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The Effects of Emotional Visual Context on the Encoding and Retrieval of Body Odor Information

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Abstract

Conditions during information encoding and retrieval are known to influence the sensory material stored and its recapitulation. However, little is known about such processes in olfaction. Here, we capitalized on the uniqueness of body odors (BOs) which, similar to fingerprints, allow for the identification of a specific person, by associating their presentation to a negative or a neutral emotional context. One hundred twenty-five receivers (68 F) were exposed to a male BO while watching either criminal or neutral videos (encoding phase) and were subsequently asked to recognize the target BO within either a congruent or an incongruent visual context (retrieval phase). The results showed that criminal videos were rated as more vivid, unpleasant, and arousing than neutral videos both at encoding and retrieval. Moreover, in terms of BO ratings, we found that odor intensity and arousal allow to distinguish the target from the foils when congruent criminal information is presented at encoding and retrieval. Finally, the accuracy performance was not significantly different from chance level for either condition. These findings provide insights on how olfactory memories are processed in emotional situations.

Keywords

body odors, context-dependent memory, emotion, olfaction

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Introduction

Despite the reduced attention for olfaction in human perception (McGann, 2017), its role in episodic memory has long been investigated. It has even become paradigmatic to refer to the "Proust effect" to present the ability of odors to allow us to relive memories from our past (Chu & Downes, 2002; Herz & Schooler, 2002; Willander & Larsson, 2006). If an odor, like the odor of the Proustian madeleine dipped in the tea, is contextual to the encoding of a specific event (e.g., Sunday mornings at Proust aunt's house; Proust, 1913 in Jellinek, 2004), then such odor can later constitute a cue for the retrieval of that memory. So far, a wealth of behavioral studies demonstrated that memory performance improves when odors congruent with the to-be-retrieved information are present at encoding (Ball, Shoker, & Miles, 2010; Herz, 1997; Parker & Gellatly, 1997; Parker, Ngu, & Cassaday, 2001; Schab, 1990; Schwabe, Böhringer, & Wolf, 2009; Smith, Standing, & Man, 1992; Wiemers, Sauvage, & Wolf, 2013). Furthermore, successful retrieval of odor-congruent information seems to be associated with the reactivation of the brain state present at encoding (Reichert et al., 2017). Specifically, many emotional odor-triggered memory effects are underlined by the close anatomical connections between olfactory areas and limbic centers devoted to the processing of emotional (e.g., amygdala) and memory (e.g., hippocampus) information (Saive, Royet, & Plailly, 2014; Wilson, Best, & Sullivan, 2012).

The majority of the available studies have now considered how contextual odors modulate the accurate retrieval of information. However, in few instances, it has been investigated how odor memory can be modulated by the presence of contextual information. In a review, Herz and Engen (1996) report that the emotional context in which an odor is first encountered influences the memory for that odor. For example, an odor that is perceived as pleasant may be first experienced in a pleasant context. This effect is in line with the evidence showing that emotional contexts produce more accurate retrieval performances as compared to nonemotional contexts (e.g., Buchanan, 2007; Kensinger, 2007; Ochsner, 2000), perhaps in virtue of the greater attentional resources captured by salient information (Yiend, 2010), as in the case of emotional versus neutral processing. It is indeed common that when the contextual information of a to-be-retrieved memory is highly arousing, then memory accuracy is significantly improved (Dolcos, LaBar, & Cabeza, 2005; Holland & Kensinger, 2012; Libkuman, Stabler, & Otani, 2004). However, when encoding occurs during emotional arousal (Burke, Heuer, & Reisberg, 1992; Christianson & Loftus, 1991; Reisberg & Heuer, 1992), in particular when the arousal has a negative connotation, such memory boost can be confined to gist but not to detailed information (Adolphs, Tranel, & Buchanan, 2005; Houston, Clifford, Phillips, & Memon, 2013). Moreover, another factor that is known to have an impact in the accurate identification of encoded information is the emotional congruency between encoding and retrieval contexts, which influences the sensory material stored and its recapitulation. In previous studies manipulating context congruency, individuals could more accurately retrieve information when the context presented at encoding was reinstated (Schwabe et al., 2009; Smith, Handy, Angello, & Manzano, 2014). In olfactory contexts, these mechanisms are still under investigation.

Perceptual complexity (or informational load) is a key variable in determining the ability to retain details about objects (Eng, Chen, & Jiang, 2005). Although this basic property has been extracted by using visual stimuli, it is likely to be translated to the olfactory domain. Olfactory stimuli, and particularly of body odors (BOs), which are unique mixtures of hundreds of chemical compounds (Zeng et al., 1991) comparable to fingerprints (Penn et al., 2007), are inherently complex and, as other odors, associated with poor semantic representations (Olofsson et al., 2014). It is then expected that memory for complex olfactory stimuli, such as BOs, may suffer in identification accuracy (Cain, 1979), and particularly when the context in which the encoding occurs is incongruent to the contextual features at retrieval. Furthermore, despite the fact that the majority of the BO effects reported occurs below conscious control (Lundström & Olsson, 2010; Parma et al., 2017), the ability to explicitly report the perceptual features of the BO related to danger (i.e., disease signals) may reveal the participants' ability to distinguish specific perceptual features in the encoded BO (e.g., Olsson et al., 2014). Contrarily to the prediction that arousal may hamper identification accuracy for BOs, two recent studies from our laboratory presented BOs while participants watched criminal and neutral videos. The results showed an enhanced memory performance for target BOs that were encoded under the arousing condition (Alho et al., 2015). However, the effects seemed to be short-lived (15 min; Alho et al., 2016), and no emotional manipulation was performed at retrieval. In previous studies (e.g., de Groot, Semin, & Smeets, 2014), the emotional context is manipulated to induce in the donors different emotional states, namely to directly affect BO production. In that study, receivers were randomly presented with fear sweat and neutral sweat while watching threatening and nonthreatening videos that confirmed or contradicted the olfactory information.

Instead, in the present study, we use the BOs collected in a neutral context and manipulate the emotional context to which participants are exposed. We manipulated the emotional context not only at encoding (as previously done) but also at retrieval. Thus, we exposed two groups of participants to congruent visual contexts (either neutral [group N-N] or criminal [group C-C]) and two different groups of participants to incongruent visual contexts (either starting with a neutral [group N-C] or criminal [group C-N] video). After having smelled each of the BO items, participants were asked to explicitly rate perceptual features (i.e., intensity, pleasantness, and arousal) of each BO and finally select the target BO presented at encoding.

We expect the accuracy identification performance at retrieval to be maximal for the congruent groups (N-N and C-C), in line with the idea that emotional congruency between contexts at encoding and retrieval boosts memory performance (Schwabe et al., 2009; Smith et al., 2014). Furthermore, in light of the ability to explicitly report perceptual differences related to danger signals (Olsson et al., 2014), we hypothesize that participants exposed to congruent contextual information at encoding and retrieval may have more attentional resources to differentiate the target BO and foils based on either odor intensity or arousal. These effects should be maximal in the C-C group, in virtue of the exposure to danger information (Li, Moallem, Paller, & Gottfried, 2007; Parma, Ferraro, Miller, Åhs, & Lundström, 2015). Considering the inverse relationship linking odor intensity and pleasantness (e.g., Doty, Orndorff, Leyden, & Kligman, 1978), we would expect odors perceived as more intense (e.g., C-C and C-N) to be considered less pleasant when they act as targets rather than foils.

Materials and Methods

All the experimental procedures of this study were approved by the scientific council of the University of Aveiro and were in accordance with the Declaration of Helsinki and the standards set by the American Psychological Association. Written informed consent was obtained from all the individuals enrolled in the study, and they were rewarded with course credits. Below, we will separately report the materials and methods for the BO collection and the BO transmission part of the study.

BO Collection

Donors and Collection Procedure

BO samples were collected from the armpits of 25 healthy male university students, aged between 17 and 29 years ($M = 21.4$, $SD = 2.6$) who volunteered to participate. Selected donors were reported to be healthy; not to suffer from any type of physical, metabolic, or mental disease; nonsmokers; and heterosexual (Martins et al., 2005). To ensure the quality of the collected BO, participants followed dietary and hygienic restrictions since the day before the collection (e.g., Alho et al., 2015; Parma et al., 2017). Previously to the BO collection, each participant was given a kit with the necessary material. These included a ziplock bag containing two cotton disks (*Laboratoires Mercurochrome*; identified with an L and an R, which should be placed on the left and right armpits, respectively), a hypoallergenic fragrance-free body shower gel (*A-Derma Avoine Rhealba*), a portion of medical adhesive tape (to hold the cotton disks and prevent displacements), and a paper towel and a white cotton T-shirt (*SportZone*), packed separately. In order to ensure that the T-shirts were clean and fragrance-free, which could damage the quality of the collected BOs, these were washed with a fragrance-free detergent (ECOS^{TM}, earth-friendly products) and water (Alho et al., 2015; Heckmann, Teichmann, Pause, & Plewig, 2003). Oral and written instructions were given regarding the BO collection procedure, and a written informed consent was signed by each donor, as well as a sociodemographic questionnaire. Therefore, on the BO collection day, using the materials provided in the kit, donors had to shower with the body shower gel drying their bodies with the paper towel and posteriorly securing the cotton disks on the respective armpits with the medical adhesive tape. Next, they wore the T-shirt to prevent displacements of the disks. The collection was always done during the morning, placing the cotton disks from 9:00 a.m. and removing them 4 hr later (1:00 p.m.). Subsequently, the disks were removed and carefully sealed in the ziplock bag and frozen at a temperature of $-20\,^{\circ}$C. All donors were debriefed, and the compliance to the procedures was verified. Course credit reward was provided upon completion of the donation procedures.

BO Transmission

Receivers

The original sample was composed of 171 participants (94 F). The receivers included in the final sample were all those who (a) reported not to have health issues or undergoing drug treatment known to be related to olfactory alterations (excluded $N = 18$), (b) reported to be heterosexual (excluded $N = 3$), (c) scored at the 16-item Sniffin' Sticks identification test above the cutoff of 11 (excluded $N = 24$), (d) reported to be younger than 35 ($N = 1$ older was excluded), and (e) did not show emotional dysregulation in the range of clinical anxiety (State-Trait Anxiety Inventory [STAI] > 55, $N = 16$) and depression (Beck Depression Inventory [BDI] > 19, $N = 2$). The final sample included 125 receivers (68 F) between the ages of 17 and 31 ($M = 21.6$, $SD = 2.99$). The sample was divided into four groups, each of which was administered one experimental condition in line with a between-subject design. Specifically, a group was presented with a neutral video at encoding and retrieval (N-N), a group was presented with a criminal video at encoding and retrieval (C-C), and two groups were presented with an emotional-incongruent video at encoding and retrieval (N-C and C-N). The presentation order of the target BO and the foils was randomized across participants. No significant sociodemographic, olfactory identification skills or anxiety trait and depressive mood differences—known to contribute to altered olfactory or memory processing—were revealed across groups. Please refer to Table 1 for details.

Experimental Stimuli

The previously collected BOs were presented in odor-free glass jars and constituted the target and foil odor stimuli (Alho et al., 2015, 2016). Please note that the foils were four BOs of the same emotional tone of the target which were not presented at encoding. BOs were thawed at least 1 hr before testing and placed in the glass jars, always using disposable gloves when handling the samples. In order to prevent any investigator interference on the target position in the lineup, a double-blind procedure was used. As visual contextual stimuli, 1-min audiovisual presentations (video clips) were used (the same as in Alho et al., 2015). Five of these were rated as emotionally neutral (e.g., couple walking by the sea) and five as arousing, given the criminal nature of the images portrayed (e.g., domestic violence).

Table 1. Sample Description.

	N-N $N = 27$	C-C $N = 34$	N-C $N = 30$	C-N $N = 34$	p value	N
Age	21.8 (3.17)	21.5 (3.03)	21.2 (3.56)	21.9 (2.72)	.845	125
Sex: Female	55.6%	55.9%	50.0%	55.9%	.958	125
Contraception: No	52.6%	44.8%	55.6%	44.0%	.838	91
Smoking: No	81.5%	88.2%	90.0%	70.6%	.187	125
Odor ID	13.0 (12.0, 14.0)	13.0 (12.0, 13.0)	12.0 (11.0, 13.0)	13.0 (11.2, 14.0)	.055	125
STAI Trait	39.0 (10.1)	36.8 (7.01)	37.0 (9.82)	37.1 (9.81)	.785	117
BDI	5.67 (4.84)	4.57 (2.98)	5.87 (4.64)	6.50 (5.12)	.407	117

Note. Group combination based on the emotional context presented at encoding—context at retrieval. N = neutral; C = criminal; Odor ID = 16-item Sniffin' Sticks identification test; STAI Trait = Trait anxiety measure; BDI = Beck Depression Inventory.

All receivers watched the video clips on the same computer monitor (DELL E198FP, 1280 × 1024) while using headphones to minimize interferences from external noise.

Procedures

First, recipients were asked to sit comfortably in front of the computer and to complete the informed consent, a sociodemographic questionnaire, a Visual Analogue Scale (VAS) rating their perceived stress, and the STAI-State questionnaire. Next, they watched a 1-min audiovisual clip of an event involving a man and a woman, being informed that the BO belonged to the man present in the video clip. The target BO was presented continuously during the video clip in widemouthed jars, which the receivers held under their noses with their dominant hand. Receivers were instructed to breathe naturally through their noses and to close the jar after the video clip ended. Subsequently, receivers were asked to rate the video clip in terms of vividness, pleasantness, and arousal and to complete a VAS rating their perceived stress, the STAI Trait, and the BDI. This was done to allow a 15-min break from the target BO presentation and the retrieval phase. Receivers watched a new video clip (no odor presentation) and were unaware that they would have to perform a recognition task. The task included five glass jars (one target BO and four foils) aligned horizontally, and the receivers were instructed to identify the odor of the man whose BO they smelled during the first video clip presentation. This five-alternative, forced-choice, target-present procedure was chosen in order to obtain a high-power and bias-free measure of the identification performance. Thus, the receivers were given instructions to smell each BO at a time, from left to right, with no time restriction to smell but without the chance to resample previous BOs. Between smelling each BO, receivers also had to complete a VAS rating on the odor's intensity, pleasantness, and arousal. This measurement only occurred at retrieval. The position of the BO in the lineup was counterbalanced. Next, they rated the second video clip in terms of vividness, pleasantness, and arousal and completed a VAS assessing their perceived stress and the STAI State. As a last task, the receivers completed the 16-item Sniffin' Sticks identification test and were debriefed and rewarded with course credits.

Dependent Variables and Data Analysis

All data were analyzed using R with the *lme4* package (Bates, Mächler, Bolker, & Walker, 2014). To determine whether the movies were effective in inducing different emotional contexts, we performed separate linear mixed models (LMMs) to analyze the subjective emotional ratings (vividness, pleasantness, arousal) of the receivers when watching the videos. The perceptual features of the BOs as rated by the receivers (intensity, pleasantness, familiarity) were treated similarly. The LMMs used for these analyses included the subjective emotional ratings as dependent variable, the Subject ID as a random factor. As fixed factors, we used for the analysis on the video ratings Session (two levels, encoding vs. retrieval) and Emotion (two levels, neutral vs. criminal). For the analysis on the BO ratings (only collected at retrieval), we used Emotion of Video at encoding (two levels, neutral vs. criminal), Emotion of Video at retrieval (two levels, neutral vs. criminal), and Target versus Foil (two levels, target vs. foils) as predictors. ANOVA results were retrieved from the LMM models via the *ANOVA* function. Post hoc contrasts were run via the function *glht* of the *multcomp* package (Hothorn, Bretz, & Hothorn, 2009), following the Tukey method and the Bonferroni correction, which adjust for multiple comparisons. Results reported include the mean and standard deviations. A receiver operating characteristic (ROC) curve analysis was performed to determine the classification accuracy of the ability of participants to recognize the target BO. Such analysis was computed via the klaR package (Roever et al., 2006) using the Naïve Bayes machine learning algorithm, which assumes that the presence of a particular feature in a class (e.g., target in the C-C) is unrelated to the presence of any other feature (e.g., emotional context at encoding, emotional context at retrieval, perceptual information of the odor). Results are visualized via the *ROCR* package (Sing, Sander, Beerenwinkel, & Lengauer, 2005). ROC curves plot the performance of binary classifiers by graphing true positive rates versus false positive rates, with cutoff value from 0 to 1. The closer the curve is to the top-left corner of the graph (the smaller the area above the curve), the better the performance of the model. In an ROC curve, we can compare the performance of a classifier with that of a random guess that would lie at a point along a diagonal line running from the origin (0, 0) to the point (1, 1; this line is sometimes called the line of no discrimination). Anything to the left of this line indicates a better prediction, and anything to the right indicates a worse prediction than chance discrimination. The best possible prediction performance would be denoted by a point at the top-left of the graph at the intersection of the x and y axis (perfect classification). The area under the curve (AUC) is the space in the graph that appears below the ROC curve, and it is a value between 0 and 1. The closer the value of AUC is to 1, the better the performance of the classification model. In all instances, the significance level is set at $p < .05$.

Results

Criminal Videos Were Rated as More Vivid, Unpleasant, and Arousing Than Neutral Videos Both at Encoding and Retrieval

As expected, receivers rated the criminal videos and the neutral videos as being significantly different (please refer to Table 2 for the statistical tests). Indeed, the criminal videos were

Table 2. Video Ratings for All Groups.

	num DF	den DF	*F*	*p* value
Vividness video				
(Intercept)	1	124	815.53	<.001
Session	1	121	1.43	.23
Emotion	**1**	**121**	**44.50**	**<.001**
Session × Emotion	1	121	0.99	.32
Pleasantness video				
(Intercept)	1	124	564.00	<.001
Session	**1**	**121**	**13.51**	**<.001**
Emotion	**1**	**121**	**205.28**	**<.001**
Session × Emotion	**1**	**121**	**7.36**	**.01**
Arousal video				
(Intercept)	1	124	656.04	<.001
Session	1	121	3.28	.07
Emotion	**1**	**121**	**62.40**	**<.001**
Session × Emotion	1	121	0.13	.72

Note. The significant results for all contrasts (excluding the intercept) are reported in bold. num DF = degrees of freedom at the numerator; den DF = degrees of freedom at the denominator.

rated as more vivid either at encoding (C-C: $M = 5.86$, $SD = 2.39$; C-N: $M = 5.94$, $SD = 2.19$) or retrieval (C-C: $M = 5.95$, $SD = 1.76$; N-C: $M = 5.56$, $SD = 2.97$) when compared to the neutral videos. Please refer to Figure 1, Panel A, for visualization. Similarly, in terms of arousal, the criminal videos were once again considered to be significantly more arousing when presented both at encoding (C-C: $M = 5.67$, $SD = 2.56$; C-N: $M = 5.17$, $SD = 2.34$) and retrieval (C-C: $M = 5.98$, $SD = 2.26$; N-C: $M = 5.88$, $SD = 3.01$; please see Figure 1, Panel C). In line with this, the criminal videos were rated at encoding (C-C: $M = 1.61$, $SD = 2.15$; C-N: $M = 1.50$, $SD = 1.44$) and retrieval (C-C: $M = 1.48$, $SD = 1.90$; N-C: $M = 1.88$, $SD = 1.70$) as less pleasant (see Figure 1, Panel B). In summary, the criminal videos were rated as more

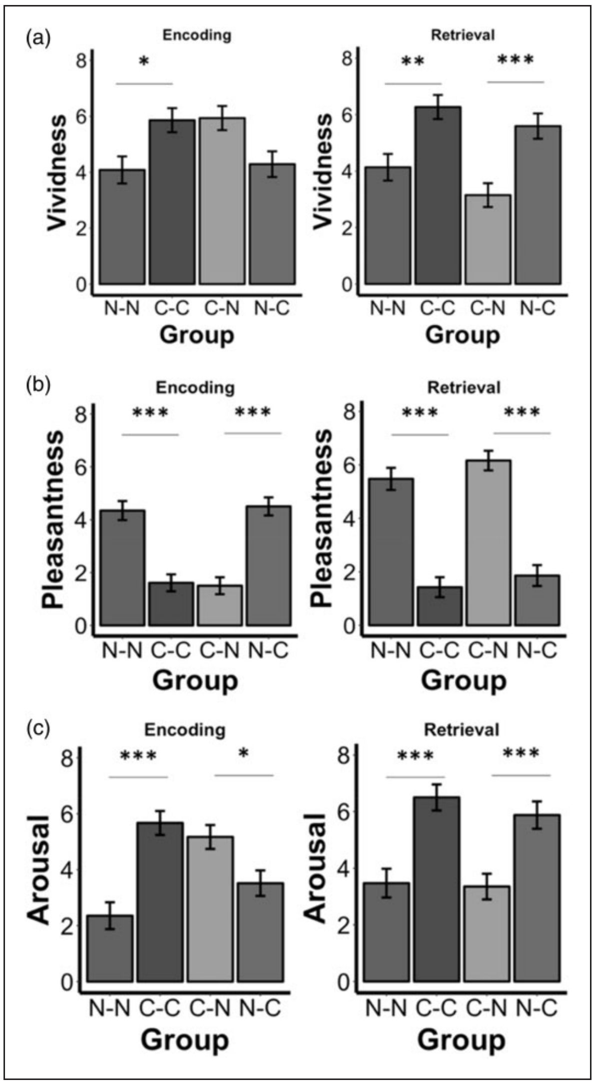

Figure 1. Subjective video ratings in terms of Vividness (a), Pleasantness (b), and Arousal (c) at encoding and retrieval.
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

vivid, arousing, and unpleasant by receivers, either at encoding or retrieval in comparison to the neutral videos.

Odor Intensity and Arousal Allow to Distinguish the Target From the Foils When Congruent Criminal Information Is Presented at Encoding and Retrieval

As reported in Table 3, the LMM revealed a main effect of Target/Foil using intensity as dependent variable. This suggests that the intensity of the BOs, as expected from naturally produced stimuli, would differ across targets and foils (targets being more intense than foils). A two-way interaction between the emotion presented at encoding and at retrieval also reached the significance level, as well as the three-way interaction. Post hoc analyses revealed that only in the case of the C-C group, the intensity of the BO was significantly greater for the target as compared to the foils (C-C$_{target}$: $M = 6.90$, $SD = 2.14$; C-C$_{foils}$: $M = 5.23$, $SD = 1.70$, $p < .05$). Please refer to Figure 2, Panel A, for a visual representation.

Similarly, a main effect of Target/Foil was found when using arousal as dependent variable. Post hoc analyses also indicated that in the C-C group, the arousal of the BO

Table 3. Odor Ratings for All Groups.

	num DF	den DF	*F*	*p* value
Intensity BO				
(Intercept)	1	121	1772.85	.00
EV at encoding	1	121	2.40	.12
EV at retrieval	1	121	1.15	.29
Target vs. Foil	**1**	**121**	**9.13**	**<.001**
EV at encoding × EV at retrieval	**1**	**121**	**6.29**	**.01**
EV at encoding × Target vs. Foil	1	121	0.22	.64
EV at retrieval × Target vs. Foil	1	121	0.88	.35
EV at encoding × EV at retrieval × Target vs. Foil	**1**	**121**	**5.15**	**.02**
Pleasantness BO				
(Intercept)	1	121	611.26	.00
EV at encoding	1	121	0.02	.88
EV at retrieval	1	121	0.38	.54
Target vs. Foil	1	121	0.67	.41
EV at encoding × EV at retrieval	1	121	3.45	.07
EV at encoding × Target vs. Foil	1	121	0.09	.77
EV at retrieval × Target vs. Foil	1	121	1.27	.26
EV at encoding × EV at retrieval × Target vs. Foil	**1**	**121**	**4.06**	**.05**
Arousal BO				
(Intercept)	1	121	757.41	.00
EV at encoding	1	121	2.94	.09
EV at retrieval	1	121	2.73	.10
Target vs. Foil	**1**	**121**	**16.94**	**<.001**
EV at encoding × EV at retrieval	1	121	0.01	.91
EV at encoding × Target vs. Foil	1	121	1.67	.20
EV at retrieval × Target vs. Foil	**1**	**121**	**5.59**	**.02**
EV at encoding × EV at retrieval × Target vs. Foil	1	121	0.64	.43

Note. The significant results for all contrasts (excluding the intercept) are reported in bold. EV = emotion of the video; BO = body odor; num DF = degrees of freedom at the numerator; den DF = degrees of freedom at the denominator.

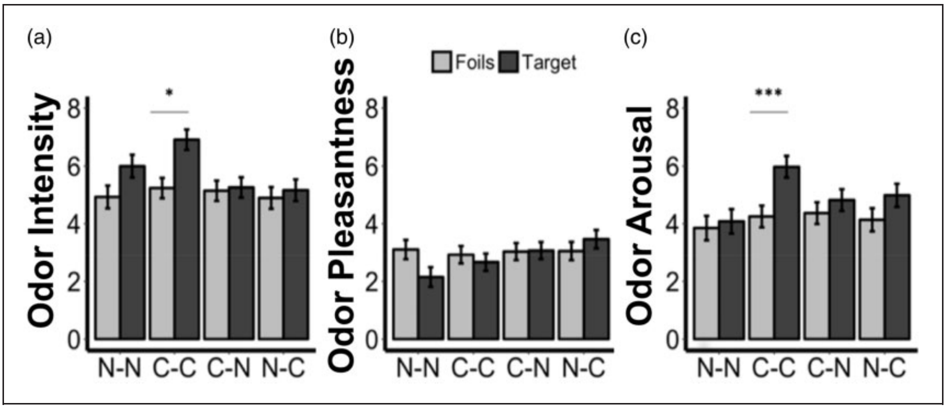

Figure 2. Subjective BO ratings in terms of Intensity (a), Pleasantness (b), and Arousal (c) for target and foils.
BO = body odor.
$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

was significantly greater for the target in comparison with the foils (C-C$_{\text{target}}$: $M = 5.97$, $SD = 2.14$; C-C$_{\text{foils}}$: $M = 4.25$, $SD = 1.73$) as you can see in Figure 2, Panel C. The two-way interaction between the emotion presented at retrieval and the Target/Foil factor also reached the significance level, with the criminal video inducing a greater arousal ratings than the neutral videos for the targets rather than the foils.

As evident from Figure 2, Panel B, a significant main effect of Target/Foil was retrieved on the pleasantness ratings. The two-way interaction between the emotion of the video presented at retrieval and the rating done on the target or the foils is significant; however, post hoc contrasts do not survive the Bonferroni correction. Nominally, in accordance to what was expected and in line with the previously presented information, the target was rated as less pleasant than the foils in the congruent groups (N-N$_{\text{target}}$: $M = 2.15$, $SD = 1.74$; N-N$_{\text{foils}}$: $M = 3.10$, $SD = 1.47$; C-C$_{\text{target}}$: $M = 2.66$, $SD = 2.50$; C-C$_{\text{foils}}$: $M = 2.92$, $SD = 1.27$).

Identification Accuracy Is at Chance Level for All Groups

The results from the Naïve Bayes machine learning algorithm run on a training set (70% of the observations) and validated on the remaining 30% of the observations indicate that the accuracy performance is not significantly different from chance level (the black diagonal line). The predicted performance in order of accuracy is the following: C-N (59% of correct recognitions); C-C and N-N (55%); and N-C (50%; see Figure 3).

Discussion

The purpose of the present study was to further the understanding of how odor memory can be modulated by the presence of emotional contextual information. By presenting criminal and neutral videos, we created different emotional contexts within which a BO was encoded and subsequently retrieved. The analysis of the subjective ratings of the videos revealed that we were able to induce different emotional experiences in the receivers. Indeed, criminal videos were rated as more vivid, unpleasant, and arousing than neutral videos, both at encoding and retrieval.

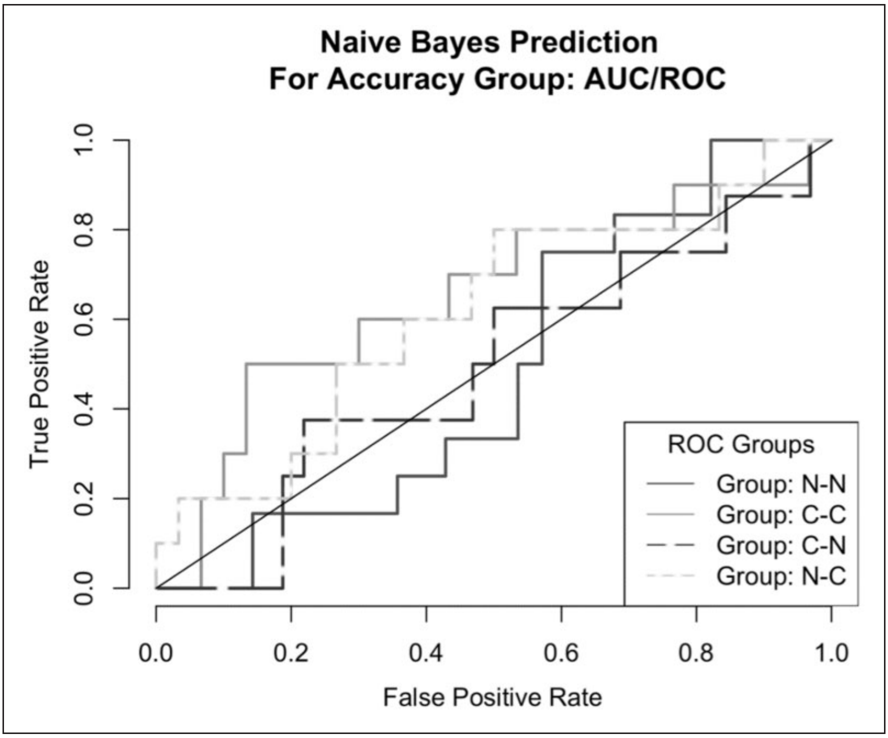

Figure 3. ROC curves based on the accuracy of BO identification for each group based on the Naïve Bayes prediction algorithm.
ROC = receiver operating characteristic; AUC = area under the curve; BO = body odor.

With respect to the accuracy identification performance, we hypothesized that it would be maximal for congruent groups; however, our results did not corroborate this hypothesis. Indeed, the accuracy performance for each prediction was not significantly different from chance level. Despite some differences, the identification performance is similar for all groups, suggesting that even the emotional quality of the context may not facilitate the accurate retrieval of the encoded BO information. One aspect contributing to this finding is that better odor identification is achieved when a verbal label can be paired with the odor. In other words, more namable odors lead to better recognition performances (Jönsson, Møller, & Olsson, 2011). Thus, complex and hard to verbalize stimuli, such as BOs, may lead to impairments in the accuracy performance (Cain, 1979). If this were generally true, it would go against the evidence produced by Alho et al. (2015, 2016), who revealed a facilitation effect in the identification of the BO paired with a criminal video, with a recognition delay of up to 15 min. Another option is that the nature of the memory here used to correctly remember the BO is implicit in nature, and therefore explicitly questioning the participants on the recognition of the BO may not be ideal to reveal whether and how the odor information was encoded. This would not be uncommon in the olfactory domain since implicit learning occurs reliably for odors, as repeatedly demonstrated by Köster, Degel, and Piper (2002).

Indeed, a methodological change implemented in the present study may have increased the difficulty of the recognition task when compared to Alho et al. (2015, 2016) and consequently reduced the accuracy performance. At retrieval, receivers immediately identified the target BO and only rated the perceptual features of the BOs after the identification (Alho et al., 2015), whereas in the present study, receivers only identified the target BO after providing the ratings to all the BOs included in the lineup. As a result, the time passed between encoding and retrieval may be slightly longer than 15 min, and in line with the findings by Alho et al. (2016), incrementing the delay between encoding and retrieval may have a disruptive effect in the accuracy of the identification performance.

Furthermore, we cannot exclude that focusing on the ratings of the perceptual features of all the BOs in the lineup may have retroactively interfered with the ability to identify the target BO. The fact that this BO-dependent memory does not last over long periods of times may suggest that new learning (the exposure and rating of the foils) may have reduced the ability to accurately recollect the prior memory, that is, the target BO. However, such interference effects were not able to disrupt the perceptual analysis of the BOs, whether target or foils. We hypothesized that the exposure to congruent contextual information at encoding and retrieval would facilitate the identification of the target BO over the foils, based on either odor intensity or arousal. Indeed, this hypothesis was confirmed. Receivers included in the C-C group, possibly due to the exposure to threatening information (Li et al., 2007; Parma et al., 2015), were able to differentiate the target BO, rating it as significantly more intense and arousing than its foils. These results are in line with previous findings which indicate that we are able to explicitly report perceptual differences related to signals of danger embedded in BOs (Olsson et al., 2014). In fact, the congruent negative arousing context in the C-C group may have communicated the existence of threatening information inducing an increased attentive state, which consequently facilitated the detection of the target and is reflected in the intensity and arousal ratings. One might then speculate that possibly instructing the receivers to focus on the BO intensity and arousal at encoding may facilitate an accurate retrieval of the BO information. Furthermore, even asking at retrieval to think of the intensity and arousal of the odor before selecting the target BO may improve identification accuracy. At present, these potential sensory-based strategies to improve odor memory accuracy are only hypothetical, but they set the stage for future studies on the topic. Instead, odor pleasantness does not seem to be critical in this process, perhaps due to the fact that the presence of visual negative information experienced by three out of four groups before the ratings may have overridden the effect on the subsequently presented olfactory stimuli.

As for most studies, the present one also is not free from limitations. First, we should acknowledge that given the interpersonal variability of olfactory skills, it is preferred to design within-subject experiments. However, in this particular case, this may bring other downsides (such as previous exposure on the criminal material) which could impact on the encoding of BO information subsequent to the first encounter. Furthermore, due to the targets' statistically significant subjective ratings in terms of intensity and arousal in comparison to foils, besides collecting subjective ratings as in the present study, future studies should also collect physiological measures (e.g., heart rate, skin conductance) to investigate if the target BO in fact caused somatic alterations in receivers, even if they do not explicitly recognize the target BO. This could be used as an implicit measure to evaluate the ability to recognize the target BO implicitly. In addition, it would be interesting to study the effect of anxiety BO collected in negative emotional contexts in the BO recognition accuracy. Previous findings indicate that this type of BOs can lead the receivers to feel the same emotion as the donors, a condition that could possibly exploit emotional contagion and lead to a better performance in odor recognition (de Groot, Smeets, Kaldewaij, Duijndam, & Semin, 2012). Furthermore, we only contrasted negative and neutral emotional stimuli, not allowing to disentangle valence/arousal differences in memory retrieval, for which a positive condition would be required.

Taken together, these results confirm the dissociation between the ability to identify odors and to describe their perceptual features and extend it to the BO domain. This difference supports the idea that despite the fact that we are able to discriminate BOs based on features such as intensity and arousal, we may not be able to correctly identify them, irrespective of the emotional context in which they are encoded or retrieved. In the effort of providing insights on how to promote strategies to improve BO identification accuracy, we highlight that even a slight increase in the delay between encoding and retrieval highly disrupts BO identification and that focusing on perceptual features of the BO such as intensity and arousal may constitute a strategy to improve BO identification.

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