Investigation of individual and environmental factors modulating the chemical communication of positive emotions in humans

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Abstract

Humans use their senses to adapt to different social contexts. Several studies highlight the capacity of humans to communicate negative emotions (fear, stress ...) to others via their body odors (BO). However, an understanding of the transmission of positive emotions remains elusive. The current study investigates whether chemical communication of positive emotions by looking for aspects of the humans communicating which may act as modulating factors : relationship type and duration, level of sociability, and perfume use.

We created an innovative at-home method by testing dyads. A positive state was induced in the donors by a video emotional induction procedure, while BO was collected on a cotton t-shirt. Then the other member of the dyad, the perceiver, was asked to smell the t-shirt and perform behavioral tasks to assess creativity, either without perfume and with added. In the control condition, the same procedure was carried out with donors watching neutral videos. In addition, several questionnaires were filled out by the dyad members to determine their level of sociability and the characteristics of their relationship.

The results suggest that communication of positive emotions via BO depends on the relationship of the dyad, with a transmission of positive emotional state likely to be more efficient in couples than roommates.

This experiment suggests the possibility of formulating new cosmetic products with emotional benefits and of new ways to develop personalized beauty routines. The innovative at-home method inspire new naturalistic approaches to testing products with emotional benefits.

Keywords: Chemical communication; positive emotions; perfume; mood-induction; emotional contagion.

1. Introduction

Consumer's needs have shifted towards feel-good scents and a search for wellbeing. Emotional balance has begun to be increasing sought in beauty rituals and fragrance use. More than ever before, personal care products and perfumes have to provide offer wellbeing and emotions.

Humans communicate information to others via volatile compounds contained in their body odors (BO) [1]. Several important emotions have recently been shown to be possibly transmitted by this way of communication. There is evidence that the BO of an individual (namely the "donor") experiencing fear, as well as other negative emotions, influences the physiology and cognition of another person (namely "perceiver") and therefore influence his/her emotional state [2-6]. This communication seems to occur in a non-conscious way, and has chemical underpinnings that are just beginning to be explored [7]. Although positive emotions have been much less explored, there is increasing evidence that their transmission through emitted BO is likely [8,9] as shown by their effects on perceivers' physiology and behavior. However, the factors affecting this communication are still largely unexplored.

Some factors have been pinpointed and discussed, such as the nature and the intensity of the emotion induction procedures (EIP) [7]. Haviland-Jones et al. also found important interindividual differences, some individuals being "super-detectors" or "anosmic" in identifying happiness and fear in BO samples. Moreover, several studies have started to explore the influence of personality. Socially anxious participants exposed to anxiety chemosignals were found to engage more neuronal resources during pre-attentive stimulus processing [10] and "socially open" individuals had stronger activations in brain regions involved in the recognition of emotions in response to BO [11]. The role of sociability levels as a modulation factor of positive emotions communication has never been studied.

We previously investigated the communication of positive emotions in humans via chemical signals contained in BO and the influence of perfume thereon, using an experimental

paradigm in which donors were exposed to video-clips to either induce Positive or Neutral emotions (i.e. Emotional Induction Procedure, EIP) [9]. During this EIP, the BO produced by the donors were sampled from the armpit regions. Then, perceivers were exposed to these collected BO samples. During the exposure, parameters were measured to evaluate the positive emotional contagion, such as the performance in behavioral creativity tasks. These tasks are used as a proxy of positive emotional contagion because creative problem-solving and divergent thinking have been robustly found to be impacted by positive affect [12,13]. In this experiment, the perceivers responded differently when they were exposed to BO of donors having experienced positive induction compared to neutral induction. This initial study suggested that positive emotions could be transmitted from a donor to a perceiver.

Here, we present a study using a version of the previous design modified for implementation in the participant's home. This modification aims to place the participant in more familiar and comfortable conditions, which should overcome the difficulties associated with emotion induction in the laboratory. We examined the emotional communication through BO between "donor-perceiver" dyads and how this was affected by the following factors: nature and duration of the relationship (couples or roommates, short or long), sociability (sociability level: high or low), perfume addition near BO. In this study, both participants of the dyads acted as BO donors and as perceivers.

2. Materials and Methods.

2.1. Participants

After collecting their informed consent, 19 dyads participated in this study (i.e. 38 participants; mean age ± SD: 26.33 ± 4.27 years old). These dyads had been living together as either couples (14 dyads; mean age ± SD: 26.83 ± 3.86 years old) or roommates (5 dyads; mean age ± SD: 25 ± 5.02 years old) for a period of time ranging between 0 and 2 years (hereafter called "short relationships") and between 2 and 4 years (hereafter called "long relationships") (Figure 1). The participants reported that they were non-smokers and did not suffer from any psychological, cardiac, respiratory or olfactory diseases. They all agreed to follow nutritional and hygiene instructions to limit exogenous influences on BO quality. Inclusion was possible only for participants having a house or apartment large enough to allow the assignment of two rooms specifically for the experiment (not including the kitchen

to avoid food-related odors and where one room had a window for ventilation). All dyads received monetary compensation. This research was conducted in accordance with the Declaration of Helsinki and was approved by the local Sud Méditerranée III ethical review board (May 13, 2019).

	Roommates	Couples	Total
Short relationships	2	7	9
mean age ± SD	21.75 ± 0.86 yo	26.77 ± 4.21 yo	25.59 ± 4.28 yo
Long relationships	3	7	10
mean age ± SD	27.17 ± 5.48 yo	26.89 ± 3.52 yo	26.97 ± 4.19 yo
Total	5	14	19
mean age ± SD	25 ± 5.02 yo	26.83 ± 3.86 yo	26.33 ± 4.27 yo

Figure 1. *Distribution of the dyads involve in the at-home experiment.*

2.2. Procedure

2.2.1. *From Lab to Home: Material and installation*

A parcel was sent to the recruited participants including all the instructions and material for the at-home experiment (unperfumed soap, deodorant, prewashed t-shirts, perfume bottle, a 30mL amber glass jar, gloves, etc). A unique code was previously sent by email allowing the participants to follow step-by-step the written and filmed instructions and to take part in the different tasks. At any given moment of the experiment, they could contact the experimenters by phone if needed, to ask questions or if they encountered a problem. The participants were told to not communicate with their partners about the experiment until the end of the entire procedure. At the very end of the experiment, the participants filled a short survey designed to identify any difficulty or error that could have occurred and they had to upload two photographs of how they installed the setting.

2.2.2. *At-home experiment*

From two days before the first experimental day and until the end of the procedure we asked to the participants to use only unperfumed hygiene products that we provided. Before BO

collection, the donor participant washed their axillae with unperfumed soap, and then to wear one of the prewashed cotton t-shirts that we provided to them to prevent odor contamination from their personal clothes and to serve as BO collection media.

Each participant took part in a Neutral EIP and in a Positive EIP (in a randomly determined order) alternatively on 2 days.

- ***Day 1***

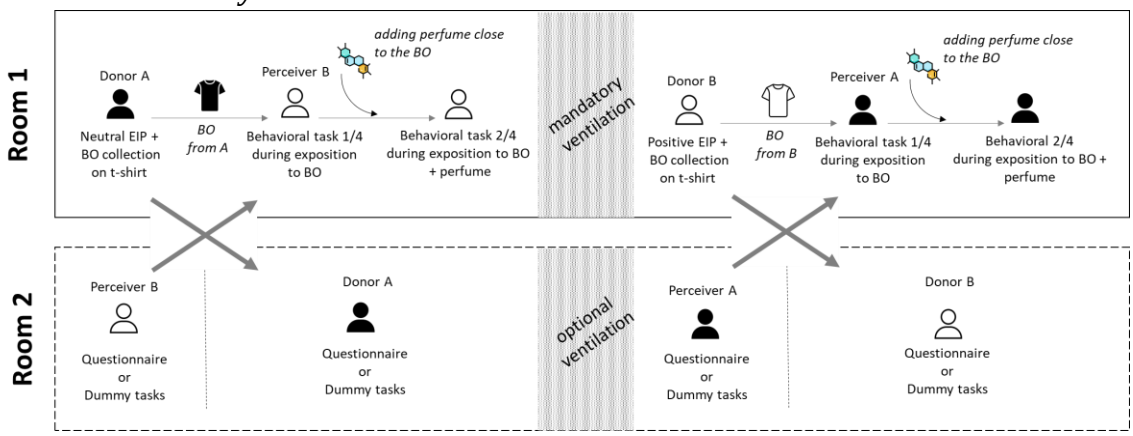

Figure 2. *Experimental design for a dyad on Day 1 in the 2 rooms of the same house. EIP: Emotion Induction Procedure; BO: Body Odors. Participant A serves as a donor in the Neutral EIP. Participant B is the perceiver. Then, participant B serves as a donor in the Positive EIP while participant A is the perceiver. BO was presented alone, and then close to specific perfume. On Day 2, the exact same procedure was repeated by swapping participant / the condition combinations.*

On day 1, participant A, as the donor, was asked to wear the t-shirt and to settle in room 1. Next, they watched short film clips on the web interface assembled to provide a 30-minute sequence which were considered repetitive and Neutral (Neutral EIP). Participant A then left the room 1 after leaving the worn t-shirt on the table and let participant B (perceiver) enter room 1. Participant B (perceiver) prepared the experimental setup by putting the t-shirt on top of a cardboard box (included in the sent parcel) and put both axillary areas of the t-shirt at the center of the cardboard box. Participant B (perceiver) then has to adjust the height of the box by stacking books underneath it until they could rest their chin on the box without discomfort. Once ready, participant B took part in a first session involving behavioral tasks (*see below 1.3. Emotional state measurement)* while exposed to the BO without any additional odor (Without perfume condition). For the second session, the participant used nitrile gloves to spray perfume once into a 60mL amber glass jar which already contained a piece of polypropylene fabric (2x5cm). This perfumed bottle was then positioned in front of

the box on the table. The perfume was chosen because it received the highest pleasantness score in a pre-test (N=29) where it was tested along with other perfumes. All perfumes were created specifically for the study.

During this second session (With perfume condition), the emotional state was also measured by creativity tasks.

While participants were taking part in the EIP or the behavioral creativity tasks, the other participant was kept busy in room 2 with standardized tasks, i.e. questionnaire completion *(see below 1.4. Questionnaires*) interleaved with dummy tasks (memory/attention tasks, not analyzed). After having closed the perfumed bottle, moved it away, and carefully ventilated the room (by opening the window for at least 15 min), the participants switched roles, participant B being the donor and undergoing the Positive EIP, and participant A being the perceiver.

- ***Day 2***

The same procedure was repeated on day 2 (one day after) swapping participant/condition combination. Participant B first acted as a donor while undergoing the Neutral EIP, and participant A then acted as a donor while undergoing the Positive EIP. Note that the Positive EIP always took part after the Neutral EIP to avoid potential residues of chemical signals of positive emotions to remain in the air and influence the next task.

At the end of day 2, both participants have been donors and perceivers in each of the 4 conditions (Neutral and Positive EIP, each With and Without Perfume).

2.3. Emotional state measurement: behavioral tasks

All participant took part in 4 different behavioral tasks, that were each repeated 4 times, once for each conditon. On each new repetition, the stimuli words changed. Before all the creativity tasks, an example page was first shown to the participants with dummy stimuli words and example answers, so that they could get familiarized with each task.

- ***Guilford's Alternate Uses Task*** (Guilford, 1967)

In this test, the participants are asked to list as many non-obvious uses as possible for common objects in a limited time. Perceivers were given 2 minutes per object (8 different ones in total: brick, barrel, pencil, shoe, car tire, hanger, pan, journal). Two objects were given in each task per condition. Their fluency (i.e., number of alternative uses found, after

filtering out irrelevant answers) was measured. Perceivers' fluency was computed as the mean number of alternative uses found per object for each perceiver across the 2 objects. 0-pas de maxi

- ***Metaphor generation Task*** *(based on Kasirer and Mashal, 2018)* [14]

Here, participants were given an incomplete sentence (e.g., being ashamed is ____) and they had to complete it by finding a new original and creative way to express the concept. Per session, they had 1 minute to generate 4 metaphors, which corresponds to 16 different metaphors in total. Each response was scored depending on the originality of its response: 1 for non-creative metaphors or literal expressions (e.g. being ashamed is to be shameful), 2 for transparent metaphors (e.g. being ashamed is wishing a wall would rise up) and 3 for "opaque" metaphors (e.g. being a monster who is afraid of his own face). Here, score for one condition was the mean score of the 4 metaphors of the condition. This score is out of 3 because the highest rating is 3.

- ***Chain Free Association Task*** *(based on Isen et al., 1985)* [15]

This task was used to measure creative divergent thinking. After a first word was given to the participants (e.g., "wax"), they had to type another word that this first word makes them think of (e.g., "candle"), and so on ("candle" leads to "flame", etc.) until they had completed a 10-word chain. They had 4 minutes to form as many word chains as possible, and this number was recorded as the score. Here, the score for one condition was the mean number of chains each participant completed.

- ***8 series of riddles*** taken from previous experiments on creativity [16].

In each session, the participants were asked to solve 2 riddles within a 2-min slot per riddle. Here, the score for one condition is the mean of correct answers, represented by a score out of 2 (1 point per riddle if correct, 0 if incorrect).

A global creativity score per participant per condition was computed by averaging the normalized scores of the four behavioral tasks. By normalizing the scoring on each behavioral task, the same weight was given to all tasks in the global creativity score. The normalization was done as follows. 1 was either the maximum possible (Metaphors, Riddles)

or the best performance among the participants' scores (Alternate Uses Task, Chain Free Association Task). The global creativity score is out of 1.

2.4. Questionnaires

- ***Relationship's characteristics.***

Each member of the dyad was asked to indicate the nature of the relationship with their partner (couple or roommates). They also reported how long they had known their partner and how long they had been living together. In order to limit biases linked to dyads going through a bad patch at the time of the experiment, they were also asked how good their relationship currently was, how close they feel to their partner and how often they communicate daily.

- ***Sociability.***

To measure participants sociability, the McCroskey's Introversion Questionnaire (1997) and the Emotional Intelligence Scale [17] were used. The first one, based on Eysenck's (1970) extraversion-introversion scale [18], is designed to determine relative levels of extraversion/introversion and is composed of questions about how people behave during social experiences (e.g. "Do you like to mix socially with people?"). The second one measures the respondent's ability to interpret other's emotions and to manage their own emotions. Because the scores of the two scales were highly correlated (Pearson correlation coefficient=0.44), a composite score was computed to reduce the number of variables by adding the individual z-scores to each scale. Statistical analyzes were conducted on a categorial variable separating "low sociability" (scores<0, N=16 participants) and "high sociability" (scores>0, N=22 participants).

2.5. Data analysis

Linear mixed-effect models were conducted with the global and individual creativity scores as a dependent variable, with Condition (Positive/Neutral BO), Perfume (With/Without), Sociability (high/low), Relationship type (Couples/Roommates), and Relationship Duration (long/short) as fixed factors, and with Subject as a random factor.

3. Results.

Using linear mixed-effect models, we found a main effect of the type of the Relationship (F(1,33.472)=4.830, p=0.0350). We analyzed the effect of Condition (Positive/Neutral BO) and Perfume (With/Without) on behavioral responses on the performance in the creativity tasks (Figure 4). The global creativity score of Couples perceivers was significantly improved in the Positive BO condition when compared to the Neutral BO

(Figure 3, Mean ± SD, Positive BO: 0.518 ± 0.15, Neutral BO 0.458 ± 0.13, t(103.72) =2.328, p = 0.011), while in the Roommates group it was not (Figure 3, Mean ± SD, Positive BO: 0.545 ± 0.15, Neutral BO 0.546 ± 0.13, t(37.09)= -0.019, p = 0.508). Overall, we did not find an effect of Perfume (F(1,106.085)=0.0404, p=0.841) whatever the type of the relationship (data not shown).

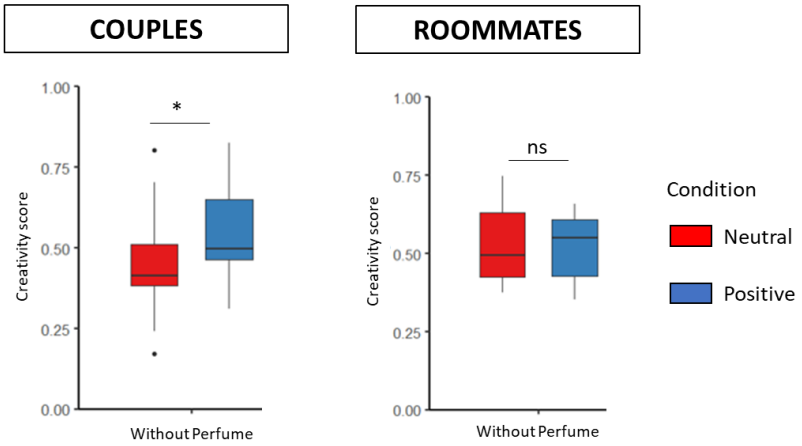

Figure 3. Global creativity score. *Mean score obtained by the perceivers of the Couples or Roommates groups exposed to the BO of the donors in the Neutral EIP (Neutral) and the Positive EIP (Positive), without perfume. ns: not significant, *: p<0.05*

Looking more deeply, when considering each behavioral task independently (Figure 5), we generally observed the same pattern of significance as for the mean global creativity score, except for the "series of riddles" task. Indeed, there were a main effect of Positive condition during the “Chain-Free Association Task” (Figure 4A; Mean ± SD, Positive BO: 0.378 ± 0.12, Neutral BO 0.33 ± 0.13, t(97.74)=1.830, p=0.035) and the “Metaphor generation Task” (Figure 4C ; Mean ± SD, Positive BO: 0.604 ± 0.14, Neutral BO 0.561 ± 0.12, t(99.521)=1.760, p=0.041) in Couples group. There was a trend in the “Guildford’s Alternate

Uses Task" for a higher score in the Positive BO condition, though it did not reach significance (Figure 4E ; Mean ± SD, Positive BO: 0.433 ± 0.23, Neutral BO 0.419 ± 0.21, W=1657.5, p=0.054). The binary scoring (1 point if correct, 0 if incorrect) of the "series of riddles" task could explain the lack of finesse in the results and not obtain statisitcs of interest (Figure 4G). We did not observe a significant effect of the Positive BO compared with the Neutral BO in the Roommates group, whatever the creativity task (Figure 5B,D,F,H). Moreover, we also did not obtain any significant differences related to perfume in both conditions (data not shown).

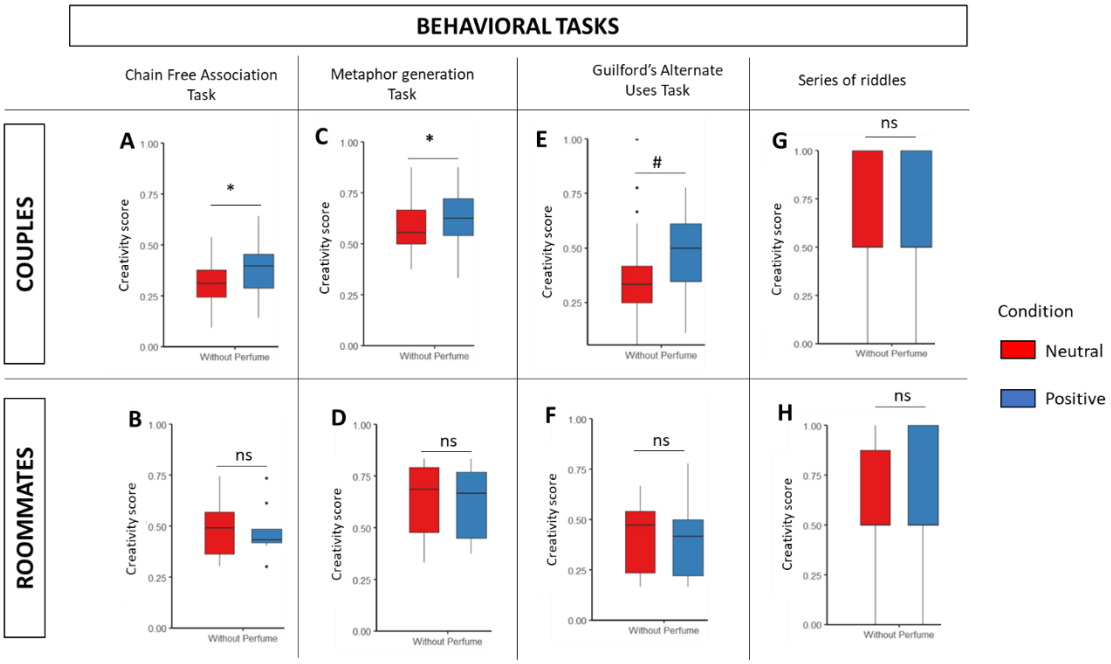

Figure 4. Creativity score for each behavioral tasks. *Mean score obtained by the perceivers in the Couples or Roommates groups exposed to the BO of the donors in the Neutral EIP (Neutral) and the Positive EIP (Positive), without perfume. ns: not significant, #: p<0,1*: p<0.05*

We also investigated the influence of the sociability level of perceivers on emotional transmission. The performance in creativity tasks was enhanced in perceivers with lower levels of sociability compared with higher level of sociability (Figure 5; F(1,33.948)=6.9550, p=0.012). We did not find any significant effect of the Condition within sociability levels in the Couples group (Figure 5; Mean ± SD, Low/Positive BO 0.552 ± 0.11, Low/Neutral BO

0.516 ± 0.12, t(50.085)=1.1259, p=0.131 ; High/Positive BO 0.479 ± 0.15, High/Neutral BO 00.404 ± 0.12, W=414, p=0.078).

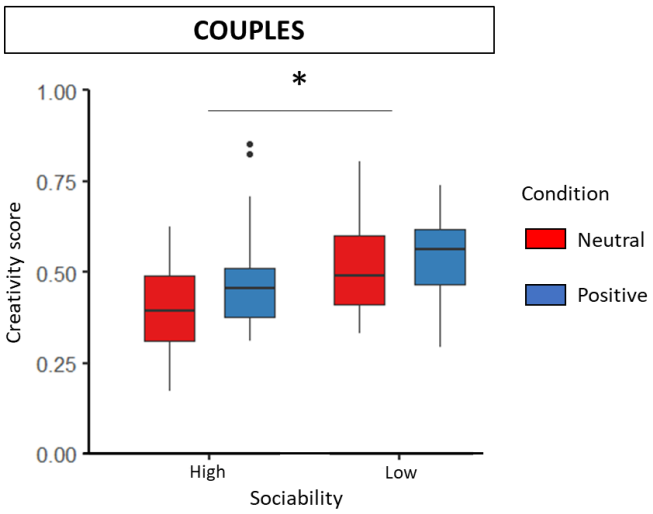

Figure 5. Perceivers sociability level. *Mean creativity scores obtained by the perceivers of the Couples group with high and low level of sociability, exposed to the BO of the donors in the Neutral EIP (Neutral) and the Positive EIP (Positive), independently of the use or not of perfume.*

4. Discussion & Conclusion.

Our research aimed at exploring whether human chemical communication of positive emotions is conveyed and modulated through BO. Here, we developed a new methodology to explore further this chemical communication and better understand the modulating factors. We found that the emotional transmission via BO occurs differently depending on the relationship proximity. Couples seem to communicate their positive emotions better through BO than Roommates.

In our previous studies using Videos-based EIP or Virtual Reality-based EIP we revealed that a communication of positive emotion is possible [9, 19, 20]. We showed that when smelling Positive BO, participants took less time to solve a problem (Duncker's candle problem) even though it did not always reach significance. This result suggested that smelling Positive BO could improve creativity and problem solving, indicating that a positive emotional transmission had taken place. In past studies, communication has been investigated between unrelated people and the BO samples were collected from multiple

individuals suggesting that emotional communication may occur between people whether they are related to each other or not [8,9]. These previous studies were also conducted in a laboratory environment and by smelling unknown samples increasing the stress of participants. This less ecological context may increase the vigilance of individuals to unknown odors from their own species, enhancing sensitivity and responsiveness to emotional communication. Here, participants know that the samples are armpit BO from their partners, and these BO were collected and smelled in a familiar and ecological environment. In this non-stressful environment, we found that the effect of the communication on the emotional state of the perceiver seems to be modulated by the proximity of the relationship. Moreover, this result suggests that being romantically or sexually involved with someone may amplify the sensorial inputs, including olfactory. In a romantic relationship, it may be necessary and important to be more attune to partner's odors. Spending time in close proximity under different intense emotional states (such as being naked during a sexual relationship) could provide more experience of the partner's odors, as a training exercise. However, we did not find any effect of the duration of the relationships. In order to draw firm conclusions about these relationship characteristics (type/duration), it would be interesting to increase the size of our groups, especially of the Roommates group and to further study the proximity of Couples.

In this study, we also observed a significant effect of the perceiver's level of sociability in the chemical emotional transmission. Sociable persons seek social contact, while introverts shy away from it and communicate less than extroverts [21-23]. It would then be possible to consider that highly sociable individuals would be the most likely to detect and respond to emotional cues contained in BO. Surprisingly, we obtained the opposite results, less sociable perceivers seem to be more receptive to the communication of positive emotions. This new finding raises questions about the role of emotions transmission via BO in human social interactions. Are introvert people very or too sensitive to this communication and try to avoid it? Or, are they very receptive in order to improve their level of sociability?

Finally, we did not find possible effect of perfume on the chemical communication in the "With perfume" condition. In our previous studies, we found a synergic effect of the perfume (higher intensity and familiarity of the Positive BO vs. the Neutral ones when they were presented with perfume, while no difference occurred when presented alone) [9], and BO

also were associated to a higher basic peak amplitude in the skin conductance recordings and a higher number of contractions of the major zygomatic muscle [19]. Here, similar results were expected, since the perfume used was pre-selected to be pleasant, and was clearly perceivable by contrast with the BO which most of the time presumably were not consciously perceived. The perfume was added near the BO, evoking rather the use of a home fragrance. In our at-home experiment, this type of "perfuming", instead of being perceived as closely mixed with the BO could rather have been perceived by the participants as a disruption in the usual smell present in their home. As a future perspective, it might be interesting to deepen the role of perfume in the emotional state transmission by mixing both BO and perfume.

This research presents a novel method of evaluating the capacity of human BO to communicate and modify others' emotional states and opens up interesting perspectives to develop new fragranced products capable of enhancing the social communication between individuals and other holistic wellbeing benefits.

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Conflict of Interest Statement. NONE.

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