Smell Recognition and Odor-Shape Matching

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Abstract

This study focuses on the ability of recognizing presented smells and successfully matching them with shapes which were presented alongside the given smells, as compared to matching two other dimensions with shape (Number-Shape; Color-Shape). A total of 18 participants (9 females, Mean Age=25.22) were studied in three different groups (2 objects, 3 objects, 4 objects) on three different tasks (Odor-Shape matching, Number-Shape matching, Color-Shape matching). Results showed that participants are significantly less successful in smell recognition and odor-shape matching in comparison to the other two tasks. The number of objects did not have a significant effect on the results in any tasks, however, the ratio of correct answers in smell-shape matching decreased as the number of objects increased. The findings of this study suggest that humans are not as successful in associating smells with visual cues as they are in associating numbers or colors with shape.

Keywords: Smell recognition, smell memory, recognition memory, visual memory

Introduction

Smell is a vital sense with three important functions: First, deciding what can be eaten by discriminating between healthy, edible objects and inedible, toxic or rotten objects such as a person smelling milk can decide whether it has gone bad. Second, avoiding environmental hazards, such as detecting the smell of fire or hazardous gas. Third, social communication, which is observed more saliently in animals but can also be observed in humans as unconscious behavior (Köster, 2002; Stevenson, 2010).

In wild life almost every animal depends on smelling to identify objects, and studies have shown that humans also show a certain level of success in odor identification tasks (Cain, 1979; Shepherd, 2004). Skill in odor identification can be improved by training (Cain, 1979).

Research has shown that olfaction is a very strong memory cue for autobiographical memory, especially for the first two decades of life (Willander & Larsson, 2006) and memories cued by odors cause more emotional arousal than memories cued by other senses (Herz & Schooler, 2002; Willander & Larsson, 2007). The reason for this emotional tendency is thought to be the result of the dominance of Dorsolateral Pre-Frontal Cortex (DLPFC) during the process of remembering (Arshamian et al., 2012). Also, the amygdala is more involved in the processing of smell memory in comparison to memories regarding other modalities (Buchanan, Tranel & Adolphs, 2003). However, the same cortical areas, namely dorsal and ventral prefrontal cortices, are involved in working memory for both visual and olfactory stimuli (Dade, Zatore, Evans & Jones-Gotman, 2000). Therefore, olfactory memories tend to be of episodic nature more often than semantic (Köster, 2002).

In the human brain, piriform cortex is the most important cortical area for olfaction (Howard et al., 2009). and cross-modal memory retrieval for vision and olfaction (Gottfried, Smith, Rugg & Dolan, 2004). Another study also showed a significant activation in hippocampus during trials in which odor and visual cues were related, and attributes the cross-modal association to the hippocampus (Gottfried & Dolan, 2003). The literature in the field suggests that odor cues facilitate visual recognition (Cann & Ross, 1989).

Hypotheses

The aim of this study is to assess the correlation between different modalities in object identification, and the ability to associate between different cues. Our research questions are: (i) What is the level of success in smell recognition compared to visual recognition? (ii) Does the level of success differ between odor-shape association and other visual associations? (iii) Does the number of presented objects affect the performance on recognition tasks?

Our hypotheses are, H1: Since the sense of olfaction is not as strong as vision for humans in daily life, we expect that participants will be less successful in odor recognition task. H2: Similar to H1, we expect better results in number-shape and color-shape association in comparison to odor-shape association. H3: The number of presented items would increase the cognitive load for recognition and we expect that success will decrease as presented objects increase.

Method

18 participants (9 females, mean age=25.22) were tested in 3 groups of 6 participants. Groups were distributed randomly and number of females and males were balanced. Groups consisted of 2-objects presented, 3-objects presented and 4-objects presented participants. All participants were tested with all three tasks: odor-shape association, number-shape association, color-shape association. The order of the tasks were counterbalanced. All participants joined the study voluntarily.

For odor-shape association, participants were presented with odors on a filter paper in small bottles labeled with shapes (see Figure 1). Unfamiliar odors were used so people cannot memorize them by their names. Odors were narrow-leaved paperbark (Malaleuca alternifolia), Indian sandalwood (Santalum album), ylang-ylang (Cananga odorata), Turkish sweetgum (Liquidambar orientalis), cedar (Cedrus sp.), lemon balm (Melissa officinalis), and Madonna lily (Lilium candidum). After the introduction of the odors, a 5-minute break was given. Then, participants were asked which shapes were presented. After that, novel and presented odors, in random order, were conveyed to participants with air flow from 50 cc plastic syringes and participants were asked if they were presented in the previous phase and if so, which shape was on the bottle.

Figure 1: Set of odors and smells as they were used in the experiment.

For number-shape association, participants were shown pairs of shape and number was placed side by side on A6 sized paper (see Figure 2). After a 5-minute break, participants were asked which shapes were presented. Then novel and presented numbers, in random order, were shown and participants were asked if they were presented in the previous phase and if so, which shape was it paired with.

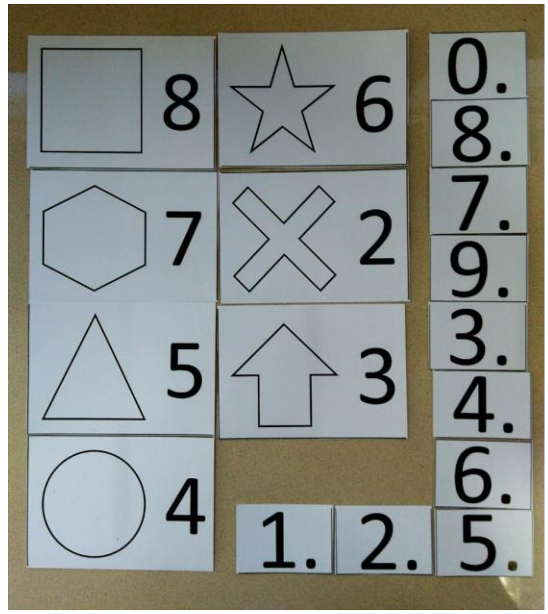

Figure 2: Number and shape cards as used in the experiment.

For color-shape association, participants were shown colored shapes on A6 sized paper (see Figure 3). After a 5-minute break, they were asked which shapes were presented. Then novel and presented colors were shown in random order and participants were asked if they were presented previously and if so, what was the shape.

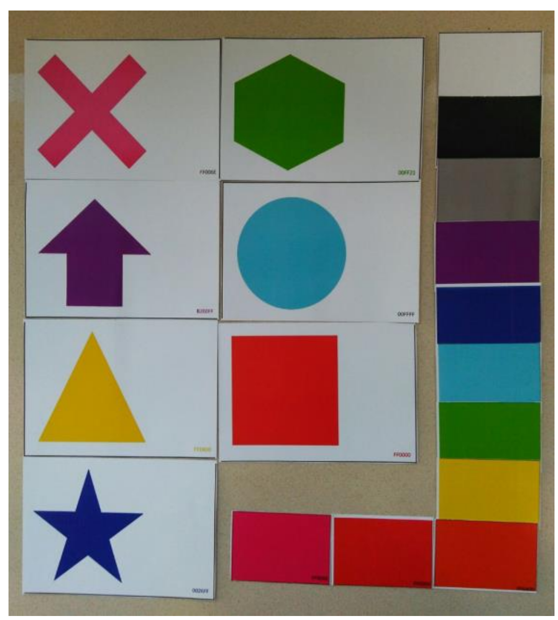

Figure 3: Color and shape cards as used in the experiment.

Results

The data collected after all experiments were analyzed for object recognition between groups, object association between groups and the level of success in different tasks.

4.1. Object Recognition Between Groups
In order to assess the level of success in object recognition, d' values were calculated for each groups which shows the distance between the means of hits and false alarms. Please see Table 1 and Figure 4 for descriptive statistics.

Table 1: Descriptive Statistics for recognition tasks.

	Mean Hit Ratio (SD)	Mean False Alarm Ratio (SD)	d'
2-Objects	.416 (.129)	.208 (.102)	.605
3-Objects	.361 (.125)	.139 (.125)	.722
4-Objects	.438 (.068)	.229 (.146)	.588

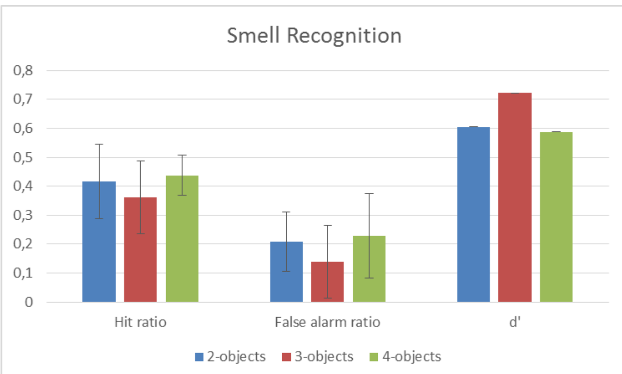

Figure 4: Graphic chart for each group on smell recognition. Error bars show standard deviation.

4.2. Object Association Between Groups
Match scores are determined with true match answers divided by total match answers, and analyzed in Minitab 13. Please refer to Table 2 and Figure 5 for descriptive statistics on successful match ratios between groups for all tasks.

Table 2: Mean Match Ratios(SD) for association tasks.

	Odor-Shape Association	Number-Shape Association	Color-Shape Association
2-Objects	.413(.326)	.888(0.274)	1(0)
3-Objects	.318(.291)	.888(0.274)	1(0)
4-Objects	.235(0.133)	.833(0.408)	1(0)

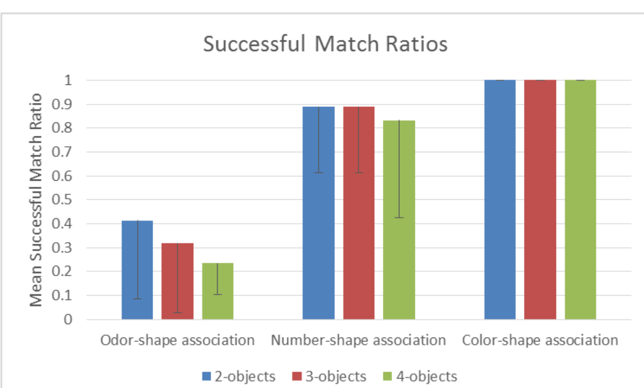

Figure 5: Graphic chart for mean match ratios of each group on all tasks. Error bars show standard derivation.

4.3. Comparison of Task Success
In this analysis, match results analyzed with Minitab 13. Match scores are determined with true match answers divided by total match answers. Odor–shape matching had lower accuracy (*M*=0.3222, *SD*=0.2587) in comparison to number–shape matching (*M*=0.8700, *SD*=0.3062) and color–shape matching (*M*=1, *SD*=0).

Discussion

The results of this study showed that participants were very successful in recognizing presented numbers and colors as well as associating them with shapes. However, their success levels were significantly lower for smell recognition and smell-shape recognition in comparison to numbers and colors. So the results support our first hypothesis that participants would be less successful in olfaction tasks in comparison to visual tasks. Also, in line with our second hypothesis, participants were less successful in smell-shape association than associating other visual cues. However, the results of this study did not reveal a significant difference in the ratio of recognized odors depending on the number of odors presented, in contrast to our third hypothesis that the cognitive load would increase with the number of presented items and thus the level of success would decrease. Still, there was a negative correlation between the number of items presented and the ratio of correctly recognized items. Since participants were almost totally successful in visual cues, the increase in number of presented objects did not have a significant effect on recognition success in number-shape association or color-shape association tasks either.

Several studies conducted in the field of recognition memory showed that humans are capable of cross-modal memory retrieval and the facilitation of visual recognition by odor cues (Cann & Ross, 1989; Gottfried & Dolan, 2003; Gottfried, Smith, Rugg & Dolan, 2004). However, results of this study contradicts the literature as we have seen little success in odor-shape association. Also, when we compare hit ratios in smell recognition with match ratios in odor-shape association, match scores are lower than hit ratios, so the existence of shapes did not facilitate the recognition of smells which were presented with those shapes.

There could be two main reasons behind the findings observed in this study. The memory of smell is regarded to be more emotional in nature compared with other senses, especially vision (Herz & Schooler, 2002; Willander & Larsson, 2007). Also, smell memories are usually episodic and not semantic (Köster, 2002). Verbal feedback obtained from participants after the experiments include that when they were presented with the odors in the training phase they thought of them as "fresh", "heavy", "spicy" and during the test phase they found it difficult the distinguish between two different objects both of which made them feel "fresh" or any other emotion they felt in the training phase. So, it might be possible that participants used their episodic memory instead of semantic memory for smells. In contrast, visual cues are encoded simply as they are, "five" is "five" and usually not associated with any other feeling such as “fresh”, and it is safe to assume that participants used their semantic memory for number or color recognition. The reason behind the low level of success in odor-shape association in comparison to almost perfect success in number-shape association and color-shape association might also be the result of the failure in smell recognition but there can also be a second reason behind. Neurophysiologically, all senses go through thalamus except the sense of smell and thalamus is very important for the association of the received senses and organization of acquired information (Stein et al., 2000). Since olfactory input does not go through thalamus, this could be the reason why it is not as successfully associated as other senses.

Conclusion

This study revealed that people are less successful in recognizing novel odors a short while after their presentation, even though they are very successful if the same test is applied with numbers or colors instead of odors. In addition, smell-shape association is similarly difficult for humans to perform whereas number-shape association and color-shape association is performed almost perfectly. Finally, this study also showed that the number of presented objects, at least in the range of 2 to 4 items, do not have a major impact on the cognitive performance. However, it should also be noted that there is at least some level of negative correlation between the number of presented objects and the ratio of successful recognition. The existence of shapes did not facilitate the recognition of odors. The fact that smell is the only sense that does not go through thalamus (Stein et al., 2000) might have an effect on the low success seen in odor-shape association in comparison to other senses.

For future studies, investigating the effect of odor familiarity might provide interesting results. Several studies in the field use daily odors such as pines and oranges (Gottfried, Smith, Rugg & Dolan, 2004) in contrast to our study in which we used rarely encountered odors. It can be argued that participants found it harder to recognize and name, and thus to associate this unfamiliar odors and they might perform better with more familiar odors. A study which compares the success in recognition of familiar odors and unfamiliar odors would help to assess the effect of familiarity on smell recognition and evaluated together with this study would provide additional insight for human cognitive ability of smell recognition.

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