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Beyond self-report measures of arousal: A new priming task to capture activation of relaxing and energizing feelings elicited by odors

Donato Cereghetti [a,*], Géraldine Coppin [b,c], Christelle Porcherot [a], Isabelle Cayeux [a], David Sander [b,d], Sylvain Delplanque [b,d]

[a] DSM-Firmenich AG, Rue de la Bergère 7, 1242 Satigny, Switzerland
[b] Swiss Center for Affective Sciences, CISA - Université de Genève, Chemin des Mines 9, 1202 Geneva, Switzerland
[c] Department of Psychology, UniDistance, Suisse, Schinerstrasse 18, 3900 Brigue, Switzerland
[d] Laboratory for the Study of Emotion Elicitation and Expression (E3 Lab), Department of Psychology, FPSE, University of Geneva, Bd du Pont d'Arve 40, CH 1205 Geneva, Switzerland

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ABSTRACT

The Olfactory Priming Task (OPT) is a new implicit measure developed to capture associations between odors and feeling-related words that was inspired by previous priming techniques. Participants are presented with feeling-related words and asked to categorize them as "relaxing" or "energizing" as quickly and accurately as possible, while supposedly relaxing or stimulating odors are delivered as a prime. Accuracy and response times are recorded, and participants are expected to react faster and more accurately with feeling-related words that are congruent with the primed odor. We validated the OPT in two experiments with the use of menthol/vanillin and fine fragrances, respectively. Results indicated that the OPT could discriminate odors from their relaxing/energizing properties, with participants showing faster responses to energizing-related words after priming with menthol or "Perfume 1" and to relaxing-related words after priming with vanillin or "Perfume 2." These associations were further confirmed by subjective reports, with participants rating menthol and Perfume 1 as more energizing and vanillin and Perfume 2 as more relaxing. The results suggest that exposure to relaxing/energizing odors activates congruent feelings in consumers. The results also demonstrate the validity and reliability of the OPT as an implicit measure for capturing associations between odors and feeling-related words, making it a valuable tool for measuring consumers' affective response to flavors and fragrances.

1. Introduction

Measuring consumers' emotions during product experience has gained growing attention in recent years. Emotions may provide valuable insights beyond traditional measurements of sensory properties and subjective pleasure, thus providing a deeper understanding of consumer attitudes and behaviors (Cardello & Jaeger, 2021). Standardized questionnaires have been developed and validated for measuring consumers' affective response to products, such as the Emotion and Odor Scales (EOS) (Chrea et al., 2009; Ferdenzi et al., 2013; Ferdenzi et al., 2011), ScentMove™ (Porcherot et al., 2010), and the EsSense Profile® (King et al., 2010). Although such questionnaires proved their ability to measure consumers' affective response to products, they are subject to several limitations. For example, consumers' responses may be affected by response bias such as social desirability (Bargh, 2002; Greenwald & Banaji, 1995), and the quality of their response may depend on introspective skills (Choi & Pak, 2005; Nisbett & Wilson, 1977). In addition, self-report measures cannot specifically capture cognitive or affective processes occurring outside of conscious awareness (Gawronski & De Houwer, 2014; Nosek et al., 2011). To overcome the limitations of self-report measures, researchers have developed procedures that do not require participants to explicitly report their attitudes or affective reactions (De Houwer, 2006). As extensively reviewed by Nosek et al. (2011), examples of such indirect procedures include the Evaluative Priming Task (EPT) (Fazio et al., 1986), the Implicit Association Test (IAT) (Greenwald et al., 1998), the Go/No-Go Association Task (GNAT) (Nosek & Banaji, 2001), and the Single-Category IAT (SC-IAT) (Karpinski & Steinman, 2006). Not surprisingly, indirect procedures have also rapidly become popular in consumer research (Dimofte, 2010; Kraus & Piqueras-Fiszman, 2018), together with the idea that consumer

* Corresponding author.
E-mail address: donato.cereghetti@dsm-firmenich.com (D. Cereghetti).

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attitudes, affective reactions, motivations, and choices can be shaped not only by explicit cognitive processes, but also by automatic processes that occur outside of conscious awareness (Bargh, 2002; Dijksterhuis et al., 2005; Fitzsimons et al., 2002). Although indirect procedures have been widely used to study consumer attitudes and behaviors in the visual domain, their application in other sensory domains, particularly olfactory perception, has been scarce. However, given that olfactory information is primarily processed unconsciously (Köster, 2002; Köster et al., 2014), using implicit measures may provide a deeper understanding of the emotional processes elicited by odors and fragrances.

In a previous study (Lemercier-Talbot et al., 2019), we presented a modified version of the IAT that can be used to assess automatic associations between odors and feeling-related words. The IAT is a speeded task that requires participants to categorize stimuli rapidly and accurately into their categories by using two response keys. Participants are expected to respond more quickly and accurately when stimuli that are strongly associated share the same response key (e.g., "flower-pleasant" vs. "insects-unpleasant," the compatible block) than when they do not (e.g., "insect-pleasant" vs. "flower-unpleasant," the incompatible block), which is known as the IAT effect. In three experiments, we demonstrated that the IAT could effectively measure automatic associations between odors and words related to energizing vs. relaxing feelings. In Experiment 1, we used odor labels ("mint" and "vanilla"); in Experiment 2, we used simple compounds (menthol and vanillin); and in Experiment 3, we used fine fragrances ("Perfume 1" and "Perfume 2"). The three experiments found an IAT compatibility effect, where participants responded faster when associating the mint label, menthol, and Perfume 1 with energizing-related words, and the vanilla label, vanillin, and Perfume 2 with relaxing-related words, as compared to the opposite associations. Although the IAT is the most popular method used in implicit cognition research (Nosek et al., 2011), it also comes with a significant limitation that may restrict its applicability in product testing. Specifically, the IAT measures the association strength between a target and an attribute relative to another pair, rather than the absolute strength of the associations between each target and each attribute. For instance, the compatibility effect observed in Experiment 1 of Lemercier-Talbot et al. (2019) could be driven by (1) exclusive associations between mint and energizing words, with vanilla having no clear associations with either energizing or relaxing feelings, or (2) exclusive associations between vanilla and relaxing words, with mint having no clear associations with either energizing or relaxing feelings, or (3) a combination of both mint-energizing and vanilla-relaxing associations.

In this study, we aimed to develop and validate a new cross-modal implicit measure for capturing associations between odors and feeling-related words that can (1) measure the absolute association strengths between each odor and each feeling; (2) be executed relatively quickly, making it well-suited for the needs of consumer applied research; and (3) minimize the risks of sensory adaptation and olfactory habituation. To achieve this goal, we developed a procedure based on priming techniques. In a classic EPT (Fazio et al., 1986), participants are presented with a series of targets (e.g., words) that they must quickly and accurately evaluate as pleasant or unpleasant by using two response keys. Each target is quickly preceded by a prime, a valenced stimulus that participants are usually instructed to ignore. The effect of the prime on subsequent target processing is then assessed. Participants are expected to respond faster and more accurately when the prime and target share the same emotional valence (e.g., "flower" as prime and "gift" as target) than when the prime and target are affectively incongruent (e.g., "insect" as prime and "gift" as target). The classic EPT has been successfully adapted for use with odors (Hermans et al., 1998), visual stimuli conditioned with odors (Hermans et al., 2005), and flavors (Veldhuizen et al., 2010), all of which have been used as primes, with valenced words used as targets. These studies have focused on evaluative priming, where participants were found to react faster to positive targets after being primed with a pleasant odor/flavor (or a positively conditioned stimulus), and to negative targets after being primed with an unpleasant odor/flavor (or a negatively conditioned stimulus). In our study, we aimed to expand the use of these procedures beyond the dimension of valence, by investigating associations between odors and arousal.

To test and validate our procedure, we used the same odors previously used by Lemercier-Talbot et al. (2019). Specifically, we used vanillin and menthol in Experiment 1 and two fine fragrances labeled Perfume 1 and Perfume 2 in Experiment 2. We predicted that priming with menthol and Perfume 1 would result in faster responses to energizing-related words, whereas priming with vanillin and Perfume 2 would lead to faster responses to relaxing-related words.

2. Experiment 1

2.1. Method

2.1.1. Participants

Forty-six participants (24 women, 22 men) with an average age of 36.6 years ($SD = 14.5$) were recruited from various departments of DSM-Firmenich AG. Among them, 28 were permanent employees and 18 were temporary employees or trainees. They were not paid for their participation in the study, but they received snacks upon completion. The participants provided written informed consent and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Two participants were excluded from the sample due to technical issues, resulting in a final sample of 44 participants.

In this study, we employed a new implicit measure to capture associations between odors and feeling-related words. As a result, we could not determine the appropriate sample size a priori on the basis of known effect sizes. Therefore, we conducted a sensitivity analysis, using G*Power 3 (Faul et al., 2007) to identify the minimum effect size that our sample size of 44 participants would be able to detect in paired t-tests. The analysis indicated that our study had sufficient statistical power to detect effect sizes of Cohen's $d_z = .43$, assuming a significance level of $\alpha = 0.05$ and power of $(1 - \beta) = 0.80$.

2.1.2. Materials

2.1.2.1. Visual stimuli. The Olfactory Priming Task (OPT) used eight French words from the Swiss version of the EOS (Chrea et al., 2009; Ferdenzi et al., 2013) as targets. Four of the words were associated with a relaxing feeling, namely, "relaxé," "apaisé," "serein," and "réconforté" (which translate to "relaxed," "soothed," "serene," and "reassured," respectively). The other four words were associated with an energizing feeling, namely "revitalisé," "rafraîchi," "tonifié," "énergique" (which translate to "revitalized," "refreshed," "invigorated" and "energetic," respectively).

2.1.2.2 Olfactory stimuli and olfactory display system

In this experiment, we used menthol and vanillin because they were shown to elicit energizing and relaxing feelings, respectively, at both explicit and implicit levels (Lemercier-Talbot et al., 2019). The odors were diluted to 10 % each in dipropylene glycol and then injected into the tampon of empty olfactory sticks (Burghart® GmbH). The tampons were placed inside glass vials (22 mm diameter × 120 mm high) and then inserted in a computer-controlled olfactometer that was built in-house (Ischer et al., 2014). This olfactory device allows odors of known concentration to be delivered in a precise, reproducible manner without any interfering tactile or thermal sensation. The flow rate of the air was fixed at 2 L per minute, which is similar to that used in previous research conducted in our laboratory (Cereghetti et al., 2021; Lemercier-Talbot et al., 2019).

2.1.3. Procedure

The experimental procedure consisted of two parts: the odor evaluation phase and the OPT.

2.1.3.1. Odor evaluation phase. During the odor evaluation phase, participants were presented with a series of odors to assess. The odors were presented to participants through the olfactometer, each for a duration of 6 s. After each odor presentation, participants rated it on various dimensions by using visual analog scales. These scales ranged from 0 to 100 and were displayed on a computer screen. Participants used a scale that ranged from "very unpleasant" to "very pleasant" to evaluate the pleasantness of the odors, a scale that ranged from "not perceived" to "very strong" to evaluate the intensity of the odors, and a scale that ranged from "not familiar at all" to "very familiar" to evaluate the familiarity of the odors. In addition, two distinct scales that ranged from "not at all" to "extremely" were used to evaluate the intensity of energizing and relaxing feelings evoked by the odors.

2.1.3.2. Olfactory priming task. The Olfactory Priming Task (OPT) is an experimental procedure that explores how olfactory stimuli, presented as primes, impact participants' ability to categorize feelings-related words, subsequently presented as targets. Taking about 15 min, this task consists of two phases: a practice phase and a test phase.

The practice phase was designed to familiarize participants with the task and the words used in it. In this phase, participants were instructed to press one of two response keys to indicate whether the words presented on the screen were related to relaxing or energizing feelings. The practice phase consisted of 32 trials in total, with each word presented 4 times as target. Each trial involved presenting a word in the center of the screen, with the two feeling categories ("energizing," "relaxing") displayed on the top left and right corners of the screen. Participants used their dominant hand to press one of two keys (either "B" or "N") to indicate whether the word presented belonged to the category on the left or the category on the right. The "B" key was used to indicate the category on the left, while the "N" key was used to indicate the category on the right. The key-response assignment was counterbalanced across participants, with half categorizing relaxing-related words on the left and energizing-related words on the right, and the other half categorizing energizing-related words on the left and relaxing-related words on the right. Error feedback in the form of a red capital "X" was displayed on the screen when an incorrect response was provided, and participants were required to provide the correct response to end the trial. At the end of the trial, a fixation cross was displayed on the screen for a random duration of between 100 and 400 ms, serving as the intertrial interval (ITI).

The test phase was similar to the practice phase, with the exception that participants were briefly exposed to either menthol or vanillin, which they were explicitly instructed to ignore. The test phase consisted of 96 trials in total, with each word presented 12 times as target. The 96 trials were organized into 48 blocks, with half of the blocks (24 blocks) involving menthol delivery and the other half involving vanillin delivery. Notably, unlike classic evaluative priming techniques where each prime is followed by one target (Fazio et al., 1986; Guerdoux et al., 2014; Hermans et al., 1998; Hermans et al., 2005; Veldhuizen et al., 2010), in our study, each block consisted of two targets (T1, T2) following each olfactory prime. There were three reasons why we opted to use this block design. First, we aimed to shorten the task duration to meet the needs of consumer applied research. Second, we wanted to

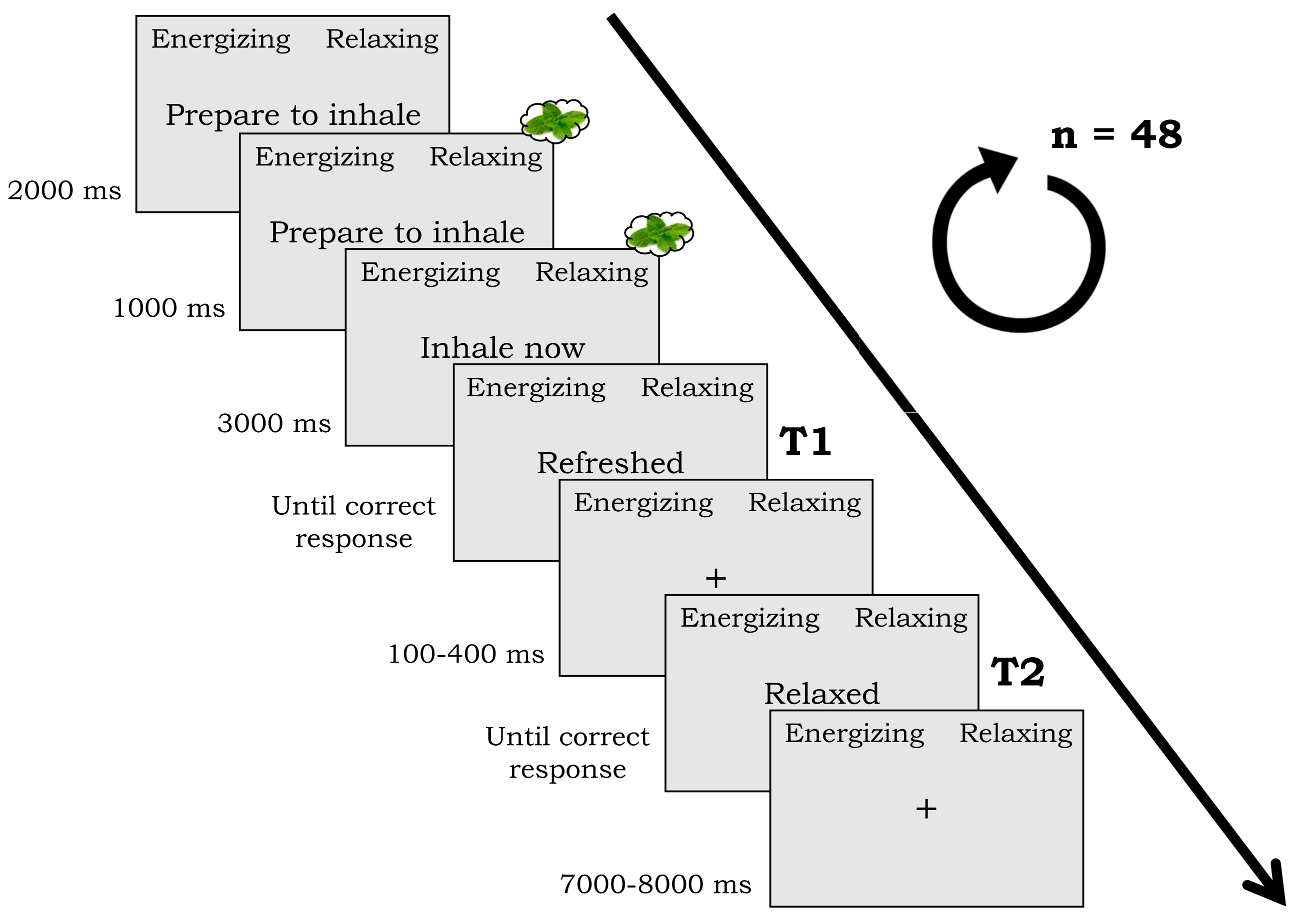

Fig. 1. Block design. The participants were instructed to inhale while an olfactory prime was delivered through an olfactometer. Two targets were then displayed on the screen, and the participants had to indicate whether the targets were relaxing or energizing by using two keys on the computer keyboard.

reduce the amount of odor released to minimize the risks of sensory adaptation and olfactory habituation, which can potentially result in the loss of the priming effect. Last, our decision was supported by a prior study (Cereghetti et al., 2021) in which we successfully used a design block involving multiple targets per olfactory prime. Fig. 1 illustrates the block design of the OPT. At the beginning of each block, participants were primed with an odor. The instruction "prepare to inhale" was shown for 3 s, followed by "inhale now" for another 3 s. The olfactometer released the odor 1 s before the instruction to inhale, ensuring that the odorants were present in the final delivery pieces of the olfactometer during participants' inhalation. After the olfactory prime, two targets (T1 and T2) were presented sequentially on the screen, and participants were instructed to indicate whether the targets were relaxing or energizing by pressing either "B" or "N." After each response, an ITI was provided, which consisted of presenting a fixation cross in the center of the screen. The duration of the ITI was randomized between 100 and 400 ms after T1 and between 7 and 8 s after T2. This longer ITI was used to minimize the risks of sensory adaptation and olfactory habituation. Word presentation was randomized to ensure that each word was presented three times per each prime (menthol, vanillin) × target (T1, T2) level. In addition, participants could not predict their response to T2 from their response to T1, since T1 and T2 could belong to the same or a different category. The influence of olfactory priming on performance was investigated by analyzing the accuracy and reaction times (RTs) to T1 and T2. Faster and more accurate responses were expected for congruent odor-word pairs (i.e., menthol + energizing-related words and vanillin + relaxing-related words).

2.2. Results

The R statistical software (R Core Team, 2021) was used for all analyses. The effect sizes for analyses of variance (ANOVAs) and t-tests were estimated by using partial eta squared (η_p^2) and Cohen's d (d_z), respectively, along with their corresponding 90 % or 95 % confidence intervals (Lakens, 2013). To compute effect sizes, we used the functions written by Stussi et al. (2021), which are available at the Open Science Framework (https://osf.io/9w8rn/). Raincloud plots (Allen et al., 2021) were generated by using JASP 0.16 (Love et al., 2019). Both the data and the analysis script are available at the Open Science Framework (https://osf.io/nj238/).

2.2.1. Odor evaluation phase

Three paired t-tests were conducted to compare differences in perceived intensity, familiarity, and liking between vanillin and menthol. Results showed that vanillin was perceived as more familiar ($M = 86.1$, $SD = 12.5$) ($t(43) = 2.71$, $p = .01$, $d_z = .41$, 95 % CI [.10,.71]) and more pleasant ($M = 76.2$, $SD = 19.6$) ($t(43) = 2.09$, $p = .04$, $d_z = .31$, 95 % CI [.01,.62]) than menthol (familiarity: $M = 79.9$, $SD = 18.6$, liking: $M = 69.9$, $SD = 16.1$). Menthol intensity ($M = 66.7$, $SD = 16.6$) did not statistically differ from vanillin intensity ($M = 64.0$, $SD = 16.2$; $t(43) = -1.00$, $p = .32$, $d_z = -.15$, 95 % CI [-.45,.15]). Four additional paired t-tests were conducted to evaluate differences in the relaxing and energizing rating scales. Results indicated that menthol was rated as more energizing ($M = 71.9$, $SD = 16.3$) than vanillin ($M = 33.2$, $SD = 22.2$) ($t(43) = 9.88$, $p < .001$, $d_z = 1.49$, 95 % CI [1.05, 1.92]) and vanillin was rated as more relaxing ($M = 76.5$, $SD = 15.1$) than menthol ($M = 44.2$, $SD = 21.0$) ($t(43) = 8.48$, $p < .001$, $d_z = 1.28$, 95 % CI [.87, 1.67]). Menthol was also rated as more energizing than relaxing ($t(43) = 5.69$, $p < .001$, $d_z = .86$, 95 % CI [.51, 1.20]), and vanillin was rated as more relaxing than energizing ($t(43) = 10.40$, $p < .001$, $d_z = 1.57$, 95 % CI [1.12, 2.01]).

2.2.2. Olfactory priming task

2.2.2.1. Response accuracy. Response accuracy was analyzed by using a repeated-measures ANOVA with prime (menthol, vanillin), target category (relaxing, energizing), and target position (T1, T2) as within-subject factors. The results revealed a significant main effect of the target category ($F(1, 43) = 10.54$, $p = .002$, $\eta_p^2 = .20$, 90 % CI [.05,.35]), indicating higher accuracy for relaxing-related words ($M = 0.95$, $SD = 0.04$) than for energizing-related words ($M = 0.92$, $SD = 0.07$). In contrast, there were no significant effects of the target position ($F(1, 43) = .78$, $p = .38$, $\eta_p^2 = .02$, 90 % CI [.00,.12]) or prime ($F(1, 43) = 3.20$, $p = .08$, $\eta_p^2 = .07$, 90 % CI [.00,.21]), or any interaction effects, including the critical prime-target interaction ($F(1, 43) = .13$, $p = .72$, $\eta_p^2 = .003$, 90 % CI [.00,.07]).

2.2.2.2. Reaction times. Incorrect trials (6.3 %), trials with response latencies faster than 300 ms (0.2 %) and slower than 1500 ms (4.4 %), and RTs that fell outside 2.5 SD from each participant's mean (1.0 %) were excluded from the analysis. A repeated-measures ANOVA was then conducted with prime (menthol, vanillin), target category (relaxing, energizing), and target position (T1, T2) as within-subject factors. The results showed a significant effect of target position ($F(1, 43) = 266.70$, $p < .001$, $\eta_p^2 = .86$, 90 % CI [.79,.90]), with faster responses in T2 ($M = 615$, $SD = 91$ ms) than in T1 ($M = 839$, $SD = 136$ ms). A significant three-way interaction was also observed ($F(1, 43) = 8.40$, $p = .006$, $\eta_p^2 = .16$, 90 % CI [.03,.32]), indicating that the target position influenced the critical prime-target interaction. Two repeated-measures ANOVAs were then conducted to assess the prime-target interaction at each target position level. The prime-target interaction was significant for T1 ($F(1, 43) = 14.93$, $p < .001$, $\eta_p^2 = .26$, 90 % CI [.09,.41]), but not for T2 ($F(1, 43) = 0.01$, $p = .91$, $\eta_p^2 < .001$, 90 % CI [.00,.02], as shown in Figure S1 in the supplementary materials). Paired t-tests revealed that, in T1, participants had faster responses to energizing-related words ($M = 818$, $SD = 147$ ms) than to relaxing ones ($M = 847$, $SD = 153$ ms) after being primed with menthol ($t(43) = 2.07$, $p = .04$, $d_z = .31$, 95 % CI [.01,.61]; Fig. 2A); they had inversely faster responses to relaxing-related words ($M = 829$, $SD = 136$ ms) than to energizing ones ($M = 865$, $SD = 157$ ms) after being primed with vanillin ($t(43) = 2.76$, $p = .01$, $d_z = .42$, 95 % CI [.11,.72]; Fig. 2B).

2.3. Discussion

The goal of Experiment 1 was to investigate whether the OPT could implicitly capture associations between menthol, vanillin, and words related to energizing vs. relaxing feelings. The study showed that when participants were primed with menthol, they responded faster to energizing-related words than to relaxing ones. Similarly, when participants were primed with vanillin, they responded faster to relaxing-related words than to energizing ones. These findings support the existence of automatic associations between menthol and energizing-related words and between vanillin and relaxing-related words, as previously found by Lemercier-Talbot et al. (2019). Subjective reports provided further support for these findings, with participants explicitly rating menthol as more energizing and vanillin as more relaxing.

The study showed that participants had shorter RTs for T2 than for T1, possibly due to a reduction in cognitive load in T2, as they had already partially processed the olfactory prime, and to motor facilitations due to task repetition (Hyman, 1953; Mawase et al., 2018). Most important, the priming effect was observed only for T1 and not T2. Although it is always delicate to discuss the absence of a statistically significant effect, we believe that the most likely and non-exclusive reasons could be, firstly, the long interval between the odor and T2, which may have weakened or dissipated the odor's priming effect. This is consistent with previous studies on sequential priming paradigms, which have shown that facilitation of target processing by the prime only occurs when the interval between the prime and target onset, also known as the stimulus onset asynchrony (SOA), is brief (Fazio et al., 1986). Second, the interval between the odor and T2 varies substantially

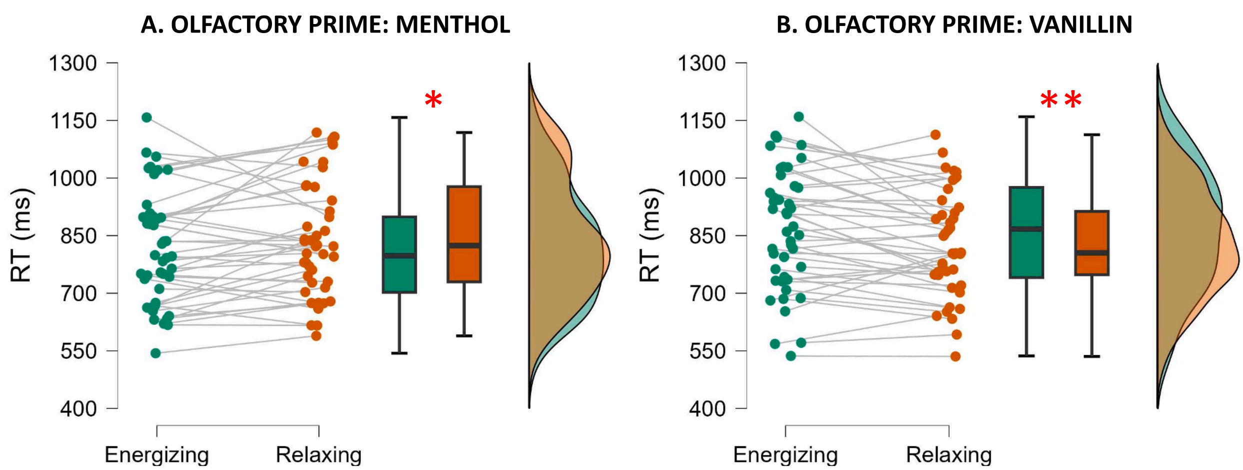

Fig. 2. Reaction times (ms) in T1 as a function of the olfactory prime and the target category. *p < .05, **p < .01.

across trials, depending on the participant's RT on T1 and the random duration of the ITI after T1, further complicating any analysis on T2. Nonetheless, we conducted two exploratory analyses to investigate whether the category of T1 and response time on T1 could impact olfactive priming on T2. We did not find any significant evidence to support the existence of such an impact (analysis available on supplementary material). Although T2 was introduced to optimize the OPT, it is worth noting that sequential priming procedures typically involve only one target after each prime. From the results of this initial experiment, it appears that T2 may not provide any benefits to the OPT.

Experiment 1 provided a first validation of the OPT as an implicit measure for exploring associations between simple compounds and feeling-related words. In Experiment 2, we wanted to replicate the exact procedure with complex olfactory stimuli, such as fine fragrances, to evaluate its potential for the perfume industry.

3. Experiment 2

3.1. Method

3.1.1. Participants

In Experiment 2, we recruited the same number of participants as in Experiment 1. Forty-six participants (29 women, 17 men) with an average age of 38.1 years ($SD = 12.6$) were recruited from various departments of DSM-Firmenich AG. Among them, 35 were permanent employees and 11 were temporary employees or trainees. They were not paid for their participation in the study, but they received snacks upon completion. The participants provided written informed consent and the study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Two participants were excluded from the sample due to technical issues, resulting in a final sample of 44 participants. As in the first experiment, a sensitivity analysis conducted with G*Power 3 showed that our study had sufficient statistical power to detect effect sizes of Cohen's $d_z = .43$ in paired t-tests, assuming a significance level of $\alpha = 0.05$ and power of $(1 - \beta) = 0.80$.

3.1.2. Materials

3.1.2.1 Visual stimuli

The same set of words used as targets in Experiment 1 was also used in Experiment 2.

3.1.2.2 Olfactory stimuli and olfactory display system

We used two fine fragrances in this experiment: Perfume 1 and Perfume 2. These fragrances had previously been used in the study by Lemercier-Talbot et al. (2019), which demonstrated that Perfume 1 was associated with energizing-related words, whereas Perfume 2 was associated with relaxing-related words, both at an implicit and explicit level. Perfume 1 is a fragrance belonging to citrus and aromatic olfactory families. The top notes of Perfume 1 include bergamot, lemon, mandarin, and green notes. The heart notes include jasmine, rose, lily-of-the-valley, and iris, while the base notes include cedar, sandalwood, oakmoss, and amber. In contrast, Perfume 2 is a fragrance belonging to oriental and floral olfactory families. The top notes of Perfume 2 include hawthorn and blackcurrant. The heart notes include violet blossom, jasmine, and rose, while the base notes include vanilla, opopanax, and white musk. The same olfactory display system used in Experiment 1 was also used in Experiment 2.

3.1.3. Procedure

The same procedure used in Experiment 1 was also used in Experiment 2.

3.2. Results

The R statistical software (R Core Team, 2021) was used for all analyses. The effect sizes for ANOVAs and t-tests were estimated by using partial eta squared (η_p^2) and Cohen's d (d_z), respectively, along with their corresponding 90 % or 95 % confidence intervals (Lakens, 2013). To compute effect sizes, we used the functions written by Stussi et al. (2021), which are available at the Open Science Framework (https://osf.io/9w8rn/). Raincloud plots (Allen et al., 2021) were generated by using JASP 0.16 (Love et al., 2019). Both the data and the analysis script are available at the Open Science Framework (https://osf.io/nj238/).

3.2.1. Odor evaluation phase

Three paired t-tests were conducted to compare differences in perceived intensity, familiarity, and liking between the two perfumes. Results showed that Perfume 1 was perceived as less intense ($M = 70.0$, $SD = 16.4$) ($t(43) = -2.44$, $p = .02$, $d_z = -.37$, 95 % CI [-.67, −.06]) and marginally more pleasant ($M = 72.7$, $SD = 17.3$) ($t(43) = 1.81$, $p = .08$, $d_z = .27$, 95 % CI [-.03,.57]) than Perfume 2 (intensity: $M = 74.6$, $SD = 12.2$; liking: $M = 66.6$, $SD = 17.9$). However, no statistical difference was found in familiarity (Perfume 1: $M = 75.9$, $SD = 14.6$, Perfume 2: $M = 72.7$, $SD = 16.8$) ($t(43) = 1.18$, $p = .25$, $d_z = .18$, 95 % CI [-.12,.47]). Four additional paired t-tests were conducted to evaluate differences in the relaxing and energizing rating scales. As expected, results indicated that Perfume 1 was rated as more energizing ($M = 76.1$, $SD = 12.5$) than Perfume 2 ($M = 35.5$, $SD = 21.9$) ($t(43) = 9.86$, $p < .001$, $d_z = 1.49$, 95 %

CI [1.05, 1.91]), and Perfume 2 was rated as more relaxing ($M = 59.5$, $SD = 24.1$) than Perfume 1 ($M = 37.1$, $SD = 21.0$) ($t(43) = 3.96$, $p < .001$, $d_z = .60$, 95 % CI [.27,.91]). Perfume 1 was also rated as more energizing than relaxing ($t(43) = 9.21$, $p < .001$, $d_z = 1.39$, 95 % CI [.97, 1.80]), and Perfume 2 was rated as more relaxing than energizing ($t(43) = 4.36$, $p < .001$, $d_z = .66$, 95 % CI [.33,.98]).

3.2.2. Olfactory priming task

3.2.2.1. Response accuracy. As in Experiment 1, response accuracy was analyzed by using a repeated-measures ANOVA with prime (Perfume 1, Perfume 2), target category (relaxing, energizing), and target position (T1, T2) as within-subject factors. A significant interaction was found between the target position and target category ($F(1, 43) = 7.36$, $p = .01$, $\eta_p^2 = .15$, 90 % CI [.02,.30]). Post hoc t-tests revealed that, in T1, accuracy was higher for relaxing-related words ($M = 0.97$, $SD = 0.03$) than for energizing-related words ($M = 0.94$, $SD = 0.07$) ($t(43) = 3.30$, $p = .002$, $d = .50$, 95 % CI [.18,.81]). This was, however, not the case for T2 ($t(43) = -.09$, $p = .93$, $d = -.01$, 95 % CI [-.31,.28]). Finally, there was no influence of the olfactory prime on accuracy ($F(1, 43) = .35$, $p = .56$, $\eta_p^2 = .01$, 90 % CI [.00,.10]), nor were there any significant interaction effects, including the prime-target interaction ($F(1, 43) = .36$, $p = .55$, $\eta_p^2 = .01$, 90 % CI [.00,.10]).

3.2.2.2. Reaction times. Following the same procedure as used in the first experiment, incorrect trials (4.6 %), trials with response latencies faster than 300 ms (0.02 %) and slower than 1500 ms (3.4 %), and RTs that fell outside 2.5 *SD* from each participant's mean (1.1 %) were excluded from the analysis. One participant was excluded due to having an average RT ($M = 1046$, $SD = 233$ ms) that was more than 2.5 *SD* above the general mean for the population ($M = 713$, $SD = 106$ ms). We then conducted a repeated-measures ANOVA on the remaining 43 participants with prime (Perfume 1, Perfume 2), target category (relaxing, energizing), and target position (T1, T2) as within-subject factors. The results showed an expected effect of the target position ($F(1, 42) = 375.15$, $p < .001$, $\eta_p^2 = .90$, 90 % CI [.84,.92]), with participants responding faster in T2 ($M = 597$, $SD = 75$ ms) than in T1 ($M = 820$, $SD = 129$ ms). There was also a significant three-way interaction between these factors ($F(1, 42) = 11.93$, $p = .001$, $\eta_p^2 = .22$, 90 % CI [.06,.38]). Separate repeated-measures ANOVAs were conducted to assess the prime-target interaction at each target position level. Similar to that in the first experiment, the prime-target interaction was significant for T1 ($F(1, 42) = 16.31$, $p < .001$, $\eta_p^2 = .28$, 90 % CI [.10,.43]), but not for T2 ($F(1, 42) = .10$, $p = .75$, $\eta_p^2 = .002$, 90 % CI [.00,.07], as shown in Figure S2 in the supplementary materials). For T1, paired t-tests revealed that participants had faster responses to energizing-related words ($M = 808$, $SD = 141$ ms) than to relaxing ones ($M = 844$, $SD = 148$ ms) after being primed with Perfume 1 ($t(42) = 2.09$, $p = .04$, $d_z = .32$, 95 % CI [.01,.62]; Fig. 3A) and inversely faster responses to relaxing-related words ($M = 797$, $SD = 125$ ms) than to energizing ones ($M = 829$, $SD = 146$ ms) after being primed with Perfume 2 ($t(42) = 2.70$, $p = .01$, $d_z = .41$, 95 % CI [.10,.72; Fig. 3B]).

3.3. Discussion

The goal of Experiment 2 was to investigate whether the OPT could implicitly capture associations between two fine fragrances and words related to energizing vs. relaxing feelings. The study showed that when participants were primed with Perfume 1, they responded faster to energizing-related words than to relaxing ones. Similarly, when participants were primed with Perfume 2, they responded faster to relaxing-related words than to energizing ones. These findings support the existence of automatic associations between Perfume 1 and energizing-related words and between Perfume 2 and relaxing-related words, as previously found by Lemercier-Talbot et al. (2019). Subjective reports provided further support for these findings, with participants explicitly rating Perfume 1 as more energizing and Perfume 2 as more relaxing.

The findings of Experiment 2 were in line with those of Experiment 1, as the priming effect was evident only for T1. These findings provide further evidence that T2 did not discriminate between products and could be removed from the procedure. We conclude that this experiment's outcomes endorse the OPT as a valid implicit measure for exploring associations between fine fragrances and feeling-related words, making it a valuable tool for the flavors and fragrances (F&F) industry.

4. General discussion

The main goal of this study was to assess the ability of the OPT to implicitly measure associations between odors and feeling-related words. The results revealed that participants responded more quickly to energizing-related words after being primed with menthol or Perfume 1, and to relaxing-related words after being primed with vanillin or Perfume 2. These findings support the existence of automatic associations between menthol, Perfume 1, and energizing-related words, as well as between vanillin, Perfume 2, and relaxing-related words, which is consistent with the results previously reported by Lemercier-Talbot et al. (2019). The effect sizes were similar for both experiments and moderate in magnitude (menthol: $d_z = .31$, vanillin: $d_z = .42$; Perfume 1: $d_z = .32$; Perfume 2: $d_z = .41$). Subjective reports also provided further evidence, with participants explicitly rating menthol and Perfume 1 as more energizing and vanillin and Perfume 2 as more relaxing.

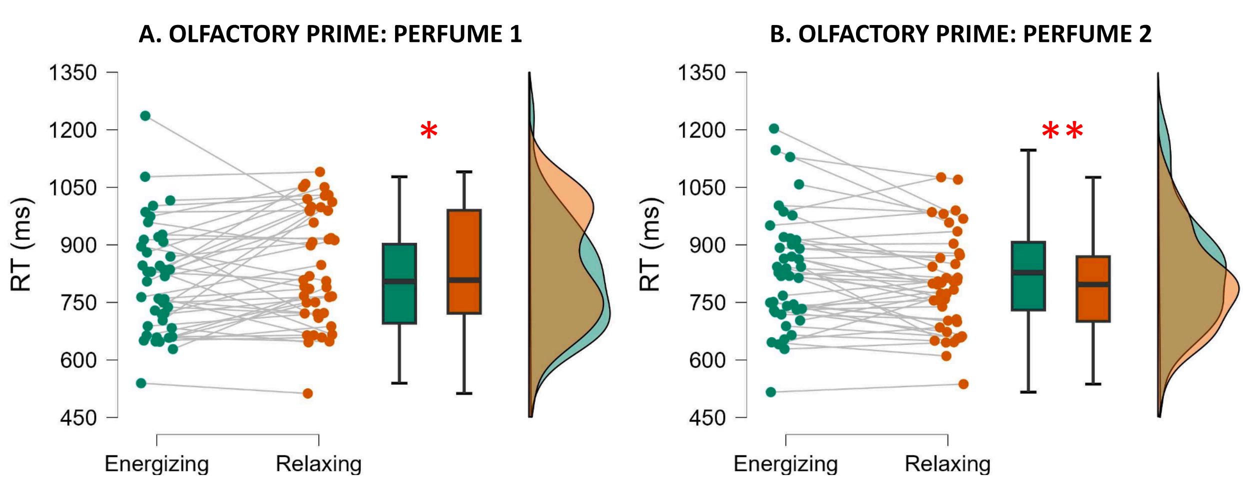

Fig. 3. Reaction times (ms) in T1 as a function of the olfactory prime and the target category. *p < .05, **p < .01.

Interestingly, the effect sizes for subjective ratings were larger (menthol: $d_z = .86$, vanillin: $d_z = 1.57$; Perfume 1: $d_z = 1.39$; Perfume 2: $d_z = .66$), indicating that they may be more effective in discriminating between products.

These results demonstrate that the OPT is a valid implicit measure for exploring associations between odors and feeling-related words. The OPT's sensitivity has been evaluated with both simple and very familiar compounds, such as menthol and vanillin, and more complex and less familiar odors, such as fine fragrances. As a result, we are confident that the OPT can be used to assess a wide range of odors, including food and non-food, simple and complex, making it a versatile and valuable tool for consumer research. The block design of the OPT was developed to shorten the task duration and to reduce the amount of odor released. To achieve these objectives, we designed a block design that included two targets for each olfactory prime. However, in both experiments, the priming effect was evident only for T1. Therefore, it may be reasonable to remove T2 to align the procedure with traditional sequential priming techniques, in which each prime is followed by only one target (Fazio et al., 1986; Guerdoux et al., 2014; Hermans et al., 1998; Hermans et al., 2005; Veldhuizen et al., 2010). Since it is highly unlikely that the T2 target could retroactively affect T1 reaction times, further studies would probably confirm that the priming effect on T1 remains intact if T2 is removed from the procedure.

Recent research has shown that odors can have a range of effects on cognition and behavior (Delplanque et al., 2017), for example, by distorting time perception (Baccarani et al., 2021), shifting attention (Ischer et al., 2021), activating approach/avoidance tendences and wanting behaviors (Cereghetti et al., 2020; Cereghetti et al., 2021), facilitating sound localization (La Buissonniere-Ariza et al., 2012), activating cleaning behaviors (Holland et al., 2005), affecting facial attractiveness perception (Dematte et al., 2007), orienting attention and modulating inhibitory control with respect to food stimuli (Mas et al., 2020; Mas et al., 2019), and modulating appetite, food choice, and food intake (Chambaron et al., 2015; Gaillet-Torrent et al., 2014; Gaillet et al., 2013; Ramaekers et al., 2014; Sulmont-Rossé et al., 2018; Zoon et al., 2016). Our study provides further evidence that odors are powerful primes (Smeets & Dijksterhuis, 2014), demonstrating that odors can trigger the activation of congruent feeling-related words. We posit that the OPT may capture the activation of memories related to previous experience with the olfactory primes, which are likely acquired through associative learning (Herz, 2005, 2009). That is, exposure to olfactory primes may activate the feelings, or their cognitive representation, that co-occurred in past events, thereby facilitating their processing when they are presented as targets. Two mechanisms, which are not mutually exclusive, have been proposed to account for priming effects: automatic and controlled activations (McNamara, 2005; Neely, 1991; Yap et al., 2017; Zeelenberg et al., 2003). Automatic activation involves the rapid and involuntary spread of activation from the internal representation of the prime to other related nodes via associative pathways (Collins & Loftus, 1975). Controlled activation, in contrast, is a slower and voluntary process in which participants generate expectancies for targets during the SOA. Although the OPT was not designed to disentangle these two mechanisms, it is possible that both contributed to the effects observed in our study. Expectancy-based strategies are typically effective at longer SOA, and so the 3-second interval between inhalation and T1 onset may have allowed participants to use such strategies, also considering that "odor objects" can emerge as early as 1 s from sniff (Olofsson, 2014; Olofsson et al., 2013). Future research could attempt to reduce the SOA interval to minimize the influence of potential expectancy-based strategies. In addition, alternative delivery methods for olfactory primes could be investigated, such as synchronizing odor delivery with the respiratory cycle (Wang et al., 2017; Wang et al., 2014), thereby making the delivery more incidental and preventing participants from drawing their attention to the primes. Additional data is thus required to fully understand the nature of the cognitive mechanisms underlying the OPT.

Both Experiment 1 and Experiment 2 revealed subtle differences in odor preferences. Specifically, in Experiment 1, participants showed a preference for vanillin over menthol, whereas in Experiment 2, participants showed a slight preference for Perfume 1 over Perfume 2. Although it could be argued that the OPT effects were due to evaluative priming, we believe that this is unlikely. First, the differences in liking between odors were relatively small (menthol vs. vanillin: $d_z = .31$; Perfume 1 vs. Perfume 2: $d_z = .27$) compared with the larger differences in relaxing and energizing rating scales (menthol: $d_z = .86$, vanillin: $d_z = 1.57$; Perfume 1: $d_z = 1.39$; Perfume 2: $d_z = .66$). Second, if evaluative priming was the primary mechanism driving the OPT effects, one would expect to see consistent effects across experiments, with the most pleasant odor facilitating the processing of the same category of words. However, this was not the case, as in Experiment 1, vanillin (the preferred odor in that experiment) facilitated processing of relaxing-related words, whereas in Experiment 2, Perfume 1 (the preferred odor in that experiment) facilitated the processing of energizing-related words. Future studies could include a measure of the pleasantness of feeling-related words or categories to investigate this question considering individual preferences.

An intriguing question is whether the olfactory IAT (Lemercier-Talbot et al., 2019) and the OPT capture similar or different processes. In the olfactory IAT, odors are task-relevant, whereas in the OPT, the olfactory primes are task-irrelevant. It can thus be speculated that, in the OPT, participants are less likely to engage in odor recognition, making the task less likely to be modulated by top-down processes. The OPT offers two advantages over the IAT. As mentioned in the introduction, it can disentangle the IAT compatibility effect by measuring the absolute association strengths between each combination of products and attributes. The findings from our study suggest that menthol, vanillin, Perfume 1, and Perfume 2 similarly contributed to the compatibility effects reported by Lemercier-Talbot et al. (2019). Additionally, the OPT can potentially be used with more than two odors within a single experiment, which could increase its efficiency and applicability. However, this remains to be tested, and further research is needed to determine the maximum number of odors that can be used in a single session without altering the validity of the procedure. Additional adaptations to the OPT, such as increasing the ITI and adjusting the number of trials and repetitions, may be necessary.

The OPT and the olfactory IAT have, moreover, some limitations. First, both procedures were validated using odors that were clearly distinct on the dimension of interest, i.e., arousal. Future research should address systematic sensitivity studies to evaluate their ability to discriminate between odors with more subtle differences. Additionally, the applicability of the IAT and OPT to other feelings should be explored. An interesting question for further studies would be to evaluate to what extent the OPT and the IAT are limited to dimensions having opposite ends, such as arousal and valence, or could also be adapted to assess odor-related fine-grained feelings, such as sensuality or nostalgia. Finally, both olfactory IAT and OPT can be used with only two feeling categories (left category vs. right category), which is limiting considering that the emotional response to F&F is covered by multiple dimensions (Chrea et al., 2009; Ferdenzi et al., 2013; Ferdenzi et al., 2011; Porcherot et al., 2010). This limitation emphasizes the need for new implicit measures that can assess full emotional profiles of F&F within a single test session.

5. Conclusion

Here, we introduced the Olfactory Priming Task (OPT), a new cross-modal implicit measure for evaluating associations between odors and feeling-related words. Two experiments were performed to validate the procedure with simple compounds and actual consumer products (i.e., fine fragrances). The results showed that the OPT could be used to discriminate odors from their relaxing/energizing properties, demonstrating that exposure to odors activates congruent feelings in consumers.

Ethical Statement

The Corresponding Author certifies on his honor that the experiment was conducted in accordance with the ethical principles stated in the Declaration of Helsinki. The research was carried out with appropriate protocols to safeguard the rights and privacy of all participants. There was no coercion to participate, and written consent was obtained from all participants. Additionally, participants were informed of their right to withdraw from the study at any time.

CRediT authorship contribution statement

Donato Cereghetti: Conceptualization, Methodology, Formal analysis, Investigation, Software, Visualization, Writing – original draft. **Géraldine Coppin:** Writing – review & editing. **Christelle Porcherot:** Supervision, Resources. **Isabelle Cayeux:** Supervision, Project administration. **David Sander:** Writing – review & editing. **Sylvain Delplanque:** Conceptualization, Methodology, Writing – review & editing.

Declaration of competing interest

Donato Cereghetti, Christelle Porcherot, and Isabelle Cayeux were employed by DSM-Firmenich AG. The remaining authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data and R scripts are available on the OSF link mentioned in the paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2024.105227.

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