al.* (2003) participants were trained on both odor–odor and on color–odor combinations. Subsequently presenting some of the colors and odors on their own (extinction treatment) again affected memory for the color–odor combinations but left odor–odor learning unaffected. Such results point to the conclusion that the effect of experiencing a hitherto unfamiliar odor in combination with either another odor or with a taste results in a change in that odor's qualities that become peculiarly resistant to further change.

A casual account for the changes in perception and hedonic value of an odor described here is that they depend upon the odor evoking a memory of some past experience. However, it should be stressed that this is almost always an implicit memory; participants show little explicit recall of what odor went with which taste or which other odor. It is also based on incidental learning; participants are not instructed to learn about the various combinations. As proposed elsewhere in more detail, implicit memory of some odor–odor or odor–taste experience appears to be based on configural encoding (Stevenson and Boakes, 2004). How this might produce unusual resistance to extinction is uniquely predicted by an associative learning theory based on configural encoding (Pearce, 2002).

References

De Houwer, J., Thomas, S. and **Baeyens, F.** (2001) *Associative learning of likes and dislikes: a review of 25 years of research on human evaluative conditioning*. Psychol. Bull., 127, 853–869.

Harris, J.A., Shand, F.L., Carroll, L.Q. and **Westbrook, R.F.** (2004) *Persistence of preferences for a flavor presented in simultaneous compound with sucrose*. J. Exp. Psychol. Anim. Behav. Proc. (in press).

Pearce, J.M. (2002) *Evaluation and development of a connectionist theory of configural learning*. Anim. Learn. Behav., 30, 73–95.

Stevenson, R.J. and **Boakes, R.A.** (2004) *Sweet and sour smells: the acquisition of taste-like qualities by odours*. In Calvert, G., Spence, C. and Stein, B.E. (eds), Handbook of Multisensory Processes. MIT Press, Cambridge, MA.

Stevenson, R.J., Boakes, R.A. and **Prescott, J.** (1998) *Changes in odour sweetness resulting from implicit learning of a simultaneous odour–sweetness association: an example of learned synesthesia*. Learn. Motiv., 29, 113–132.

Stevenson, R.J., Boakes, R.A. and **Wilson, J.** (2000) *Resistance to extinction of conditioned odor perceptions: evaluative conditioning is not unique*. J. Exp. Psychol. Learn. Mem. Cogn., 26, 423–440.

Stevenson, R.J., Case, T. and **Boakes, R.A.** (2003) *Smelling what* was *there: acquired olfactory percepts are resistant to further modification*. Learn. Motiv., 34, 185–202.

Yeomans, M.R., Mobini, S., Elliman, T.D. and **Walker, H.C.** (2004) *Changes in the sensory and hedonic characteristics of odours conditioned by association with tastants*. Appetite, 42, 415.