BJPS
Brazilian Journal of Pharmaceutical Sciences
http://dx.doi.org/10.1590/s2175-97902022e20335

Article

Sensory Priming: The olfaction as an attention inducer

Carolina Roberto Carrieri[1], Airton Rodrigues[2], Patricia Santos Lopes[1], Newton Andréo-Filho[1], Yasmin Rosa Santos[1], Orpheu Bittencourt Cairolli[1], Milica Stevic[3], Marcelo Dutra Duque[1], Paulo Roberto Regazi Minarini[1], Vânia Rodrigues Leite-Silva*[1,4]

[1]UNIFESP – Instituto de Ciências Ambientais Químicas e Farmacêuticas, Universidade Federal de São Paulo, Diadema SP, Brasil, [2]FATEC – Faculdade de Tecnologia de Diadema Luigi Papaiz, Diadema SP, Brasil, [3]London College of Fashion, University of the Arts London, London, United Kingdom, [4]Therapeutics Research Centre, Translational Research Institute, Diamantina Institute, University of Queensland, Brisbane, Qld, Australia

In this study, we investigated the influence of the olfactive stimulus on visual attention. Two groups of 30 subjects participated in two experiments. Both experiments presented two arrays of fruits stimulus intercalated by an olfactive intervention. The stimulus was received in the form of images by the first group and in the form of words by the second group. An eye-tracking device monitored the timekeeping of visual attention dispensed in each stimulus. The results showed that olfactive priming influenced visual attention in both cases but with a greater degree in the images stimulus group. This study shows for the first time that image information is more susceptible to priming olfactive information than wording information. This effect may be associated with the formation of mental images in working memory, aroused by fragrances.

Keywords: Cognition. Olfactive priming. Visual attention.

INTRODUCTION

Olfaction has a strong relationship with the way people understand the world and exerts influence on underlying cognitive processes (Auffarth, 2013; Li *et al*., 2007). Odors can unconsciously modify behaviors, awakening emotions, or even evoking moments of the past (Morrot, Brochet, Dubourdieu, 2001). In addition to other senses, sensory integration is responsible for the perceptual construction regarding the external environment (O'Carroll, 2015).

The multisensory or crossmodal stimulation happens when specific information affects different senses simultaneously (Colonius, Diederich, 2017; Nehmé *et al*., 2016) e.g., by a crossmodal stimulus combination and that evoked by the most effective of its components separately. Being responsive to multiple sensory modalities does not guarantee that a neuron has actually engaged in integrating its multiple sensory inputs: it could simply respond to the stimulus component eliciting the strongest response in a given trial. Crossmodal enhancement is commonly expressed as a proportion of the strongest mean unisensory response. This traditional index does not take into account any statistical dependency between the sensory channels under crossmodal stimulation. We propose an alternative index measuring by how much the multisensory response surpasses the level obtainable by optimally combining the unisensory responses, with optimality defined as probability summation under maximal negative stochastic dependence. The new index is analogous to measuring crossmodal enhancement in reaction time studies by the strength of violation of the \"race model inequality', a numerical measure of multisensory integration. Since the new index tends to be smaller than the traditional one, neurons previously labeled as 'multisensory' may lose that property. The

***Correspondence:** V. R. Leite-Silva. Instituto de Ciências Ambientais Químicas e Farmacêuticas. UNIFESP Universidade Federal de São Paulo. Rua São Nicolau, 210 - Prédio de Pesquisa. CEP:09913-030 Campus Diadema, SP, Brasil. Phone: 11 40440500 R- 3576. E-mail: vania.leite@unifesp.br. ORCID: http://orcid.org/0000-0001-5913-1425

index is easy to compute and it is sensitive to variability in data. The olfactory and visual sensory systems appear to share robust and consistent associations. It is well known that culture specific experiences with odors may influence different aspects of odor perception such as intensity, pleasantness or edibility. Differences in terms of odor-color association might therefore be culturally specific. In order to determine the role of culture in odor-color associations, the responses of 155 French, 96 Lebanese and 110 Taiwanese subjects to the same 16 odorants were compared. The results highlight the role of culture and culinary habits on edibility ratings and color associations of some odors. Both perceptual and semantic factors seem to play a role in the odor-color associations in each country. Odor-color associations could indeed be affected by the function of odors in different countries. Culture-induced experiences influence the perception of odors familiarity, which will affect the prevalence of either perceptive (intensity, irritancy and hedonics. Murray *et al.* (2016) reported that multisensory processes are essential for constructing and maintaining perceptive and cognitive representations, affecting the learning process and individuals' behavior. A form of multisensorial processing is the integration between olfaction and the vision. Demattè, Sanabria and Spence (2009) demonstrated that olfaction and vision do not have a balanced relationship; indeed, they identified that different visual information types (e.g., color and shape) could modulate olfactory information in different wayswhich has typically been explained in terms of multisensory perceptual interactions. However, such crossmodal effects may equally well relate to interactions taking place at a higher level of information processing as well. In fact, it is well-known that semantic knowledge can have a substantial effect on people's olfactory perception. In the present study, we therefore investigated the influence of visual cues, consisting of color patches and/or shapes, on people's olfactory discrimination performance. Participants had to make speeded odor discrimination responses (lemon vs. strawberry). Seo *et al.* (2010) found that odor can increase attention towards a congruent visual object compared to an odorless condition. Another effect of crossmodal stimulation is that sensory cues create a context of facilitation by guiding the individual toward an environmental task, like consumption (Mas *et al.*, 2020).

Another particular characteristic of the olfactory sense is that it relies on phonological associations to be described (Morrot, Brochet, Dubourdieu, 2001). Odor processing has a bottom-up process (perception flow from olfactory information to the brain regions), and the sensory meaning of odor demands a top-down process (it is a higher-order representation that impinges on earlier steps in information processing) (Han *et al.*, 2020). In another way, the odor meaning depends on complex cognitive processing to be understood.

This study investigated whether an olfactive intervention can affect gaze patterns in a free visual task (the participants did not receive any gaze recommendation). The main hypotheses rely on the expectation that a fragrance administrated before a visual inspection can affect eye movement patterns. This effect is called priming: secondary stimuli that influence higher-order cognitive outcomes (Mas *et al.*, 2020). Seo *et al.* (2010) already got some similar results: when participants smelled an odor, they looked more frequently and longer at a corresponding object than the odorless condition. However, in this study, Seo and collaborators (2010) only used images and disregarded the possible effect of priming words as a visual pattern. This study seeks to fill this gap. The two experiments described below compare visual connection with images and words after olfactive priming.

MATERIAL AND METHODS

The Ethics Committee (UNIFESP) approved this study, protocol number 69563617.7.0000.5505.

Participants: Sixty participants (women and men) took part in the study after signing the consent form. All participants followed the same experimental protocol and were divided into two different groups: half of them took part in the Pictorial experiment, which involved observing images, and the other half took part in the Lexical experiment, which involved observing written words (Figure 1).

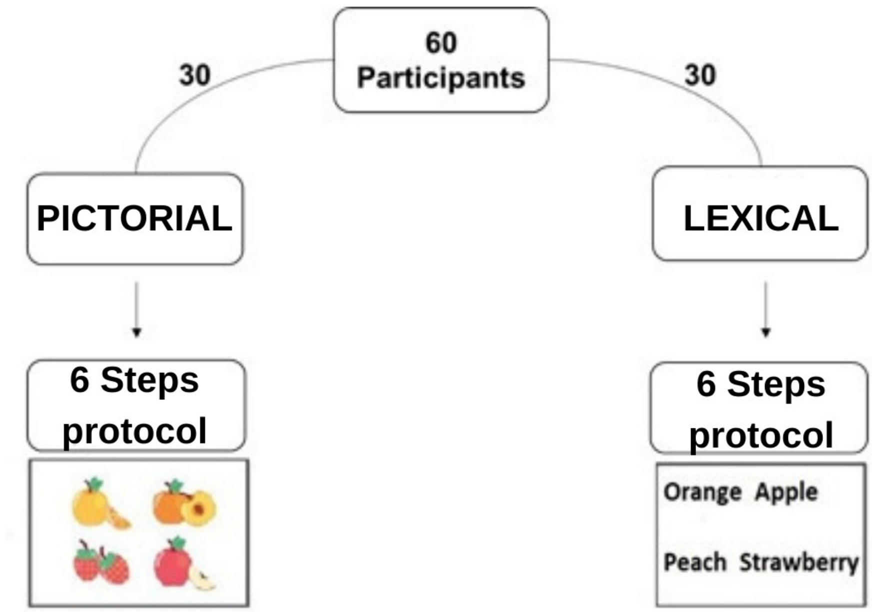

FIGURE 1 – Scheme of the experimental protocol.

Equipment used: The **eye-tracking** instrument used was *Eyetribe (*http://theeyetribe.com*)*. This device identifies eye gaze movement through a special camera with infrared illumination (Nyström, Hooge, Andersson, 2016). The EventIDE Software® (Okazolab, Netherlands) controlled eye-tracking and presentation of the stimulus. The visual stimuli (picture or words) were presented in a 2x2 array (one fruit per quadrant), in a 17-inch monitor, and the eye-tracking instrument recorded the dwell time fixations in a millisecond ratio.

Protocol:. The experiment started with a visual calibration of the eye-tracking device (step1). EventIDE displayed in the first screen instructions about the experiment: *Two identical arrays of images/words will appear on the screen. Between them, a tube with fragrance will be placed near your nose. All you have to do is view the images/words.* After this briefing, the participant was ready to start the experiment by pressing the space bar on the computer keypad. The second screen was a fixation cross, and the experiment forwarded only if the software detected gaze fixation in this area. It is critical to ensure that all participants started in the exact visual coordinates (step 2). Step 3 was the presentation of the fruit images or word array for 5 seconds (Figure 2).

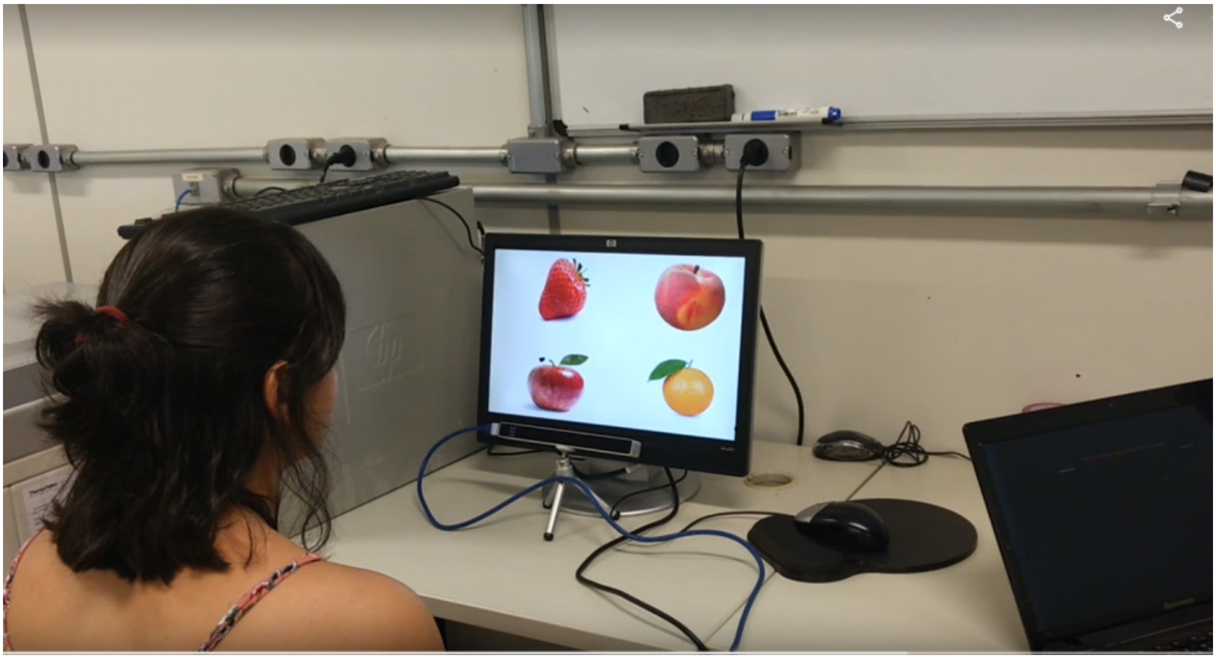

FIGURE 2 – Participant viewing the images.

The step 3 experiment was performed identically using the images (Figure 3) as a visualization array and using a verbal description of the images (Figure 4). During this time, the participant performed a free visual investigation.

The same array was presented twice. An olfactive intervention task (with a sample of 2 mL of peach essence diluted into 2 mL of water) happened between the arrays' presentation. The distance between participants and monitor was 6.7 inches.

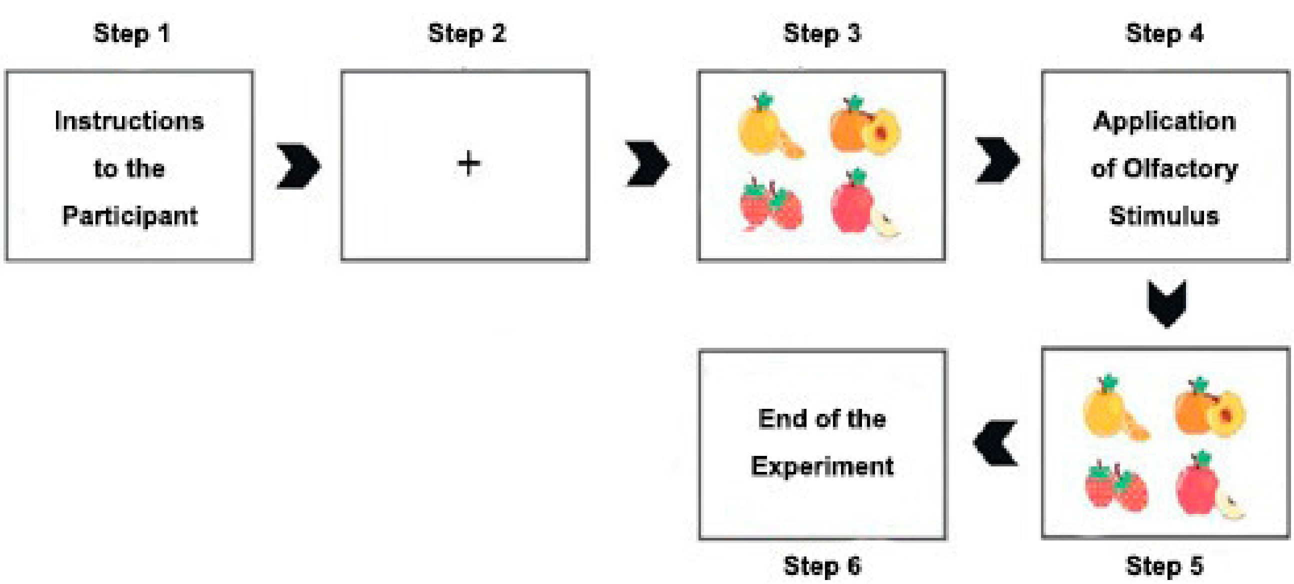

FIGURE 3 – Scheme of the experimental with images.

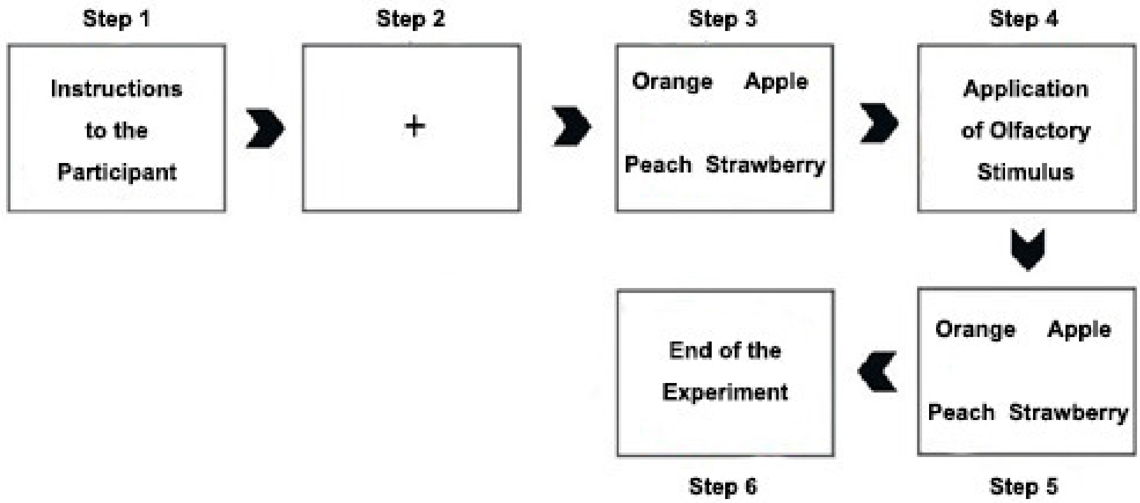

FIGURE 4 – Scheme of the experiment with words.

The olfactive intervention (about 3 seconds) happened after the first array inspection (step 4). The research assistant presented the test tube with the fragrance close to the participant's nose for a short interval for the cognitive processing of odor information (3 seconds), and, finally, step 5 displayed the same array presented in step 3 for 5 seconds. The last screen (step 6) was a thanks message for the participant. It is imperative to observe that the arrangement of the images remained the same throughout the task because it is essential to keep a memory location of images. However, all subjects received a new, random order of images, specified through random numbers generated by *MS* Excel® (each number was associated with an image).

One of the precautions taken in the experimentwas to keep the tube with the fragrance solution away from the test area. This was done to avoid the saturation of the experimental environment with the fragrance. In addition to this, the room was regularly ventilated, and the air was circulated.

The images and words were considered as a factor in an ANOVA (Analysis of Variance), and the dwell time in the first and second arrays as a dependent variable.

RESULTS AND DISCUSSION

This study measured the crossmodal relationship between an olfactory activity and a visual task to understand if olfactory priming could influence the visual search pattern. Participants undertook a visual task first, which included view in images of two fruits on a monitor, followed by an olfactory task that involved smelling a fragrance. The olfactory task between the first and second arrays of images was introduced to identify if the perceived fragrance could affect the visual scanning pattern.

Figure 5 shows the data for visualization (dwell) time for four different fruits investigated in the study, apple, peach, orange, and strawberry, before applying the fragrances (control) and after administering the stimulus (test). In the control condition (pre-olfaction), the visualization duration shows an even distribution between the four fruits images with no statistical difference between factors.

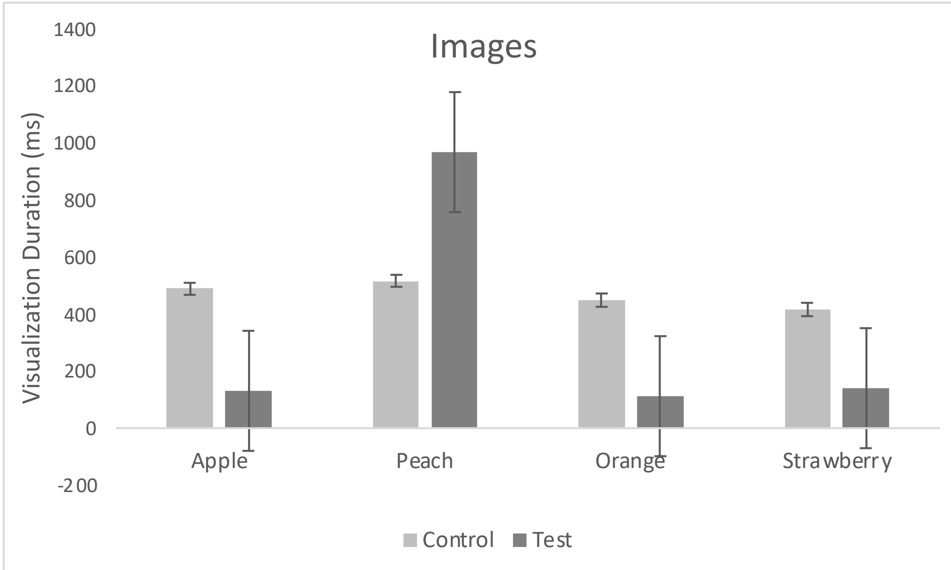

FIGURE 5 – Dwell time for different images of fruits (apple, peach, orange, and strawberry) before applying the fragrances (control) and after administering the olfactory stimulus (test).

In contrast to this, the olfactive priming stimulus (in test condition) affected the visual pattern significantly. The dwell time distribution, which was flat, concentrated in the congruent image of smell with significant statistical effect ($p<0.01$) between the averages in visualization time. Based on the results presented in Figure 5, it can be concluded that smelling the fragrance before viewing the second array of images directed the visualization focus of the participants to the image of the fruit that was matching the fragrance presented.

In the second experiment, a new group of participants was involved in viewing the names of fruits on the screen (as opposed to the images in the first experiment) was involved. The data obtained in this experiment were analyzed using the same statistical analysis as in the first experiment.

The results obtained in the experiment with words were different from those observed in the experiment with the images. The fixation duration for the focus stimulus (word 'peach') in test condition presented a significantly higher time ($p < 0.01$) of fixation than the other fruit names in the test condition. However, in a post hot test, there was no statistical significance between 'peach' word with control and test condition (Figure 6).

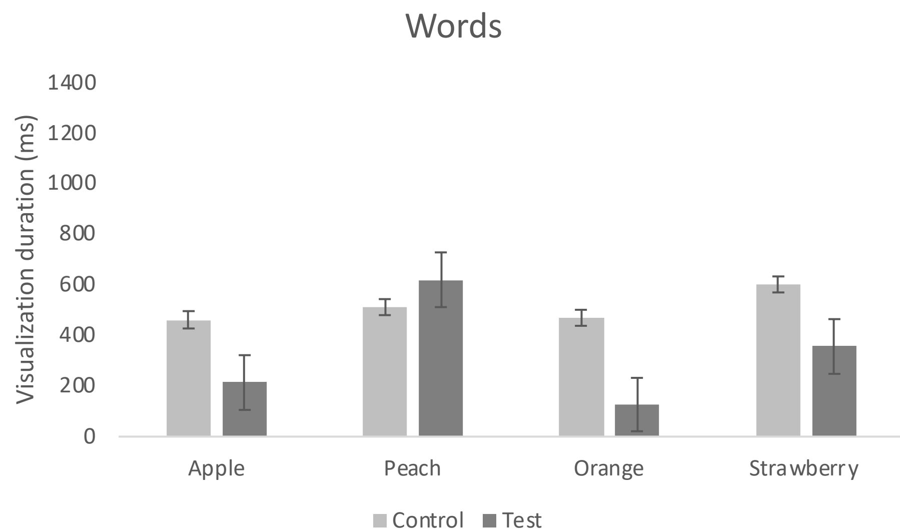

FIGURE 6 – Dwell time for different words of fruits (apple, peach, orange, and strawberry) before applying the fragrances (control) and after administering the olfactory stimulus (test).

The results showed that both experimental conditions (images and words of peach) could establish a visual connection with congruent information (peach fragrance); however, the intensity and the effect of this connection are very particular. The effects of olfactory information in the case of the image stimulus condition are more intense than in the case of the word experiment condition. In the first case, the peach images differentiate from other images in the array as the odorless control condition. On the contrary, the word 'peach' presentation could promote an effect compared to other fruits in the array; however, it was not significant from the control condition.

Some factors may explain the better performance of the image in contrast to words. First, the images were colored and, when this color is characteristic of its object, it can facilitate the identification of the odor (Demattè, Sanabria, Spence, 2009). The color would work as a visual cue, like, for example, the red color of the strawberry. Second, studies have demonstrated that the effort to identify the origin of an odor leads to the mental construction of the image of the object congruent to the smell, with consequent activation of visual areas responsible for the odor recognition (Jadauji *et al*., 2012; Qureshy *et al*., 1999). Therefore, the fragrance would be referred primarily to its image (peach) instead of the associated word. Maric and Jacquot (2013) reported that odors of ordinary objects, such as food, can have their perception built through their visual form, in this case, the fruit itself. Third, it is possible that the participants that received the word visual stimulus perceived that the fragrance would be familiar but may have had some difficulty labeling it phonologically (Lawless, Engen, 1977).

Previous studies have achieved similar results and endorse the relationship between olfactory priming and vision (Gottfried, Dolan, 2003; Michael, 2003). When there is a congruent odor to an object of visual interest, Seo *et al.* (2010) assert that odor increases visual attention compared to a situation without olfactory stimuluslittle is known about the reverse case: the influence of odor on visual performance. This study aimed to determine whether odors can enhance attention towards visually presented objects congruent with the odors. Sixty healthy participants were presented with four odors (orange, lavender, coffee, and liquorice. However, no studies have compared images and lexical stimuli, which makes these findings unpublished yet.

Otherwise, the working memory has an essential role in this scenario. The concept of working memory is a multicomponent and specialized structure responsible for controlling attention, process, and consolidate visual and verbal information (Logie, Camos, Cowan, 2020). One of the main characteristics of working memory is its low information processing capacity, which leads to a selective attention process regulating this memory capacity (Baddeley, 2017). An exciting and relevant hypothesis that can help explain the difference between the effects is that the words may have caused an overload of the working memory and loss of some cognitive information, differently from the images results. Another explanation that can insert working memory at the forefront of these effects is that building the mental image process is based on this mnemonic component (Baddeley, Hitch, Richard, 2020). It is a significant finding because there is still little evidence that visual and verbal information overload the cognitive system asymmetrical (Baddeley, 2017). All this evidence sustains and sheds a little light on the mechanisms that operated in the experimental groups.

The finding that the sense of smell with vision has a higher cognitive effect than words brings substantial benefits to cosmetics. One of the fields that can benefit from these findings is the area of packaging and marketing. There are huge investments to build memorable fragrance names; however, how strong can this relationship be? Is a fragrance more connectable to an image than a name? It is a fascinating issue to be understood. Are these findings valid just for fragrances that have a previous meaning and offer a precise mental construction, as the fruit fragrance, or is it possible to create new associative forms that can explore this connection between smell and sight?

Research in the multisensorial field using neuroscience resources is becoming less challenging, thanks to advances in technology. Therefore, this paper may support future work in the field.

The results showed that olfactive priming influenced visual attention in both cases Pictorial (images) and Lexical (words) but with a greater degree in the images' stimulus group. This paper demonstrates for the first time that image information is more susceptible to priming olfactive information than wording information. This effect may be associated with the formation of mental images in working memory, aroused by fragrances.

ACKNOWLEDGMENT

The authors would like to thank FAV 105 FRAGRANCES LTDA (São Paulo – Brazil) which kindly provided the peach fragrance and Dr Patrice Bellon from Cosmetoscent (France) for his valuable comments.

REFERENCES

Auffarth B. Understanding smell-The olfactory stimulus problem. Neurosci Biobehav Rev. 2013;37(8):1667-79.

Baddeley A. Exploring Working Memory: selected works of Alan Baddeley. Routledge, London. 2017. 394 p.

Baddeley A, Hitch G, Richard AA Multicomponent Model of Working Memory. In: LOGIE, Robert; CAMOS, Valérie; COWAN, Nelson. Working Memory: The state of the science. 1st ed. Oxford: Oxford University Press. 2020. p. 10-43.

Colonius H, Diederich A. Measuring multisensory integration: From reaction times to spike counts. Sci Rep. 2017;7(1):1-11.

Demattè ML, Sanabria D, Spence C. Olfactory discrimination: When vision matters? Chem Senses. 2009;34(2):103-9.

Gottfried JA, Dolan RJ. The nose smells what the eye sees: Crossmodal visual facilitation of human olfactory perception. Neuron. 2003;39(2):375-86.

Han P, Croy I, Raue C, Bensafi M, Larsson M, Cavazzana A,Hummel T. Neural processing of odor-associated words: An fMRI study in patients with acquired olfactory loss. Brain Imaging Behav. 2020;14(4):1164-1174.

Jadauji JB, Djordjevic J, Lundström JN, Pack CC. Modulation of olfactory perception by visual cortex stimulation. J Neurosci. 2012;32(9):3095-100.

Lawless H, Engen T. Associations to odors: Interference, mnemonics, and verbal labeling. J Exp Psychol Hum Learn Mem. 1977;3(1):52-9.

Li W, Moallem I, Paller KA, Gottfried JA. Subliminal smells can guide social preferences. Psychol Sci. 2007;18(12):1044-9.

Maric Y, Jacquot M. Contribution to understanding odour-colour associations. Food Qual Prefer. 2013;27(2):191-5.

Mas M, Brindisi M-C, Chabanet C, Chambaron S. Implicit food odour priming effects on reactivity and inhibitory control towards foods. Plos One. 2020;15(6):1-32. https://doi.org/10.1371/journal.pone.0228830

Michael G. Ambient odors modulate visual attentional capture. Neurosci Lett. 2003;352(3):221-5.

Morrot G, Brochet F, Dubourdieu D. The color of odors. Brain Lang. 2001;79(2):309-20.

Murray MM, Lewkowicz DJ, Amedi A, Wallace MT. Multisensory processes: A balancing act across the lifespan. Trends Neurosci. 2016;39(8):567-79.

Nehmé L, Barbar R, Maric Y, Jacquot M. Influence of odor function and color symbolism in odor-color associations: A French-Lebanese-Taiwanese cross-cultural study. Food Qual Prefer. 2016;49:33-41.

Nyström M, Hooge I, Andersson R. Pupil size influences the eye-tracker signal during saccades. Vision Res. 2016;121:95-103.

O'Carroll DC. Multisensory perception: Pinpointing visual enhancement by appropriate odors. Curr Biol. 2015;25(5):196-8.

Qureshy A, Kawashima R, Imran MB, Sugiura M, Goto R, Okada K, et al. Functional PET mapping of human brain in olfactory processing. J Neurophysiol. 2000;84(3):1656-66. https://pubmed.ncbi.nlm.nih.gov/10980035/

Seo HS, Roidl E, Müller F, Negoias S. Odors enhance visual attention to congruent objects. Appetite. 2010;54(3):544-9.

Received for publication on 14th May 2020
Accepted for publication on 15th May 2021