Measuring Automatic Associations between Relaxing/Energizing Feelings and Odors

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Abstract

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Abstract

The extent to which automatic associations exist between relaxing and energizing feelings and odors is unclear. To investigate this question, we used a modified version of the Implicit Association Test. In this task, participants had to make speeded discrimination responses between stimuli and words related to energizing vs. relaxing feelings. These stimuli were either visual stimuli (i.e., vanilla vs. mint labels in Experiment 1) or olfactory (vanillin vs. menthol in Experiment 2, and two fine fragrances in Experiment 3). In compatible blocks, purportedly related items (e.g., vanillin and a label related to relaxing feelings) shared the same response key, while in incompatible blocks they did not (e.g., vanillin and a word related to energizing feelings). In the three experiments, the participants responded significantly faster in the compatible blocks than in the incompatible ones. The stronger the association between purportedly related items, the faster the participant responds in compatible blocks and the slower in incompatible blocks. Consequently, this differential speed of response supports the existence of associations between the stimuli that were considered to be compatible. This argues for the existence of automatic associations between relaxing/energizing feelings and odors, associations that can influence behavior.

Keywords: Odors; relaxing; energizing; emotions; Implicit Association Task; automatic associations
Highlights

- We tested the existence of automatic associations between feelings and odors
- In three experiments we used the Implicit Association Test
- Participants responded faster when olfactory-feeling associations were compatible
- The results suggest that automatic associations between feelings and odors exist
1. Introduction

It is commonly believed that certain odors (like mint or citrus) can help feeling awake and focused, while others (like lavender or vanilla) could facilitate relaxing and drifting off to sleep. An increasing number of scientific studies tend to confirm this belief – relaxing/energizing properties of odors can influence behavior, induce mood changes and affect physiological states (e.g., Diego et al., 1998; Moss, Cook, Wesnes, & Duckett, 2003; for reviews, see Herz, 2002, 2009).

The relaxing/energizing dimension is an important feature of the subjective component (i.e., feeling) of odor-evoked emotions (e.g., Delplanque, Coppin, & Sander, 2017), present in different European cultures (Ferdenzi et al., 2011; Perrouty-Perret, 2007). This has been demonstrated mostly with questionnaires and scales (the Emotion and Odor Scales (EOS), Chrea et al., 2009, Ferdenzi et al., 2011; Ferdenzi et al, 2013; EsSense®, King, Meiselman & Carr, 2010; ScentMove®, Porcherot et al., 2010).

Although fruitful, we believe this approach is limited for four main reasons.

First, the feeling is only one component of an emotion, besides the cognitive, physiological, expressive, and motivational components (e.g., Coppin & Sander, 2016; Scherer, 2005; for a discussion of this aspect in relation to olfaction, see Baer et al., 2018; Delplanque et al., 2017; Pichon et al., 2015). Second, although self-report measures provide important explicit information about the relaxing/energizing properties of the odors, and are currently the most common measures in the field (see Herz, 2009), they rely on individual introspective abilities and are subject to biases (e.g., Choi & Pak, 2005). Third, relaxing/energizing properties of the odors affect behavior and performance even if the organism is not actively engaged in an explicit evaluation of these properties (e.g., Degel & Köster, 1999; Jarlier et al., 2018). This suggests that automatic associations between feelings and odors exist.

Investigating these automatic associations could consequently lead to a significant gain of knowledge, exploring the role of factors other that explicit expectations in mediating odor-evoked behavioral, mood and performance impact (see e.g., Campenni, Crawley, & Meier, 2004; Coppin, Delplanque, Porcherot,
Cayeux, & Sander, 2012). Fourth, implicit measures have several advantages over explicit measures. Besides being less susceptible to the biases (e.g., social desirability) mentioned in point 2, they purportedly capture processes that cannot be consciously accessed (see e.g., Gawronski & De Houwer, 2014).

The main objective of this series of studies was to investigate the existence of automatic associations between relaxing/energizing feelings and odors. To do so, we used the Implicit Association Test (IAT). In this test, the strength of an association between target concepts (e.g., fat people, lean people) and attributes (e.g., good, bad) is measured. Classically, participants are asked to sort words in a speeded discrimination task. Reaction times (RTs) in compatible vs. incompatible blocks are compared. In compatible blocks, purportedly related items (e.g., fat people and bad) share the same response key, while in incompatible blocks they do not. The stronger the association between an attribute and target concepts (e.g., fat people and bad), the faster the participant responds in compatible blocks and the slower in incompatible blocks.

This test is typically used in the visual modality, but it has been successfully adapted to the olfactory modality (e.g., Bulsing, Smeets, & van den Hout, 2007; Demattè, Sanabria & Spence, 2006, 2007; Guerdoux, Trouillet, & Brouillet, 2014). Demattè et al. (2006) created a modified version of the IAT to investigate cross-modal associations between colors and odors. They showed that participants responded more rapidly and accurately to odor–color pairings having a strong association (e.g., pink color and strawberry odor) than to those having a weaker (or no) association (e.g., pink color and spearmint). Demattè et al. (2007) reported similar cross-modal associations between olfaction and touch: participants responded significantly more rapidly in the compatible blocks (i.e., when the lemon odor and soft fabric were mapped onto the same response key) than in the incompatible blocks (i.e., when the animal odor and soft fabric were mapped onto the same response key). Bulsing et al. (2007) have investigated the association between odors and positive words. They tested whether the IAT was
able to distinguish individuals who prefer using scented consumer products as a means of relaxation (the “aromatherapy group”) from individuals who do not have such a preference (the “control group”). The results showed that the aromatherapy group had a significantly more positive attitude toward odor words in the IAT than a control group. Moreover, results from the IAT were not always associated with explicitly stated attitudes toward the odor words, reflecting the fact that the IAT measures attitude in a different way.

In the three studies reported here, we investigated whether relaxing/energizing feelings could be automatically associated with odors using a modified version of the IAT (Greenwald, McGhee, & Schwartz, 1998). In all three experiments, we used two odors, one explicitly reported as unambiguously energizing and one as relaxing. We chose this sub-set of odors (i.e., evoking clear energizing/relaxing feelings) in order to test whether the IAT measures could reflect these associations at an automatic level. If that is the case, future research could then consider the IAT while using odors evoking more moderate relaxing/energizing feelings. In the first experiment, we presented participants with odors’ labels (‘vanilla’ and ‘mint’ labels) and visual targets (words related to the relaxing vs. the energizing feeling). As classically done in IATs, we assessed the consequences of varying the stimulus-response mapping (i.e., by varying which odor label and word category were paired with a given response key) on the latency and accuracy of participants’ responses. We hypothesized that participants will respond faster in compatible blocks (i.e., when vanilla label and relaxing feeling and when mint label and energizing feeling are on the same response key) than in incompatible ones. In the second experiment, the procedure was identical, except that the participants were presented with the actual odors without

1 We will talk about labels to refer to the odor names presented in experiment 1.

2 We will talk about words to refer to the relaxing vs. energizing feelings words presented in all three experiments.
their labels. Just before the test, vanilla and menthol were presented as respectively “Odor 1” and “Odor 2” and participants had to memorize this association. The third experiment’s procedure was also identical to the second experiment, except that participants were presented with two fine fragrances (one explicitly reported as relaxing and one energizing) presented as “Odor 1” and “Odor 2”.
2. Experiment 1

2.1. Method

2.1.1. Participants

32 participants (mean age = 40.6 ± 12.3 years, 55% female, French and/or Swiss citizenships) were recruited in different departments of the Firmenich, SA and took part in the experiment. Before starting the experiment, each participant gave written informed consent form. They were not paid for their participation. This experiment, as well as experiments 2 and 3, was validated by the internal Firmenich ethical committee and conducted in accordance with ethical and deontological codes of the declaration of Helsinki.

2.1.2. Apparatus and materials

Ten visual stimuli were used in this experiment as targets for the IAT task. We used eight French words from the Swiss version of EOS (Chrea et al., 2009, Ferdenzi et al., 2013). Four of these words were related to the relaxing feeling (“relaxé”, “apaisé”, “serein”, “réconforté”; i.e.“relaxed”, “soothed”, “serene” and respectively “reinsured”) and four to the energizing feeling (“revitalisé”, “rafraîchi”, “tonifié”, “énergique”; i.e.“revitalized”, “refreshed”, “invigorated” and respectively “energetic”). Two additional target words were used in this experiment: “vanilla” and “mint”. Vanilla and mint labels were selected based on their odors’ ratings of respectively high relaxing and energizing evoked feelings in previous studies (e.g., Ilmberger et al., 2012; Porcherot et al., 2012; Warrenburg, 2005).

2.1.3. Procedure

The participants sat on a chair 70 cm from the computer and they were instructed to look at the center of the monitor and to sort each visual target presented on the screen by pressing one of two adjacent keys (“B” for left or “N” for right) with their dominant hand. Importantly, they were instructed to perform this task as fast as possible, by keeping mistakes to a minimum. Following the classical Greenwald et al. (1998) procedure, our IAT was composed of seven successive blocks: 5 training blocks...
(1, 2, 3a, 4, 5a) and 2 testing blocks (3b and 5b, see Figure 1). Each block was preceded by specific instructions guiding participants throughout the task.

Each trial of each block was defined by three successive screens. In the first screen, a target word was presented in the center of the screen while the categories were presented on the top left-hand corner and respectively on the top right-hand corner of the screen. The first screen was presented until participant response. On the second screen, a visual feedback was provided for 500 ms and informed participants about the correctness of their answers. Finally, a fixation cross was presented in the center of the screen for 500 ms. During the first block, participants were trained to sort two targets words (“vanilla” and “mint”) into the respective category (“vanilla” and “mint”). Each word was presented 8 times, resulting in 16 trials. Following a counterbalanced design, half of the participants were asked to categorize vanilla on the left and mint on the right while the remaining half was asked to categorize vanilla on the right and mint on the left. During the second block, participants were trained to sort eight target words (“relaxed”, “soothed”, “serene”, “reinsured”, “revitalized”, “refreshed”, “invigorated” and “energetic”) into two emotional attribute categories (“relaxing” and “energizing”). Each word was presented twice, resulting in 16 trials. Following a counterbalanced design, half of the participants were asked to categorize relaxing words on the left and energizing words on the right while the remaining half was asked to categorize relaxing words on the right and energizing words on the left. During the practice block 3a, the former tasks were combined: participants were asked to sort both odor labels and emotional words by following the classification rules learned in the first block (for odor labels) and in the second block (for emotional words). Each odor label was presented 4 times and each emotional word was presented once, resulting in 16 trials. Half of the participants were asked to sort together vanilla with relaxing words and mint with energizing words while the remaining participants were asked to sort together vanilla with energizing words and mint with relaxing words. Block 3b was the same as Block 3a,
IMPLICIT PROCESSING OF RELAXING/ENERGIZING FEELINGS EVOKED BY ODORS

except that this block was used in order to analyze performance and reaction times. In block 3b, each odor label was presented 8 times and each emotional word was presented twice resulting in 32 trials. The fourth block was similar to the first block except that the position of the odor target categories was reversed, resulting in a required switched response. Participants who were asked in the first block to sort vanilla on the left and mint on the right were thus asked in the fourth block to sort vanilla on the right and mint on the left, and inversely. Similar to the first block, each word was presented 8 times, resulting in 16 trials. The practice Block 5a was a new combined task in which participants were asked again to sort both odor labels and emotional words by following the classification rules learned in the second block (for emotional words) and in the reversed fourth block (for odor labels). Participants who were asked to sort together vanilla with relaxing words and mint with energizing words in the 3a block had to sort together vanilla with energizing words and mint with relaxing words in the 5a block. Inversely, participants who were asked to sort together vanilla with energizing words and mint with relaxing words in the 3a block had to sort together vanilla with relaxing words and mint with energizing words in the 5a block. Similar to the 3a block, each odor label was presented 4 times and each emotional word was presented once, resulting in 16 trials. Block 5b was the same as Block 5a except that this block was used in order to analyze performance and reaction times. In block 5b, each odor label was presented 8 times and each emotional word was presented twice resulting in 32 trials. When the odor target and word attributes mapped onto a given response key were a priori considered to share a more straightforward association (i.e., vanilla with relaxing feeling related word and mint with energizing feeling related word), the block was labeled as “compatible”; trials in which the odor label and emotional word mapped onto a particular response key were assumed to be less easily associated (i.e. mint with the relaxing feeling related words and vanilla with the energizing feeling related words) were labeled as “incompatible”. Both the assignment of the stimuli to the response keys and the order of presentation of the various stimuli were counterbalanced across participants with compatible and
incompatible response mappings alternating over successive blocks of trials. For a visual representation of the design of the experiment, please refer to Figure 1, Experiment 1.

After the IAT procedure, participants were asked to assess odor labels through visual analogic scales the pleasantness, from “very unpleasant” (left of the scale) to “very pleasant” (right of the scale), familiarity, from “not familiar at all” (left) to “very familiar” (right; see Delplanque et al., 2008 for more details). In addition, participants were also asked to assess their feelings using Global ScentMove® (including energizing and relaxing ratings; Porcherot et al., 2016), through visual analogic scales ranged from “not at all” (left of the scale) to “extremely”, (right of the scale). All subjective scales were ranged from 0 to 10. Participants were instructed to follow their first impressions.

2.2. Results

2.2.1. Explicit ratings

We conducted two paired t-tests in order to assess differences on perceived familiarity and liking between the two odors labels (see Figure 2). Mint and vanilla labels were neither different in familiarity $[8.9 \pm 1.3$ and $8.6 \pm 1.4$, $t(31) = 1.27$, $p = .21$, $d = 0.23$, 95% CI[-.28, .73]] nor in liking ratings $[7.8 \pm 2.0$ and $7.8 \pm 1.9$, $t(31) = 0.16$, $p = .87$, $d = 0.03$, 95% CI[-.47, .53]]. We additionally performed four paired t-tests Bonferroni corrected to evaluate differences on the energy/refreshed and soothing/peacefulness scales, to check whatever the mint was predominantly perceived as energizing scent and the vanilla as relaxing.

As expected, the mint label was rated as more energizing ($7.7 \pm 1.6$) than the vanilla label ($1.7 \pm 1.5$) $[t(31) = 17.82$, $p < .001$, $d = 3.15$, 95% CI[2.40, 3.90]] and the vanilla label was rated as more relaxing ($6.2 \pm 2.2$) than the mint label ($3.6 \pm 2.7$) $[t(31) = -5.65$, $p < .001$, $d = -0.99$, 95% CI[-1.53, -.47]]. Moreover, the mint label was rated as more energizing than relaxing $[t(31) = 9.97$, $p < .001$, $d = 1.76$, 95% CI[1.17, 2.35]] and the vanilla label was rated as more relaxing than energizing $[t(31) = -10.26$, $p < .001$, $d = -1.81$, 95% CI[-2.41, -1.22]]. Mean scores are represented in Figure 2.
2.2.2. IAT task

Response accuracy. A participant was excluded from IAT data analysis because his/her error rate on test blocks was higher than 3 standard deviations from the mean of the study population (participant accuracy = 87.5%, population accuracy = 96.6% ± 3.0%). We performed further analyses on performance and reaction times on the remaining 31 participants. We performed a repeated measures ANOVA with the factors block (compatible, incompatible), stimulus type (odor labels, feeling related words) and category (relaxing, energizing) as within subject factors on participants’ response accuracy. A significant main effect of stimulus type [$F(1,30) = 16.68, p < .001, \eta^2_p = .36, 90\% CI[.13, .52]]$ reflected a better accuracy for odor labels (98.1% ± 2.4%) than for related feeling words (95.7% ± 3.5%). The main effect of block was not statistically significant [$F(1,30) = 1.70, p = .20, \eta^2_p = .05, 90\% CI[.00, .21]]$, but the interaction between the block and the stimulus type was [$F(1,30) = 5.15, p = .03, \eta^2_p = .15, 90\% CI[.01, .33]]$. We performed two post hoc t-tests with Bonferroni correction to characterize this interaction. Participants’ performance was marginally higher in the compatible (97.2% ± 3.9%) compared to the incompatible block (94.2% ± 6.0%) for feeling related words [$p = .06$]. This was not true for odor labels [$p = .65$]. Accuracy was neither influenced by the category [$F(1,30) = 0.30, p = .59, \eta^2_p = .01, 90\% CI[.01, .13]] nor by further interaction effects.

Reaction Times (RTs). Following Demattè et al. (2007) procedure, error trials and responses falling outside 2.5 standard deviations from the participant’s mean were discarded from any further analysis; leading to the removal of 6.0% of trials. We then performed a repeated-measures ANOVA with the factors block (compatible, incompatible), stimulus type (odor label, feeling related word) and category (relaxing or energizing) as within subject factors on participants’ reaction times (see Figure 3). Results revealed a significant effect of stimulus type [$F(1,30) = 25.73, p < .001, \eta^2_p = .46, 90\% CI[.23, .61]]$ with participants responding faster to odor labels (761 ± 197 ms) than to feeling related words (925 ± 339 ms). The main effect of the block was significant [$F(1,30) = 45.70, p < .001, \eta^2_p = .60, 90\% CI[.39, .71]]$
demonstrating that participants responded faster in compatible (776 ± 253 ms) than in incompatible trials (910 ± 281 ms) – i.e. IAT effect. We also observed a significant interaction effect between the block and the stimulus type [$F(1,30) = 9.14, p = .005, \eta^2_p = .23, 90\% CI[.05, .41]]$, revealing that the IAT effect was more important for feeling related words than for odors labels. The effect of category was not statistically significant [$F(1,30) = 1.59, p = .22, \eta^2_p = .05, 90\% CI[.00, .21]]$.

2.3. Discussion Experiment 1

Here we tested the existence of automatic associations between odor labels and relaxing/energizing feelings in a classical IAT setting. Our results provide support to the existence of an automatic association between the vanilla label and relaxing-related words and between the mint label and energizing-related words.

The participants’ subjective reports showed that they explicitly dissociated the two labels on the energizing-relaxing dimension, i.e. vanilla was perceived as relaxing and mint as energizing.

Moreover, we found that participants were faster in compatible than in incompatible blocks, demonstrating a strong association between the labels and the feeling words. This 150 ms difference constitutes a large effect ($\eta^2_p = .60$). Thus, odor labels of vanilla and mint were automatically associated to relaxing/energizing feelings.

The performance results also showed that participants were better and faster at categorizing odors labels than feelings terms. This is not surprising because participants had to categorize more feelings terms, which can lead to more errors and takes more time to do. For the same reasons, participants were better at categorizing the feeling terms in compatible blocks than in incompatible blocks in which the reversing effect between the two blocks may be more pronounced.

Although those results demonstrated an automatic association between vanilla and mint labels with relaxing/energizing feelings, this result does not prejudge such an association for the odors themselves.
In the second experiment, we tested whether there was an automatic association between the relaxing/energizing dimension and the actual odors of menthol and vanillin, and not just their labels. To do so, we used a modified version of the IAT adapted to the use of odors.

3. Experiment 2

3.1. Material and methods

3.1.1. Participants

Thirty-one participants (mean age = 44.6 ± 10.4 years, 58% female, French and/or Swiss citizenships) were recruited in different departments of the Firmenich, SA Company and took part in the experiment. Before starting the experiment, each participant gave written informed consent form. They were not paid for their participation.

3.1.2. Apparatus and materials

Olfactory stimuli. Vanillin and menthol (provided by Firmenich SA) were diluted in odorless dipropylene glycol at 10% each, these dilutions leading to (i) the odors to be well perceived and well discriminated (ii) a similar mean subjective intensity for the two odors as reported in other studies (e.g., Porcherot et al., 2012). Odorants were injected into tampons of cylindric felt-tip pens (14 cm long, inner diameter 1.3 cm) cut in two parts and disposed in a custom-built computer-controlled olfactometer composed of thirty-two solenoid valves (described in Ischer et al., 2014). During inter-stimuli interval (ISI) the clean air valve was opened. During odor delivery the clean air valve was automatically closed and the relevant odor valve was opened. The olfactometer delivered odorized and odorless air at a flow rate of 2 L.min\(^{-1}\).

Olfactory stimuli were delivered in the participants’ noses by means of sterilized stainless steel tips.

Visual stimuli. We used the same eight relaxing and energizing word stimuli as in the first experiment.

3.1.3. Procedure

The participants sat on a chair 70 cm from the computer screen positioning their noses on the stainless steel tips. They were instructed to look at the center of the monitor and to sort each target presented
regardless of its modality (i.e., olfactory or visual) by pressing one of two adjacent keys (‘B’ for left or ‘N’ for right) with their dominant hand. Importantly they were instructed to perform this task as fast as possible, by keeping mistakes to a minimum. Our olfactive IAT was composed of seven successive blocks: 5 training blocks (1, 2, 3a, 4, 5a) and 2 testing blocks (3b and 5b, see Figure 1, Experiment 2). Each block was preceded by specific instructions guiding participants throughout the task. During the first block, participants were trained to sort two target odors (vanillin and menthol). Each odor was presented 8 times, resulting in 16 trials. Each trial was composed by four successive screens. In the first screen (duration: 2000 ms), participants were instructed to prepare to inhale. In the second screen (duration: 500 ms), participants were invited to inhale while the target odor was delivered by the olfactometer. On the third screen, the odor target categories (“odor1”, “odor2”) were presented on the top left-hand corner and respectively on the top right-hand corner of the screen and participants were asked to sort as fast as possible the perceived odor into the relevant category using the key ‘B’ (for left) or ‘N’ (for right). Participants had thus to memorize a particular association between an odor (vanillin or menthol) and a neutral label (“odor 1” or “odor 2”) in order to correctly sort them in their respective target categories. Following a counterbalanced design, half of the participants were asked to categorize vanillin on left and menthol on right while the remaining half was asked to categorize vanillin on right and menthol on left. The third screen and the odor were both presented until participant’s response. Following the participant’s answer, a visual feedback was provided for 500 ms informing the participant of whether the answer was correct or not. During the second block, participants were trained to sort eight words into two emotional attribute categories (“relaxing” and “energizing”). Each word was presented twice, resulting in 16 trials. Each trial was composed by three successive screens. In the first screen, a target word was presented in the center of the screen while the emotional attribute categories were presented on the top left-hand corner and respectively on the top right-hand corner of the screen. Similarly to the previous block, participants were asked to sort as fast as possible the visual targets using
the key “B” (for left) or “N” (for right). Following a counterbalanced design, half of the participants were asked to categorize relaxing words on the left and energizing words on the right while the remaining half was asked to categorize relaxing words on the right and energizing words on the left. The first screen was presented until participants' responses. On the second screen, a visual feedback was provided for 500 ms and informed participants about the correctness of their answers. Finally, a fixation cross was presented in the center of the screen for 500 ms. During the practice block 3a, the former tasks were combined: participants were asked to sort both odor and word targets by following the classification rules learned in the first block (for odors) and in the second block (for words). Each odor was presented 4 times and each word was presented once, resulting in 16 trials. Four successive screens composed each trial. In the first screen (duration: 2000 ms), participants were informed about the sensory modality of the target stimulus. In visual trials, the label “word” was presented in the center of the screen. In olfactory trials, the label “odor” was presented in the center of the screen and participants were instructed to prepare to inhale. The second screen (duration: 500 ms) also depended on the sensory modality of the target stimulus. In visual trials, a fixation cross appeared in the center of the screen. In olfactory trials, participants were invited to inhale while the relevant odor was delivered by the olfactometer. On the third screen, the odor target categories (“odor1”, “odor2”) and the emotional attribute categories (“relaxing”, “energizing”) were presented on the top left-hand corner and on the top right-hand corner of the screen and participants were asked to sort the olfactory and the word targets presented in the center of the screen as fast as possible. Half of the participants were asked to sort together vanillin with relaxing words and menthol with energizing words while the remaining participants were asked to sort together vanillin with energizing words and menthol with relaxing words. Similar to previous blocks, the third screen and the odor (for olfactory trials only) were presented until participant's response. Finally, in the fourth screen a visual feedback was provided (duration: 500 ms) in the center of the screen. Block 3b was the same as Block 3a, except that this block was used in
order to analyze performance and reaction times. In block 3b, each odor was presented 8 times and each word was presented twice resulting in 32 trials. The fourth block was similar to the first block except that the position of the odor target categories was reversed, resulting in a required switched response. Participants who were asked in the first block to sort vanillin on the left and menthol on the right were thus asked in the fourth block to sort vanillin on the right and menthol on the left, and inversely. Similar to the first block, each odor was presented 8 times, resulting in 16 trials. The practice Block 5a was a new combined task in which participants were asked again to sort both odor and word targets by following the classification rules learned in the second block (for word) and in the reversed fourth block (for odors). Participants who were asked to sort together vanillin with relaxing words and menthol with energizing words in the 3a block had to sort together vanillin with energizing words and menthol with relaxing words in the 5a block. Inversely, participants who were asked to sort together vanillin with energizing words and menthol with relaxing words in the 3a block had to sort together vanillin with relaxing words and menthol with energizing words in the 5a block. Similar to the 3a block, each odor was presented 4 times and each word was presented once, resulting in 16 trials. Block 5b was the same as Block 5a except that this block was used in order to analyze performance and reaction times. In block 5b, each odor was presented 8 times and each word was presented twice resulting in 32 trials.

After the IAT procedure, participants were asked to assess the odors through visual analogic scales of pleasantness, from “very unpleasant” (left of the scale) to “very pleasant” (right of the scale), intensity from “not perceived” (left) to “very strong” (right) and familiarity, from “not familiar at all” (left) to “very familiar” (right; see Delplanque et al., 2008 for more details). In addition, participants were also asked to assess their feelings using Global ScentMove® (including energizing and relaxing ratings; Porcherot et al., 2016), through visual analogic scales ranged from “not at all” (left of the scale) to “extremely”, (right of the scale). All subjective scales were ranged from 0 to 10.
3.2. Results

3.2.1. Explicit ratings

Similarly to the Experiment 1, we performed three paired $t$-tests to assess differences on pleasantness, intensity and familiarity scales. The menthol was perceived as more intense ($7.0 \pm 1.6$) [$t(30) = 4.60, p < .001, d = 0.83, 95\% \text{ CI}[,30, 1.36]]$ and more familiar ($8.8 \pm 1.1$) [$t(30) = 3.38, p = .002, d = 0.61, 95\% \text{ CI}[,09, 1.13]]$ than the vanillin (intensity: $5.8 \pm 2.4$, familiarity: $7.7 \pm 2.2$). In contrast, no significant difference was observed for the liking scale (menthol: $7.3 \pm 2.0$, vanillin: $7.0 \pm 2.2$) [$t(30) = 0.62, p = .54, d = 0.11, 95\% \text{ CI}[-.40, .62]]$.

We additionally performed four paired $t$-tests Bonferroni corrected to evaluate differences on the energy/refreshed and soothing/peacefulness scales. The menthol was rated as more energizing ($7.5 \pm 1.5$) than the vanillin ($2.1 \pm 2.0$) [$t(30) = 11.87, p < .001, d = 2.13, 95\% \text{ CI}[1.50, 2.77]]$ and the vanillin was rated as more relaxing ($5.7 \pm 2.7$) than the menthol ($2.9 \pm 2.1$) [$t(30) = -4.34, p < .001, d = -0.78, 95\% \text{ CI}[-1.31, -.25]]$. Moreover, the menthol was rated as more energizing than relaxing [$t(30) = 10.43, p < .001, d = 1.87, 95\% \text{ CI}[1.26, 2.48]]$ and the vanillin was rated as more relaxing than energizing [$t(30) = -6.62, p < .001, d = -1.19, 95\% \text{ CI}[-1.74, -.64]]$. Mean scores are represented in the Figure 4.

3.2.2. IAT task

Response accuracy. A participant was excluded from IAT data analysis because his/her error rate on test blocks was higher than 3 standard deviations from the mean of the study population (participant accuracy = 60.9%, population accuracy = 93.7% ± 7.6%). We performed further analyses on performance and reaction times on the remaining 30 participants. We performed a repeated-measures ANOVA with the factors block (compatible, incompatible), stimulus type (odor, word) and category (relaxing, energizing) on participants’ response accuracy. We found a main effect of the category [$F(1,29) = 4.46, p = .04, \eta^2_p = .13, 90\% \text{ CI}[,00, .32]]$ showing that participants’ performance was slightly higher when
categorizing relaxing stimuli (96.0% ± 5.1%) than energizing stimuli (93.5% ± 6.2%). In contrast, the response accuracy was neither influenced by the block \(F(1,29) = 0.68, p = .42, \eta^2_p = .02, 90\% \text{ CI} [.00, .16]\) nor by the stimulus type \(F(1,29) = 0.20, p = .66, \eta^2_p = .007, 90\% \text{ CI} [.00, .12]\), nor by further interaction effects.

**Reaction Times (RTs).** Following Demattè et al. (2007)'s procedure, we excluded wrong answers and outliers. This led to the removal of 7.7% of trials. We submitted remaining trials to a repeated-measures ANOVA with the factors block (compatible, incompatible), stimulus type (odor, word) and category (relaxing, energizing) as within subject factors (see Figure 5). We found a significant effect of stimulus type \(F(1,29) = 18.56, p < .001, \eta^2_p = .39, 90\% \text{ CI} [.16, .55]\] with participants responding faster to words (940 ± 359 ms) than to odors (1460 ± 730 ms). The main effect of the category was not statistically significant \(F(1,29) = 0.67, p = .42, \eta^2_p = .02, 90\% \text{ CI} [.00, .16]\), but the interaction between the category and the stimulus type was \(F(1,29) = 7.41, p = .01, \eta^2_p = .20, 90\% \text{ CI} [.03, .39]\]. Subsequent post hoc t-tests with Bonferroni corrections suggested that participants were faster in responding to relaxing words (906 ± 338 ms) compared to energizing ones (978 ± 396 ms) \(p = .05\). On the contrary, participants were faster to answer in responding to the energizing odor (menthol; 1369 ± 658 ms) compared to the relaxing one (vanillin; 1549 ± 833 ms) \(p = .02\). We observed a critical significant main effect of block \(F(1,29) = 5.32, p = .03, \eta^2_p = .16, 90\% \text{ CI} [.01, .34]\], revealing that participants responded significantly faster in compatible (1072 ± 338 ms) than in incompatible trials (1359 ± 753 ms), i.e. the IAT effect.

3.3. Discussion Experiment 2

In Experiment 1, we demonstrated the existence of automatic associations between odor labels and relaxing/energizing feelings. In Experiment 2 we successfully extended this demonstration to actual odors (without labels) and relaxing/energizing feelings using an adapted version of the IAT to odors.
First, the existence of an explicit association was supported by participants assessing vanillin as more relaxing than menthol. Second, participants were faster in compatible than in incompatible blocks, demonstrating that the association between the odors and the feeling words was automatic. Thus, our results provide support the existence of an automatic association between the vanillin odor and relaxing-related words and between the menthol odor and energizing-related words.

Note that this experiment does not bring insight on potential underlying mechanisms of this automatic association. Thus, some authors (e.g., Herz and von Clef, 2001) have suggested that participants always try to put a label on an unlabeled odor, independently on the task they are asked to do. Consequently, we cannot exclude that the participants were very familiar with the odors, even did recognize them, or at least tried to, as odor identification is known to be very difficult (e.g., Cain, 1979; Olofsson & Gottfried, 2015). Successfully naming the odor could have significantly affected the categorization task that was required (Lupyan, 2012) and would have, even implicitly, activated the same associations as when the odor labels were presented (Experiment 1).

One way to make this possibility highly unlikely is to use odors that cannot be precisely identified and associated with known olfactory sources – in other words, odors which are less familiar but are still explicitly assessed as more or less relaxing. We consequently used fine fragrances, which fit precisely this description, rather than vanillin and menthol odors in a third experiment. Besides this change, the third experiment was the same as the second one.

4. Experiment 3

4.1. Material and methods

4.1.1. Participants

Thirty-five participants (mean age = 39.8 ± 10.4 years, 66% female, French and/or Swiss citizenships) were recruited in different departments of the Firmenich, SA Company. They were not paid for their
participation and completed a consent form. A participant had to be removed from analysis because of problems in data acquisition.

4.1.2. Apparatus and materials

The apparatus and materials were identical to experiment 2, except that two fine fragrances were used instead of menthol and vanillin compounds. The two fragrances were selected \textit{à priori} based on preexisting data collected in Firmenich, S.A. The first one (named “Perfume 1” here below) belongs to the citrus – aromatic olfactory families and was purportedly explicitly perceived as an energizing fragrance. The second one (named “Perfume 2” here below) belongs to the oriental-floral olfactory families and was supposed purportedly perceived as a relaxing fragrance.

4.1.3. Procedure

The procedure was identical to experiment 2 (Figure 1, Experiment 3).

4.2. Results

4.2.1. Explicit ratings

A participant was excluded from explicit ratings analysis due of technical issues. Analysis on explicit rating was thus performed based on the remaining 34 subjects. Similarly to the previous experiment, we performed three paired $t$-tests to assess differences on intensity, familiarity, liking. The perfumes did not statistically differ in intensity (Perfume 1: 6.6 ± 1.6, Perfume 2: 6.6 ± 1.5) [$t$(33) = 0.16, $p = .88$, $d = 0.03$, 95% CI[-.46, .51]], nor familiarity (Perfume 1: 6.6 ± 2.5, Perfume 2: 6.9 ± 2.1) [$t$(33) = -0.63, $p = .53$, $d = -0.11$, 95% CI[-.59, .38]], nor liking (Perfume 1: 6.0 ± 3.2, Perfume 2: 5.8 ± 2.6) [$t$(33) = 0.23, $p = .82$, $d = 0.04$, 95% CI[-.45, .52]] scales. We additionally performed four paired $t$-tests Bonferroni corrected to

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evaluate differences on the energy/refreshed and soothing/peacefulness scales. As expected, the Perfume 1 was rated as more energizing (6.2 ± 2.5) than the Perfume 2 (2.9 ± 2.3) \( t(33) = 4.84, p < .001, d = 0.83, 95\% CI[.33, 1.33] \) and the Perfume 2 was rated as more relaxing (5.2 ± 2.7) than the Perfume 1 (2.7 ± 2.5) \( t(33) = -4.41, p < .001, d = -0.76, 95\% CI[-1.26, -.26] \). Moreover, the Perfume 1 was rated as more energizing than relaxing \( t(33) = 6.02, p < .001, d = 1.03, 95\% CI[.52, 1.55] \) and the Perfume 2 was rated as more relaxing than energizing \( t(33) = -4.17, p < .001, d = -0.72, 95\% CI[-1.21, -.22] \). Mean scores are represented in the Figure 6.

**4.2.2. IAT task**

*Response accuracy.* A participant was excluded from IAT data analysis because his/her error rate on test blocks was higher than 3 standard deviations from the mean of the study population (participant accuracy = 71.9%, population accuracy = 92.8% ± 5.7%). We performed further analyses on performance and reaction times on the remaining 34 participants. We performed a repeated measures ANOVA with the factors block (compatible, incompatible), stimulus type (odor labels, feeling related words) and category (relaxing, energizing) as within subject factors on participants’ response accuracy. A significant main effect of stimulus type \( F(1,33) = 12.12, p = .001, \eta^2_p = .27, 90\% CI[.07, .44] \) reflected a better accuracy for words (95.5% ± 5.2%) than for odors (91.3% ± 6.2%). In contrast, the response accuracy was neither influenced by the block \( F(1,33) = 0.75, p = .39, \eta^2_p = .02, 90\% CI[.00, .15] \) nor by the category \( F(1,33) = 2.20, p = .15, \eta^2_p = 0.06, 90\% CI[.00, .22] \), nor by further interaction effects.

*Reaction Times (RTs).* Following Demattè et al. (2007)’s procedure and as performed in Experiments 1 & 2, we excluded wrong answers and outliers. This led to the removal of 8.5% of trials. We submitted remaining trials to a repeated-measures ANOVA with the factors block (compatible, incompatible), stimulus type (odor, word) and category (relaxing, energizing) as within subject factors (see Figure 7). We found a significant effect of stimulus type \( F(1,33) = 32.39, p < .001, \eta^2_p = .50, 90\% CI[.28, .63] \)
revealing that participants responding faster to words (904 ± 227 ms) than to odors (1719 ± 867 ms).

We also observed a significant main effect of block \[ F(1,33) = 4.47, \ p = .04, \ \eta^2_p = .12, \ 90\% \ CI[.00, .29] \], revealing that participants responded significantly faster in compatible (1244 ± 507 ms) than in incompatible trials (1364 ± 477 ms, i.e. the IAT effect). In contrast, the RTs was neither influenced by the category \[ F(1,33) = 2.36, \ p = .13, \ \eta^2_p = .07, \ 90\% \ CI[.00, .23] \] nor by further interaction effects.

4.3. Discussion Experiment 3

This experiment was designed to determine the existence of automatic associations between fine fragrances and relaxing/energizing feelings. It was designed as a replication of Experiment 2 with odors that could not easily be identified and are considered as less familiar (i.e., fine fragrances). We controlled that vanillin and menthol were together evaluated as more familiar (8.24 ± 1.48) than the two fine fragrances together (6.73 ± 1.73), \( t(63) = 3.77, \ p < .001, \ d = 0.94, \ 95\% \ CI[.41, 1.46] \). One of these fine fragrances was selected for its energizing aspect (“perfume 1”) and one for its relaxing one (“perfume 2”). Our results did provide support the existence of an automatic association between “perfume 1” and energizing-related words and between “perfume 2” and relaxing-related words.

These results were congruent with Experiment 2’s findings, where we found evidence of a privileged association between the vanillin odor and relaxing-related words and between the menthol odor and energizing-related words. Taken together, these findings support the existence of an automatic association between relaxing/energizing feelings and a sub-category of odors, namely fine fragrances.

5. D-scores analysis

Additional analyses were performed with the intent to compare the IAT effects observed in the three experiences. Following the Improved Implicit Association Test Scoring Algorithm (Greenwald, Banaji, & Nosek, 2003), we extracted the D-score for each participant and for each stimulus type (odors, feeling related words). The calculation of the D-score makes possible the evaluation of the effect size at the
individual level, allow effect size comparisons across studies that, for example, may not have used the
same stimulus material (e.g., words and odors or different kind of odors). We were more particularly
interested to investigate to what extent there are differences in association strengths when different
types of smells are used (experiments 2 and 3). As recommended by Greenwaled et al., (2003): (1) we
used data from blocks 3a, 3b, 5a and 5b, (2) we excluded trials with latencies above 10’000 ms (0 trial
removed in the first study, one trial removed in the second study and two trials removed in the third
study), (3) we excluded participants for whom more than 10% of trials have latencies below 300ms (no
participants were excluded), (4) we replaced each error latency with an error penalty, computed as
mean latency of correct responses in the block in which the error occurred plus 600 ms, (5) we
computed the “inclusive” standard deviation for all trials in Block 3a and 5a and another one for all trials
in Block 3b and 5b, (6) we computed mean of latencies for Blocks 3a, 3b, 5a and 5b, (7) compute two
differences score Blocks 5a minus 3a and Blocks 5b minus 3b, (8) we divided each difference score by its
associated “inclusive” standard deviation, and finally (9) we computed the D-score, i.e. the average of
the two ratios. We performed a 3x2 mixed model ANOVA with the factors study (first, second, third) as
between subject factor and stimulus type (odor, feeling related words) as within subject factor on
extracted D-scores. Interestingly, we did not observed a statistically significant effect of the study
\[F(2,92) = 1.02, p = .36, \eta^2_p = .02, 90\% CI[.00, .08]\], nor an effect of the stimulus type \[F(1,92) = 0.15, p = .70, \eta^2_p = .00, 90\% CI[.00, .04]\], nor an interaction effect \[F(2,92) = 0.64, p = .53, \eta^2_p = .01, 90\% CI[.00, .06]\]; see Figure 8.

[PLEASE INSERT FIGURE 8 AROUND HERE]
6. General discussion

In the series of experiments, we investigated the existence of an automatic association between relaxing/energizing feelings and olfactory stimuli. In all three experiments, we tested the existence of an explicit association by asking participants to assess how relaxing/energizing the stimuli used were. Participants assessed the stimuli as intended – i.e., purportedly relaxing ones (e.g., vanillin odor) were, and purportedly energizing ones (e.g., menthol odor) were too. As mentioned before, we chose odors and fine fragrances evoking clear energizing/relaxing feelings in order to test whether the IAT measures could reflect these associations at an automatic level.

Hence, we tested whether automatic associations existed between odor labels (vanilla and mint) and relaxing/energizing feelings terms (Experiment 1) using the IAT (Greenwald, McGhee, & Schwartz, 1998). Using modified versions of this paradigm, we then investigated whether such associations could exist with actual odors and the relaxing/energizing terms (Experiment 2 and 3).

In Experiments 1 and 2, we used vanilla/vanillin, purportedly associated with relaxing feelings and mint/menthol, purportedly associated with energizing feelings. Participants responded faster when the vanilla label (Experiment 1) or vanillin odor (Experiment 2) and words related to relaxing feelings category were paired onto the same response key. The same was true when the mint label (Experiment 1) or menthol odor (Experiment 2) and words related to the energizing feeling were paired onto the same response key. The results consequently support the existence of automatic associations between (i) a vanilla label or odor and words related to relaxing feelings and (ii) a mint label or odor and words related to energizing feeling.

In Experiment 3, we used two fine fragrances, one purportedly associated with relaxing feelings and one purportedly associated with energizing feelings. Results were similar to Experiment 2. Thus, the existence of automatic associations between specific odors (commonly encountered ones like vanilla
and mint, but also fine fragrances) and relaxing vs. energizing feelings can be assessed without labeling odors. Moreover, the IAT paradigm is as good as detecting these automatic associations with odors (here, simple monomolecular compounds) as with fine fragrances (which are more complex).

Although understanding the mechanisms underlying this automatic association was not the goal of this work, it may be worth considering possible ones as leads for future work. Two main hypotheses exist regarding the relaxing and energizing effects of odors: a pharmacological and a psychological one (Herz, 2009).

According to the first hypothesis, the effects of odors on behavior, mood and physiological states are due to their direct impact on the central nervous system and/or endocrine systems. Stimulations of the trigeminal system increase alertness (e.g., Frasnelli & Hummel, 2005). One may consequently argue that the trigeminal aspect of the odorants drove the association with an energizing/relaxing dimension. It would be congruent with recent findings showing that the physiological response to odors is partially driven by the trigeminality of the odorants (Licon et al., 2018).

According to the second one, we may experience the combination of odors and relaxing or energizing situations often enough in everyday life to acquire them through a mechanism of associative learning (e.g., Engen, 1982; Herz, 2002; Stevenson & Boakes, 2003; Van den Bergh et al., 1999). Thus, when we subsequently perceive an odor or we see its name, we may also automatically imagine the context in which the odor is usually smelled. Consequently, during an IAT-like task, these expectations may result in differences in RTs, with the expected combinations of stimuli (i.e., compatible response mapping block of trials) being advantaged relative to the unexpected combinations (i.e., incompatible response mapping blocks of trials). After reviewing the literature on the topic, Herz concluded that this is currently the best hypothesis. Congruently, we found here that odor labels, without olfactory stimulation, are reliably associated with energizing/relaxing words. Thus, the IAT could be a very helpful tool to uncover these associations. Moreover, although we used both identifiable (Experiment 2) as well
as hardly identifiable (Experiment 3) odors, we cannot rule out that some participants recognize some of the odors. If that is the case, the automatic association between the odors and the energizing/relaxing dimension (Experiments 2 and 3) could have been driven by associative learning, as in Experiment 1. Future studies could benefit from adding a recognition test of the odors at the end of similar experimental designs in order to rigorously address this question.

We also would like to point out that we used a modified version of the IAT, closer to Demattè et al. (2006, 2007) than to Greenwald et al. (1998)’ original one. Because of these adjustments, the mechanisms underlying our results are likely to be somewhat different from the ones described by Greenwald et al. (1998). For instance, the use of olfactory stimuli in Experiments 2 and 3 did not allow for the rapid presentation of successive stimuli, as the olfactory modality is one of the slowest sensory modalities (see e.g., Croy, Krone, Walker, & Hummel, 2015; Sela & Sobel, 2010). The relative slowness of this system is evident when comparing the RT in Experiment 1 (with odor labels) to the ones in experiments 2 and 3 (with odor stimuli).

Rather than a limitation, we believe that the modified IAT paradigm outlined here may provide a potentially important tool for future research on odors and feelings. Our results constitute the first empirical demonstration that the relaxing/energizing character of an odor can be assessed using the IAT. With Demattè et al. (2007), these results support the claim that the IAT can be adapted to detect associations between stimuli presented in sensory modalities other than vision.

Being able to properly measure automatic associations between odors and feelings is important for two reasons. First, it allows knowing whether feelings reported by individuals are only based on conscious introspection mechanisms or also underpinned by automatic processes that cannot be consciously accessed (see e.g., Gawronski & De Houwer, 2014). Second, as mentioned in the introduction, self-reported measures rely on individual introspective abilities and are subject to biases (e.g., Choi & Pak, 2005). Consequently, we believe that our work is a first but important step in
establishing that the IAT can measure automatic associations between energizing/relaxing feelings and odors unambiguously evoking such feelings. Future work can now replicate these experiments with odors not so clearly evoking energizing/relaxing feelings. By doing so, this work will provide evidence regarding the extent to which the IAT provides parallel findings to explicit judgments. As implicit and explicit measures are not always positively correlated (e.g., Gawronski & Hahn, 2019), results could substantially differ from the ones reported here.

7. Conclusion

These three experiments show that odors known as relaxing vs. energizing can be automatically associated with relaxing vs. energizing feelings. This is true when odor labels were presented without any olfactory input, but also when odors were presented without labels. These results suggest that the automatic association between odors and the energizing/relaxing dimension could have been driven by associative learning.
References


IMPLICIT PROCESSING OF RELAXING/ENERGIZING FEELINGS EVOKED BY ODORS


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ALT, CP, IC and SD designed the studies; ALT run the three experiments; GC, DC and SD analyzed and interpreted the data; GC, DC and SD wrote the manuscript with a first draft from ALT.
**Figure 1.** Design of the IAT for the three experiments. Half of the participants started the combined task with the compatible block and then completed the incompatible block the other half started the combined task with the incompatible block and then completed the compatible block. Blocks 3a/3b are compatible, blocks 5a/5b are incompatible. In Exp. 3 green and yellow colors symbolized the relaxing versus energizing perfume, respectively.
IMPLICIT PROCESSING OF RELAXING/ENERGIZING FEELINGS EVOKED BY ODORS

Figure 2. First study: mean scores on energy/refresed, soothing/peacefulness dimensions, liking and familiarity scales. Each vertical bar represents the confidence interval of the mean at 95%.

Figure 3. First study: reaction times depending on the block and stimulus type. Each vertical bar represents the confidence interval of the mean at 95%.
Figure 4. Second study: mean scores on energy/refreshed, soothing/peacefulness dimensions, intensity, liking and familiarity scales. Each vertical bar represents the confidence interval of the mean at 95%.

Figure 5. Second study: reaction times depending on the block and stimulus type. Each vertical bar represents the confidence interval of the mean at 95%..

Figure 6. Third study: mean scores on energy/refreshed, soothing/peacefulness dimensions, intensity, liking and familiarity scales. Each vertical bar represents the confidence interval of the mean at 95%.
Highlights

- We tested the existence of automatic associations between feelings and odors
- In three experiments we used the Implicit Association Test
- Participants responded faster when olfactory-feeling associations were compatible
- The results suggest that automatic associations between feelings and odors exist