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When the mask falls: The role of facial motor resonance in memory for emotional language

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ABSTRACT

The recognition and interpretation of emotional information (e.g., about happiness) has been shown to elicit, amongst other bodily reactions, spontaneous facial expressions occurring in accordance to the relevant emotion (e.g. a smile). Theories of embodied cognition act on the assumption that such embodied simulations are not only an accessorial, but a crucial factor in the processing of emotional information. While several studies have confirmed the importance of facial motor resonance during the initial recognition of emotional information, its role at later stages of processing, such as during memory for emotional content, remains unexplored. The present study bridges this gap by exploring the impact of facial motor resonance on the retrieval of emotional stimuli. In a novel approach, the specific effects of embodied simulations were investigated at different stages of emotional memory processing (during encoding and/or retrieval). Eighty participants underwent a memory task involving emotional and neutral words consisting of an encoding and retrieval phase. Depending on the experimental condition, facial muscles were blocked by a hardening facial mask either during encoding, during retrieval, during both encoding and retrieval, or were left free to resonate (control). The results demonstrate that not only initial recognition but also memory of emotional items benefits from embodied simulations occurring during their encoding and retrieval.

1. Introduction

Enjoying one's favorite sweets can put a smile on one's face; however, a mere picture of those sweets or even the word "sweets" can produce similar effects. Recently, this phenomenon has been explained by embodied simulations, in which the emotion originally experienced from an emotional stimulus is automatically re-enacted (Niedenthal, 2007; Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005; Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009; Semin & Cacioppo, 2008). Embodied simulations correspond to the activation of emotion-related and modality-specific sensations or physical actions caused by conceptual knowledge about emotions (Halberstadt, Winkielman, Niedenthal, & Dalle, 2009). For example, simulated emotional responses are linked to bodily reactions, such as facial expressions. This has been demonstrated using the electromyography technique (EMG; Cacioppo & Petty, 1981), as well as the facial action coding system (FACS; Ekman & Friesen, 1978; e.g., Hawk, Fischer, & Van Kleef, 2012). EMG recordings have repeatedly shown the spontaneous activation of an observer's facial muscles compatible with the emotional content of a stimulus. For example, matched facial muscle activation occurs in response to facial expressions (e.g., Dimberg, Thunberg, & Elmehed, 2000; Dimberg, Thunberg, & Grunedal, 2002) or non-facial stimuli such as emotional words (Foroni & Semin, 2009; Niedenthal et al., 2009), prosody (e.g., Hietanen, Surakka, & Linnankoski, 1998; Quené, Semin, & Foroni, 2012), and also more generally with positive and negative affect-inducing pictures, sounds, and words (Larsen, Norris, & Cacioppo, 2003). While the former is often referred to as facial mimicry (see Hess & Fischer, 2014 for a review), the latter is often denoted as facial motor resonance, a condition in which the perceiver attributes emotional meaning to a stimulus at hand. It has been argued that this proprioceptive feedback facilitates the comprehension and processing of emotional information (e.g., Foroni & Semin, 2009; Niedenthal et al., 2009; Zwaan & Taylor, 2006).

Evidence in line with this interpretation comes from studies in which facial muscles' activity is blocked by external manipulations. For example, by instructing participants to hold a pen laterally between their teeth, facial responses can be prevented, impairing the recognition of emotional words and facial expressions (Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Niedenthal et al., 2009; Oberman, Winkielman, & Ramachandran, 2007). In a study by Havas, Glenberg, Gutowski, Lucarelli, and Davidson (2010), participants were found to be slower in reading emotionally negative sentences after they had received Botulinum Toxin-A (BOTOX) injections into the corrugator supercilii (muscles used in frowning). The authors argued that facial motor resonance is thus not only an accessorial phenomenon, but is causally and selectively involved in emotion processing. Growing

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evidence supports the claim that the role of embodied simulations may go well beyond initial processing: they also seem to guide our behavior and judgments (e.g., Foroni & Semin, 2009, 2011, 2012; Winkielman, Berridge, & Wilbarger, 2005).

The phenomenon of facial motor resonance is especially interesting. It has been correlated to activations in the limbic regions and in the amygdala, which are known to be involved in experiencing and processing emotions (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Lee, Josephs, Dolan, & Critchley, 2006; Wild, Erb, Eyb, Bartels, & Grodd, 2003; see Dalgleish, 2004 for a review). In fact, lesion and neuroimaging studies suggest that the amygdala is specifically associated with memory for emotional but not neutral information (e.g., Adolphs, Cahill, Schul, & Babinsky, 1997; Brierley, Medford, Shaw, & David, 2004; Cahill, Babinsky, Markowitsch, & McGaugh, 1995; Markowitsch et al., 1994). In agreement with theories of embodiment, when facial muscles are blocked, the activity in the amygdala is attenuated (Hennenlotter et al., 2009). Hence, previous findings suggest an important role for facial motor resonance in the processing of emotional content.

Another important aspect of emotion processing that has so far been neglected by the embodiment literature is the enhancement of our memory for emotional content in comparison to neutral stimuli (see Buchanan & Adolphs, 2002; Hamann, 2001; LaBar & Cabeza, 2006, for reviews). The Enhanced Emotional Memory (EEM) effect has been demonstrated for a wide range of emotional stimuli, such as narratives (Laney, Campbell, Heuer, & Reisberg, 2004), words (Kensinger & Corkin, 2003) and pictures (Chainay, Michael, Vert-Pré, Landré, & Plasson, 2012). A question then arises as to whether the EEM effect is due to and supported by bodily reactions, such as facial motor resonance. According to some studies, memory for emotional stimuli is facilitated if a stimulus's affective tone is congruent with the participant's mood during retrieval (Cloitre & Liebowitz, 1991; Fitzgerald et al., 2011; Liu, Wang, Zhao, Ning, & Chan, 2012). Indeed, it is widely accepted that memory can be improved when affect at encoding or retrieval matches the valence of emotional stimuli, which is generally referred to as mood congruent memory (Blaney, 1986). A related but distinct phenomenon is that memory can be improved by the reinstatement of the learning environment at retrieval (see Smith & Vela, 2001 for a review). This context- or state-dependent memory effect can be established by any meaningful contextual cue, such as ambient odor (Herz, 1997), music (Mead & Ball, 2007), or internal mood states (see Eich, 1995 for a review). For example, mismatching participants' internal mood states during encoding and retrieval leads to impaired memory for words (Lang, Craske, Brown, & Ghaneian, 2001), as well as for symbols and photographs (Robinson & Rollings, 2011). But do embodied simulations play any role in this mood-congruency and context- and state-dependency memory effect? Or are these effects simply produced by better integration of information due to external cues and context? Concrete attempts to study the effects of body movements on emotion retrieval were conducted by Casasanto and Dijkstra (2010) and Förster and Strack (1996). Both studies led to conceptually similar results. Motor movements schematically associated with “positivity”, such as moving marbles upward or shaking one's head vertically, and movements schematically associated with “negativity”, such as moving marbles downward or shaking one's head horizontally, influenced retrieval of autobiographical memory and recognition of positive and negative words, respectively. Förster and Strack (1996) concluded that performing incompatible motoric and conceptual tasks (e.g. shaking the head horizontally while encoding positive words) requires more cognitive capacity than performing compatible motoric conceptual tasks (e.g. shaking the head vertically while encoding positive words). This additional demand in attentional resources eventually resulted in decreased performance during incompatible conditions. Although these studies provide evidence for a motor-to-meaning congruency effect on memory, they did not aim at investigating the role of embodiment in memory retrieval. Since Casasanto and Dijkstra (2010) did not control for mood, it is moreover possible that the active body movements (moving marbles upwards or downwards) induced a positive or negative emotional state similar to the emotional state under which the information had been originally encoded, hereby causing improved memory by means of a state-dependency effect. A more concrete approach to study the role of embodiment in object recognition was recently employed by Decloe and Obhi (2013), who applied Single pulse Magnetic Stimulation (TMS) over the motor cortex during observation of a model thumb typing on a cell phone. Their findings suggest that embodied simulation indeed are linked to the recognition of objects of action, but they results are restricted to embodied actions and non-emotional objects. Thus, the general role of facial motor resonance and embodied processes in emotional memory remains speculative.

Given this information, the present study seeks to investigate the putative role of embodiment during encoding and retrieval of emotional language. We expect that the role of facial motor resonance goes beyond the initial processing and recognition of emotional stimuli (Havas et al., 2010; Niedenthal et al., 2001; Niedenthal et al., 2009), and also affects memory for emotional information. To test this prediction, participants performed a memory task involving the encoding and retrieval of emotional and neutral words. Depending on the experimental condition, facial muscles were blocked by a hardening facial mask either during encoding, during retrieval, during both encoding and retrieval, or never (control). In contrast to the blocking methods used in previous studies (e.g., Foroni & Semin, 2009, 2011, 2012; Havas et al., 2010; Niedenthal et al., 2001, 2009; Oberman et al., 2007), we implement a new method involving the application of a hardening cosmetic mask that aims to block all relevant muscles at once, allowing us to investigate the effects of blocked facial muscles on the encoding and retrieval of a wider range of emotional words. By testing the effect of blocking facial muscles on memory for both positive and negative emotional content, we were also able to avoid the possible mood-congruency confounding (see Casasanto & Dijkstra, 2010; Havas et al., 2010). For the encoding phase, we used a categorization task (following Niedenthal et al., 2009) that involved the categorization of words as being either related or unrelated to emotion. We predicted that if our blocking manipulation successfully interfered with facial motor resonance, performance on the categorization task should be impaired for words from all emotion types as shown by Niedenthal and colleagues implementing a different blocking manipulation.

Our primary hypothesis was related to the performance on the memory task. We expected that in comparison to when facial muscle action is free (control), memory for emotional but not for neutral words would be impaired if facial muscles are blocked during encoding, during retrieval, or during both. Specifically, we were interested in whether blocking facial motor resonance during encoding or retrieval only produces similar effects, or whether the effects are specifiable. If facial motor resonance supports the initial identification and processing of emotional information and its later recognition and retrieval, then blocking facial muscles during encoding or during retrieval should likewise interfere with the memory of emotional words. In these two conditions the encoding and retrieval phases also provided no contextual cues: during the blocking conditions, a hardening dry mask interfered with facial muscle activity, while in the free conditions a soft creamy control mask ensured free muscle activity. In the memory literature, it's found that similarity between encoding and retrieval context may help memory performance. Thus, the predictions regarding the inhibition of facial resonance during both encoding and retrieval were less definitive: on the one hand, it is possible that blocking during both encoding and retrieval leads to even stronger interference with memory of emotional content, on the other hand, it is possible that a contextual effect might compensate for any additional interference that such a double blocking may cause.

2. Method

2.1. Participants

Eighty young healthy Italian native speakers (49 females; mean age: 23.7 ± 3.8) participated in the experiment. Participants were randomly assigned to one of four possible conditions. Depending on the assigned condition, participants' facial expressions were either: a) blocked during encoding but not during retrieval, b) not blocked during encoding but blocked during retrieval, c) blocked during both encoding and retrieval, or d) blocked neither during encoding nor retrieval (control group).

2.2. Stimuli

Stimulus material consisted of 144 Italian words. Seventy-two words were strongly related to one of the three emotional concepts (24 words for each emotion): disgust (e.g., *Bacteria*, *Vomit*), happiness (e.g., *Joy*, *Sweets*), and fear (e.g., *Panic*, *Danger*). Those emotional categories were meant to provide maximal diversity in the possible facial motor resonance they would trigger to allow some generalizability. The remaining 72 words were neutral (e.g., *Code*, *Subject*). The words used for the study were selected based on the result of pre-test conducted with an independent sample of 13 Italian native speakers (eight females, mean age: 24.2 ± 3.4) from an initial pool of 318 words (selected on the basis of a word list used by Niedenthal et al., 2009 and from different written sources of Italian language, such as newspapers). During piloting, participants judged the degree of association of each word separately to disgust, happiness, and fear using a scale from 1–9 (1 being "not at all associated" and 9 being "highly associated" with a given emotion). The ratings relative to each emotion were done in different blocks separated by short breaks. In addition to the ratings for the three specific emotions, each word was rated a fourth time on the degree of its general association to emotion using again a scale from 1–9 (1 being "not associated with emotion" and 9 being "highly associated with emotion"). These ratings were similar to those performed by Niedenthal et al. (2009) and were used to determine that a given word was indeed neutral with respect to any emotional content, including those emotions that were not explicitly rated.

To be selected as an "emotional word", a word had to be judged as highly associated with one of the three emotions considered (rating > 5), to be associated with emotional content in general (rating > 3), and not be associated with the other emotions considered (rating < 3.5). Words were considered as neutral when they were rated below 3, both on the general and the three specific emotionality scales. The stimulus material was selected from words that matched these criteria. Words were grouped into four categories: neutral, happiness, disgust, and fear. Univariate Analysis of Variance (ANOVA) confirmed that the four word types differed significantly from each other in their ratings on the general emotion association scale ($F(3, 140) = 419.30$, $p < .001$), and that this effect was due to the neutral words being rated significantly lower on emotionality in comparison to each of the three emotion categories, $ps < .001$ (Bonferroni-corrected). Furthermore, ANOVA for the ratings on the specific emotion scales indicated that emotional word types differed significantly on the ratings for each scale: $F(3, 140) = 779.14$, $p < .001$ (happiness scale); $F(3, 140) = 647.57$, $p > .001$ (disgust scale); $F(3, 140) = 767.91$, $p < .001$ (fear scale). Specifically, post-hoc comparisons showed that words categorized as happy were more strongly associated with happiness than fear and disgust words ($ps < .001$, Bonferroni-corrected); words categorized as disgusting were more strongly associated with disgust than happiness and fear words ($ps < .001$, Bonferroni-corrected); and, finally, words categorized as fearful were more strongly associated to fear than happiness and disgust words ($ps < .001$, Bonferroni-corrected).

The final list of words (total $N = 144$) was divided into two separate sets of 72 words each. Each set included 12 words for each of the three emotions (36 emotional words) and 36 neutral words. A list of words used as one of the sets can be found in the Appendix A. The two sets were designated not to differ in word frequency ($t(142) = 0.17$, $p = .86$), and word length, ($t(142) = 0.41$, $p = .96$). Moreover, neutral words and emotional words of set 1 were compared to the respectively neutral and emotional words of set 2 to assure that they were not different on emotionality ratings. As expected, the emotionality rating for both emotional words ($t(70) = 0.18$, $p = .45$) and neutral words ($t(70) = 1.30$, $p = .26$) did not differ from set 1 to set 2. These two sets were necessary for the memory test, as one set served as the target and was presented during the encoding and retrieval phase and the second set served as distractor during the retrieval phase. The presentation of one set as target or distractor was counterbalanced across participants.

2.3. Muscle-blocking strategy

In order to test the effect of motor resonance on memory we implemented a novel blocking procedure. Facial muscles were blocked by a mask containing pure green algae (*Green Clay Paste, Argiletz Laboratoire*), which solidifies into a hard shell that clings to the face after approximately 10 min. Because facial muscles, unlike other skeletal muscles, attach either to other muscles or directly to the skin, our hardening mask left the facial area largely immovable. This is in contrast to the study by Neal and Chartrand (2011) that used a gel that turns into a thin skin-like film. By application of the gel, Neal and Chartrand aimed at creating a subjective feeling of resistance in order to increase muscle activity and hence proprioceptive feedback. However, importantly the gel was meant to preserve the initiation of muscle movements and unlike our mask, it was not meant to block them at any point. In order to compare the blocking condition to the no-block condition in a way that differed only in the blocking of the muscle, the participants assigned to the no-blocking condition received a non-hardening cosmetic cream with a similar thickness (*Burro di Karite, Erboristica*).

2.4. Procedure

The experimental session was carried out in a soundproof chamber where participants were seated approximately 50 cm away from a computer screen (Samsung; resolution 1280×1024 pixels). Instructions were presented on the screen describing the experiment as an investigation of the effect of changed skin conductance on word processing and that the experiment was performed on two separate sessions. Participants were not informed about the hypothesis related to the blocking of muscles and about the subsequent memory test. Instead they were told that in order to restore skin conductance levels, a break of an hour was required before the second session.

The experiment involved an encoding phase and a retrieval phase, separated by a 1-hour break, in which participants were free to make use of the institute's library and garden, with the restriction of not consuming any caffeine. During the *encoding phase* participants performed a classification task. The procedure for this task followed exactly that outlined by Niedenthal et al. (2009). Words (size 27 in Arial font) were presented electronically, one at a time after a fixation point (500 ms), in random order using E-Prime software (*Psychology Software Tools, Pittsburgh, PA*). Participants' task was to categorize each word as being "*associated with emotion*" or "*not associated with emotion*" by pressing one of two pre-instructed buttons on the keyboard. Two signs next to each side of the computer helped participants to remember the key-assignment during the task. Key-assignment was counterbalanced across participants and responses were not time-limited. After the response the next trial started. Before the actual task, participants had a short practice session to familiarize themselves with the task (five trials). After the practice trials, participant's questions were answered and the first mask was applied to their face. According to the participant's experimental group, the mask either blocked facial movements (blocking mask) or allowed movements (control mask). In both cases, however, the experimenter waited 10 min after applying the mask. At the end of the encoding phase participants washed off the mask and filled in the Italian version of the Positive Affect and Negative Affect Schedule (PANAS; Terracciano, McCrae, & Costa, 2003), requiring participants to self-report their current state in relation to 20 given negative/positive mood states (e.g., 'attentive', 'interested', 'nervous', 'jittery') on a scale from 1–5.

After the 1-hour break, participants returned to the laboratory and took part in the *retrieval phase*. To begin, the second mask was applied (either the blocking mask or the control mask according to participant's condition). After another 10 min of waiting time, participants were presented with an unexpected memory task. In this task the words from both set 1 and set 2 were presented one at a time in random order on a computer screen. Participants were asked to indicate for each word whether it had been presented during the first (encoding) phase ("*old*") or it had not been presented before during the experiment ("*new*"). They were instructed to give a spontaneous but accurate answer by pressing one of two pre-instructed buttons. Just as during the encoding phase, there was no time limit to the responses and key-assignment was counterbalanced across participants and cued by 2 signs on each side of the computer.

Again, at the end of the task, participants washed off their mask and filled in the PANAS for a second time. In an additional questionnaire, they were asked to rate on a scale from 1 to 10 the (a) difficulty of the tasks, (b) the discomfort they felt because of the masks separately in encoding and retrieval phase, and (c) how stressful the experiment was in general. Before participants were finally thanked and informed about the actual purpose of the study, they were asked about their thoughts and opinion regarding the study and about the masks. If participants speculated that the masks were not meant to change skin conductance the experimenter asked additional questions such as "What do you think was the real purpose of the masks?" and "In what way do you think the masks have influenced your behaviour?" This was done to ensure that none of the participants had guessed the relationship between the masks and their facial motor activity.

3. Results

3.1. Data preparation and data analyses approach

In line with the procedure applied by Niedenthal et al. (2009), we only considered words that were categorized with high agreement by participants. A word was considered neutral (or emotional) and included in the analyses if during encoding at least 75% of the participants in the no-blocked condition agreed on its classification. This criterion left 93% of all words for analyses.

Reaction times (RTs) data were prepared by eliminating trials with response times below 300 ms or above 3 standard deviations (*SD*) of participant's individual mean (total excluded trials: 2% and 4% for the categorization task and for the subsequent memory task respectively). All RTs were log transformed before being analyzed.

One participant's data were discarded from the analysis when the debriefing interview revealed that he had understood that the purpose of the hardening mask was to interfere with muscle activity. The final sample was composed of 79 participants (free in encoding & retrieval (control): $N = 20$; blocked in encoding: $N = 19$; blocked in retrieval: $N = 20$; blocked in encoding & retrieval: $N = 20$).

We first present the results relative to the categorization task (i.e., manipulation check) supporting the success of our blocking manipulation (blocking mask) in interfering with the processing of emotional content as expected by a blocking manipulation. Subsequently, we present the data relative to the memory task analyzing the impact of the blocking manipulation during encoding and retrieval.

3.2. Manipulation check

3.2.1. Categorization accuracy

The dependent variable was the index of sensitivity d' (Green & Swets, 1966)[1] discriminating emotional words from neutral words. An independent-samples t-test showed that participants whose muscles were free during encoding were significantly more accurate at categorizing emotional and neutral words ($d' = 3.85$, $SD = .54$) than those whose muscles were blocked during encoding ($d' = 3.07$, $SD = .75$), $t(77) = 5.35$, $p < .001$.

To investigate the specific effect that the blocking manipulation might have on the single emotional word-types we also computed an index of sensitivity (d') for each individual emotion (disgust, happiness, fear). For each word-type, the d' value was independently computed on the basis of false alarm rates of 12 randomly chosen neutral words from the neutral word set. The individual indexes were analyzed by a mixed-measures analysis of variance with condition (free at encoding vs. blocked at encoding) as the between-subjects factor and word-type (disgust vs. happiness vs. fear) as the within-subjects factor. Degrees of freedom were corrected when necessary using Greenhouse-Geisser correction for violation of sphericity. Because the self-ratings of the PANAS revealed a significant difference in negative affect between participants whose muscles were free ($M = 1.2$) during encoding and participants whose muscles were blocked ($M = 1.4$) during encoding ($t(77) = 2.3$, $p = .03$), we used the negative affect scores at encoding time as a covariate. Analysis revealed a main effect of condition ($F(1, 76) = 8.0$, $p = .001$), but not for word-type ($F(2, 111) = 2.7$, $p = .13$), and no significant interaction ($F(2, 152) = .53$, $p = .59$). In general, blocking facial muscles impaired the ability to discriminate between emotional words and neutral words. Pair-wise comparisons for all three types of emotional words are presented in Fig. 1. This effect was present for each emotion.

3.2.2. Control variables

Participants who were blocked during encoding rated the categorization task as more difficult ($M = 3.7$, $SD = 2.1$) than those whose muscles were free during encoding ($M = 2.8$, $SD = 1.1$), $t(77) = 2.5$, $p = .016$. They also gave higher ratings to feelings of exhaustion ($M = 2.8$, $SD = 1.9$) after the experiment than participants whose muscles had been free during encoding ($M = 1.9$, $SD = 1.3$), $t(77) = 2.5$, $p = 0.16$. None of the other ratings regarding the discomfort caused by the masks or the positive affect differed between the encoding conditions, $t(77) = 1.07$, $p = .29$ and $t(77) = 1.01$, $p = .32$, respectively.

3.2.3. Categorization RTs

Reaction times were analyzed with a 2 (condition: free at encoding vs. blocked at encoding) × 2 (word-type: neutral vs. emotional) mixed-measures ANOVA with the first factor being between-subjects and the last one within-subjects. This ANOVA showed no significant effects of word-type ($F(1, 77) = .28$, $p = .60$), or condition ($F(1, 77) = .69$, $p = .31$), and no interaction ($F(1, 77) = .44$, $p = .51$).

[1] Unlike Niedenthal et al. (2009) we used d' to determine performance on the categorization task as a better index of accuracy in a classification task. However, in order to facilitate the comparison of our results with those of Niedenthal et al. (2009) we also analyzed the simple accuracy with a 2 (condition: free at encoding vs. blocked at encoding) × 3 (word-type: disgust, happiness, fear) mixed-measures ANOVA, with the first factor being between subjects and the last one being within-subjects. When necessary, degrees of freedom were corrected using Greenhouse-Geisser correction for violation of sphericity. Analysis revealed a main effect of word-type ($F(1.5, 114) = 13.5$, $p < .001$), a significant main effect of encoding condition, $F(1, 77) = 18$, $p < .001$, and an expected interaction between condition and word-type, $F(1.5, 114) = 5$, $p = .016$. The results replicate those reported by Niedenthal and colleagues (2009) supporting the validity of the mask manipulation in blocking muscle movements similarly to Niedenthal and colleagues' pen manipulation.

Fig. 1. Classification task. Accuracy of word classification expressed in d' as a function of word-type (disgust vs. happiness vs. fear) and encoding condition (free vs. blocked). Error bars represent ± 1 S.E. * $p < .05$.

3.3. Memory task

3.3.1. Retrieval accuracy

The main hypothesis of the present experiment was that blocking facial muscles during encoding and/or retrieval would impair the memory of emotional words compared to neutral words. The dependent variable for the memory performance was d' which represents a measure of performance in discriminating between words presented during encoding ("*old words*") and words not presented during encoding ("*new words*"). This d' index was computed separately for neutral and emotional words and submitted to a mixed-measures 2 (word-type: emotional vs. neutral) × 4 (condition: free in encoding & retrieval vs. blocked during encoding vs. blocked in retrieval vs. blocked in encoding & retrieval) ANOVA with the first factor being within-subjects and the last one being between-subjects. This revealed a significant interaction of the factors word-type and condition, $F(3, 75) = 3.23$, $p = .027$. Consequently, we ran two one-way ANOVAS, comparing the retrieval performance of the four conditions for neutral and emotional words separately. As expected, this analysis revealed a significant effect for emotional words $F(3, 75) = 2.9$, $p = .042$ but did not reveal any differences between conditions for the retrieval of neutral words ($p > .05$). We performed planned pairwise comparisons in order to explore whether the difference between the conditions in the retrieval of emotional words was as expected driven by better performance of the group whose muscles were free at all time during the experiment in comparison to the three experimental groups (see Fig. 2). The results suggest that blocking embodied simulations impairs memory for emotional content irrespectively to when it occurs (in encoding, retrieval, or both).

To further investigate whether this assumption is true for each of the specific emotional word-types used in the present study (disgust, happiness, and fear), we computed memory performance expressed in d' values separately for each of the three emotional word-types. These d' values were submitted to a 2 (condition: free vs. blocked) × 3 (word-type: disgust vs. happiness vs. fear) mixed-measures ANOVA with the first factor being between-subjects and the last one being within-subjects. The between-subjects factor compared any participant that had his/her muscles blocked either during encoding or retrieval or both ($N = 59$) against the control participants whose muscles were free during the complete experiment ($N = 20$). This analysis revealed a significant effect of word-type ($F(2, 154) = 3.6$, $p = .03$) and condition ($F(1, 77) = 5.9$, $p = .018$), but no interaction ($F(2, 154) = .26$, $p > .05$).

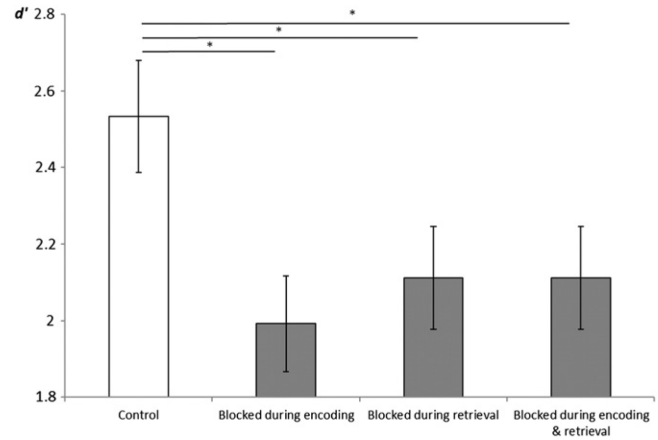

Fig. 2. Memory accuracy for all emotional words expressed in d' as a function of condition (free condition in white; blocked conditions in gray). Error bars represent ± 1 S.E. * $p < .05$.

In order to test whether each emotion showed the effect, three independent t-tests were computed and results are reported in Fig. 3. Blocking the muscles (compared to leaving muscles free during the experiment) significantly impaired the memory for the word-types happiness ($t(77) = 2.0$, $p = .045$) and fear ($t(77) = 1.9$, $p = .028$, one-tailed) but not significantly for disgust ($t(77) = 1.1$, $p = .26$) which, however, showed a similar pattern of means.

In order to test for the presence of an EEM in participants whose muscles were blocked at least once during the experiment against those participants whose muscles were never blocked, we ran two paired-samples t-tests (for the free and blocked conditions separately) comparing the retrieval for emotional words vs. neutral words. Results revealed that participants with free muscles tended to remember emotional words ($d' = 2.54$, $SD = .66$) slightly better than neutral words ($d' = 2.35$, $SD = .66$). This pattern was, however, only marginal $t(19) = 1.5$, $p = .07$ (one-tailed). Further inspection showed that there was a tendency for enhanced memory for all emotional word-types in comparison to neutral words, which reached significance for words related to disgust and happiness but not significantly for words related to fear (see Fig. 4) supporting the claim of the presence of a memory advantage for emotional words over neutral (significantly in two of the three emotion categories). This trend for an EEM effect was however absent when participants had

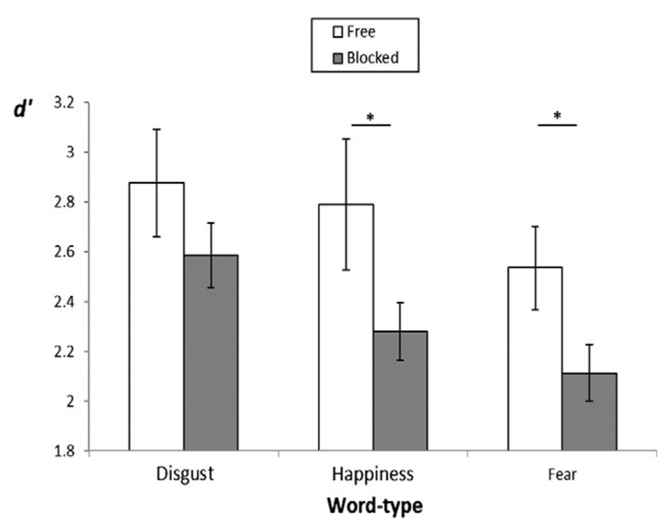

Fig. 3. Memory accuracy for emotional words expressed in d' as a function of word-type (disgust vs. happiness vs. fear) and condition (free vs. blocked). Error bars represent ± 1 S.E. * $p = .05$ (one-tailed).

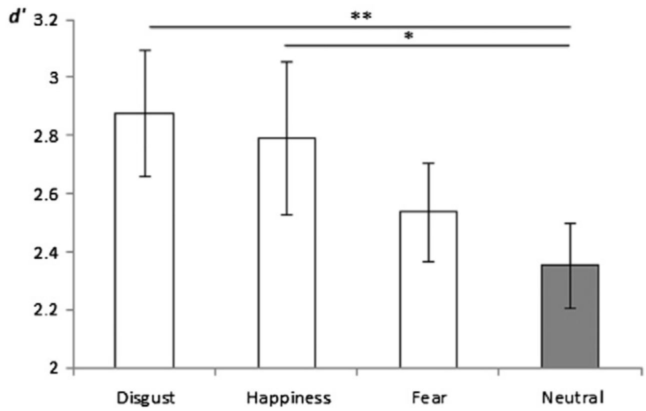

Fig. 4. EEM effect. Memory accuracy for each emotional word type expressed in d' in comparison to neutral words for participants in the free condition. Error bars represent ± 1 S.E. ** $p < .05$ (two-tailed), * $p < .05$ (one-tailed).

been blocked at least once during the experiment. In this case emotional ($d' = 2.1$, $SD = .58$) and neutral words ($d' = 2.1$, $SD = .67$) were equally well remembered, $t(58) = .21$, $p = .84$.

The different conditions might have caused different effects on memory by providing either congruent or incongruent contextual clues; therefore we tested for the presence of a context-dependency effect. Since such an effect should modulate emotional and neutral words equally, we ran an independent samples *t*-test comparing the general memory performance d' for all words regardless of word-type between participants who had received the same mask during encoding and retrieval (congruent conditions) and those who had received different masks during encoding and retrieval (incongruent conditions). This comparison revealed no significant result ($t(77) = .36$, $p = .60$), suggesting that participants in the congruent mask conditions did not show better memory ($d' = 2.23$, $SD = .60$) in comparison to those in the incongruent conditions ($d' = 2.18$, $SD = .52$).

3.3.2. Control variables

To ensure that affective states did not differ between participants in the four conditions, the positive and negative affect ratings were submitted to two separate mixed-measures ANOVAs with the within-subjects factor time (after the encoding phase vs. after the retrieval phase) and the between-subjects factor condition (free in encoding & retrieval vs. blocked in encoding vs. blocked in retrieval vs. blocked in encoding & retrieval). Both ANOVAs revealed a main effect of time (positive affect: $F(1, 75) = 6.85$, $p = .011$; for negative affect: $F(1, 75) = 6.86$, $p = .011$). This result was due to a decrease over time of positive and negative affect across all conditions. Importantly though the between-subjects factor condition did neither reveal any significant main effects nor any interactions effects with the factor time (all $ps > .05$). Thus participants assigned to the different conditions did not differ in their self-reported positive and negative states. Due to the discussed difference in negative affect ratings during encoding between participants in the blocking condition and participants whose muscles were free, we re-ran the ANOVA analyses described above taking negative affect during encoding as a covariate. This did not change the results and the covariate did not show any effect and no significant interactions with retrieval performance (all $ps > .05$). It is thus very unlikely that the presented results were driven by differences in affect rather than by the hypothesized blocking manipulation. Regarding the stress-levels experienced during the experiment a one-way between-subjects ANOVA demonstrated that also here participants did not differ between conditions ($F(3, 78) = 2.2$, $p = .10$).

3.3.3. Retrieval RTs

Reaction time data were cleaned as was done for the RTs in the categorization task. The dependent measure was the log-transformed mean RT and the design was a 4 (condition: free in encoding & retrieval vs. blocked in encoding vs. blocked in retrieval vs. blocked in encoding & retrieval) × 2 (word-type: neutral vs. emotional) mixed-measures ANOVA with the first factor being between-subjects and the last one within-subjects. There was no main effect for word-type ($F(1, 75) = 1.65$, $p = .20$) or condition ($F(1, 75) = 0.11$, $p = .98$), and no interaction between them ($F(3, 75) = 2.2$, $p = .10$).

4. Discussion

In the present investigation, we examined whether facial motor resonance supports the encoding and retrieval of emotional words. The results confirmed this hypothesis: participants who had their facial muscles blocked during encoding, during retrieval, or during both remembered fewer emotional words than participants whose facial muscles were let free to resonate. This effect was specific for emotional words and was not found for neutral words. To our knowledge this is the first study to show that embodied simulations support the encoding and later retrieval of emotional content. The data are aligned with theories of embodied cognition (see e.g., Barsalou, 2008; Semin & Cacioppo, 2008; Niedenthal, 2007; Niedenthal et al., 2005), which predict that embodied processes are involved in the processing of emotional content and should do so both during encoding and during retrieval.

Previous research had demonstrated that processing of emotional stimuli relies on facial motor resonance. Our results add on these findings by showing for the first time that blocking facial muscles also interferes with memory of the emotional information. Further analyses revealed that the impairment of emotional words was mainly driven by a significantly reduced recall of fear and happiness words. The disgust words showed a decrease in memory accuracy in the blocking conditions but failed to reach standard significance. This weaker impairment displayed by disgust words could be explained by the fact that disgust words also contained taboo words, such as *Anus* and *Pee* (e.g., Arnell, Killman, & Fijavz, 2007). Taboo words are generally better remembered than emotional non-taboo words (e.g., Jay, Caldwell-Harris, & King, 2008; Kensinger & Corkin, 2003). This is probably caused by the high arousal level that they evoke (e.g., Kensinger & Corkin, 2003; Sharot & Phelps, 2004), as arousal has frequently been shown to modulate memory (e.g., Cahill & McGaugh, 1995; Kensinger & Corkin, 2004; McGaugh, 2004; Sharot & Phelps, 2004). Based on this evidence one may expect that high-arousing words might continue to be successfully remembered because of their salience even in the blocking condition, which may have led to the smaller effect shown in the present experiment.

Our results also extend previous research on the EEM. Even though we found only a marginal overall EEM effect, suggesting that the control group had the tendency to remember emotional words better in comparison to neutral words. Split by emotional word-type, the EEM effect was statistically significant for the words related to disgust and happiness. Fear words showed the same pattern but in this case it was not significant. This may indicate that the emotional connotation of fear words is less accessible and meaningful in a neutral lab environment, potentially due to a decrease in imageability associated to them. However, when facial muscles were blocked at either time point during the experiment this pattern vanished. This pattern cannot be explained by a contextual effect provided by the masks, as participants in the double blocking condition did not show an enhanced memory effect in comparison to participants who received two different masks during encoding and retrieval (see also Fig. 2), nor can it be explained by mood congruency or state-dependency effects (as in other research: e.g., Casasanto & Dijkstra, 2010), as both negative and positive emotions were affected.

These findings suggest that embodied simulations play a role in the enhancement of emotional content. Since EEM has been shown to be correlated to amygdala activity (see Hamann, 2001; McGaugh, 2004, for reviews), our pattern is in accordance with the assumption that blocking facial motor resonance interferes with amygdala activity as suggested by Hennenlotter et al. (2009). Still, future studies are needed to explore this putative interaction between embodied simulations, amygdala activity, and EEM.

Another relevant aspect of our study is the use of a novel facial blocking manipulation (green algae mask). Blocking strategies implemented thus far tend to interfere with activity of specific muscles (e.g., *corrugator supercilii* using botulinum toxin-A injections; or *zygomaticus major* using specific pen-holding manipulations). Our goal was to block multiple facial muscles at the same time. In order to test the blocking effects of our blocking mask, we chose three categories of emotional words (disgust, happiness, and fear) meant to evoke motor resonance in different facial muscles (see Ekman & Friesen, 1978). Confirming our expectations, the blocking mask manipulation successfully interfered with the ability to discriminate neutral words from emotional words, irrespectively of their emotional content. This is important for future research because even when emotional facial expressions predominantly involve one muscle, many facial expressions result in the activation of multiple muscles. The facial resonance to sad stimuli, for instance, involves an increased activation of the corrugator supercilii and of the depressor anguli oris (Schwartz, Fair, Salt, Mandel, & Klerman, 1976). The possibility of blocking all muscles will provide flexibility allowing, for instance, the testing of the role of facial simulations in more complex situations where multiple emotions may be at play. Furthermore, the control mask seemed to have successfully provided a similar context, as our analysis did not reveal any differences in disliking or distraction of the two masks nor did we find a context-dependency effect.

Our study intended to establish a link between previous research on embodiment and earlier research on memory. The results are in line with embodied theories of cognition and extend them by showing that embodied simulations play a role in memory for emotional information both at the encoding and retrieval stage. This interpretation does not exclude the possibility that the contribution of embodied simulations is restricted to semantic activation of word's affective content, which in turn serves as an online cue for memory. Indeed, the way by which the blocking of facial motor resonance affects the normal recruitment of neural substrates associated with memory is an important question for future research. As discussed above, Decloe and Obhi (2013) found that embodied simulations of thumb movements have a causative role in the retrieval of action objects. Whether this link can also be established between facial motor resonance and retrieval of emotional content remains speculative at this point. Furthermore, the encoding and retrieval of emotional words in the blocking conditions may not only depend on the creation of a motor representation but also on attenuated activity of the amygdala (e.g., Adolphs et al., 1997; Brierley et al., 2004; Cahill et al., 1995; Markowitsch et al., 1994) since blocking facial muscles seems to interfere with neural activity in the amygdala (Hennenlotter et al., 2009). However, previous findings are limited to amygdala activation during active imitation of facial expressions and, thus, they do not necessarily apply to the case of encoding and retrieval of emotional stimuli in general. Hence, future studies should explore whether the observed decrease in memory for emotional words reported here may be ascribed to an interference of the blocking manipulation with motor cortex and/or amygdala activation.

In summary, we showed that blocking facial muscles interferes with the encoding and retrieval specifically of words with emotional content. Hence, we suggest that facial motor resonance plays a role and supports the processes involved in emotional memory when facial muscles are free. Facial motor resonance might not only elicit a smile when reading an emotional word such as *sweets*, but might also help to remember it later on.

Appendix A

Word	Emotion	Word	Emotion
accessori (accessory)	n	ano (anus)	d
angolo (corner)	n	batteri (bacteria)	d
bottiglia (bottle)	n	brufolo (pimple)	d
carico (load)	n	caccole (booger)	d
cavo (cord)	n	cesso (crapper)	d
circuito (circuit)	n	dissenteria (dysentery)	d
codice (code)	n	escrementi (excrements)	d
cubo (cube)	n	muffa (fustiness)	d
dispositivi (devices)	n	nausea (nausea)	d
dizionario (dictionary)	n	puzza (stink)	d
etichetta (label)	n	voltastomaco (queasiness)	d
foglia (sheet)	n	vomito (vomit)	d
gomito (elbow)	n	abbraccio (hug)	h
lampadina (bulb)	n	bellezza (beauty)	h
legno (wood)	n	coccole (caress)	h
lunghezza (length)	n	cucciolo (puppy)	h
matita (pencil)	n	gioia (joy)	h
neutro (neutral)	n	ottimismo (optimism)	h
penna (pen)	n	primavera (spring)	h
pietra (stone)	n	risate (laughter)	h
programma (progam)	n	soddisfazione (satisfaction)	h
repertorio (repertoire)	n	tramonto (sunset)	h
sintesi (synthesis)	n	vacanza (holiday)	h
tasca (pouch)	n	vincita (winning)	h
borsa (bag)	n	abisso (abyss)	f
carta (card)	n	angoscia (anxiety)	f
corridore (runner)	n	annegamento (drowning)	f
idioma (idiom)	n	attacco (attack)	f
sostantivo (substantive)	n	barbarie (barbarianism)	f
orologio (watch)	n	catastrofe (catastrophy)	f
stampante (printer)	n	male (evil)	f
camicia (shirt)	n	minaccia (threat)	f
catene (chain)	n	oscurità (darkness)	f
giornale (newspaper)	n	panico (panic)	f
attributo (attribute)	n	shock (shock)	f
cifra (cipher)	n	vendetta (vendetta)	f

List of Italian words used in one set divided by emotion (n = neutral; d = disgust; h = happiness, f = fear). English translation is given between parentheses.

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