Olfactory dreams, olfactory interest, and imagery: Relationships to olfactory memory.

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Existing evidence for olfactory imagery is mixed and mainly based on reports from hallucinations and volitional imagery. Using a questionnaire, Stevenson and Case (2005) showed that olfactory dreams provided a good source for olfactory imagery studies. This study applied an extended version of the same questionnaire and examined olfactory dreams and their relation to real-life experienced odors, volitional imagery, and olfactory interest. Results showed that olfactory dreams were similar to real-life odors, positively related to olfactory interest and in some extent to volitional imagery. In a follow-up study, two subgroups, one with olfactory dreamers who scored high in olfactory interest and volitional imagery, and one non-olfactory dream group with low scores in interest and imagery, completed an olfactory test battery including odor threshold, episodic odor memory, and odor identification. The group of olfactory dreamers was significantly better in both odor identification and memory, but there were no differences between groups in threshold. These findings support the notion of olfactory imagery, and that individuals experiencing olfactory dreams, score high in olfactory interest and volitional imagery and also remember more olfactory information than persons who score low in these measures.

The sense of smell provides us with the resources to understand and evaluate our surroundings, to detect potentially harmful substances and situations and thus helping us in maintaining a chemical correspondence with the world. The olfactory system and the sensation of smell are based on chemical input, giving us the means to form an olfactory sensation (Buck, 2000). But could it be possible to have a sensation of smell without having the appropriate stimuli, i.e. would it be possible to form an olfactory image?

The evidence for the ability to form mental images without any appropriate stimuli is convincing when the modality at hand is visual or auditory (Richardson, 1999). Unfortunately, the same thing cannot be said about the claim that we can experience taste or smell in the absence of a physical trigger. Data concerning various parts of olfactory imagery, be it dreaming, hallucination, or volitional imagery has been inconclusive. There are both those authorities claiming the implausibility of olfactory imagery, (Crowder & Schab, 1995; Engen, 1991; Herz, 2000), and those claiming the opposite (Cain & Algom, 1997; Elmes, 1998; Stevenson & Case, 2005).

The similarity between odor and visual perception is widely debated with no satisfying answer. In the latter one it is thought that a person forms a visual image by first retrieving information from the long-term memory, then keeping it in the short-term visual store, and finally having a perceptual form of representation (Baddeley & Andrade, 2000; Kosslyn, Gains, & Thompson, 2003; Kosslyn & Thompson, 2003). The short-term memory system,
crucial in image formation, has not been found in olfaction, (Baddeley & Andrade, 2000; White, 1998). In addition, opposite to other perceptions, like vision and audition, the olfactory system has a weak link to language. Larsson (1997) showed that even the most common odors were hard to name, a difficulty not found in the other senses (Hertz & Engen, 1996). This frail constitution of language in olfaction could also be a reason for the difficulties associated with olfactory imagery. If successful retrieval of an image is associated with successful retrieval of a name, connecting memory to consciousness, then a poor link between these constitutions would be a reason for the difficulty found in odor imagery (Engen, 1991; Lawless & Engen, 1977).

Hallucinations are the main source of reported olfactory imagery in the literature, and even if the authenticity of these imageries is disputed, they are of great interest (Greenberg, 1995). There are many reports of olfactory hallucinations mostly found in groups and patients with some psychological or physical disorder like epileptics, people with migraine, patients suffering from cerebral aneurysm or schizophrenia (Acharya, Acharya & Luders, 1998; Mizobuchi et al., 1999; Stedman & Clair, 1998).

Some bizarre olfactory hallucinations, generally found in schizophrenics, can best be described as pure delusions with no correspondence to reality, e.g. angel smell (Greenberg, 1995). But not all of the hallucinations are bizarre, and even if some of the olfactory hallucinations can be explained by nasal pathology, most of them cannot. Smutzer, Trojanowski, Lee and Arnold (1998) did a postmortem examination of the olfactory mucosa in elderly schizophrenic patients to explore potential histochemical and morphological differences between the patients and a control group. No significant changes were discovered between the two groups, indicating that olfactory hallucinations in schizophrenics may be due to abnormalities in the central nervous system, rather than in the olfactory epithelium. Reports of olfactory hallucinations associated with the use of drugs, such as cocaine, amphetamine, opiates, alcohol and medications, can be explained by the pathological effect of the substances on the sensory organ (Ohayon, 2000). The study of the general population in Europe by Ohayon (2000) also shows that almost 8.6% has experienced olfactory hallucinations with a rate of less than one a month. Furthermore, Mohr, Hubener and Laska (2002) studied 42 healthy subjects comparing the frequencies of deviant olfactory experiences in relation to “psychotic-like” features. The results showed that higher “psychotic-like” features in a subject were positively correlated with olfactory hallucinations.

But olfactory hallucinations are not the only source of olfactory imagery. Studies focusing on volitional olfactory imagery, mostly found in self-report data, show that there are many reports on olfactory imagery ability. Nevertheless, when comparing the frequency of, and vividness in, volitional imagery across the different senses it has been shown that olfaction is the sense in which least people report imagery, and the one with the poorest vividness (Ashton & With, 1980; Gilbert, Crouch & Kemp, 1998; Lawless, 1997). Lawless (1997) found that 25% never experienced imagery in olfaction, making it the sense with the smallest number of imagery reports.

Gilbert et al. (1998) compared volitional odor and visual imagery ability between olfactory experts and non-experts. The results showed that there was a positive correlation between the average scores in both modalities, and that the olfactory experts had more vivid images than the control group. The fact that volitional olfactory imagery is reported as being hard to evoke, and weak in vividness compared to all other sensory modalities, could be related to the weaker correspondence between language and the olfactory sense (Engen, 1991; Lawless &
Engen, 1977). However, the observation that olfaction is the sense given the smallest amount of attentiveness in everyday life could also explain this limitation (Engen, 1982). The lack of awareness could thereby make it difficult for a person to evoke an image.

In addition, Cain and Algom (1997) argued that the limitation of vividness in olfactory imagery could have its source in the observation that it is hard to confirm odors by other means than olfaction itself, this being the reason to why there is more false-alarm reports in olfactory recognition tests as compared to other modalities (Engen, 1991), and to why there is a higher rate of abnormal olfactory experiences compared to other modalities in the general population (Ohayon, 2000). The absence of correct and informative environmental factors in everyday life could contribute to the misattribution in olfactory imagery. This notion and its consequence can be seen by a rather different study were the experimenters implications affected the subjects experiences in how they perceived an odor as being pleasant, neutral or unpleasant (Knasko, Gilbert & Sabini, 1990). Moreover, exaggerated volitional experiences found in volitional visual imagery, due to desirability and prestige, could also pose a potential problem for subjects reporting on olfactory imagery (Vesta, Ingersoll & Sunshine, 1971).

McKelvie (1995) showed that there were correlations between volitional visual imagery and experimental tasks. However, studies concerning the correlation between volitional olfactory imagery and behavior provide a more mixed pattern of observations. Lyman (1988) found no correlation, and Djordjevic, Zattore, Petrides and Jones-Gotman (2004) found only one correlation in a female sample.

As noted above, the study of olfactory hallucinations, the most reported source of imagery, has had some limitations. Being associated with psychological and physical pathology and drug abuse, these reports pose a problem. Even if there have been reports from the normal population (Ohayon, 2000), a majority of the studies ignore normal subjects, making it difficult to derive correct conclusions about normal variation in olfactory imagery ability. The concerns raised for volitional imagery, i.e. low frequency, poor vividness, and lack of correlation to behavior, gives doubts about its resemblance to actual olfaction.

Olfactory imagery studies have been limited to hallucinations and different forms of volitional imagery for a long time. Nevertheless, findings from dream studies appear to be another good source for imagery studies. Although there are only a small number of olfactory dream studies in the literature, the results of these are intriguing. For example, in a study examining the prevalence of sensory imagery in dreams, Zadra, Nielsen, and Donderi (1998) found that, when stated in retrospective, 35% of all men and 41% of all women recalled having experienced smell in their dreams. However, a total of 3372 dream reports completed directly after waking showed that olfactory sensations only occurred in about 1% of all the dream reports. There was also a greater proportion of women (1.33%) reporting dreams with an olfactory reference than men (0.11%).

In a recent study by Stevenson and Case (2005) the results from retrospective olfactory dream reports were similar to Zadre et al. (1998). Their questionnaire showed that almost 31.7% of the subjects recalled having experienced sensations of smell and taste. The authors included gustatory sensations only when they had an olfactory component. Furthermore, Stevenson and Case (2005) asked the subjects to write down an example dream for every sense and estimate its qualities of sensation. They found that olfactory dreams were more emotive and lasted a shorter time compared to vision dreams. The notion of emotiveness (Hinton & Henley, 1993) and briefness (Engen, 1982) in normal olfaction is well studied, thus making the connections
between olfactory dream sensations and real olfaction even more compelling. Stevenson and Case (2005) also found that a large number of the reported smells were those related to smoke and burning, similar to those results in olfactory hallucinations reported by Burstein (1987) and Crosley and Dhamoon (1983). Moreover, Stevenson and Case compared the ability in odor identification between subjects who previously had reported an olfactory dream to those who had not. The subjects who experienced olfactory dreams were significantly better at identifying odors. Stevenson and Case (2005) also showed that the obtained results were independent of both motivation and social desirability. These findings showed for the first time a correlation between olfactory imagery in dreams and actual behavior. Furthermore, the questionnaire by Stevenson and Case (2005), which also focused on odor interest and volitional imagery, revealed a positive correlation between these two variables and odor identification. Wrzesniewski, McCauley, and Rozin (1999) who introduced the odor interest scale - used by Stevenson and Case (2005) - also showed significant relations between odor interest subscales and olfactory tasks.

It should be noted that the sensation of flavors results from a combination of olfactory and gustatory inputs, thereby making it confusing to only focus on taste stimuli when studying experiences such as eating and drinking. A great deal of what we think of as the taste of foods derives from information provided by the olfactory system (Buck, 2000). The stimulation of the tongue by the somatosensory system in concurrence with retronasal passage of odorants is the main reason why we experience taste in the mouth and not in the nose (Buck, 2000; Pierce & Halpern, 1996). The gustatory system distinguishes only between five primary stimulus qualities: sweet, sour, salty, bitter and umami.

The similarity between consciousness given by everyday waken life and that found in dreaming is a question concerning the phenomenal representation in the brain. Hence, studying the different sensory modalities in dreams and how they differ from normal sensation is of great interest in the search for a good explanatory model of consciousness. Although dream studies, and particularly those concerned with the senses, are modest in size, they play an interesting and important role in consciousness studies.

These considerations prompted the present study to conduct a revised and extended version of the Stevenson and Case (2005) study. Using a modified version of the Stevenson and Case (2005) dream questionnaire, Study 1 focused on the ability to form olfactory images in dreams and relationships to olfactory interest and volitional odor and visual imagery capacity. Study 2 compared a group of olfactory dreamers who scored high in olfactory interest and volitional imagery and a group of non-olfactory dreamers who were low in interest and imagery in a set of olfactory tests. Specifically, potential differences between groups in olfactory threshold, episodic odor memory, and odor identification were addressed.

Study 1

Method

Subjects
One hundred and nineteen subjects took part in the study for course credit. Of these subjects, 29 were male and 90 female, with a mean age of 28.8 (SD = 7.5, range = 19-50 years). No subject reported a relevant sensory impairment.
Materials

The subjects completed a modified version of the dream questionnaire designed by Stevenson and Case (2005). The questionnaire was made up of seven parts, the first one concerning the subjects’ own estimation of how good or bad each of their senses were using a 3-point category scale (below average, average, above average), and the second part regarding how often subjects remembered their dreams (7-point scale from Never to Almost every day). The third part was a retrospective dream report for each sensory modality with the same type of questions presented for each sensory modality. For example subjects were asked if they recalled having a dream with the sensation of touch. If subjects remembered they were asked how often they had similar dreams (4-point category scale from Never to All the time) and how vivid those images were (4-point category scale from Perfectly clear and vivid to Vague and dim). Then subjects were asked to write down a specific dream with the sensation of touch and to note the duration (3-point category scale: The whole dream, Part of the dream, A brief part of the dream) and the hedonic tone of the reported image (5-point category scale: from Very pleasant to Very unpleasant).

The fourth part of the questionnaire focused on physical and psychological aspects that could affect olfactory imagery and dreaming, e.g. episodes of psychosis, epilepsy, or depression. Subjects were asked if they had experienced or suffered from these conditions (scale: No, Unsure, Yes). The fifth set of questions consisted of five subscales and dealt with olfactory interest. The first subscale focused on affective impact of odors, e.g. subjects were asked if the odor of a person they just met contributed in them liking the person (4-point category scale from Never to Often). The second subscale explored odor mediated memory, e.g. subjects were asked if a pleasant odor ever had brought forth memories of people they had not seen in a while (4-point category scale from Never to Often). The third subscale addressed attention to odors, e.g. subjects were asked if they had experienced situations were no one apart from themselves had experienced a smell (4-point category scale from Never to Often). The fourth subscale focused one odors affect via association, e.g. subjects were asked if they ever liked an odor only because they associated it with a person they liked (2-point bipolar scale: No, Yes). The fifth subscale explored interest in food and other olfactory realms, e.g. subjects were asked if they ever bought flowers to themselves or to there home (2-point bipolar scale: No, Yes).

The sixth set of questions addressed volitional visual imagery ability (VVIQ) (Marks, 1973) and volitional olfactory imagery ability (VOIQ) (Gilbert, Crouch & Kemp, 1998). The VVIQ had a 5-point category scale from Perfectly clear and vivid and exactly as normal vision to No image at all, I only “know” what object I am thinking of. The VOIQ had a 5-point category scale from Perfectly real and vivid and exactly as the normal smell to No smell at all, I only “know” what smell I am thinking of. Finally, subjects submitted background information regarding health and lifestyle factors that could affect the olfactory sense negatively, e.g. smoking habits.

Procedure

Subjects were given the questionnaire and asked to complete it at home or at the university and to hand it in within a two-week period.
Results

The frequencies of the different sensory modalities that were reported being experienced in dreams are illustrated in Table 1. The results show that the visual, auditory, and tactile senses were by far the most common experienced sensations in dreams. Both the olfactory and gustatory senses were reported being experienced by a minority of the subjects, olfaction being the least experienced of them all. As noted by Pierce & Halpern (1996) and Buck (2000) gustatory sensations, such as food and drink, are often in fact sensations of smell. With this in mind most of the reported gustatory experiences had in fact a central olfactory component, making the sensation of smell in dreams more frequent than it was reported for.

In total, 49 subjects reported a gustatory or olfactory dream and of these 45 subjects (37.8% of the total sample) were considered having an olfactory dream when explicit sensations of tastes, such as sweet, sour, salty and bitter, were excluded. 21 subjects reported having both an olfactory dream and a taste dream with an olfactory component. There were no significant age or gender differences between the different experienced sensations. The subjects also provided 25 example dreams for taste and 15 example dreams for smell, yielding 40 dreams from 28 subjects. The majority of the provided gustatory dreams, which had an olfactory component, were those concerned with foods or drinks (24/25) (see table 2). In the reported olfactory dreams the most common odors were those concerned with burning or gas (5/17). None of the reported smells were bizarre, i.e. they were natural smells and they appeared in relation to objects.

Table 1. Percentage of subjects reporting recall of experienced sensation in their dreams at least once.

<table>
<thead>
<tr>
<th>Sensory modality</th>
<th>Experienced</th>
<th>n</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual</td>
<td></td>
<td>115</td>
<td>96.6</td>
</tr>
<tr>
<td>Auditory</td>
<td></td>
<td>93</td>
<td>78.2</td>
</tr>
<tr>
<td>Tactile</td>
<td></td>
<td>102</td>
<td>85.7</td>
</tr>
<tr>
<td>Olfactory</td>
<td></td>
<td>31</td>
<td>26.1</td>
</tr>
<tr>
<td>Gustatory</td>
<td></td>
<td>39</td>
<td>32.8</td>
</tr>
</tbody>
</table>

Table 2. Olfactory dream content: Number of times mentioned by subjects as an olfactory dream or as a “taste” dream.

<table>
<thead>
<tr>
<th>“Taste” dream</th>
<th>Olfactory dream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food: Food (1), Oysters (1), Blood (1), Dove (1), Daal (1), Meat (1), Salad dressing (1), Chocolate (2), Blackberry marzipan (1), Sweets (3), Pizza bread (1), Whisky (1), Flour (1), Soft drinks (1), Intestines (1), Liquorice candy (1), Cookies (1), Garlic (1), Cream (1), White wine (1)</td>
<td>Food: White wine (1)</td>
</tr>
<tr>
<td>Smoke: Gas (2), Burning (2) Incense (1)</td>
<td></td>
</tr>
<tr>
<td>Other: Wild boar droppings (1), Horse (1), Dog (1) Perfume (3), Soil (1), Dust (1), Shoes (1), Shoe shine (1) Windscreen cleaner (1)</td>
<td></td>
</tr>
</tbody>
</table>

Subjects also rated the duration and the emotiveness, i.e. the hedonic state, in the different modalities. When comparing the ratings given for duration and the hedonic state between vision and olfaction, two one-way ANOVAs on the ratings showed trends toward briefer
olfactory dreams: (Duration: $M = 2.3$, $SD = 0.8$ for vision, $M = 2.6$, $SD = 0.6$ for olfaction), $[F (1, 138) = 3.53, p = 0.062]$; Hedonic: $M = 3.0$, $SD = 1.2$ for vision, $M = 2.6$, $SD = 1.4$ for olfaction, $[F (1, 138) = 2.25, p = 0.136]$).

The olfactory dreamers reported recalling more dreams in general ($M = 4.9$, $SD = 1.0$) than non-dreamers ($M = 3.8$, $SD = 1.5$), $[F (1, 117) = 20.95, p < 0.0001$). Olfactory dreamers estimated their capacity to remember odors as better than non-dreamers (olfactory dreamers: $M = 3.7$, $SD = 0.98$ vs. non-dreamers: $M = 3.3$, $SD = 0.95$, $[F (1, 117) = 4.96, p < 0.05$). Olfactory dreamers recalled smelling more odors the previous day than the non-dreamers ($M = 5.5$, $SD = 4.3$, $M = 3.6$, $SD = 3.4$, $[F (1, 117) = 6.96, p < 0.01$). There were no differences between the two groups in how they estimated their odor sensitivity, and how well they estimated their ability to name odors.

An ANOVA showed that the olfactory dreamers had higher scores on the overall odor interest scale (olfactory dreamers: $M = 60.1$, $SD = 8.0$ vs. non-dreamers: $M = 54.6$, $SD = 7.4$, $[F (1, 117) = 19.27, p < 0.0001$]. An ANOVA also showed a tendency for the olfactory dreamers to rate themselves as better in VOIQ when compared to the rest of the subjects (olfactory dreamers: $M = 38.4$, $SD = 11.5$ vs. non-dreamers: $M = 43.5$, $SD = 16.4$, $p = 0.069$. Note that lower rating on this scale indicates better VOIQ. There were no differences between olfactory dreamers and non-dreamers in reported volitional visual imagery (VVIQ).

A correlational analysis including all participants showed a significant relationship between VOIQ and VVIQ, $r = 0.407$, $p < 0.01$ (2-tailed). The subjects’ odor interest scores also correlated significantly with their ratings of VOIQ, $r = -0.186$, $p < 0.05$ (2-tailed). The odor interest scores were not correlated with VVIQ, but it was significantly correlated to the total volitional imagery scores, $r = -0.196$, $p < 0.05$ (2-tailed). In addition, VOIQ in the olfactory dream group significantly correlated with the odor image vividness in their reported dreams, $r = 0.241$, $p < 0.05$ (1-tailed).

**Study 2**

**Method**

**Subjects**

Forty subjects that had completed the questionnaire took part in the second experiment. Two groups, one with olfactory dreamers and one with non-olfactory dreamers, were selected based on the results from the questionnaire. Two compound scores were calculated for the two groups based on the following two factors: odor interest and volitional olfactory imagery. The twenty olfactory dreamers that had the highest scores in odor interest and volitional olfactory imagery where chosen. In cases where the selected subjects’ scores in the two subscales did not correlate, selection was based on the proportion of the two scores. In the non-dreamers group, the subjects were selected based on the opposite, i.e. those with the lowest scores in odor interest and volitional olfactory imagery. There were significant differences between the two groups in total volitional imagery and in olfactory interest. Lower ratings on the volitional imagery scales indicate more vivid imagery. Total volitional imagery, i.e. both visual and olfactory: Olfactory dreamers $M = 63.1$, $SD = 14.5$ and non-dreamers $M = 90.5$, $SD = 25.3$, $[F (1, 38) = 17.74, p < 0.0001]$. Volitional olfactory imagery: olfactory dreamers $M = 31$, $SD = 8.8$, and non-dreamers $M = 53$, $SD = 14$, $[F (1, 38) = 35.54, p < 0.0001]$. Odor interest:
olfactory dreamers $M = 64.2$, $SD = 7.6$, and non-dreamers $M = 47.5$, $SD = 6.7$, $[F (1, 38) = 54.45, p < 0.0001]$. 

There were no significant age and sex differences between the two groups.

In the olfactory dreamers group, 5 were male and 15 were female, with a mean age of 27.0 ($SD = 6.1$, range = 19-41 years), and in the non-dreamers group, 7 were male and 13 were female, with the mean age of 26.2 ($SD = 7.3$, range = 20-47 years). No subject reported a relevant sensory impairment.

**Materials**

For all olfactory tests, the normated and validated Sniffin’ Sticks test was used. (Hummel, Sekinger, Wolf, Pauli & Kobal, 1997). Olfactory performance was assessed in three different tasks: olfactory threshold (i.e., threshold), episodic odor memory, and odor identification. The odor threshold test included $n$-butanol as test odor and consisted of 16 different concentrations. The number 16 pen contained the lowest concentration of $n$-butanol, followed by falling numbers and an increasing $n$-butanol concentration. The 16 odor pens were matched with 16 pens containing a solvent with no odor, thereby serving as the blanks.

For episodic odor memory and odor identification, 16 'Sniffin'Sticks' filled with different liquid odors were used. The following odors were included: apple, banana, clove, coffee, cinnamon, fish, garlic, gasoline, lemon, leather, liquorice, peppermint, pineapple, rose, tar, turpentine.

The 'Sniffin'Sticks' were divided into three different presentation orders for the odor memory and identification tests, each one with a different line up of target odors and distractors. For episodic memory, 8 odors were used as targets and 8 as distractors. The presentation order was counterbalanced. Odors serving as targets on one test occasion were used as distractors in the next. Odor identification of the 16 odors was assessed by both free and cued identification.

**Procedure**

All subjects were tested individually. In the threshold test, two pens, one with odor and one blank, were presented to the subjects below both nostrils for ~ 3 s, and if the subject correctly could discriminate the target odor from the blank five times in a row the subjects’ threshold was reached. If the subject failed, a new pair of pens with a stronger concentration was presented until the subjects’ threshold was established. There were 20 s between each trial to prevent effects of adaptation.

Following completion of the threshold test, subjects were presented with the episodic odor memory and identification test protocols. Subjects were presented with 8 target odors and instructed to memorize the odorants. After encoding, the subjects were once again presented with the target odors intermixed with 8 distractor odors. For each presented odor the subjects were asked if they recognized the odor from the earlier presentation, and if they could freely identify the specific odor. If they were unable to correctly identify the odor they were given four different odor names to choose from, with one of the names being equivalent to the target odor. The subjects were blindfolded across all olfactory tasks.
Results

In instances when the subject correctly recognized the odor from the encoding phase the score was described as a hit. In instances when a distractor was denoted old it was classified as a false alarm. One subject from the non-olfactory dreamers group did not participate in the experiment, leaving the non-olfactory dreamers group with 19 subjects.

There was no difference in olfactory threshold between non-dreamers \((M = 10.9, \ SD = 2.8)\), and dreamers \((M = 10.4, \ SD = 3.1)\). It is noteworthy that two of the subjects in the olfactory-dream group had the lowest possible olfactory threshold given by the 'Sniffin'Sticks', i.e. 16. Because of this extreme olfactory sensitivity the two subjects were controlled three extra times before settling their results. When using a less strict criterion, i.e. four correct answers in a row instead of five, the subjects with extreme threshold increased to three - all in the olfactory group.

A one-way analysis of variance on hit rates showed that non-olfactory dreamers produced significantly fewer hits than olfactory dreamers (Olfactory dreamers: \(M = 7.8, \ SD = 0.41\), non-dreamers: \(M = 7.2, \ SD = 0.64\)), \([F (1, 38) = 12.67, p < 0.001]\). An ANOVA on the false alarms showed that the non-olfactory dreamers produced significantly more false alarms than the olfactory-dreamers (Olfactory dreamers: \(M = 0.35, \ SD = 0.59\), non-dreamers: \(M = 1.5, \ SD = 1.4\)), \([F (1, 38) = 11.52, p < 0.002]\). The proportions of hits and false alarm rates were transformed to \(d'\) scores to obtain an index of recognition (Elliott, 1964). An ANOVA on the \(d'\) scores showed that olfactory-dreamers had significantly better episodic olfactory memory than non-olfactory dreamers (Olfactory dreamers: \(M = 0.93, \ SD = 0.07\), non-dreamers: \(M = 0.71, \ SD = 0.23\)), \([F (1, 38) = 17.76, (p < 0.0001)\].

As noted above, odor identification was assessed in two ways: free identification when no support was provided, and cued identification when the correct answer was provided together with three foils. An ANOVA showed that the olfactory-dream group had a significantly better odor naming ability in free identification than non-dreamers (Olfactory dreamers: \(M = 7.2, \ SD = 2.4\), non-dreamers: \(M = 5.7, \ SD = 1.8\)), \([F (1, 38) = 4.70, \ (p < 0.05)\], whereas there was no difference in cued odor identification. Furthermore, to examine whether odor naming mediated episodic odor memory, odor identification was entered as a covariate in an ANCOVA on the hit, false alarm and \(d'\) scores. The results showed that there was no effect of odor naming ability on odor memory performance.

Discussion

The results from study 1 indicate that the frequencies found in dream sensations are equivalent to those reported by Zadre et al. (1998) and Stevenson and Case (2005). In the former study, 35% of all men and 41% of the women experienced olfactory dream sensations, and in the latter one, 31% had sensations of smell and taste, making the current results of 37.8% to fall somewhere in the middle. The majority of reported odors, namely food and drink, mirror the experiences found in normal living. Odors of gas, smoke and burning, which were also frequent, correspond to the results stated by Stevenson and Case (2005) and to findings reported in the olfactory hallucination literature (Burstein, 1987; Crosley & Dhamoon 1983). The lack of bizarreness in the olfactory odors, also noted by Stevenson and Case (2005), makes them appealing. Bizarreness in olfactory hallucinations, e.g. those found by Greenberg (1995), poses problems in interpretation of true olfactory imageries.
Although there were no significant differences between the two modalities, vision and olfaction, in experienced duration and emotiveness, there is a tendency towards similar results as documented by Stevenson and Case (2005). Their results show a significant difference in duration in the within-participant comparison, but not in the between-participant comparison. And in the hedonic condition the results were opposite, i.e. there were no differences in the within-participant comparison, only one in the between-participant comparison. In the present study the lack of significant results in the within-participant comparison could partially be explained by the small number of subjects reporting in all of the essential modalities, i.e. in the olfactory, gustatory and vision variables. Although the current study did not produce significant results, the notion that dream smells are more similar to those found in normal olfaction than those found in olfactory hallucinations is a good indicator of the existence of olfactory dreams.

There were also differences between the Stevenson and Case (2005) study and the present one in the volitional imagery results. Where they could show significant differences between olfactory dreamers and non-dreamers in both VOIQ and VVIQ, the study at hand could only present a tendency towards better VOIQ results for the olfactory dreamers \((p = 0.069)\). On the other hand VOIQ for the olfactory dreamers significantly correlated with odor imagery vividness in the reported dreams, a result also obtained by Stevenson and Case (2005). These two variables appear to be related to each other, thereby locating the source for vividness in these abilities to a common origin. All of the subjects total interest scores correlated with VOIQ, but not with VVIQ, making the odor interest scale a good indicator for the possibility of actual VOIQ.

The results of the overall interest scale also showed that the olfactory dreamers differed a lot from the non-dreamers in their everyday life experiences. The olfactory dreamers showed a greater interest in smells than the non-dreamers. This awareness of and curiosity to smells, derived from the specific questions, is a good way to measure differences in odor behavior. In addition to this the olfactory dreamers recalled smelling more odors the previous day than the non-dreamers. The results also showed that they reported recalling more dreams regardless of modality, a fact that could support a better memory for dreams in general.

Using dream studies as a tool for new imagery studies has several advantages compared to olfactory hallucinations and volitional imagery, e.g. the populations in dream studies reflect the general population in a much better way than populations from olfactory hallucination studies. There are also several pathological conditions corresponding to olfactory hallucinations, e.g. those identified by Ohayon (2000), which are not to be found in dream studies. Furthermore, methodological problems, such as desirability and prestige, in volitional imagery - as presented by Vesta et al. (1971) - have not been discovered in dream studies (Stevenson & Case, 2005).

With these results in mind - results that single-handedly point to the existence of olfactory dreams - the findings in study 2 amplify the notion of olfactory imagery. In study 1, the subjects answered questions regarding their ability in specific olfactory performances, namely the capacity in odor sensitivity, and the ability to remember and name odors. Although there were no differences between the two groups in naming and sensitivity, there were significant differences in odor memory. Olfactory dreamers estimated their capacity to remember odors as better than non-dreamers. The results from study 2 showed that the olfactory dreamers indeed had a better memory for odors –a result obtained for the first time. What is more they
were also significantly better in naming and identifying odors than the non-dreamers – a result first obtained by Stevenson and Case (2005). On the other hand there was no difference in the obtained threshold between the two groups. These findings show differences in olfactory behavior that to some degree is connected to olfactory dreams.

However, the process of selecting and determining which of the subjects that would be included in study 2 was not entirely based on the prevalence of olfactory dreams. Apart from the basic condition of olfactory dreams, the scores in volitional imagery and total interest played a crucial role in the formation of the compound scores. The creation of a specific compound score, based on these two notions, is a method that, to the best of our knowledge, has been applied for the first time. Unfortunately selecting subjects for study 2 based on the highest possible compound scores in one group, and the opposite in the other, is a technique that poses some methodological problems. Constructing the experiment based on three different factors makes the matter of causality and its direction hard to distinguish. One could argue that significant changes in olfactory performance could be attributed, single handedly, to either interest in odors, VOIQ or to the ability to form olfactory dreams. Even if this possibility is not a likely one, it cannot be ruled out. The large differences in olfactory capacity between the two groups are more likely a result based on all three factors.

The creation of a compound score was based on the idea that the olfactory dreamers were more extreme in their olfactory abilities than the rest of the population. If using other olfactory capacity markers, and thereby enhancing the extreme elements, it would be possible to create a super-focused olfactory group. The group of non-olfactory dreamers would as a result be created based upon the opposite idea, making a potential non-difference between the two groups a good proof that these three variables did not influence olfactory behavior. Using the notions derived from Stevenson and Case (2005) and Wrzesniewski et al (1999) in the use of interest scores for olfactory behavior, and combining them with Gilbert et al. (1998) experimental results in volitional imagery - was, as can be seen - a good strategy. The presented compound scores collect factors that point towards an olfactory awareness in the subjects, making the compound score a key to locate odor-obsessed people.

As noted in the introduction, theories regarding the difficulty in olfactory imagery are mostly based on the concept that olfaction has a weak link to language (Engen, 1991; Lawless & Engen, 1977). The formation of imagery is based on links between perceptual representation and information stored in semantic memory (Lawless & Engen, 1977). Stevenson and Case (2005) present the idea that not only the links from perceptual representation to its name are weak, but also that the opposite, i.e. the links from a name to the representation are weak. This notion both explains the difficulty found in volitional imagery studies and the fact that subjects rating themselves better at olfactory imagery also were better in odor identification (Stevenson and Case, 2005). The findings of poor naming skills in olfaction by Larsson (1997) and the inferior capacity in the same function compared to other senses (Herz & Engen, 1996) raises questions about the similarity between olfactory memory and that found in vision (Baddeley & Andrade, 2000; White, 1998). Stevenson and Case (2005) present the idea that there is no dissociable short-term memory system in olfaction and that a single memory-system, holding both the short- and long time stores, single handedly could control olfactory imagery. The imagery obtained in olfactory dreams is not due to the volitional capacity; rather it would be considered that the connections from visual and semantic memory would be the reason to olfactory dream imagery (Stevenson and Case, 2005). The lack of bizarreness and the fact that almost all of the described dreams in this and other studies show a direct link between the odor and a cue, e.g. cues of vision, confirms this idea. Furthermore,
both Stevenson and Case (2005) and the present study, show that subjects with olfactory dreams are better in odor naming. In addition, this study also shows that olfactory dream subjects with higher odor focus have better odor memory than unfocused subjects. The superior olfactory performance demonstrated by the olfactory dream group could be seen as the equivalent to the olfactory experts presented in Gilbert et al. (1998). If the view that the weak link between language and olfaction is wrong and not the prime cause for the difficulties found in odor identification, then the search for these explanations must be located to other domains. One way to explain the differences found between the olfactory dreamers and the non-dreamers could be to attribute the difficulties in identification to variations in odor threshold – but, as the results from the second study clearly show, this is not the case.

In conclusion, this study has, by using a compound score in the search for superior olfactory behavior created a unique tool for localizing olfactory experts. Moreover, the unique results presented by Stevenson and Case (2005) has in some degree been replicated and also extended by the inclusion of tests of odor memory, threshold, and compound scores. The existence of olfactory imagery is a notion with good support both in the literature and in the present study, making the question of a possible one-to-one relation between the pseudo reality of dreams, imagery and waking life an easier one.

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