Behavioral and neural evidence of enhanced long-term memory for untrustworthy faces

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In daily life, we automatically form impressions of other individuals on basis of subtle facial features that convey trustworthiness. Because these face-based judgements influence current and future social interactions, we investigated how perceived trustworthiness of faces affects long-term memory using event-related potentials (ERPs). In the current study, participants incidentally viewed 60 neutral faces differing in trustworthiness, and one week later, performed a surprise recognition memory task, in which the same old faces were presented intermixed with novel ones. We found that after one week untrustworthy faces were better recognized than trustworthy faces and that untrustworthy faces prompted early (350–550 ms) enhanced frontal ERP old/new differences (larger positivity for correctly remembered old faces, compared to novel ones) during recognition. Our findings point toward an enhanced long-lasting, likely familiarity-based, memory for untrustworthy faces. Even when trust judgments about a person do not necessarily need to be accurate, a fast access to memories predicting potential harm may be important to guide social behaviour in daily life.

During social interactions, individuals automatically form impressions of others based on facial cues. These impressions, which mainly rely on valence evaluation, reflected by trustworthiness judgments1, occur rapidly2 and unintentionally3,4 and have significant consequences for social behavior. For instance, individuals with untrustworthy faces have lower chances to have their loans funded5 and are more likely to be sentenced for a crime6. Hosts with trustworthy faces, on the other hand, more likely rent their assets with higher charges in the sharing economy domain7.

From a neuroscience perspective, it has been suggested that the detection of trustworthiness signals from faces may be mediated by a phylogenetically old survival circuit, which mobilizes the organism for approach and avoidance behavior in social interactions8. Critically, the amygdala, a bilateral structure from the medial lobe, seems to be involved by engaging neural systems that support attention, learning and memory processes9–11. Accordingly, perception of trustworthy and untrustworthy faces is associated with enhanced amygdala3,12–14 (for meta-analyses see15,16), as well as occipital and temporal cortical region activation12 to prioritize perceptual processing of socially salient information. This pattern of neural activity has also been found for positively and negatively valenced faces17,18 suggesting that the processing of cues signaling trustworthiness is rather related to general valence processing. Therefore, these findings support the emotion face overgeneralization hypothesis2,19,20, i.e. that responding appropriately to emotional states is such an adaptive function that prioritized processing also extends to facial cues that only resemble certain emotional expressions.

Interestingly, despite a prominent role of the amygdala in extracting subtle cues of both positive and negative faces, a negativity bias has been often reported: For instance, individuals with bilateral amygdala damage perceive untrustworthy faces as more trustworthy21. Consistent with this finding, greater amygdala sensitivity for untrustworthy than trustworthy faces is also reported in healthy individuals5,12,14,22. This suggests that processing signals of untrustworthiness may have higher adaptive value than signals of trust2,23,24, which is also consistent with animal and human studies showing a generally stronger defense motivation for aversive cues and contexts than for cues triggering approach motivation14,25,26.

Perceived untrustworthiness not only affects perception but also learning and memory processes27,28. When individuals learn that another individual cannot be trusted, they avoid strangers who look similar to that individual27. Interestingly, this avoidance pattern toward a putative untrustworthy individual is also reflected in amygdala...
activation. Furthermore, recent recognition memory studies using immediate testing from our own group and others suggest that the mere exposure to untrustworthy faces result in better memory for untrustworthy than for trustworthy faces28–30. These findings indicate that subtle cues of untrustworthiness are automatically learned and remembered. This memory advantage for untrustworthy faces may serve an adaptive function to avoid potential exploitation and harm in future social interactions.

Following up on recent recognition memory studies28–30, the present study addressed two open research questions: First, because these studies only tested recognition memory using short retention intervals, it is not known whether the memory advantage for untrustworthy faces persists after longer delays or only occurs when retrieval is tested immediately. The use of a longer retention interval would also clarify whether memory for untrustworthy information undergoes deeper consolidation or is just attributed to enhanced perceptual processing during encoding2,21,32 as recently suggested30. Second, it is widely agreed upon that recognition memory can be based on two qualitatively distinct cognitive processes: familiarity and recollection33–35. Familiarity is assumed to reflect a fast-acting and automatic process that is generally associated with the feeling of knowing an item without being able to recall specific details. Recollection, on the other hand, is considered a slower more elaborate memory process that includes the ability to recognize past events with additional spatial, temporal or contextual information36. Currently, it is not understood whether memory retrieval for untrustworthy faces is more relying on the process of familiarity or recollection. We therefore measured differences in brain potentials during viewing old and new items during a recognition memory test36–39. An early frontal Old/New difference (300–500 ms) is hypothesized to be sensitive to memory processes based on familiarity, while a later parietal Old/New difference (>500 msec) has been proposed as a neural correlate of recollection, as it is enhanced by depth of processing, as well as for correct source and “remember” judgments in a recognition task39.

In line with our behavioral study28 we expected to find enhanced recognition memory for untrustworthy, compared to trustworthy faces. For ERPs, two hypotheses can be assessed predicting the influence of trustworthiness on the electrophysiological indicators of familiarity and recollection: Given that prior long-term memory ERP studies reported enhanced recollection-based retrieval for motivationally relevant stimuli37,38, memory performance and late parietal Old/New differences may be heightened for untrustworthy, compared to trustworthy faces. Alternatively, features of trustworthiness are only subtle and help to rapidly form impressions about potential harm or joy2 that do not necessarily need elaborated (contextual) memory storage. Better memory for untrustworthy faces could therefore also be related to the process of familiarity, as reflected by early frontal ERP Old/New differences.

Method

Participants. Participants were 32 German-speaking students (6 male, 26 female; mean age: 25.1 years; 4 left-handed) from the University of Potsdam who participated for course credits or financial compensation. Based on our prior recognition memory study28 showing a medium-sized effect size (Cohen's $d = 0.57$) difference in memory for untrustworthy and trustworthy faces effect size we estimated a sample size of $n = 26$ for the present study ($\alpha = 0.05; \beta = 0.20$). Prior experience has shown a small number of drop-outs, for instance, due to bad ERP quality. We therefore increased the number of participants to the final sample size. Each individual provided written informed consent for a protocol approved by the Review Board of the German Psychological Society and in accordance with the Declaration of Helsinki. All participants had normal or corrected-to-normal vision.

Stimuli. The stimulus material consisted of 120 neutral faces with direct gaze, which were previously evaluated as high (30 female, 30 male faces) and low (30 female, 30 male faces) in trustworthiness by an independent sample (see31 for details on set construction). Following an established procedure40, the faces were converted into greyscales, equalized in size, position and luminance and surrounded by an elliptic mask using Adobe Photoshop CS4 (Adobe Systems Inc., San Jose, CA) and Matlab 7.7 (MathWorks Inc., Natick, MA) to minimize the influence of expression-relevant features on face processing during the present task.

Procedure. The study consisted of two experimental sessions: an encoding session and a recognition memory session one week later. The sessions took place in a sound-attenuated dimly lit room. Procedure and stimuli were the same as in our prior studies28,31. Participants viewed 60 faces (30 trustworthy and 30 untrustworthy faces) in pseudorandom order. Participants were instructed to pay attention to the faces but were not informed that the faces differed in trustworthiness and that a recognition test would follow (incidental encoding). Each face was presented once for 3,000 ms, followed by an intertrial interval (ITI) of 5,500, 6,000, or 6,500 ms. A fixation cross was present in all faces trials and ITIs to ensure that participants fixated the center of the screen.

One week later, participants returned to the lab for the recognition memory session. After the electrode net was placed on the head, participants viewed the 60 old faces together with 60 (30 trustworthy and 30 untrustworthy) new faces in pseudorandom order. Each trial started with the presentation of a face for 3,000 ms. After picture offset, the question “Old/New?” was presented and participants had to decide whether the face had been viewed before during encoding (i.e., by pressing “Old”) or not (i.e., by pressing “New”). Responses were made on two different buttons on a keyboard and response buttons were counterbalanced across participants. The assignment of the faces to the old and new face set was counterbalanced across participants. After the recognition memory task, the participants rated one of the two sets (i.e., their encoding set) for subjective trustworthiness using a similar rating task as in our previous studies38,31. In this task, participants were encouraged to rely on their feelings and to rate the trustworthiness of the faces as fast as possible on a rating scale, ranging from 1 (untrustworthy) to 9 (trustworthy). In line with our prior work38,31, analyses of these ratings revealed that the preselected untrustworthy faces were rated as less trustworthy (M = 4.36; SD = 1.21) than the preselected trustworthy faces.
results

Behavioral performance. Table 1 lists participants’ memory performance for trustworthy and untrustworthy faces. Hit rates did not differ between untrustworthy and trustworthy faces (t(31) < 1). However, new trustworthy faces were more easily recognized than new trustworthy faces, as indicated by significantly lower false alarm rates, t(31) = 3.56, p = 0.001. As expected, recognition accuracy was higher for trustworthy than for trustworthy faces as shown by larger Pr. t(31) = 3.41, p = 0.002, and d’ values, t(31) = 2.75, p = 0.01. Response bias for faces did not differ as a function of trustworthiness as indicated by similar Br values when tested after a one week retention interval.

ERPs. Frontal Old/New effect reflecting familiarity. Figure 1A illustrates the grand average ERPs for correctly recognized old and new faces that differed in trustworthiness collapsed across a representative frontal sensor cluster.

At frontal regions, in the early time window (350–550 ms), a main effect of the factor Trustworthiness was found, F(1,31) = 6.90, p = 0.013, ηp² = 0.18, which interacted with the factor Memory, F(1,31) = 4.47, p = 0.043.
Follow-up testing revealed that the Old/New difference was larger for untrustworthy than for trustworthy faces, $t(31) = 2.11, p = 0.043$ (see Fig. 1B). In the later time window (550–750 ms), the ERP old/new difference continued, $F(1,31) = 5.71, p = 0.023, \eta^2_p = 0.16$, but the interaction with Trustworthiness only reached trend level, $F(1,31) = 3.75, p = 0.062, \eta^2_p = 0.11$. Trustworthiness did not reach significance ($F < 1$).

Parietal Old/New effect reflecting recollection. Figure 2A illustrates the grand average ERPs for correctly recognized old and new trustworthy and untrustworthy faces. The shaded area represents the late (550–750 ms) time window used for the analyses. (B) ERP Old/New difference of the mean amplitudes and scalp topographies of the ERP difference (550–750 ms) for trustworthy and untrustworthy faces.

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Parietal Old/New effect reflecting recollection. Figure 2A illustrates the grand average ERPs for correctly recognized old and new faces that differ in trustworthiness collapsed across a representative centro-parietal sensor cluster.

No significant main effects or interactions (all $F$s < 3.19; $p > 0.084$) were observed at centro-parietal regions in the early time window (350–550 ms). However, in the time window between 550 and 750 ms, old faces prompted larger ERP positivity than new faces, as reflected by a main effect of Memory, $F(1,31) = 6.49, p = 0.016, \eta^2_p = 0.17$ (see Fig. 2B). No other main effects or interactions reached significance in this later time window (all $F$s < 1).

Taken together, untrustworthy faces generated larger early ERP old/new effects over frontal electrodes than trustworthy faces, indicating facilitated familiarity-based recognition. No such differences were observed for the recollection-sensitive late centro-parietal ERP Old/New effect.
Discussion

In the present study, ERPs were measured to assess the effects of facial trustworthiness on long-term memory. Consistent with prior behavioral studies using immediate recognition tests, better memory discrimination was found for untrustworthy than for trustworthy faces after a one week retention interval. During memory retrieval, correctly recognized old faces evoked enhanced ERP positivity, relative to unseen novel faces. This ERP Old/New difference was most pronounced for untrustworthy faces over frontal electrode sites in an early 350–550 ms window. The results provide behavioral and neural evidence for a long-lasting memory advantage for untrustworthy faces.

Using ERPs, we were able to assess how memory for trustworthy and untrustworthy faces is formed and retrieved. In line with previous studies, we found enhanced ERP positivity for old, relative to new items with specific spatio-temporal characteristics. While the late ERP Old/New effect reflecting the memory process of successful recollection did not vary as a function of trustworthiness, we found that particularly untrustworthy faces modulated the early Old/New effect, a putative correlate of familiarity-based remembering (which may also involve implicit memory processes). According to dual-process theory, familiarity has been considered as a fast-acting, less effortful and relatively automatic memory process that works with greater efficiency than recollection. While familiarity supports simply knowing that an event was encountered before, recollection is understood as retrieving additional (contextual) details (e.g., spatial, temporal, situational) that are associated with an event. For instance, prior ERP studies (for review see) found that the early frontal old/new effect, compared to the late parietal old/new effect, is insensitive by depth of processing and divided attention during encoding. Furthermore, the early frontal old/new effect varies with familiarity strength and memory confidence, the parietal old/new effect, on the other hand, is specific for recollection (e.g., sensitive to the amount of information recollected, correct source judgments and recollection based remember judgments and high confidence memory judgments). The ERP finding that recognition of untrustworthy individuals is based on familiarity (reflected by early frontal old/new differences) fits with the emotion overgeneralization hypothesis, which posits that face-based valence judgments are an adaptive mechanism, which helps in a rapid and efficient way to avoid upcoming harm. From this view, the potential cost of responding with approach behavior to an untrustworthy individual is higher than the potential cost of avoiding a trustworthy individual. This also implies that untrustworthy faces do not necessarily need to be stored in a more complex contextual fashion (e.g., recollection) when the evolutionary purpose is to quickly recognize socially relevant information. Interestingly, contrary to prior ERP studies using emotional scenes or faces, we did not find a modulation in the recollection-sensitive parietal old/new effect. However, emotional scenes and faces contain more contextual feature information and draw more attention than neutral faces, which may have resulted in enhanced recollection-specific contextual binding and enhanced parietal ERP old/new differences in these studies.

Enhanced acontextual familiarity-based memory for untrustworthy faces may also have serious consequences on social decision making. For instance, previous lab and more real life studies found that individuals whose faces are perceived as untrustworthy are less trusted, are less likely to have their loans funded and are more likely to be sentenced for crimes. Given that face-based social inferences about a person's trustworthiness are not necessarily accurate and reliable in general, familiarity-based remembering may come at costs. On the one hand, untrustworthy faces may in turn also affect other social preferences for fairness and cooperation and contribute to less prosocial behavior and emotions, including altruism and empathy. On the other hand, familiarity-based memory for untrustworthy faces may even more strongly hinder to derive valid appearance-based impressions about other persons. Social decision making strongly relies on available contextual information (e.g., reputational information, social context etc., see). Recognizing an untrustworthy face including remembrance of such contextual information may therefore also be adaptive (in the long term) in a sense that it helps to correct invalid appearance-based judgments. It must be noted, however, that our study was intended to investigate long-term recognition memory for trustworthy and untrustworthy looking faces that were incidentally encoded once, mimicking a brief social encounter in real life. Future research need to explore whether additional reputational information and increased experience (e.g. through repetition of trials) may also enhance recollection memory.

Finally, we can only speculate about the underlying neural mechanism leading to enhanced familiarity-based remembering for untrustworthy faces in the present study. As suggested by Tsukiura, valence-based memory for faces is mediated by the amygdala, which detects emotional properties of the faces (such as conveyed by subtle cues) and interacts with the medial orbitofrontal cortex (OFC) and insular cortex (IC) to process positive and negative signals, respectively. These regions in turn may modulate a network consisting of hippocampus (HC) and fusiform faces area to enhance memory for these faces depicting affective signals. Given that memory for untrustworthy faces was mediated by familiarity, it is likely, however, that the perirhinal cortex (PrC) rather than the HC, contribute to the memory-enhancing effect since the PrC has been specifically related representing item familiarity.

Taken together, we found that the memory advantage for faces signaling untrustworthiness is remarkably stable over time. In support of the overgeneralization hypothesis, we found electrophysiological evidence that memory for trustworthy faces is likely linked to familiarity-based recognition, a fast, less specific and automatic retrieval process, which helps to quickly recognize those who may cause potential harm in social interactions.

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M.W. and A.L. designed the study. M.W. and C.V.B. collected the data. M.W. and C.V.B. analyzed the data. M.W. wrote the manuscript. M.W., C.V.B., J.W. and A.L. contributed to writing, reviewing and editing of the manuscript. All authors approved the final version of the manuscript.

Competing interests
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