Chem. Percept.
DOI 10.1007/s12078-008-9035-z

Sniff Your Way to Clarity: The Case of Olfactory Imagery

Artin Arshamian · Jonas K. Olofsson · Fredrik U. Jönsson · Maria Larsson

Received: 17 July 2008 / Accepted: 4 November 2008

Abstract This study addressed the effects of blocking spontaneous sniffing during olfactory imagery. A group of subjects (n=40) who scored high in olfactory focus and imagery ability rated the vividness in olfactory and visual imagery content under conditions of blocked sniffing, blocked vision, and a nonblocked control. The imagery stimuli consisted of 90 common words that could represent either an odor or a visual object. Blocked sniffing was expected to impair olfactory imagery vividness, but since visual imagery entails eye movements, which was not affected by the "blocked vision" manipulation, visual imagery ratings were effectively used as a placebo control. Confirming our hypotheses, the results showed that preventing sniffing resulted in a selectively poorer olfactory but not visual vividness, whereas blocked vision showed no effect on either the visual or olfactory vividness ratings. These observations confirm that sensorimotor activity is an important aspect for the quality of evoked olfactory images.

Keywords Olfaction · Imagery · Sniffing · Vision · Sensorimotor

A. Arshamian · J. K. Olofsson · F. U. Jönsson · M. Larsson (✉)
Department of Psychology, Stockholm University,
Frescati Hagväg 14,
106 91 Stockholm, Sweden
e-mail: maria.larsson@psychology.su.se

A. Arshamian · J. K. Olofsson · F. U. Jönsson · M. Larsson
Stockholm Brain Institute,
Stockholm, Sweden

J. K. Olofsson
Department of Psychology, Umeå University,
Umeå, Sweden

Introduction

The evidence for the ability to form mental images without any physical stimuli are convincing in vision (Farah 1989; Kosslyn et al. 2001; Richardson 1999), audition (Halpern and Zatorre 1999; Zatorre and Halpern 1993), and in the motor systems (Jeannerod 1995; Jeannerod and Frak 1999). Although some researchers have suggested that humans are unable to form olfactory images (Crowder and Schab 1995; Engen 1991; Herz 2000), support for olfactory imagery is available from different sources such as volitional imagery (Djordjevic et al. 2004), dreams (Stevenson and Case 2005), and hallucinations (Acharya et al. 1998). Research suggests a neuroanatomical overlap between perceptual processing and mental evocation across the visual, auditory, and motor modalities (see Kosslyn et al. 2001 for a review). For instance, Sirigu et al. (1996) showed that patients with lesions to the posterior parietal cortex have a diminished ability to perform motor imagery. Similarly, in vision, lesions to associative visual pathways inhibit both volitional visual imagery and dreams (Farah et al. 1988; Goldenberg 1989, 1992). Recently, Djordjevic et al. (2005) investigated olfactory imagery using positron emission tomography and found that brain areas activated under olfactory perceptual processing also were activated during olfactory imagery (i.e., piriform, orbifrontal, and anterior insular cortices).

An important component of normal smelling is sniffing (see Mainland and Sobel 2006 for a review). When smelling a physical odor, the motor activity of sniffing contributes to the transportation of molecules to the olfactory receptors (Hahn et al. 1994), but it also influences the percept of smell (Laing 1983), and the mere act of sniffing activates primary olfactory cortex (Sobel et al. 1998). Furthermore, sniffing might affect the evocation and quality of olfactory images. Bensafi et al. (2003) reported that sniffing activity during olfactory imagery resembled that during normal olfactory perception. For example, during olfactory imagery, participants spontaneously sniffed, an act that did not occur in visual or auditory imagery. Also, sniffing behavior interacted with hedonics such that sniffs were larger for imagined pleasant as compared to unpleasant odors. Interestingly, when sniffing was prevented, olfactory vividness ratings were lower as compared to a control condition where sniffing was encouraged. Notably, sniffing appears to be more important for olfactory imagery in good compared to poor olfactory imagers (Bensafi et al. 2005). Proficient olfactory imagers took bigger sniffs when imagining a pleasant odor as compared to an unpleasant odor, whereas there was no difference in sniff magnitude in poor olfactory imagers.

One aim of the present study was to address whether blocked sniffing reduces vividness in olfactory imagery compared to a neutral condition where the participant is not instructed to sniff. An important feature of the experiment was that the participants were not given any information that could serve as a cue regarding the hypothesized role of sniffing in olfactory imagery. A classic observation in psychology is effects of "demand characteristics"; participants in psychological investigations provide responses that are influenced by the perceived aims of the study (Orne 1962). Often, participants' behavior is changed towards confirming what they believe to be the experimenters' hypotheses. Blocking the nose of a participant during an olfactory imagery task makes the data highly susceptible to confounding influences of such demand characteristics. In previous experiments of olfactory imagery and sniffing, participants were encouraged to sniff at the beginning of each trial, that may make the participants aware of the sniffing element in imagery (Bensafi et al. 2003). The present study was designed to address this potential confounder. Olfactory and visual imagery were investigated in three different modes: blocked sniffing, blocked vision, and a nonblocked control condition. During olfactory and visual imagery tasks, a nose clip and an eye mask were used to block olfactory and visual perception, respectively. As the eye mask prevented visual input but not oculomotor activity, we hypothesized that visual imagery ratings would not be influenced by the eye mask (cf Laeng and Teodorescu 2002). As this was not explained to the participants, this feature served as a "placebo" control. We hypothesized further that vividness ratings in olfactory imagery would diminish only in the blocked sniffing condition. As participants were led to believe that blocked vision and blocked olfaction were comparable experimental manipulations, this procedure constituted a means of controlling for the possibility that blocked sniffing would influence olfactory imagery by means of a confound of demand characteristics. Furthermore, this feature controlled for the possibility that blocked sniffing decreases the vividness of olfactory imagery simply through unspecific effects of distraction or discomfort due to the nose clip, as this would produce comparable effects on olfactory and visual imagery. Given that sniffing effects have been reported to vary as a function of imagery proficiency, a group of subjects who scored high in olfactory focus and imagery ability was selected.

Methods

Participants

Forty participants (seven men and 33 women, mean age 29.9, range 19–52) were selected from a total population of 111 (32 men and 79 women, mean age 27.9, range 19–52) using four different questionnaires addressing olfactory interest, olfactory dreams, and both volitional visual (VVIQ) and olfactory (VOIQ) imagery ability (Gilbert et al. 1998; Marks 1973; Stevenson and Case 2005). The questionnaires are described below. Combining the four different questionnaires is a useful method of selecting olfactory attentive participants (Arshamian et al. 2008, submitted). The 40 participants with the highest scores in each of these four questionnaires were selected. In instances where the scores in the four questionnaires were unrelated, selection was based on the highest scores in olfactory and visual imagery followed by the highest scores in olfactory interest and olfactory dreams. Hence, the selected group of 40 participants scored higher than the total population in professed olfactory imagery ($F(1,110)=149.77$, $p<0.0001$), visual imagery ($F(1, 110)=37.73$, $p<0.0001$), and olfactory interest ($F(1, 110)=9.45$, $p<0.005$).

The population of 111 participants showed significant relationships between VOIQ and VVIQ scores, $r=0.42$, $p<0.01$; between VOIQ and olfactory interest scores, $r=0.37$, $p<0.01$; and between VVIQ and olfactory interest scores, $r=0.30$, $p<0.01$. In the olfactory focused group, VVIQ and VOIQ scores were significantly correlated, $r=0.49$, $p<0.01$, as did the VOIQ and olfactory interest scores, $r=0.34$, $p<0.05$ but not VVIQ and olfactory interest scores. When subtracting this group from the total population, the remaining group ($n=71$) showed no correlation between VVIQ and VOIQ scores or between VVIQ and olfactory interest scores. The positive correlation between olfactory interest and VOIQ scores was attenuated but still statistically significant, $r=0.234$, $p<0.05$. The participants also rated their health status and their capacity to name and remember odors on five-point scales where 1=very poor and 5=very good. All of the 40 participants selected for the experiment rated their general health status, odor memory, and odor-naming capacity to be well above average. Four of the participants from the olfactory focused group did not participate in the experiment, leaving the group with 36 participants.

Materials

The Vividness of Visual Imagery Questionnaire (VVIQ; Marks 1973), the Vividness of Olfactory Imagery Questionnaire (VOIQ; Gilbert et al. 1998), and the olfactory interest and dream questionnaires (Stevenson and Case 2005) were used for the selection of good olfactory imagers. Sixteen questions adopted from Marks (1973) were used to assess visual imagery. For the assessment of olfactory imagery, 16 questions adopted from Gilbert et al. (1998) were used. Both questionnaires require subjects to mentally evoke a series of 16 objects and activities (given visual or olfactory cues, respectively) and to rate the vividness of each of the evoked images on a five-point scale (from 1, "perfectly clear and vivid," to 5, "no image at all"). The olfactory interest questionnaire consisted of five subscales focusing on interest of chemosensory information (Stevenson and Case 2005). The subscales addressed affective impact of odors, olfactory mediated memory recollections, attention to odors, odor-associated affect, and interest in food. A modified version of the dream questionnaire designed by Stevenson and Case (2005) focused on retrospective dream reports for each sensory modality. The same type of questions was posed for each sensory modality. For example, for olfaction, subjects were asked if they could recall a dream in which they had experienced an odor sensation. If so, subjects were asked how often they had had similar dreams on a four-point category scale (from 1, "never," to 4, "all the time") and how vivid those images were (from 1, "perfectly clear and vivid," to 4, "vague and dim").

The imagery stimuli consisted of 90 common Swedish words that could be associated with both an odor and a visual object (see Table 1). The words were randomly assigned to either olfactory or visual imagery lists for each participant. A nose clip and an eye mask were used in the two sensory-blocking conditions. We used a competition nose clip developed for swimmers by Speedo. The clip has an adjustable steel frame to fit a range of face shapes. The eye masks were sleeping eye patches developed by Relags.

Table 1 The test set of words used in the imagery tasks

A newly put out candle	Ginger	Public bath
A rusty nail	Gingerbread	Raspberry
Alcohol	Glue	Red apple
Alcohol pen	Grilled chicken	Red wine
Almond	Honey	Resin
Apricot	Ketchup	Rose
Banana	Leather	Rosehip soup
Basil	Lemon	Rubber tire
Beer	Lily-of-the-valley	Sawdust
Black pepper	Lime	Seaweed
Blackcurrant	Lingonberry jam	Shrimp shell
Blue cheese	Licorice	Snuff
Cardamom	Melon	Soft soap
Chocolate	Mint	Soil
Cigarette smoke	Motor oil	Soya
Cigarette-end	Mulled wine	Strawberry
Cinnamon	Mustard	Tabasco
Clove	Newly baked bread	Tar
Coffee	Newly baked cinnamon rolls	Tea
Curry	Orange	Thyme
Dill	Oregano	Tiger balm
Dog	Paint	Tobacco
Feces	Peanut butter	Urine
Fire smoke	Pear	Vanilla cream
Fish	Pelargonium	Washing powder
Fresh cut grass	Pine needle	Whisky
Fresh paprika	Pineapple	White pepper
Fungus	Plum	Vinegar
Garlic	Popcorn	Viola
Gasoline	Potato chips	Yeast

Procedure

Each subject was tested in six different conditions: in an olfactory deprivation condition using a nose clip, in a visual deprivation condition using an eye mask, and in a free, nonblocked condition, for both olfactory and visual imagery. Participants were presented with 15 words in each condition. Thus, participants performed 90 ratings altogether. Each participant was given a unique randomized presentation order of the test items. Also, the order of the experimental manipulations (blocked sniffing, blocked vision, no blocking) as well as the order of modality ratings (olfactory vs. visual) within these manipulations was counterbalanced across the 36 participants.

First, participants were told by the experimenter that the aim of the present study was to investigate the ability to imagine when the senses are open and when they are closed. They were not given any instructions or information concerning sniffing. In a practice trial session, subjects were provided with a thorough imagery instruction and a presentation of the rating scale. Here, subjects were provided with two words (not included in the subsequent test) and specifically instructed to imagine them by means of smell and to rate the olfactory vividness following a seven-point category scale (see below). The same procedure was applied for the visual vividness ratings. In addition, subjects were also informed that they during some conditions should wear an eye mask and a nose clip.

Participants were then asked to sit down in a chair facing a white wall. For each word that was orally presented by the experiment leader, participants were asked to imagine and rate the vividness of the image. Each word was presented with a 15-s interval. Vividness was rated on a seven-point category scale (olfactory vividness: 1=*no smell, I just know what I am thinking of*; 7=*very real and vivid, just as the real smell*; visual vividness: 1=*no picture at all, I just know what object I am thinking of*; 7=*very real and vivid, just as normal vision*).

Directly following the last vividness rating, participants rated the perceived uncomfortableness of both the eye mask and the nose clip (nine-point category scale: 1, *not at all uncomfortable*, to 9, *extremely uncomfortable*) and were asked to guess the aim of the experiment.

Results

Figure 1 shows the mean vividness scores as a function of modality and manipulation. The vividness data were submitted to a 2 (modality: visual, olfactory)×3 (manipulation: free, blocked vision, blocked sniffing) repeated measures analysis of variance. An alpha level of 0.05 was used as statistical threshold for significance. A main effect of modality showed that the overall vividness scores were significantly higher for visual imagery (M=5.03; SD=0.96) than for olfactory imagery, (M=4.10; SD=0.86), $F(1,35)=50.08$, $p<0.0001$. Also, there was a main effect of manipulation, $F(2,70)=17.95$, $p<0.0001$. Bonferroni adjusted post hoc tests showed that the ratings in the blocked sniffing manipulation were lower than in the free and blocked vision conditions (ps<0.0001), although the latter two did not differ ($p>0.40$).

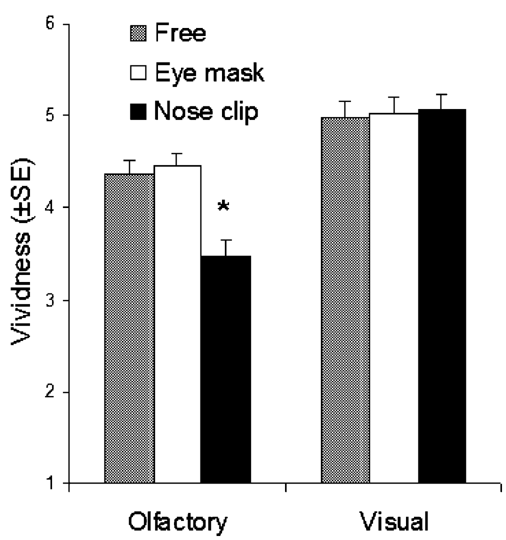

Fig. 1 Mean olfactory and visual vividness scores (+SE) across experimental manipulations

Furthermore, the interaction between modality and manipulation was significant, $F(2,70)=35.73$, $p<0.0001$. Bonferroni adjusted post hoc tests showed that the source of this interaction was that blocked sniffing produced selectively lower olfactory vividness ratings as compared to the free and visual mask manipulation, although visual blocking did not differ from the control condition ($p>0.80$). Vividness in visual imagery was unaffected by the experimental manipulations. To evaluate whether the perceived uncomfortableness of the nose clip affected the obtained results, this variable was entered as a covariate in the analysis. Ratings of comfortableness did not attenuate the observed main or interaction effects ($p>0.20$). Further, according to the post-experimental interview, none of the participants was aware of the specific aim of the study.

Discussion

The present results showed that spontaneous sniffing is an important aspect in the quality of evoked olfactory images. Specifically, preventing olfactomotor activity resulted in a selectively poorer olfactory but not visual vividness, whereas blocked vision showed no effect on either the visual or olfactory vividness ratings. The latter pattern of findings was expected given that ocularmotor activity was not manipulated in the present study but has previously been shown to influence visual imagery. For example, Laeng and Teodorescu (2002) reported that, when ocularmotor activity was obstructed in the retrieval of pictorial information, visual imagery was weakened as compared to a free-eye-movement condition. Thus, these observations suggest that sensorimotor activity is an important factor for both visual and olfactory imagery.

As noted above, blocking the nose of a participant during an olfactory imagery condition makes the task process highly susceptible to confounding influences of demand characteristics (Orne 1962). Here, participants provide responses that are influenced by the perceived aim of a specific study, often resulting in a behavioral confirmation of the anticipated experimental goal. The lack of influence of blocked vision on visual imagery suggests that participants had no a priori hypothesis that could have skewed the ratings in this condition. Also, as shown by the interviews, all participants were unaware about the specific aim of the experiment. This finding indicates that the blocking of vision and olfaction were perceived as comparable experimental manipulations and that the masking of the study's aim was successful. Further, we also pursued the possibility that blocked sniffing may affect olfactory imagery vividness through unspecific effects of distraction or discomfort. However, as shown by the analyses, perceived discomfort of nasal and visual blocking exerted no influence on the vividness ratings. Taken together, these observations favor the notion that the reduced vividness ratings following blocked sniffing most likely are driven by the inability to sniff, rather than to demand characteristics or discomfort.

In summary, the results from the present study confirm that sensorimotor activity in the form of sniffing is a crucial aspect for the experienced vividness of evoked olfactory images.

Acknowledgments We thank Stefan Wiens, Margareta Hedner, and Johan Willander for useful comments in the planning of this experiment. This work was supported by the Swedish Research Council to Maria Larsson (421-2005-2113).

References

Acharya V, Acharya J, Luders H (1998) Olfactory epileptic auras. Neurology 51:56–61

Bensafi M, Porter J, Pouliot S, Mainland J, Johnson B, Zelano C, Young N, Bremner E, Aframian D, Khan R, Sobel N (2003) Olfactomotor activity during imagery mimics that during perception. Nat Neurosci 6:1142–1144

Bensafi M, Pouliot S, Sobel N (2005) Odorant-specific patterns of sniffing during imagery distinguish 'bad' and 'good' olfactory imagers. Chem Senses 30:6521–6529

Crowder RG, Schab FR (1995) Imagery for odours. In: Crowder RG, Schab FR (eds) Memory for Odors. Lawrence Erlbaum Associates, Mahwah, NJ, pp 93–107

Djordjevic J, Zatorre RJ, Petrides M, Jones-Gotman M (2004) The mind's nose: effects of odor and visual imagery on odor detection. Psychol Sci 15:143–148

Djordjevic J, Zatorre RJ, Petrides M, Boyle JA, Jones-Gotman M (2005) Functional neuroimaging of odor imagery. Neuroimage 24:791–801

Engen T (1991) Odor sensation and memory. Praeger, New York

Farah MJ (1989) The neural basis of mental imagery. Trends Neurosci 12:395–399

Farah MJ, Levine DN, Calvanio RA (1988) A case study of mental imagery deficit. Brain Cogn 8:147–164

Gilbert AN, Crouch M, Kemp SE (1998) Olfactory and visual mental imagery. J Ment Imag 22:137–146

Goldenberg G (1989) The ability of patients with brain damage to generate mental visual images. Brain 112:305–325

Goldenberg G (1992) Loss of visual imagery and loss of visual knowledge—a case study. Neuropsychologia 30:1081–1099

Hahn I, Scherer PW, Mozell MM (1994) A mass transport model of olfaction. J Theor Biol 167:115–128

Halpern AR, Zatorre RJ (1999) When that tune runs through your head: a PET investigation of auditory imagery for familiar melodies. Cerebral Cortex 9:697–704

Herz RS (2000) Verbal coding in olfactory versus nonolfactory cognition. Mem Cogn 28:957–964

Jeannerod M (1995) Mental imagery in the motor context. Neuropsychologia 33:1419–1432

Jeannerod M, Frak V (1999) Mental imaging of motor activity in humans. Curr Opin Neurobiol 9:735–739

Kosslyn SM, Ganis G, Thompson WL (2001) Neural foundations of imagery. Nat Rev Neurosci 2:635–642

Laeng B, Teodorescu D–S (2002) Eye scanpaths during visual imagery re-enact those of perception of the same visual scene. Cogn Sci 26:207–231

Laing DG (1983) Natural sniffing gives optimum odour perception for humans. Perception 12:99–117

Mainland J, Sobel N (2006) The sniff is part of the olfactory percept. Chem Senses 31:181–196

Marks D (1973) Visual imagery differences in recall of pictures. Br J Psychol 64:17–24

Orne MT (1962) On the social psychology of the psychological experiment: with particular reference to demand characteristics and their implications. Am Psychol 17:776–783

Richardson JTE (1999) Imagery. Psychology Press, Hove, United Kingdom

Sirigu A, Duhamel JR, Cohen L, Pillon B, Dubois B, Agid Y (1996) The mental representation of hand movements after parietal cortex damage. Science 273:1564–1568

Sobel N, Prabhakaran V, Hartley CA, Desmond JE, Zhao Z, Glover GH, Gabrieli JD, Sullivan EV (1998) Odorant-induced and sniff-induced activation in the cerebellum of the human. J Neurosci 18:8990–9001

Stevenson RJ, Case TI (2005) Olfactory dreams: phenomenology, relationship to volitional imagery and odor identification. Imagin Cogn Pers 24:69–90

Zatorre RJ, Halpern AR (1993) Effect of unilateral temporal-lobe excision on perception and imagery of songs. Neuropsychologia 31(3):221–232