Chem. Senses 23: 443–445, 1998

REVIEW

Is There an Inner Nose?

David G. Elmes

Psychology Department, Parmly Hall, Washington and Lee University, Lexington,
VA 24450-0303, USA

Correspondence to be sent to: David G. Elmes, Psychology Department, Parmly Hall, Washington and Lee University, Lexington, VA 24450-0303, USA. e-mail: elmesd@wlu.edu

Abstract

Although behavioral and neuropsychological data regarding the existence of images for odors are inconclusive, reconsideration of earlier EEG work provides reasonably clear evidence for an inner nose. However, further EEG studies and neuroimaging data seem essential for conclusive demonstrations of an inner nose.

Converging data from behavioral, neuroimaging, electrophysiological and neuropsychological experiments clearly demonstrate that visual and auditory images are genuine cognitive phenomena that can exist independently of perception (e.g. Pinker, 1997). Moreover, imaging and electrophysiological results show that visual and auditory images are served by the same physiological systems active during perception in the respective modalities (Zatorre *et al.*, 1996; Farah, 1995; Halpern *et al.*, 1997). Such results provide strong evidence for the existence of an 'inner eye' and an 'inner ear'. These informal names for the mechanisms underlying visual and auditory imagery have been formalized in Baddeley's (1986) model of working memory as portions of the visuospatial scratch pad and the phonological buffer in the articulatory loop respectively. The mind's eye can see in the absence of a visual stimulus and can elaborate upon a visual stimulus (a tree is imaged in response to the printed words 'Christmas tree'). Likewise, the mind's ear can operate in the absence of an auditory stimulus and can modify existing auditory stimuli (say, by imagining the continuation of a recently heard familiar melody). These inner imaginal codes are typically manifested in behavior via referential connections to the language system (Paivio, 1979), which means that both visual and auditory images are closely intertwined with propositions in the meaning of a cognitive event.

Is there an 'inner nose'? The apparent lack of converging evidence for olfaction akin to those in vision and audition questions whether images for odors exist. Behavioral data regarding olfactory images are suggestive but, as in audition and vision, are not conclusive by themselves. Despite the claim that odor images cannot exist (Engen, 1987), a variety of different behavioral paradigms have found evidence for them (Lyman and McDaniel, 1990; Algom and Cain, 1991; Carrasco and Ridout, 1993). However, none of these studies has gone unquestioned (Crowder and Schab, 1995; Schifferstein, 1997) with regard to the inner nose question. The major complaint is that the odor images may have arisen from cognitive mediation of some sort, especially semantic knowledge. Although the exact nature of this mediation is not detailed, one possibility is that the internal representation of odors is propositional in nature. For example, the internal representation of the odor of cloves is not olfactory but verbal in the sense that cloves are spices, are used in pickling, are often smelled in the dentist's office, etc.

It is not clear how strong the semantic mediation argument is. In the first place, there is no direct evidence that semantic mediation has been involved. Secondly, it seems reasonable to expect any kind of image (odor or otherwise) to have some semantic effects, since most thinking involves semantics [i.e. the referential connections in Paivio's (1979) dual-code theory]. Thirdly, the results could be due to olfactory images, which renders the semantic argument moot. To reduce the possibility that direct semantic factors and not imaginal ones are in effect, the next steps in behavioral research are studies in which semantic confounding seems unlikely.

When possible semantic factors are minimized, only modest evidence for odor images exists (Crowder and Schab, 1995; Elmes and Jones, 1995). For example, in one experiment concerning odor identification, Elmes and Jones (1995) used an implicit memory priming procedure to minimize conscious verbal recollection of previous experience with target odors in the experiment. Two experimental groups each saw 20 photographs of common odorous objects for 5 s each. Ten of these photographs matched the target odors used in a later identification test (a photograph of lemons was presented and lemon extract was to be identified later). Participants in the Visual Group merely named the object in each photograph and were instructed to imagine it in their inner eye. Those in the Odor Group named each object and were told to create an image of the object's odor in their inner nose. A Control Group skipped this and the subsequent phase. Prior to the odor identification test, the two experimental groups engaged in a filler task for 3 min in which they rated the pleasantness of several foods and beverages. They were then asked to participate in an 'additional independent test', which was conducted by another experimenter. The control subjects were now tested identically. This attempt at an implicit test of imagery involved 20 odors, 10 of which matched the objects shown in phase one. Participants sniffed each odor for 2 s before naming it. The odorants were presented in opaque containers and were covered with gauze to obviate visual cues. About 46% of the target odors were identified correctly by the Control Group, 55% by the Visual Group and nearly 58% by the Odor Group. The Odor Group differed significantly from the Control Group, but had just slightly better than a 2% advantage over the Visual Group.

The results of Elmes and Jones show a very modest effect that can be directly attributed to odor images. This small effect of odor images tempts one to agree with Herz and Eich (1995) that odors serve as a potent retrieval cue for vital information 'without the complexity of multiple associations or internal representations' (p. 166). However, the well-documented importance of complicated cognitive processes involved in odor memory, identification, perception and sensation (e.g. Dalton, 1996; Elmes, 1997) should temper the conclusion reached by Herz and Eich. Since accepting the null hypothesis is risky, a more fruitful conclusion is that more appropriate tests are needed to assess the behavioral effects of odor images.

In the neuropsychological literature, there are reports of dysosmia—olfactory hallucinations—associated with the onset of migraine headaches (Wolberg and Ziegler, 1982; Crosley and Dahmoon, 1983). Although these olfactory auras agree with the idea that smells can be experienced without the presence of relevant olfactory stimuli, the self-report data suffer from the lack of corroborative evidence (as do all subjective reports). In principle, electrophysiological or neuroimaging data could provide relevant evidence regarding the locus of the dysosmias in the brain.

To summarize, the behavioral and neuropsychological data regarding olfactory imagery are suggestive but inconclusive. What appears necessary for conclusive evidence is the equivalent of that taken to be strong evidence for visual and auditory imagery—namely, data showing similar underlying physiological mechanisms in odor perception and odor imagery, which will provide independent corroboration for an inner nose.

Such data exist, but they were gathered to address different issues. An earlier EEG experiment by Barabasz and Gregson (1979) provides some evidence for odor images. They examined the suppression of EEG amplitudes to real and sham odors in men living in Scott Base, Antarctica. The men were tested before and after a winter-over period, because the long, cold winters minimize environmental odors and produce transient anosmia. While they monitored EEG, Barabasz and Gregson presented the participants, who had their eyes closed, with six odorants: four were chosen haphazardly from a set of six laboratory-grade liquid odors (acetone, ammonia, eugenol, isoamyl acetate, propanol and turpentine) and two non-existent odors. As the six odorants were presented on a sterile glass rod, the experimenter announced the ordinal number of the odor (not its name), and after 5 s said 'okay' to indicate the termination of that trial.

Prior to the winter-over, both the real and the sham odors reduced EEG amplitude. After the winter-over, only the sham odors reduced EEG amplitude. These data seem to show that illusory odors have central effects and can operate when real odors are ineffective. Barabasz and Gregson concluded that their results indicate neural changes generated by suggestion. It is probably best to be cautious here, because we have minimal information regarding the loci of amplitude suppression, and the relevant time parameters of EEG changes are unknown.

Lorig and Roberts (1990) provide more precise information relevant to the question of brain mechanisms related to odor images. They wanted to clarify some issues regarding the effects of odors on the contingent negative variation (CNV), which is a slow negative brain potential that occurs between a warning stimulus and an imperative stimulus. Their participants saw an odor arbitrarily named on a video monitor, smelled an odor, heard a warning stimulus, then had to make a simple motor response to an imperative stimulus. Changes in the CNV magnitude and scalp location were observed as a function of the odor label and the odor smelled. Participants received what they thought were seven different odor conditions: jasmine, galbanum, lavender and no odor (labeled for the participants as *odor a*, *odor b*, *odor c* and *odor d* respectively), and three low concentrations of jasmine, galbanum and lavender (labeled for the participants as *low a*, *low b* and *low c* respectively). Unknown to the participants, the three low concentrations were all the same odorant, which was a dilute mixture of the three target odors. The scalp topography maps for jasmine, lavender, and the supposed low concentrations of jasmine and lavender indicate highly similar patterns of positivity and negativity in the jasmine and the supposed low jasmine maps and in the lavender and supposed low lavender maps. However, jasmine and lavender yielded markedly different patterns from each other. This is despite the fact that the low lavender and low jasmine odors were physically identical and differed only in the label applied to them. Just as the words 'Christmas tree' can produce a visual image different from the words 'striped tiger', so can 'odor a' and 'odor c' produce different internal olfactory representations.

The galbanum and low galbanum maps were not as similar to each other as was the case for lavender and jasmine. So, the CNV amplitudes for the single odors and the low concentration odors as a function of hemisphere clearly show for lavender and jasmine (but not for galbanum) marked correspondences in CNV amplitude and distribution between the target and its purported low concentration.

The data of Lorig and Roberts illustrate evidence for a physiological effect of an odor in the absence of an adequate stimulus that mimics the physiological effect when that stimulus is present. It is possible that some sort of semantic mediation notion could be devised to account for the results, but it is not clear how verbal mediation would produce such similar scalp topography maps when the subjects' expected internal representation has been cleverly manipulated by the experimenters. Since subjects saw the priming stimulus *odor a* and later gave the same scalp topography for *low a* even though the two odors differed by both composition and concentration, they must have produced an internal representation that was independent of the odor and congruent with the internal representation of *odor a.* Furthermore, CNV amplitude was a function of both odor (lavender differed from jasmine) and odor label (odor *a* and *low a* were highly similar), which is contrary to the findings of Aufferman *et al.* (1993), who found markedly larger CNVs for dilute lavender than for moderately intense lavender.

These CNV data are analogous to those reported for visual and auditory images, and should be taken as strong evidence for the existence of imagery in the olfactory modality. This is especially true if we consider the titillating but inconclusive behavioral and neuropsychological data along with the electrophysiological results.

The package of behavioral, neuropsychological and electrophysiological data presents a reasonably clear picture of an inner nose, one that is not as clear as those for an inner eye and an inner ear. Neuroimaging studies on olfactory images and additional electrophysiological ones should sharpen the picture.

Acknowledgements

I am indebted to Tyler S. Lorig for giving me access to the data from Lorig and Roberts (1990), and for his critical commentary and advice regarding the contents of this paper. Preparation of this paper was supported in part by a Grant from the National Institute of Environmental Health Sciences (R15 ES/0D8838).

References

Algom, D. and **Cain, W.S.** (1991) *Remembered odors and mental mixtures: Tapping reservoirs of olfactory knowledge.* J. Exp. Psychol.: Hum. Percept. Perform., 17, 1104–1119.

Auffermann, H., Gerull, G., Mathe, F. and **Mrowinski, D.** (1993) *Olfactory evoked potential and contingent negative variation simultaneously recorded for diagnosis of smell disorders.* Ann. Otol. Rhinol. Laryngol., 102, 6–10.

Baddeley, A.D. (1986) Working Memory. Clarendon Press, Oxford.

Barabasz, A.F. and **Gregson, R.A.M.** (1979) *Antarctic wintering-over, suggestion and transient olfactory stimulation: EEG evoked potential and electrodermal responses.* Biol. Psychol., 9, 285–295.

Carrasco, M. and **Ridout, J.B.** (1993) *Olfactory perception and olfactory imagery: a multidimensional analysis.* J. Exp. Psychol.: Hum. Percept. Perform., 19, 287–301.

Crosley, C.J. and **Dahmoon, S.** (1983) *Migrainous olfactory aura in a family.* Arch. Neurol., 40, 459.

Crowder, R.G. and **Schab, F.R.** (1995) *Imagery for odors.* In Schab, F.R. and Crowder, R.G. (eds), Memory for Odors. Erlbaum, Mahwah, NJ, pp. 93–107.

Dalton, P. (1996). *Odor perception and beliefs about risk.* Chem. Senses, 21, 447–458.

Elmes, D.G. (1997) *Determinants of olfactory perception.* Arom.-Chol. Rev., 6, 4–5.

Elmes, D.G. and **Jones, S.R.** (1995) *Ineffective odor images.* 36th Annual Meeting of the Psychonomic Society, November, 1995 (Abstract).

Engen, T. (1987) *Remembering odors and their names.* Am. Scient., 75, 497–503.

Farah, M.J. (1995). *Current issues in the neuropsychology of image generation.* Neuropsychologia, 33, 1455–1471.

Halpern, A.R., Zatorre, R.J. and **Evans, A.C.** (1997) *A PET investigation of musical imagery for nonverbal tunes.* 38th Annual Meeting of the Psychonomic Society. November, 1997 (Abstract).

Herz, R.S. and **Eich, E.** (1995) *Commentary and envoi.* In Schab, F.R. and Crowder, R.G. (eds), Memory for Odors. Erlbaum, Mahwah, NJ, pp. 159–175.

Lorig, T.S. and **Roberts, M.** (1990) *Odor and cognitive alteration of the contingent negative variation.* Chem. Senses, 15, 537–545.

Lyman, B.J. and **McDaniel, M.A.** (1990) *Memory for odors and odor names: modalities of elaboration and imagery.* J. Exp. Psychol.: Learn. Mem. Cogn., 16, 656–664.

Paivio, A. (1979) Imagery and Verbal Processes. Erlbaum, Hillsdale, NJ, pp. 67–68.

Pinker, S. (1997) How the Mind Works. Norton, New York, pp. 284–295.

Schifferstein, H.N.J. (1997) *Perceptual and imaginary mixtures in chemosensation.* J. Exp. Psychol.: Hum. Percept. Perform., 23, 278–288.

Wolberg, F.L. and **Ziegler, D.K.** (1982) *Olfactory hallucination in migraine.* Arch. Neurol., 39, 382.

Zatorre, R.J., Halpern, A.R., Perry, D.W., Meyer, E. and **Evans, A.C.** (1996) *Hearing in the mind's ear: a PET investigation of musical imagery and perception.* J. Cogn. Neurosci., 8, 29–46.

Accepted March 18, 1998