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A Sniff of Happiness

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Abstract

It is well known that feelings of happiness transfer between individuals through mimicry induced by vision and hearing. The evidence is inconclusive, however, as to whether happiness can be communicated through the sense of smell via chemosignals. As chemosignals are a known medium for transferring negative emotions from a sender to a receiver, we examined whether chemosignals are also involved in the transmission of positive emotions. Positive emotions are important for overall well-being and yet relatively neglected in research on chemosignaling, arguably because of the stronger survival benefits linked with negative emotions. We observed that exposure to body odor collected from senders of chemosignals in a happy state induced a facial expression and perceptual-processing style indicative of happiness in the receivers of those signals. Our findings suggest that not only negative affect but also a positive state (happiness) can be transferred by means of odors.

Keywords
chemosignaling, olfaction, happiness, communication, EMG, open data, open materials

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The pursuit of happiness is not an individual enterprise. As a social species, humans communicate happiness by smiling, cheering, or hugging someone using the respective modalities of vision, hearing, and touch. However, the evidence whether happiness can be transferred by olfactory means—that is, by odors produced by the body, also referred to as *chemosignaling*—is inconclusive.

Chemosignals have been shown to convey social information ranging from static features, such as genetic relatedness (Jacob, McClintock, Zelano, & Ober, 2002) and gender (Penn et al., 2007), to emotional states (e.g., de Groot, Smeets, Kaldewaij, Duijndam, & Semin, 2012; Mujica-Parodi et al., 2009; Prehn, Ohrt, Sojka, Ferstl, & Pause, 2006; Zhou & Chen, 2009). The literature on emotional chemosignaling has focused almost exclusively on negative emotions, of which fear has received the most attention. However, can a positive state be communicated from the sender of a chemosignal to its receiver? Specifically, can odors produced by a happy sender of chemosignals elicit behavioral, perceptual, and affective processes in a receiver that partially reflect the state of the sender?

Communication in the context of chemosignaling entails the transfer of information from a sender to a receiver, without the requirement of communicative intent (Semin & de Groot, 2013). Transmission of dynamic information such as emotional states can occur by means of diverse modalities (e.g., visual, auditory, olfactory) through their respective manifestations (e.g., facial expressions, vocal intonation, chemosignals; Semin, 2007; Semin & de Groot, 2013). These modalities, individually or in combination, establish in a receiver a partial affective, behavioral, perceptual, and neural reproduction of the state of the sender (Semin, 2007). The word *partial* is used explicitly to denote that the receiver does not

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reproduce an exact copy of the state of the sender. Further, a partial reproduction of a state can occur automatically, outside of conscious access, and contributes to *synchronization*: the common base required for any successful communication (Semin, 2007).

A well-known case of synchronization occurs when macaque monkeys' mirror neurons discharge both when the monkey is engaged in a particular action as well as when the monkey observes another monkey engaging in the same action (e.g., Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). For humans, the range of actions supporting synchronization (for an overview, see Chartrand & van Baaren, 2009) include mimicry of facial expressions, language, behavior, and emotions (Hatfield, Cacioppo, & Rapson, 1993). Evidence for synchronization has been limited mostly to the visual and acoustic domain (Semin, 2007), yet recent research has revealed the human capability to mirror another person's sniffing behavior (Arzi, Shedlesky, Secundo, & Sobel, 2014). Body odors were long neglected as a potentially shared medium in humans (but see Wilson, 1992, for a critical review of McClintock's menstrual-synchrony research, first published in 1971). This changed only recently when researchers started to explore the role of chemosignals in transferring emotions (Chen & Haviland-Jones, 2000).

Humans appear to have the necessary makeup to engage in emotional chemosignaling. Located in the armpit, apocrine sweat glands contain adrenalin receptors that produce sweat as a function of adrenergic activity (Harker, 2013). Notably, the production of adrenalin is not limited to negative states (see Levi, 1965); states of arousal on opposing ends of the valence dimension (e.g., fear, happiness; Russell & Barrett, 1999) could lead to the release of different odor compounds (or different quantities of such compounds). As a consequence, individuals may extract statistical regularities from the environment, which may allow associations to form between the odor and the emotional state with which it usually co-occurs. For instance, androstadienone is associated mainly, but not always, with positive mood effects, which occur primarily in females when concentrations are high (Havliček, Murray, Saxton, & Roberts, 2010). Humans detect chemosignals via the main olfactory epithelium in the nose (Wysocki & Preti, 2004), as the vomeronasal organ used by animals to detect pheromones is not functional in humans (e.g., Trotier et al., 2000). By reactivating previously stored emotion-specific representations of the odor, chemosignals can serve as a medium to establish synchrony between individuals.

While robust evidence for emotional contagion via chemosignals has been reported for fear (e.g., de Groot, Semin, & Smeets, 2014b; de Groot et al., 2012; Mujica-Parodi et al., 2009; Zhou & Chen, 2009), similar effects for positive-affect-related chemosignals have been examined in only three studies, in which happiness served mainly as a control condition for fear. In a pioneering study by Chen and Haviland-Jones (2000), female participants were shown to identify above chance "the odor of people when they were happy" (p. 771) from fear odor and a control odor (unused sweat pads; for a replication, see Zhou & Chen, 2011). However, although participants exposed to fear odor more often identified the most ambiguous tested expression (i.e., one morphed halfway between happiness and fear) as fearful, similar evidence was not obtained for the happiness condition (Zhou & Chen, 2009). Moreover, participants were marginally less accurate at discriminating happiness sweat from neutral sweat than at differentiating fear sweat from neutral sweat (Zhou & Chen, 2011). Arguably, happiness does not carry as much "evolutionary salience" as fear (Zhou & Chen, 2009, p. 181) and has received no further attention in the chemosignaling literature. Hence, the evidence has remained inconclusive as to whether humans produce chemosignals of happiness. Moreover, if they do produce happiness chemosignals, then multifaceted (behavioral, affective, and perceptual) evidence would be required to verify whether the state of the receiver actually constitutes a simulacrum of the state of the sender.

Determining whether the state induced in receivers approximates the senders' state requires careful attention. Odors and the effects they elicit are hard to describe (Lorig, 1999). Therefore, in the present research, we considered implicit measures to be more reliable indicators of the affective state of receivers than self-report measures. Among the measures that would represent a behavioral, affective, and perceptual simulacrum of the state of the sender were facial expressions, mood states, and global-local processing. First, electromyographic (EMG) activity involving both the zygomaticus major and orbicularis oculi facial muscle (the *Duchenne smile*) would reflect happiness (Ekman, Friesen, & Hager, 2002), whereas EMG activity involving the eyebrow-lifting medial frontalis muscle would demonstrate an adaptive response in fearful situations because it indicates increased sensory intake (Ekman et al., 2002; Susskind et al., 2008; cf. de Groot et al., 2012; but see Hess & Fischer, 2013, for a critique on measuring discrete emotions via facial EMG). Furthermore, from the myriad tests that tap implicit affect and perceptual-processing style, we selected two options, both of which have been shown to provide affect-specific modulation of task performance, namely an implicit affect-misattribution task (Payne, Cheng, Govorun, & Stewart, 2005) and global-/local-processing tasks (see Gasper & Clore, 2002). Whereas happiness broadens the attentional scope, highly arousing negative states such as fear narrow attention (e.g., Fredrickson, 2001).

The present research examined whether sweat produced by individuals induced to be happy would modulate the facial expression (behavior), mood state (affect), and global/local processing style (perception) of receivers to reflect the sender's state. This hypothesis was tested in a within-subjects experiment that included both fearful and neutral states as control conditions. The research was divided into a sweat-sampling (sender) and a sweat-exposure (receiver) phase. In the receiver phase, exposure to sweat obtained from happy individuals was expected to elicit a Duchenne smile, positive mood, and global processing style, whereas exposure to sweat obtained from fearful individuals was expected to induce a fearful facial expression, negative mood, and more local processing style.

Method

Part 1: sweat-sample collection ("senders")

Participants and design. Twelve Caucasian males (mean age = 22.42 years, *SD* = 3.80, range = 18–35) provided written informed consent to donate sweat in three consecutive sessions (fear-inducing, happiness-inducing, and neutral stimuli), each separated by a week's interval. Participants were heterosexual nonsmokers (none had smoked in the 6 months prior to the study) who did not take any medication and had no psychological disorders. Only males were recruited because they have larger and more active apocrine sweat glands than do females (cf. the procedure used by Zhou & Chen, 2009). Only heterosexuals were included because we used only female participants in Part 2 of the experiment, and females have been shown to evaluate homosexual male sweat differently than heterosexual male sweat (Martins et al., 2005). Three of the 12 senders appeared not to have fully complied with the armpit-shaving procedure, so their samples were not used in the main study (final $N = 9$).

Materials and measures

State-induction film clips. The original versions of nine English-language film clips (Schaefer, Nils, Sanchez, & Philippot, 2011; film database codes: 7, 16, 28, 32, 38, 46, 50, 55, 66) were selected for the fear condition. These were the same clips used to induce fear in previous experiments (de Groot, Semin, & Smeets, 2014a, 2014b).

Happiness-inducing and neutral clips were selected on the basis of a pilot test ($N = 30$). Analysis of the clips that were eventually selected revealed that participants reported significantly more happiness ($M = 6.05$, $SD = 1.12$) after viewing happy clips than after viewing neutral clips (happiness: $M = 3.75$, $SD = 1.66$), $t(28) = 7.45$, $p < .001$, Cohen's $d = 2.72$. Furthermore, after viewing neutral clips, participants felt significantly more neutral ($M = 4.38$, $SD = 1.41$) than they did after viewing happy clips (neutral: $M = 3.72$, $SD = 1.53$), $t(28) = 2.67$, $p = .013$, $d = 0.97$. The clips selected for the happiness condition were "Bare Necessities" from *The Jungle Book* (4 min 29 s), Kurt Kuenne's short movie "Validation" (16 min 23 s), the opera scene from the film *The Intouchables* (2 min 12 s), and an elaborate televised prank on the Belgian TV show "Mobistar" (10 min 43 s). Nine scenes were selected for the neutral condition. The first scene (8 min) was a first-person view of a car and boat traveling through the Dutch countryside. The second scene, an excerpt from the TV show "Rail Away," displayed a train traveling through the Alps (13 min 26 s). Scenes 3 (2 min 4 s) and 4 (2 min 27 s) were American weather forecasts, whereas old Dutch weather forecasts completed the neutral condition: Scenes 5 (1 min 11 s), 6 (1 min 4 s), 7 (1 min 6 s), 8 (1 min 2 s), and 9 (1 min 22 s). The total duration of the clips in each condition was about 30 min.

Sweat production. Sweat was sampled with a 10-cm × 10-cm sterile absorbent pad (Cutisorb, BSN Medical, Hamburg, Germany) and weighed on a portable LT-TP500 scale (Shenzhen Lante Electronics, Shenzhen, China) with .01-g precision. Sweat production was determined by subtracting the weight of the pad before the emotion induction from the postinduction weight.

Chinese symbol task. The Chinese symbol task implicitly measures the misattribution of affect to seemingly unrelated, affectively neutral Chinese characters (Payne et al., 2005). Each Chinese symbol was unique, and all were obtained from a pilot-tested database (http://www.unc.edu/~bkpayne/materials.html). In this task, participants view Chinese characters one at a time and rate them as "pleasant" or "unpleasant," depending on whether they judge the character to be more or less pleasant, respectively, than the average Chinese character.

Self-report questionnaires. Participants rated to what extent they felt angry, fearful, happy, sad, disgusted, neutral, surprised, calm, and amused on separate 7-point Likert scales that ranged from 1, *not at all*, to 7, *very much*. Combinations of these ratings were averaged to create indicators of low arousal (neutral, sad, calm), high arousal (angry, fearful, happy, disgusted, surprised, amused), positive affect (happy, calm, amused), and negative affect (angry, fearful, sad, disgusted).

Procedure. Figure 1 provides an overview of the procedure. Participants followed a strict regimen to avoid sweat contamination starting 2 days before each donation session. Alcohol use, sexual activity, consumption of odorous food (e.g., garlic, onions), and excessive exercise

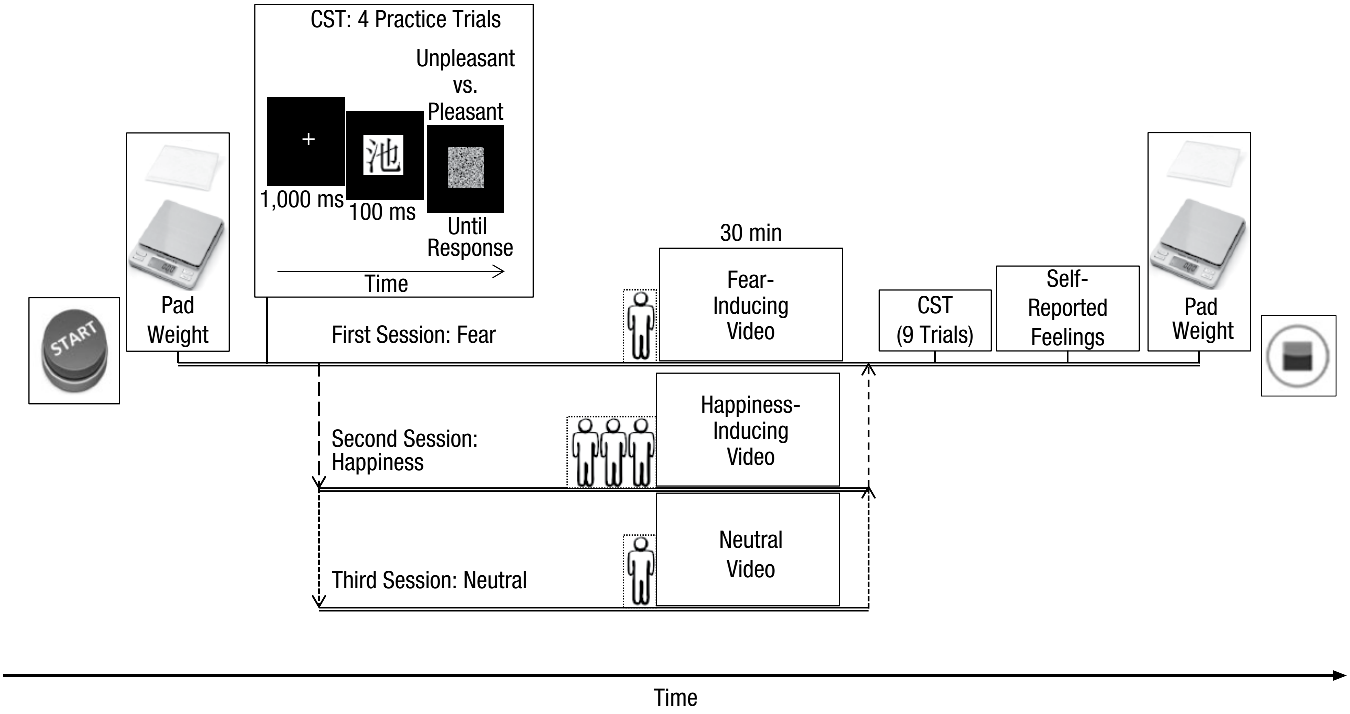

Fig. 1. Schematic overview of Part 1 of the experiment, in which sweat samples were obtained from senders. Participants completed three sessions, each 1 week apart. At the start of each session, participants performed the Chinese symbol task (CST), in which they viewed Chinese symbols and indicated whether they found them pleasant or unpleasant. The manipulation followed, in which participants were exposed to happiness-inducing, fear-inducing, and neutral videos, depending on the session. In the fear and neutral conditions, participants viewed stimuli alone, whereas in the happiness condition, they viewed stimuli in groups of 3 participants each. Afterward, participants again performed the CST and then rated to what extent they felt each of nine emotions on Likert scales from 1, *not at all*, to 7, *very much*. Sweat pads were weighed before and after the session to determine the amount of sweat obtained.

were prohibited. Senders shaved their armpits 2 days before each donation session. They were provided with scent-free hygiene products to use in the predonation period and filled in a diet diary to monitor food intake. On the donation day, senders brought a prewashed T-shirt in a ziplock plastic bag to prevent odor contamination from their clothes.

After entering the lab, senders rinsed and dried their armpits with water and paper towels. The experimenter used hypoallergenic tape to attach an absorbent pad under each armpit while wearing latex gloves to avoid bacterial contamination. Senders put on a T-shirt and sweater before entering a separate, dimly lit room (23 °C) in which the experiment was run.

Participants first completed four practice trials of the Chinese symbol task. Each Chinese symbol was presented for 100 ms and was immediately followed by a black-and-white noise mask. "Pleasant" and "unpleasant" response keys were counterbalanced across participants. Next, participants watched a series of video clips (~30 min) that were selected to induce a specific state (fear, happiness, or neutral). By presenting clips in rank order from least to most intense, we expected senders to experience a gradual buildup of emotional experience. To further maximize the effectiveness of the emotion-induction procedure, we seated senders individually in the fear and neutral conditions, whereas we seated them in groups of 3 in the happiness condition.

Directly after the state induction, senders completed nine trials of the Chinese symbol task. Participants were told to base their judgment solely on the character in question and ignore any preceding characters when making their judgment. Subsequently, they rated their feelings on 7-point Likert scales. Finally, sweat pads were removed, weighed, and stored separately in vials at −22 °C. Senders completed three sessions, each of which were the same except for the valence of the film clips they viewed. After the third session, senders were debriefed and received €50.

Statistical analysis. All data were checked for assumptions regarding normality and for outliers. The results of the Chinese symbol task in the fear condition were not included in the analysis, because a logging error in the program resulted in the loss of character ratings for 7 participants. Since self-report data were not normally distributed, a nonparametric Friedman's test was performed.

The materials from 3 of 12 senders were not used in Part 2 of the experiment, as these individuals had violated multiple aspects of the protocol. The final sender sample size (*N* = 9) was small yet sufficient, as each sender provided a 200-cm^2 pad (100 cm^2 from the left armpit and 100 cm^2 from the right armpit).

Part 2: odor exposure ("receivers")

Participants and design. Written informed consent was obtained from 36 female Caucasian undergraduates (mean age = 20.59 years, *SD* = 1.85, range = 18–35). Participants were right-handed nonsmokers (none had smoked in the 6 months prior to the study) and did not suffer from a psychological disorder, respiratory disease, illness, cold, or allergy. However, one participant was excluded because of prior participation in a similar study. Only females were recruited as chemosignal recipients because women generally have a better sense of smell and greater sensitivity to emotional signals than men do (cf. the procedure used by Zhou & Chen, 2009). Indeed, gender differences have been reported in emotional chemosignal reception; compared with males, only female recipients displayed behavioral consequences of fear following exposure to fear chemosignals (de Groot et al., 2014a). Furthermore, only heterosexual females were recruited because of demonstrated differences in the evaluation of male sweat as a function of female sexual orientation (Martins et al., 2005). The experiment employed a double-blind, counterbalanced, within-subjects design, with sweat type (three levels: happiness, fear, neutral) as the single factor.

Measures and materials

Stimulus composition. Sweat pads obtained from senders in Part 1 were prepared for presentation to receivers as follows. After being thawed, each sweat pad (10 × 10 cm) was cut into eight equal parts. Four different pad parts were placed in the vial that was presented to receivers. As in previous studies (e.g., de Groot et al., 2012), we reduced effects of interindividual variability in sweat production by combining pad parts (size: 12.5 cm^2 each) from different senders and using pads from the left (two parts) and right (two parts) armpits in a predetermined randomized order. Each receiver was exposed to the same combination of pad parts across sweat conditions. Vials containing sweat from happy, fearful, and neutral senders were presented in a counterbalanced manner using a fully randomized Latin square design. Both receiver and experimenter were unaware of the experimental condition, as each vial was marked with a three-digit code representing the sweat condition by a researcher other than the experimenter.

Facial EMG. EMG electrodes were used to measure subtle differences in facial-muscle activity as a function of the experienced emotion induced by sweat. Sintered Ag/AgCl electrodes were bipolarly applied to the left side of the face—the side most strongly involved in spontaneous affective reactions in right-handed participants (see Dimberg & Petterson, 2000; procedure is detailed in, e.g., de Groot et al., 2012). EMG signals were recorded with MindWare software (Version 2.5; MindWare Technologies, Gahanna, OH) and filtered on-line with a low-cutoff (0.5 Hz) and high-cutoff (200 Hz) filter. The EMG signal was rectified and smoothed with a 20-Hz low-pass filter with a time constant of 100 ms.

Implicit measures. Participants completed a series of implicit measures. In the Kimchi-Palmer task (Kimchi & Palmer, 1982), participants are shown a reference figure (e.g., a square consisting of triangles) above two adjacent comparison figures. One of the comparison figures is formed from the local element of the reference figure (e.g., a triangle made of triangles), whereas the other is formed from the global element (e.g., a square made of squares). In our experiment, the location of each comparison figure was randomly determined to be on the left or the right. Participants indicated which comparison figure was most similar to the reference figure by pressing one of two response keys. Response keys were counterbalanced across participants.

We also administered the Navon task, which is a nongeometrical equivalent of the Kimchi-Palmer task. In the Navon task, participants view relatively large letters (global elements) made up of smaller letters (local elements; see Navon, 1977, for the original version). Each trial consists of a reference figure (e.g., an *H* made out of *Z*s) placed above two adjacent comparison figures formed from either the local (e.g., a *T* made out of *Z*s) or global (e.g., an *H* made out of *F*s) elements of the reference figure. As in the Kimchi-Palmer task, the position of the local and global comparison figures (left or right side of screen) was determined randomly, and the response keys were counterbalanced. Participants indicated which comparison figure was most similar to the reference figure. In both tasks, a relatively greater selection of global comparison figures reflects a predominantly global processing mode.

Because the Kimchi-Palmer and adapted Navon task could be administered only once and because no directional hypothesis was postulated for the neutral condition, participants in this condition performed a dummy task in which they classified numbers ranging from −16 to 16 as either negative or positive. The task consisted of 32 trials. Response keys were counterbalanced across participants. Participants also completed the Chinese symbol task in all conditions. This task was identical to that completed by senders in Part 1.

Handedness scale. The handedness scale was included to ascertain that all members of the sample were right-handed and to control for possible handedness-related differences in facial EMG activity. On 10 items (van Strien, 1992; Cronbach's α = .98), participants indicated which hand they use to perform a range of activities. The current sample was right-handed.

Sweat ratings. In randomized order, participants evaluated how pleasant and how intense they found the sweat stimuli (happiness, fear, neutral) they were exposed to during the experiment on 7-point Likert scales (1 = *not at all*, 7 = *very much*).

Sweat-discrimination test. To assess participants' ability to discriminate between sweat obtained from happy, fearful, and neutral individuals, we asked participants to perform a two-alternative forced-choice reminder task (for the theoretical basis of this procedure, see de Groot et al., 2014b). On four trials, participants indicated which of two sweat stimuli (presented second and third) corresponded to the reference sweat stimulus (presented first). Fear-inducing (reference) and neutral stimuli were compared in Trials 1 and 2, happiness-inducing (reference) and neutral stimuli were compared in Trial 3, and happiness-inducing (reference) and fear-inducing stimuli were compared in Trial 4. Comparison stimuli were presented in a predetermined counterbalanced order.

Smell-threshold test. Participants' smell threshold was assessed with a standardized psychophysical test of olfactory function (Sniffin' Sticks, Burghart Instruments, Wedel, Germany), using a triple-forced-choice staircase method (Hummel, Sekinger, Wolf, Pauli, & Kobal, 1997). While blindfolded, participants were presented with three markers in a row and asked to identify the single marker that contained the target smell (phenethyl alcohol). Each of the markers was randomly presented for 2 s, about 2 cm below participants' nostrils. The concentration of the odor in the target marker was increased each time ($1.22 \times 10^{-4}\% - 4\%$, with 1:2 binary dilution steps) until participants made two consecutively correct identifications, after which they were presented with a lower concentration (first reversal). If participants erred, they were again presented with a higher concentration (second reversal). The smell threshold was calculated by taking the mean of the final four (out of seven) reversal points. This test indicated that participants had a normal sense of smell—mean smell threshold = 11.79 binary dilution steps (equivalent to $2.26 \times 10^{-3}\%$ phenethyl alcohol), *SD* = 2.72.

Awareness check. Funneled postexperimental debriefing revealed that 7 participants identified the olfactory stimulus as sweat; yet when probed for suspicion regarding the study's purpose, none of the participants identified the hypothesis.

Procedure. Figure 2 provides an overview of the procedure. Sweat stimuli were thawed approximately 30 min before presentation to receivers, and each receiver was presented with a new vial. The experimenters were female, because in body-odor-related experiments, male experimenters have been shown to increase positive mood in females (see Jacob, Hayreh, & McClintock, 2001).

After entering the lab, all participants were told that physiological measures would be applied to their face, after which they would have to perform computer tasks and a series of sensory tests. The experimenter first attached the electrodes (see the Supplemental Material available online for details). Participants were seated individually on an adjustable chair with their heads placed in a head-stabilizing chin rest. The chin rest functioned as a holder for a vial (placed 2 cm below the participant's nose) that contained one of the sweat stimuli (happy, fearful, neutral). The stimuli were presented in random order by the experimenter, who was blind to condition. Before the vial was placed, participants watched a relaxing 4-min video and practiced the Chinese symbol task (8 trials).

Next, with the vial still closed, participants completed six practice trials of one of three tasks, depending on condition: the Kimchi-Palmer, the Navon, or a dummy task. To assess global-local processing style, we asked participants in either the happiness or fear condition to perform the Navon or Kimchi-Palmer task (picture display: 1 s, interstimulus interval: 1.5 s). Both tasks are nonrepeatable within participants because of possible learning effects, so the two tasks were counterbalanced, with each receiver undertaking the Navon and Kimchi-Palmer task once each. In the neutral condition, a dummy task was performed.

Following the practice trials, participants were exposed to the sweat stimulus. Participants wore nose clips to prevent preliminary sniffs. The nose clip was removed directly after the vial was opened. During the opening of the vial, participants looked at a fixation cross that was presented in the middle of the screen for 5 s. Participants then performed 32 target trials of the task they had practiced in that condition, followed by 12 trials of the Chinese symbol task.

Participants completed the above process for each of the remaining two sweat stimuli, with a 5-min odor washout between conditions. After participants completed the final sweat condition, the experimenter carefully removed the electrodes from the face of the participant. Participants

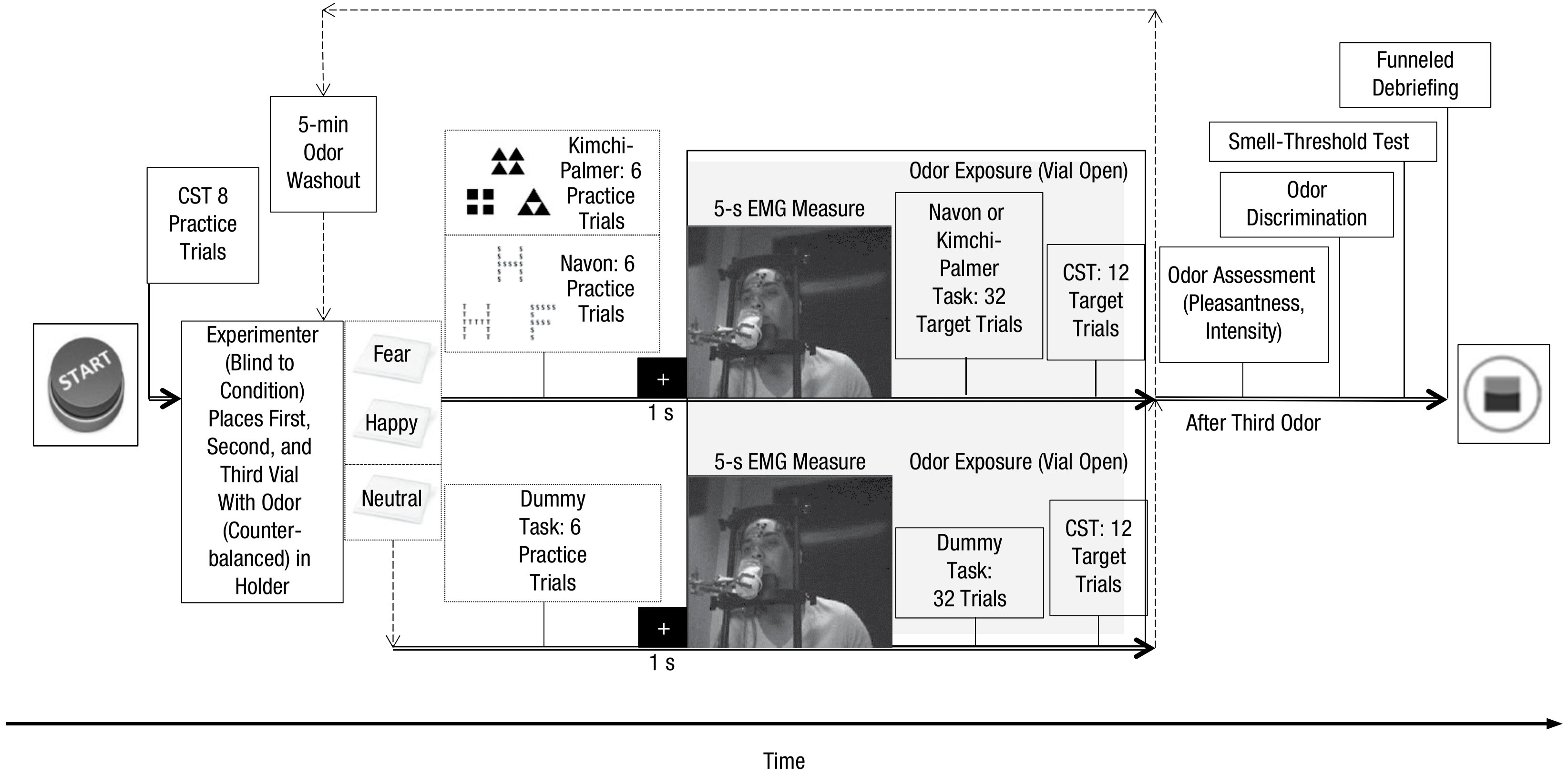

Fig. 2. Schematic overview of Part 2 of the experiment, in which sweat samples obtained in Part 1 were presented to receivers. Each participant began the experiment by performing practice trials of the Chinese symbol task (CST). The experimenter then presented but did not yet open a vial containing one of the three sweat stimuli, after which participants completed practice trials of the Kimchi-Palmer or Navon task (in the happiness and fear conditions) or a dummy task (in the neutral condition). The vial was then opened, and participants performed target trials of the task they had practiced in that sweat condition, followed by target trials of the CST. Electromyographic (EMG) data were recorded continuously while participants completed target trials, but only the first 5 s of EMG activity during sweat exposure were subsequently analyzed. After finishing practice and target trials in each of the three sweat conditions (with an odor washout between conditions), participants completed additional measures and were debriefed.

rated the previously presented sweat stimuli on pleasantness and intensity, then performed a sweat-discrimination task and smell-threshold test. Afterward, they were debriefed and paid €12.

Statistical analysis. The primary analysis of the receiver data concerned traces of EMG movement obtained from three facial muscles (medial frontalis, orbicularis oculi, zygomaticus major) during the first 5 s of exposure to each of the sweat stimuli. Before the experimenters were made aware of the sweat conditions, artifacts were removed across all three muscles (17 out of 105 cases) with MindWare software. Experimenters were not informed about the sweat conditions until after all decisions regarding data handling and statistical procedures were made.

Although facial EMG recordings provided a continuous data stream, our interest was the first 5 s after exposure, a time period that was summarized by averaging across each 200-ms interval during that period. We charted the effect of sweat from happy individuals on facial EMG activity for this time window (a) to reveal the independent effect of sweat from happy individuals on facial-muscle activity prior to the global-/local-processing task and (b) to demonstrate the effects of sweat from happy individuals in a time period that would contain at least two sniffs (Sela & Sobel, 2010), in which the second sniff was shown to be effectively modulated according to the experienced emotion (e.g., de Groot et al., 2014b; de Groot et al., 2012).

Because the variation in EMG data was positively skewed, we log-transformed all means. Prior to sweat exposure, a baseline measure of EMG activity was recorded. However, before experimenters were informed about the sweat conditions, agreement was reached that these baseline measures could not be used for analysis purposes. The baseline was recorded before nose clips were applied and the variability introduced by removing the clip eradicated the baseline score's value for its intended purpose.

To account in part for the considerable participant-to-participant variation in facial-muscle-activity profiles, we mean-centered each of four EMG parameters (maximum, standard deviation, mean response time, time to maximum peak) around zero per participant across conditions such that parameters were interpretable as relatively high or low, thus accounting for a degree of the participant-to-participant variability. So, for example, if the time to peak response were 1,000 ms, 2,000 ms, and 3,000 ms for participant X in each of the three conditions, those values would be recoded as −1,000 ms, 0 ms, and 1,000 ms, respectively. Initially, in each case, a stepwise procedure was used to identify the best discriminating subset of parameters. Discriminant analysis was then conducted to differentiate between facial-muscle-activity patterns, with distinct analyses comparing happiness versus neutral and fear versus neutral stimuli. The happiness versus fear comparison was conducted after experimenters were made aware of the sweat conditions (post hoc), as we were primarily interested in determining whether the happy response could be discriminated from the neutral response in addition to seeking additional evidence for fear (vs. neutral) chemosignaling using a different and more optimal statistical model than analysis of variance. However, on the basis of the results obtained for senders and receivers, the possibility was left open that receivers failed to show valence- or emotion-differentiated EMG responses between the happiness and fear condition. Hence, a third comparison—between fear and happiness stimuli—was carried out to complement the initial happiness versus neutral and fear versus neutral comparison.

The adequacy of the identified models was assessed using leave-one-out cross-validation. This approach results in an unbiased estimate of the adequacy of the model by sequentially omitting each participant's response and subsequently repeating the discriminant-analysis process to verify the classification accuracy of the omitted case. The robustness of our discriminant rules under the cross-validation assessment technique should offer reassurance that the one odor repetition per participant was adequate and that the model is not driven by an influential subset of observations. The strength of the findings was underlined with a binomial test. The binomial test compared with chance the proportion of receivers for whom facial EMG patterns were correctly classified. Parallel discriminant analyses were conducted on baseline-corrected and baseline-uncorrected data. Although the baseline-corrected method was both theoretically more justifiable and—in terms of cross-validation classification rate—mathematically superior, the results of both methods are reported.

Even though general linear modeling has been used in previous research (e.g., de Groot et al., 2014a, 2014b; de Groot et al., 2012) to demonstrate EMG response differences as a function of sweat sampled under different conditions, the current research adopted a discriminant-analysis method—a decision that was taken before data collection. The current study is an exploratory exercise, and we are at the stage of making observations, not claims, regarding the hypotheses. By deliberate selection of models and end points in this complex multidimensional problem, it might be possible to present an unduly favorable subset of outcomes by adopting a general-linear-model approach. Discriminant analysis does not presuppose a well-defined model and end point.

The parameters provided along with discriminant analysis should be interpreted as follows. For the baseline-uncorrected method, all numbers are expressed

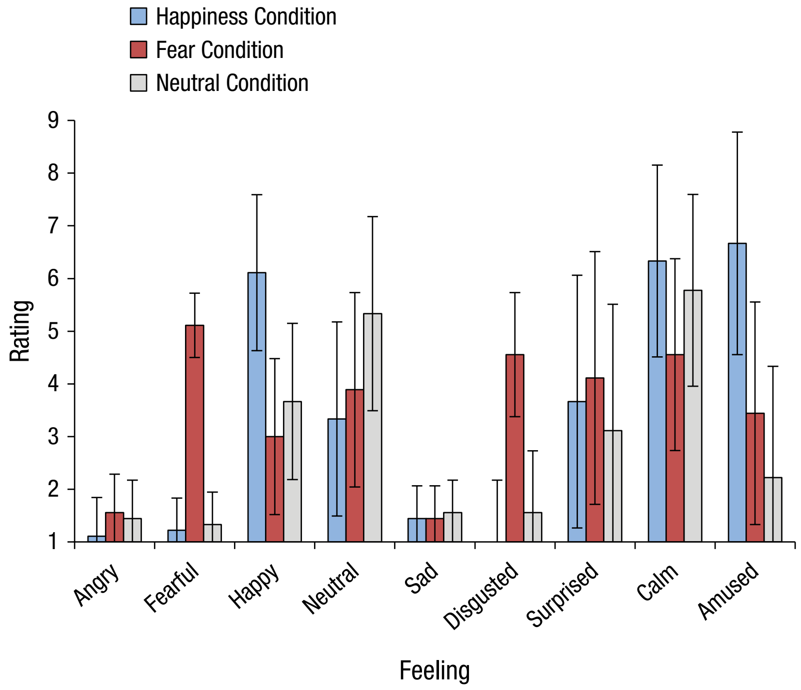

Fig. 3. Mean self-reported feelings of senders as a function of sweat condition. Higher numbers on the y-axis indicate stronger feelings. Error bars represent 95% within-subjects confidence intervals based on the mean square error of each main effect.

relative to mean per participant (i.e., standardized). For example, a figure of .12 implies that the parameter in question was, on average, .12 units higher than was typical for participants across all conditions. For the baseline-corrected method, mean figures are standardized mean differences from baseline. To take a hypothetical example, participants classified into the fear condition exhibit an average difference in medial frontalis activity (from baseline) that is .12 units on the log scale greater than the average of this value across all conditions. In contrast, participants classified into the neutral condition exhibit an average difference from baseline that is –.08 units greater than the average across all conditions.

It follows that on the original (unlogged) scale, average medial frontalis activity of the reactions classified as fear is $e^{.12} = 1.13$ times (i.e., 13%) higher than the average similar figure across all conditions. Similarly, average medial frontalis activity classified as neutral is $e^{-.08} = 0.92$ times (i.e., 8%) lower than the average similar figure across all conditions. In the Results, means and standard errors are reported for illustrative purposes, because unlike what is the case for analysis of variance, means cannot be directly related to a p value.

Generalized linear models based on logistic regression were used to assess secondary outcomes: the proportion of pleasant (vs. unpleasant) responses in the Chinese symbol task and the proportion of global (vs. local) responses in the Navon and Kimchi-Palmer tasks. In these analyses, participant was treated as a random effect, and condition, task, the condition-by-task interaction, and order of application were entered as fixed effects. Before experimenters were made aware of the sweat conditions, the absence of evidence for a difference between the Navon and Kimchi-Palmer tasks across sweat conditions of the opposite valence (happy, fear) was verified by assessing the (coded) Task × Sweat Condition interaction. Hence, although not ruling out the possibility of a difference between the Navon and Kimchi-Palmer tasks, this result indicated that both tasks assessed the same response, and thus it was valid to combine the results yielded by these tasks into a more powerful within-subjects analysis.

Results

Part 1: sweat-sample collection (senders)[1]

Because the mean room temperature did not significantly differ between the happiness (M = 23.16 °C, SD = 0.18), fear (M = 23.22 °C, SD = 0.16), and neutral (M = 23.22 °C, SD = 0.27) conditions, $F(2, 16) = 0.37$, $p = .70$, any differences in sweat production could be ascribed to physiological changes that accompanied the induced state. The effectiveness of the state-induction procedure was determined by analyzing implicit (affect projected on Chinese symbols), explicit (self-report), and objective (sweat production) measures.

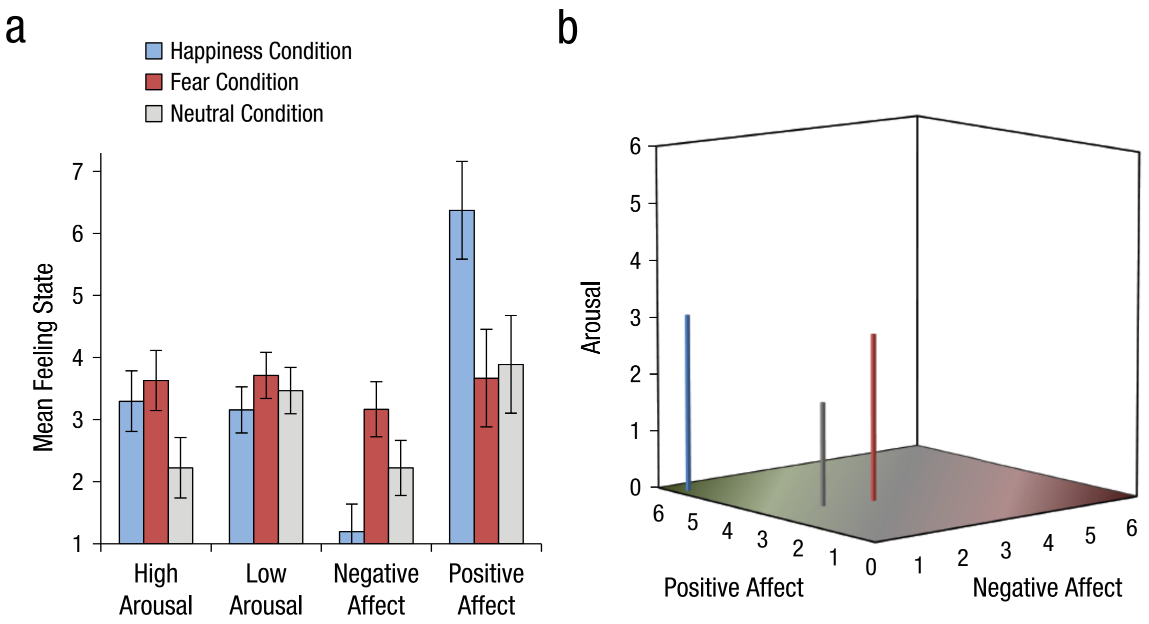

Fig. 4. Experience of senders transformed into dimensions of core affect. The graph in (a) shows mean self-reported feeling as a function of core-affect dimension and sweat condition. Combinations of self-report ratings were averaged to create indicators of low arousal (neutral, sad, calm), high arousal (angry, fearful, happy, disgusted, surprised, amused), positive affect (happy, calm, amused), and negative affect (angry, fearful, sad, disgusted). Error bars represent 95% within-subjects confidence intervals based on the mean square error of each main effect. The graph in (b) represents core-affect items in three-dimensional space, with one dimension for positive affect, one for negative affect, and one for arousal. The range of scores for positive and negative affect (0–6) corresponds to Likert-scale scores of 1 through 7; arousal scores were calculated by subtracting low-arousal-item scores from high-arousal-item scores, with higher scores indicating greater arousal.

With regard to the implicit-affect measure, a repeated measures analysis of variance (ANOVA) on the proportion of Chinese symbols rated as pleasant showed no evidence of a significant difference between the happiness (M = .57, SD = .21) and neutral (M = .60, SD = .29) conditions, $F < 1$. This was contrary to the prediction that participants in the happiness condition would rate more symbols as pleasant than would participants in the neutral condition. A larger sample size may be required to obtain evidence for this prediction about this subtle mood-manipulation check.

Nonparametric analysis of the explicit measures did reveal significant differences in self-reported feelings as a function of the induced state (Fig. 3). A Friedman's test showed significant differences across sweat conditions in reported happiness, $\chi^2(2, N = 9) = 12.77$, $p = .002$, and fear, $\chi^2(2, N = 9) = 16.76$, $p < .001$, as well as a nonsignificant trend for neutral feelings, $\chi^2(2, N = 9) = 5.03$, $p = .081$. The planned follow-up Wilcoxon signed-rank test indicated that participants reported more fear in the fear condition than in the happiness condition, $Z = 2.70$, $p = .007$, $r = .55$, and the neutral condition, $Z = 2.72$, $p = .007$, $r = .54$ (happiness vs. neutral comparison: $Z = 0.44$, $p = .66$). More happiness was reported in the happiness condition than in the fear condition, $Z = 2.69$, $p = .007$, $r = .55$, and the neutral condition, $Z = 2.54$, $p = .011$, $r = .53$ (fear vs. neutral comparison: $Z = 0.87$, $p = .39$). Finally, neutral ratings were higher in the neutral condition relative to the happiness condition, $Z = 2.23$, $p = .026$, $r = .50$, and the fear condition (a nonsignificant trend), $Z = 1.72$, $p = .086$ (happiness vs. fear comparison: $Z = -1.00$, $p = .32$). Although there were no differences in self-reported anger, $\chi^2(2, N = 9) = 2.00$, $p = .37$; surprise, $\chi^2(2, N = 9) = 1.03$, $p = .60$; and sadness, $\chi^2(2, N = 9) = 0.33$, $p = .85$, differences across conditions were observed for self-reported amusement, $\chi^2(2, N = 9) = 12.74$, $p = .002$; calmness, $\chi^2(2, N = 9) = 7.28$, $p = .026$; and disgust, $\chi^2(2, N = 9) = 15.93$, $p < .001$. The pattern of disgust is consistent with findings for senders in studies inducing fear by means of video clips, which repeatedly show high disgust ratings (e.g., de Groot et al., 2014a, 2014b).

An analysis of core affect dimensions (low arousal, high arousal, negative affect, and positive affect) furnishes a complementary understanding. A repeated measures ANOVA on combined high-arousal items (angry, fearful, happy, disgusted, surprised, amused) indicated a significant difference among sweat conditions, $F(2, 16) = 10.25$, $p = .001$, $\eta^2 = .42$. Follow-up paired t tests demonstrated that participants in the happiness condition, $t(8) = 3.31$, $p = .011$, and the fear condition, $t(8) = 3.94$, $p = .004$, scored higher on the high-arousal items, compared with participants in the neutral condition (Fig. 4).

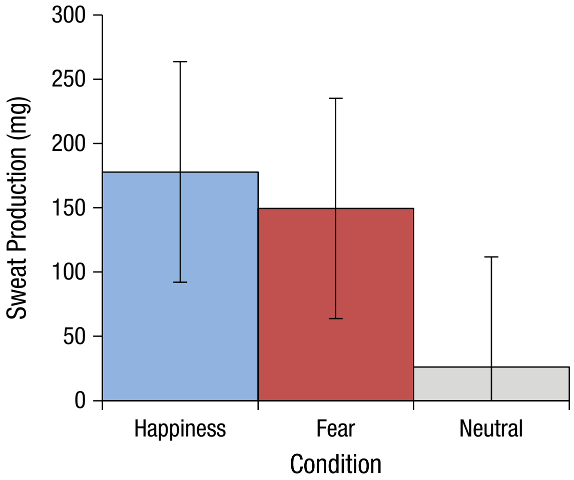

Fig. 5. Mean sweat production in senders as a function of sweat condition. Error bars represent 95% within-subjects confidence intervals based on the mean square error of the main effect.

Results for high-arousal items were not significantly different in the fear and happiness conditions, $t(8) = 1.34$, $p = .22$, and there was no main effect of sweat condition for low-arousal items (neutral, sad, calm), $F(2, 16) = 2.51$, $p = .113$. However, significant effects were observed for positive-affect items (happy, calm, amused), $F(2, 16) = 16.31$, $p < .001$, $\eta^2 = .60$, and negative-affect items (angry, fearful, sad, disgusted), $F(2, 16) = 25.97$, $p < .001$, $\eta^2 = .63$. Participants in the fear condition scored higher on negative-affect items than did participants in the happiness condition, $t(8) = 8.31$, $p < .001$, and the neutral condition, $t(8) = 4.70$, $p = .002$, whereas participants in the happiness condition scored higher on positive-affect items than did participants in the fear condition, $t(8) = 6.72$, $p < .001$, and the neutral condition, $t(8) = 4.58$, $p = .002$. Other comparisons were not significant.

Third, a repeated measures ANOVA on sweat production with sweat condition as the single factor revealed a significant main effect, $F(2, 16) = 3.98$, $p = .04$, $\eta^2 = .16$. Follow-up paired *t* tests indicated two nonsignificant trends (see Fig. 5). Relative to the neutral condition (M = 26.10 mg, SD = 43.86), people in both the happiness condition (M = 177.8 mg, SD = 207.85), $t(8) = 2.28$, $p = .052$, and the fear condition (M = 149.40 mg, SD = 170.30) produced more armpit sweat, $t(8) = 2.21$, $p = .058$. Notably, sweat production did not differ significantly between the happiness and the fear condition, $t(8) = 0.59$, $p = .569$.

In sum, the combined results suggest that predominantly positive affect was elicited in the happiness condition and predominantly negative affect was induced in the fear condition. Given that the current experimental context involved an explicit manipulation of feeling state by means of videos, the senders could further label their experience as “happy” in the happiness condition, “fearful” (but also disgusted) in the fear condition, and “neutral” (but also calm) in the neutral condition.

Table 1. Results for Receivers: Leave-One-Out Cross-Validation Outcomes for Baseline-Corrected and Baseline-Uncorrected Models

Reference stimulus and classification	Baseline corrected	Baseline uncorrected
Fear		
Fear → fear	23	22
Fear → neutral	12	13
Neutral → fear	15	13
Neutral → neutral	20	22
Incorrect	39% (27/70)	37% (26/70)
Happiness		
Happiness → happiness	29	21
Happiness → neutral	6	14
Neutral → happiness	9	10
Neutral → neutral	26	25
Incorrect	21% (15/70)	34% (24/70)
Happiness		
Happiness → happiness	26	25
Fear → happiness	8	14
Happiness → fear	9	10
Fear → fear	27	21
Incorrect	24% (17/70)	34% (24/70)

Note: Values reflect the number of observations (from a total of 35) from the sweat condition specified before the arrow that were classified into the sweat condition specified after the arrow.

Table 2. Results for Receivers: Discriminant Analysis

Comparison and method	Leave-one-out cross-validation	*p*
Happiness vs. neutral stimuli		
Baseline corrected	22/35	< .001
Baseline uncorrected	17/35	.002
Fear vs. neutral stimuli		
Baseline corrected	16/35	.006
Baseline uncorrected	12/35	.14
Happiness vs. fear stimuli		
Baseline corrected	21/35	< .001
Baseline uncorrected	19/35	< .001

Note: The leave-one-out cross-validation values indicate the number of receivers divided by the total number of receivers with both conditions correctly classified by the method. Under the null hypothesis, which implies that there was no relationship between response and treatment, only 1 in 4 receivers should be categorized completely correctly: *p* represents the *p* value of the binomial test (proportion of correct classifications under the null hypothesis = 25% vs. proportion of correct classifications under the alternative hypothesis > 25%).

Part 2: odor exposure (receivers)

The first step in analyzing the data from Part 2 was to test whether there was evidence of correspondence between the state of the receiver and the state of the sender. When exposed to sweat from happy senders, receivers were expected to show a happy facial EMG response that would partially reflect the state of the sender during sweat production. Similarly, receivers were expected to show a fearful EMG response when presented with fear sweat from senders. According to leave-one-out cross-validation, the identified models based on facial EMG activity patterns could adequately distinguish between the happiness, fear, and neutral conditions (Table 1).

The strength of the findings was underlined with a binomial test. Regardless of the application of baseline correction, receivers demonstrated significantly different patterns of facial-muscle activity following exposure to sweat obtained from senders induced to be in a happy state, compared with senders induced to be in a fearful state or in the neutral condition (Table 2).

Evidence for a behavioral simulacrum of happiness in receivers following exposure to sweat obtained from senders induced to be in a happy state would be reflected by a Duchenne smile. Discriminant analysis was used to determine to what extent facial-muscle-activity patterns in the happiness condition were different from those patterns in the neutral condition (Tables S1–S6 in the Supplemental Material present a complete list of means and standard errors of each facial EMG parameter classified into the discriminant model). The identified baseline-uncorrected method revealed that relative to the neutral condition, the happiness condition was characterized by a rapid peak in orbicularis oculi activity and a delayed peak in zygomaticus major activity. Furthermore, the baseline-corrected method indicated that happiness was characterized by a high peak and lower variation in orbicularis oculi activity in addition to high zygomaticus major activity. Further inspection of facial-muscle activity revealed patterns consistent with our hypothesis for the baseline-corrected method (Fig. 6), with high activity in the zygomaticus major (M_{log} = .14, corresponding to 15% higher than the average similar figure across all conditions, SE_{log} = .04) and orbicularis oculi (M_{log} = .10, corresponding to 11% higher than the average similar figure across conditions, SE_{log} = .03) reflecting the presence of a Duchenne smile in the happiness condition, whereas activity in these muscles in the neutral condition did not reflect a Duchenne smile (zygomaticus: M_{log} = −.19, 17% lower, SE_{log} = .04; orbicularis: M_{log} = −.13, 12% lower, SE_{log} = .05).

Next, evidence for a behavioral simulacrum of fear was derived from elevated medial frontalis activity (i.e., eyebrow lifting) following exposure to sweat from senders induced to be in a fearful state. The baseline-uncorrected method suggested that relative to the neutral condition, the fear condition was characterized by high variation in medial frontalis activity and a high peak in orbicularis oculi activity, whereas relatively high variation in orbicularis oculi activity was characteristic of the neutral condition. The baseline-corrected method again revealed that high variation in orbicularis oculi activity was characteristic of the neutral condition, whereas fear was characterized by high activity in both the zygomaticus major (M_{log} = .05, SE_{log} = .04; neutral: M_{log} = −.21, SE_{log} = .04) and medial frontalis (M_{log} = .07, SE_{log} = .02; neutral: M_{log} = −.11, SE_{log} = .03). In sum, further inspection of facial-muscle activity indicated that besides a marked increase in zygomaticus activity (+5% in fear, −19% in neutral), the hypothesized increase in medial frontalis activity occurred in the fear condition only (i.e., 7% higher than the average similar figure across all conditions; neutral: −10%).

The main purpose of the current research was to examine chemosignaling of happiness. However, comparing facial EMG responses classified as happy and fearful with only facial EMG responses in the neutral condition leaves open the possibility that participants failed to show facial EMG responses that differed in conditions representing opposite ends of the valence dimension. Hence, discriminant analysis was used to determine whether patterns of facial-muscle activity in the happiness condition were different from those patterns in the fear condition. The baseline-uncorrected method indicated that the fear condition was characterized by a high and delayed peak in zygomaticus major activity and greater variation in medial frontalis activity, whereas the

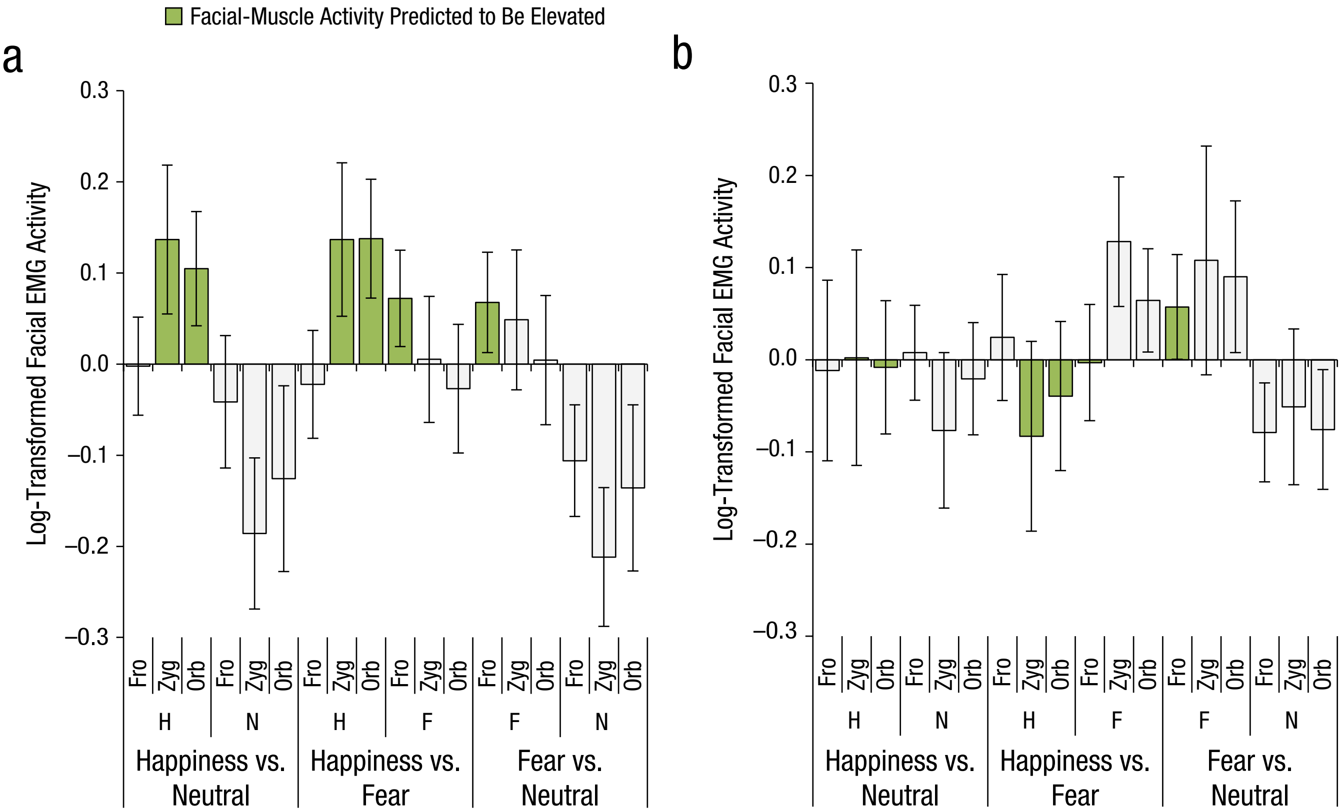

Fig. 6. Mean log-transformed facial electromyographic (EMG) activity in receivers, separately for (a) baseline-corrected data and (b) baseline-uncorrected data. Results are shown for each of the three muscles measured and for the three comparisons between sweat conditions. The green bars reflect facial-muscle activity predicted to be elevated. Fro = medial frontalis; Zyg = zygomaticus major; Orb = orbicularis oculi; H = happy; F = fear; N = neutral. Error bars represent 95% confidence intervals.

happiness condition was characterized by high variation in zygomaticus major activity, a delayed peak in orbicularis oculi activity, and high medial frontalis activity. Whereas the baseline-uncorrected method did not reveal emotion-differentiated facial EMG responses, the baseline-corrected approach again revealed results that were consistent with our hypothesis. Whereas fear was characterized by a delayed peak in zygomaticus major activity and a high peak in medial frontalis activity, the happiness condition was characterized by a delayed peak in orbicularis oculi activity and high activity in both the orbicularis oculi ($M_{\log}$ = .14, $SE_{\log}$ = .03; fear: $M_{\log}$ = −.03, $SE_{\log}$ = .03) and zygomaticus major ($M_{\log}$ = .14, $SE_{\log}$ = .00; fear: $M_{\log}$ = .01, $SE_{\log}$ = .04). Further inspection of mean facial-muscle activity indicated that receivers displayed a Duchenne smile in the happiness condition only (orbicularis oculi: happy = 15%, fear = −3%; zygomaticus major: happy = 15%, fear = 1%), consistent with our hypothesis, whereas elevated medial frontalis activity was observed in the fear condition only ($M_{\log}$ = .07, corresponding to 9% higher than the average similar figure across all conditions, $SE_{\log}$ = .03; vs. happy, 2% lower: $M_{\log}$ = −.02, $SE_{\log}$ = .03; Figs. S1 and S2 in the Supplemental Material present canonical plots showing the data that best separate the conditions in two-dimensional space).

In sum, receivers emulated the state of the sender, at least behaviorally. Exposure to sweat obtained from fearful individuals induced medial frontalis activity, which replicates previous research (de Groot et al., 2014a, 2014b; de Groot et al., 2012). More important, exposure to sweat obtained from happy individuals elicited a Duchenne smile in receivers. Hence, the current research provided the first demonstration of behavioral synchronization between sender and receiver (cf. Chen & Haviland-Jones, 2000; Zhou & Chen, 2009) realized by means of odors obtained during a positive state.

Aside from eliciting a happy facial expression, exposure to sweat from senders induced to be happy was expected to modulate perceptual processing in a manner that would partially reflect the happy state of the sender. Relative to the fear condition, receivers in the happiness condition were expected to display a more global processing style. Indeed, subsequent examination of global-local responses on the Navon and Kimchi-Palmer task revealed strong evidence of a difference in the expected direction between the happiness and fear conditions, $F(1, 64) = 5.54$, $p < .001$ (Fig. S3 in the Supplemental Material presents each individual's global:local response ratio), with a significantly greater percentage of global responses reported in the happiness condition (Navon: $M = 81.0\%$; Kimchi-Palmer: $M = 71.0\%$) than in the fear condition (Navon: $M = 66.1\%$; Kimchi-Palmer: $M = 57.4\%$). Notably, although the Navon task was significantly more likely to provoke global responses than the Kimchi-Palmer task, $F(1, 63) = 3.39$, $p < .001$, the conclusion regarding the impact of sweat condition (happiness, fear) on global/local processing style was not distorted because differences between sweat conditions were not task dependent, $F < 1$. Thus, the relatively more global focus observed while receivers were being exposed to sweat obtained from senders induced to be happy was consistent with previous research showing similar processing styles in participants under positive mood conditions (e.g., Fredrickson, 2001; Gasper & Clore, 2002).

In addition to examining whether receivers emulated the happy state of the sender in terms of behavior (facial EMG) and perception (Navon and Kimchi-Palmer tasks), we analyzed whether the affective state of receivers differentially induced by the sweat conditions would spill over to the judgment of seemingly unrelated Chinese symbols. A greater proportion of Chinese symbols was expected to be judged as pleasant in the happiness condition than in the fear condition. However, an ANOVA revealed no evidence for the influence of sweat condition on implicit affect, $F(2, 100) = 1.09$, $p = .34$, given the greater proportion of symbols identified as positive in the happiness compared with fear condition, $M_{\text{logit}} = .06$, 95% confidence interval (CI) = [−.22, .34], happiness compared with neutral condition, $M_{\text{logit}} = -.14$, 95% CI = [−.42, .14], and fear compared with neutral condition, $M_{\text{logit}} = -.20$, 95% CI = [−.48, .08].

Near the end of the experiment, receivers rated the properties of the sweat they had been exposed to. A repeated measures ANOVA found no statistically significant difference between conditions in self-reported odor intensity, $F(2, 68) = 2.07$, $p = .134$ (happiness: $M = 4.06$, $SD = 1.19$; fear: $M = 4.03$, $SD = 1.22$; neutral: $M = 3.60$, $SD = 1.09$), and pleasantness, $F(2, 68) = 0.22$, $p = .753$ (happiness: $M = 3.71$, $SD = 1.02$; fear: $M = 3.80$, $SD = 1.07$; neutral: $M = 3.86$, $SD = 1.06$). Although sweat rated as more intense was also considered less pleasant ($r = -.41$), facial EMG activity appeared to be independent of pleasantness and intensity ratings, aside from faster medial frontalis peak amplitude when more-intense sweat was presented ($r = -.26$; a complete list of multivariate correlations between odor ratings and facial EMG parameters are displayed in Table S7, Fig. S4, and Fig. S5 in the Supplemental Material). Furthermore, receivers could discriminate the sweat of fearful individuals (15/35 over two tests; proportion under the null hypothesis = .25, $p = .016$) and happy individuals (24/35; proportion under the null hypothesis = .50, $p = .02$) from that of individuals in the neutral condition, but they could not distinguish between sweat obtained from happy and fearful individuals (corrected N/total N: 17/35; proportion under the null hypothesis = .5, $p = .50$), as was revealed by a binomial test on the results of the sweat-discrimination task.

Discussion

The current research was designed to examine whether sweat produced by happy senders elicits a behavioral, affective, and perceptual simulacrum of the senders' state in receivers. Indeed, exposure to sweat from happy senders elicited a happier facial expression than did sweat from fearful or neutral senders; further, sweat from happy senders elicited a more global processing style relative to sweat from fearful senders. However, the misattribution of happy (positive) and fearful (negative) affect to the judgment of affectively neutral Chinese symbols was not observed. Furthermore, facial-muscle responses could not be related to pleasantness and intensity ratings of sweat.

Although seemingly conflicting at first, the pattern of results reported here becomes clearer when a distinction is made between measures drawing on language (e.g., sweat ratings, Chinese symbol task) and those that are unrelated to language (e.g., facial EMG, global-/local-processing tasks). The apparent disconnect between olfaction and language (Lorig, 1999) is supported by previous research revealing a similar discrepancy between EMG responses and results on the Chinese symbol task, which requires participants to select one label (e.g., pleasant) over another (e.g., unpleasant; de Groot et al., 2014b). Concerning pleasantness ratings of sweat, the current findings dovetail with the majority of emotional-chemosignaling studies (i.e., 13 out of 21) documenting no statistical differences across sweat conditions on this variable (e.g., Prehn et al., 2006). This does not imply that odor pleasantness bears no relation to EMG responses, yet it suggests that language-based measures and language-unrelated measures tap different processes. In olfaction research, directly asking receivers what they feel—a common practice in psychology (see Baumeister, Vohs, & Funder, 2007, for a critique)—may not be optimal. Alternatively, a more successful approach would be to infer the construct of interest through within-subjects designs, using implicit, non-language-related measures of what can be labeled "actual behavior" (Baumeister et al., 2007).

With regard to actual behavior, the question remains whether one can classify a state as a discrete emotion rather than as a core affect characterized by valence and arousal (Russell & Barrett, 1999). Two issues are important in this respect. First, do the measures reflect discrete emotions or core affect? Second, did the experimental context provide consciously accessible information about the state? With regard to the first point, some researchers consider facial-muscle activity indicative of discrete emotions (e.g., Ekman et al., 2002), whereas others remain skeptical as to whether one can distinguish beyond positive and negative affect (for a review, see Hess & Fischer, 2013). Because the global-/local-processing task and Chinese symbol task were additional measures of global affect rather than discrete states, the statement that receivers emulated the discrete state of the sender is probably too strong. Notably, what may distinguish the experience of the sender from that of the receiver is the presence of an explicit experimental manipulation allowing senders to label their experience as "fear" or "happiness," whereas the same did not hold for receivers, who had no (audiovisual) contextual information to explicitly label their experience. Note that this does not contest the notion of olfactory communication, as receivers showed a simulacrum of core affect based on non-language-related measures. Hence, on the basis of these relatively more sensitive measures, we can conclude that humans appear to produce different chemosignals when experiencing fear (negative affect) than when experiencing happiness (positive affect). The obvious next step is to test this assumption by examining the different chemical footprints responsible for eliciting positive and negative affect in receivers outside of awareness.

Although funneled debriefing indicated that receivers were unaware of the contents of the vials, the presence of an experimenter who applied nose clips and removed and opened vials may have elicited non-odor-related anticipatory responses, such as those recorded over the facial muscles shortly after odor onset. Although the use of a double-blind, within-subjects design may counteract potential confounds introduced by conspicuous odor presentation, future research needs to corroborate whether the exploratory baseline-correction method reported here adequately filters out non-odor-related anticipatory facial-muscle responses. Presenting odors using vials is suboptimal compared with using an olfactometer (cf. Prehn et al., 2006), which delivers odors directly to the nose with a continuous airflow following the opening of a valve by a preprogrammed trigger.

Notwithstanding these limitations, we took the first step in the present research toward resolving conflicting evidence (Chen & Haviland-Jones, 2000; Zhou & Chen, 2009, 2011) as to whether humans communicate happiness via chemosignals; we did so by exploring whether the behavioral, affective, and perceptual processes in a receiver signify a simulacrum of the happy state of the sender. Happiness benefits the individual on multiple levels, as it restores the damaging impact of negative emotions on the cardiovascular, neuroendocrine, and immune systems (Steptoe, Wardle, & Marmot, 2005) and broadens attention to inspire creative ideas (Fredrickson, 2001). Humans are a social species with the capacity to share these positive effects, using not only modalities such as vision, hearing, and touch, but also—as this exploratory study indicates—the sense of smell.

Author Contributions

G. R. Semin, M. A. M. Smeets, and in a later stage J. H. B. de Groot contributed to the study's theoretical basis. G. R. Semin, M. A. M. Smeets, J. H. B. de Groot, P. J. Bulsing, C. G. Blonk, and M. J. Rowson designed, set up, and conducted the study and interpreted the data. J. H. B. de Groot programmed the experiments. M. J. Rowson performed statistical analyses. J. H. B. de Groot wrote the manuscript. All authors reviewed the manuscript.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at http://pss.sagepub.com/content/by/supplemental-data

Open Practices

All data have been made publicly available via Dutch Dataverse Network and can be accessed at http://dataverse.nl/dvn/dv/chemosignaling. The complete Open Practices Disclosure for this article can be found at http://pss.sagepub.com/content/by/supplemental-data. This article has received badges for Open Data and Open Materials. More information about the Open Practices badges can be found at https://osf.io/tvyxz/wiki/view/ and http://pss.sagepub.com/content/25/1/3.full.

Note

1. The small sample size ($N = 9$) should be taken into account when interpreting the results reported for senders.

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