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Facial expressions yielding Context-Dependent Effect: The additive contribution of eye movements☆

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ABSTRACT

This study tested Context-Dependent Effect (CDE) on face recognition by viewing facial expressions as context and face identity as the target. Three groups were defined - Neutral, Happy and Angry, reflecting the facial expressions of the faces presented at the study phase. At the study phase, participants were presented with 42 color photos of faces for 5 s each. At the test phase, participants were presented with 84 pictures of faces, half of which had been viewed beforehand (old). One-third of the old and new faces displayed the same facial expression shown at study, and the remaining two-thirds had one of the other two expressions. Behavioral results show that consistency of facial expressions between study and test facilitated face recognition (i.e., CDE). Eye-tracking results showed that lengthier focus on a face at the study phase gives the participant an advantage only when the same face is presented again at the test phase. Angry expressions intensify binding more than happy or neutral expressions, resulting in higher costs when changing facial expression between study and test. The theoretical implications of these results in terms of the relationship between facial identity and facial expression are discussed. The practical implications, particularly for eyewitness memory literature, are also discussed.

1. Introduction

The effect of context on target memory has been tested by manipulating various types of contexts such as the environmental context (e.g., the room in which an encoding episode took place; for review see Smith & Vela, 2001). Context may be local-discrete, often trial-unique stimuli that accompany memory targets during encoding (e.g., faces and hats; Vakil, Raz, & Levy, 2007). Context can also be a feature of the target stimulus itself, such as the font or color of the words to be remembered (Macken, 2002), or the modality in which the words were presented (Vakil, Openheim, Falck, Aberbuch, & Groswasser, 1997). This study tested the effect of facial expression (context) on face identity (target – information to be remembered) recognition. Context effect is also consistent with Tulving's encoding specificity principle (Tulving & Thomson, 1973).

In their classical model of face recognition, Bruce and Young (1986) distinguished between two aspects of face recognition - identity and expression. The first is dependent on invariant facial features (e.g., shape of the nose and mouth, color of the eyes) and the second is dependent on changeable facial features (e.g., eye gaze, lip movement). Both aspects are critical for social interaction, as identifying the person we are interacting with is crucial, and recognition of facial expressions is necessary in order to correctly interpret the emotions expressed by that person (Haxby, Hoffman, & Gobbini, 2000). In her early work, Bruce (1982) already demonstrated that changes in angle (e.g., full face to 3/4), expression (e.g., smiling to unsmiling) or both, when viewing unfamiliar faces, affected recognition. It should be noted that the nature of the interaction between the face identity and facial expression systems is still under debate (for review, see Yankouskaya, Humphreys, & Rotshtein, 2014).

The dissociation between these two aspects of facial recognition, i.e., identity and expression, has been supported by behavioral, neuropsychological and neuroimaging studies. Examples of behavioral studies include research by Ellis, Young, and Flude (1990) and by Young, McWeeny, Hay, and Ellis (1986), in which matching familiarity and repetition priming were found when the task required facial identity recognition but were not found when identifying facial expressions. Neuropsychological studies have demonstrated selective impairment of either recognition of face identity or of facial expressions following different types of brain injuries (Etcoff, 1984; Young, Newcombe, de Haan, & Hay, 1993). Functional imaging studies using PET (George et al., 1993; Sergent, Ohta, Macdonald, & Zuck, 1994) and

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Table 1
Experiment design for the three groups.

Neutral group (n = 32)	Happy group (n = 28)	Angry group (n = 30)
	Study phase	
42 faces with neutral expressions	42 faces with happy expressions	42 faces with angry expression
	Test phase Old faces (42 total)	
Repeat: 14 with neutral expressions Re-pair 1: 14 with happy expressions Re-pair 2: 14 with angry expressions	Repeat: 14 with happy expressions Re-pair 1: 14 with neutral expressions Re-pair 2: 14 with angry expressions	Repeat: 14 with angry expressions Re-pair 1: 14 with neutral expressions Re-pair 2: 14 with happy expressions
	New faces (42 total)	
14 with neutral expressions 14 with happy expressions 14 with angry expressions	14 with happy expressions 14 with neutral expressions 14 with angry expressions	14 with angry expressions 14 with neutral expressions 14 with happy expressions

fMRI (Winston, Henson, Fine-Goulden, & Dolan, 2004) demonstrated that recognition of face identity is mediated primarily by the fusiform gyrus, while recognition of facial expressions is primarily mediated by the superior temporal sulcus. However, principal component analysis (PCA) has shown that facial identity and expression recognition can be represented in a single model, thus the dissociation can be considered partial rather than absolute (for review, see Calder & Young, 2005).

The effect of contextual reinstatement on recognition is referred to as Context-Dependent Effect (CDE) (Smith, Glenberg, & Bjork, 1978; Vakil et al., 2007). Accordingly, testing how changing facial expressions (i.e., context) from study to test affects facial identity recognition (i.e., target) can be considered a memory CDE paradigm. Hence, it is assumed that the presence of the original facial expressions at test serves as a cue that facilitates recollection of the face identity. In contrast, Haxby et al. (2000) claimed that "The representation of identity must be relatively independent of the representation of the changeable aspects of a face, otherwise a change in expression or a speech-related movement of the mouth could be misinterpreted as a change of identity" (p. 223). In other words, face identity will not be affected by changes in facial expressions and CDE is not expected to emerge in this case. Thus, Haxby et al. provided the rationale for their claim of independence between facial identity and expressions, that if they interact it would affect identity (i.e., CDE). However, we must admit that the statement by Haxby et al. could be interpreted differently. It is completely possible that CDE does not rely on whether or not the "context" and the "target" are independent of one another. As mentioned earlier, "context can also be a feature of the target." In this case, the emotional value of a stimulus/event may facilitate the memory of a non-emotional aspect of the same stimulus/event (e.g., Thorley, Dewhurst, Abel, & Knott, 2016; Xie & Zhang, 2018).

In addition to behavioral data, this study collected eye movement data during the study and test phases. Previous studies have shown that eye movements could provide additional insight into the underlying cognitive processes that take place when face recognition is tested (Hannula et al., 2010; Parag & Vakil, 2017). Several studies showed more fixations at the study phase on stimuli that were correctly recognized later on (Heisz, Pottruff, & Shore, 2013; Kafkas & Montaldi, 2011). Furthermore, stimuli that were presented at the study phase received longer first and overall fixation durations then new stimuli (i.e., 'Repetition effect'), regardless of the participant's answer (Chanon & Hopfinger, 2008; Hannula et al., 2010; Ryan, Hannula, & Cohen, 2007). Also, a significant positive correlation was found between the number of fixations on faces in the study phase and recognition performance during the test phase (Heisz et al., 2013; Kafkas & Montaldi, 2011). It is assumed that longer dwell time (DT) on the areas of interest, either at the study or test phase yields stronger binding between facial identity and facial expression. Hence, it is predicted that longer DT would result in a more pronounced CDE.

Thus, we asked whether changes to facial expressions between the study phase and the test phase would affect face identification. In other words, we asked whether CDE would emerge when face identity (the target to be remembered) is affected by facial expression (contextual information). To this end, the present study included three groups that viewed faces with different facial expressions at the study phase, i.e., neutral, happy or angry. Happy and angry expressions were selected in addition to the neutral expression because these two expressions are clearly dissociable and are two of the most clearly recognized emotions (Rosenberg, McDonald, Dethier, Kessels, & Westbrook, 2014) and are assumed to be processed differently. While angry faces (representing negative emotions) were shown to attract more attention and involve local, feature-based processes, happy expressions attract less attention and involve more global processing (Curby, Johnson, & Tyson, 2012; D'Argembeau & Van Der Linden, 2007).

Comparing these three groups also enables us to learn about the interaction between them, i.e., whether transitioning from one emotion to another yields similar effects. One of the strengths of the present study is that it enables us to compare the effect of facial expressions on three different groups that viewed the same faces. Furthermore, previous studies either presented neutral faces at study and then presented the faces with various expressions at test (Chen et al., 2015), or presented faces with various facial expressions at study and with neutral expression at test (D'Argembeau & Van Der Linden, 2007; Nomi, Rhodes, & Cleary, 2013). Graziano, Smith, Tassinary, Sun, and Pilkington (1996) examined the Zajonc and Markus (1984) motor theory of emotion, claiming that facial recognition could benefit from imitation of the facial expression. Although they found little support for this theory, face identity benefited from the 'concentrate and imitate' condition. These studies further confirm how reinstatement of the emotion expressed facilitates facial recognition.

The present study counterbalances the presentation of faces at study (three different groups, each viewing a different facial expression at study - neutral, happy and angry). At the test phase, each group views all three expressions, of which one is the original that serves as baseline (see Table 1).

Eye tracking provides information about participants' scanning patterns at the study and test phases for the various facial expressions. It is predicted that lengthier focus on a face at study would be an advantage when presented with the identical face at test, and a disadvantage when the face at test is presented with a different facial expression.

2. Method

2.1. Participants

Eighty-six undergraduate students from Bar-Ilan University (Israel) participated in this study. The students took part in the experiment to fulfill academic requirements. Based on self-reports, none had histories of neurologic or psychiatric disorders. The study was approved, as required, by the Institutional Review Board of Bar-Ilan University. Informed consent was obtained from all participants. Participants were divided randomly into three groups, one for each of the facial expressions used at the study phase - Neutral, Happy or Angry. The Neutral group (n = 30, 18 females), mean age = 24.60 (SD = 4.12); the Happy group (n = 27, 22 females), mean age = 23.03 (SD = 4.30); and the Angry group (n = 29, 23 females), mean age = 22.34 (SD = 2.62). The groups did not differ significantly in age, $F(2, 83) = 2.80$, $p = .07$.

2.2. Computer and software

Stimuli were displayed on a computer with a 15.6-inch PC screen, using E-PRIME 2.0 software that records the temporal parameter presentations of stimulations, and schedules the appearance of the stimuli with computer-recorded eye movements. Eye movements were recorded using a Senso Motoric Instrument (SMI) RED-M remote eye-tracker. This system allows free head movements with a sampling rate of 250 Hz, and high accuracy of 0.5 °. A 9-point calibration cycle at the beginning of the experiment provided a spatial resolution of 0.1 °. A camera with an infrared source was located at the front of the laptop screen, below the participant's eye level, 60 cm away from the participant.

2.2.1. Stimuli

A total of 84 different color facial photos of Caucasian males and females with neutral, happy or angry facial expressions were used in the current study. The photos were selected from two standardized sets representing facial affect based on high inter-rater agreement. Fifty-three faces were selected from Karolinska Directed Emotional Faces (KDEF - Lundqvist, Flykt, & Öhman, 1998) and thirty-one faces from the Radboud Faces Database (Langner et al., 2010). All of the selected stimuli were overlaid with a template of a black oval frame that covered the hair, ears and neck of the model. This method of framing was used in a previous study (Palermo & Coltheart, 2004) to ensure that attention is fully directed at the face only. The faces selected did not feature distracting facial details like beards, and had the requisite emotions (see Appendix 1, from left to right, a neutral, happy and angry face with eye movement recording).

2.3. Procedure

Participants were tested individually. Upon arrival, they were informed that they would take part in a facial recognition experiment and would be instructed to observe the faces that appear on the screen and to try to remember their identity regardless of their facial expression for a future recognition test (the same instructions appeared later on the computer screen). Participants were informed that their eye movements would be monitored. The experimenter than performed an eye calibration check in which participants were instructed to look at a dot that moved across nine points on the screen.

At the study phase, participants were presented with 42 color photos of faces (21 males and 21 females) one by one, for 5 s each. The Neutral, Happy and Angry groups viewed faces with the corresponding facial expressions. At the test phase, participants were presented with 84 photos of faces, half of which had been viewed before and half of which were new. They were asked to press a button on the keyboard indicating whether it was an old (L) or new (A) face. Unlike in the study phase, the face remained on the screen until the participant responded.

One-third of the old faces (14) were identical to the original faces, with the same face and same expression (e.g., neutral- neutral - Repeat), one-third were old faces with different expressions (e.g., neutral-happy - Re-pair 1), and one-third had the other expression (e.g., neutral-angry - Re-pair 2). Regarding the new faces, one-third of the faces were new and bore the same expression as that of the faces presented during the study phase. The remaining two-thirds bore one of the other two facial expressions (see Table 1).

3. Results

3.1. Behavioral results

As described in the Method section (see Table 1), the three groups that participated in this study viewed different facial expressions at the study phase (neutral, happy or angry). In order to test CDE, participants were presented with the Repeat (old face with the original facial expression) and two different Re-pair conditions at the test phase. The Re-pair conditions differed between groups (see Table 1) and therefore, in order to compare the CDE of the three groups (i.e., Repeat vs. Re-pair conditions) the results of the two Re-pair conditions for each group were averaged. In order to control for the response bias, that is reinstatement involving a simple criterion shift, with greater response when faces bore the expression seen at encoding, we used d' ($d' = z(H) - z(FA)$) as the sensitivity measure (Snodgrass & Corwin, 1988) as the dependent measure. The Hit Rate (H) was calculated for each participant, i.e., the number of correct "Yes" responses for the 14 old faces in each condition. Similarly, the FA rate was calculated based on the proportion of correct "Yes" responses for the 14 new faces in each condition. CDE was tested by comparing performance on the Repeat condition with average performance on the two Re-pair conditions. Mixed Analyses of Variance were conducted in order to analyze the effect of Group (Neutral, Happy, & Angry) and Context (Repeat vs. Re-pair - averaged). The former is a between-subjects factor and the latter is a within-subjects factor.

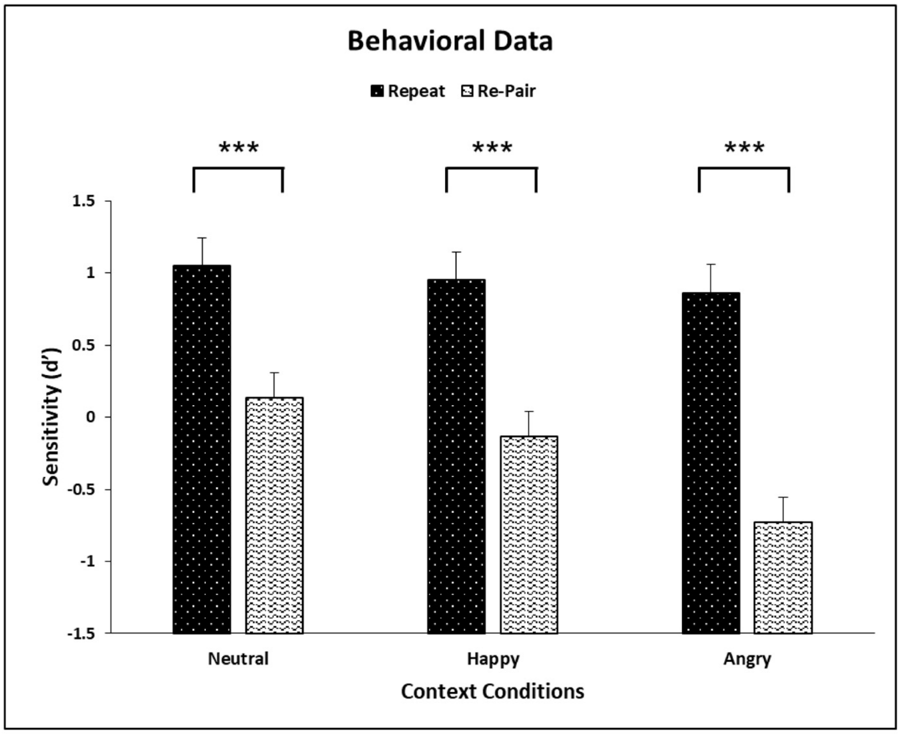
3.2. Recognition (sensitivity – d′)

CDE was evident, as the sensitivity (d') rate under the Repeat condition was significantly higher than under the Re-pair - averaged condition $F(1, 87) = 169.73$, $p < .001$, $\eta_p^2 = 0.66$. Group main effect was marginally significant $F(2, 87) = 2.56$, $p = .083$, $\eta_p^2 = 0.06$. The interaction reached significance, $F(2, 87) = 4.91$, $p < .01$, $\eta_p^2 = 0.10$. In order to reveal the source of the interaction, two separate ANOVAs, one for the Repeat and one for the Re-pair condition, were conducted. Sensitivity did not differ between the three groups under the Repeat condition, $F(2, 87) = 0.24$, $p = .79$, but they differed significantly under the Re-pair - averaged condition, $F(2, 87) = 6.50$, $p < .01$. LSD as a post-hoc procedure revealed that the groups' sensitivity (d') significantly differed from each other, Neutral = Happy > Angry. As can be seen in Fig. 1, the most pronounced CDE (i.e., difference between Repeat and Re-pair conditions) was seen in the Angry group, followed by the Happy group. CDE was the least pronounced in the Neutral group. Thus, participants were most sensitive to changes from angry expressions to neutral or happy ones, and least sensitive to changes from neutral expressions to angry or happy ones.

3.3. Recognition (response bias – C)

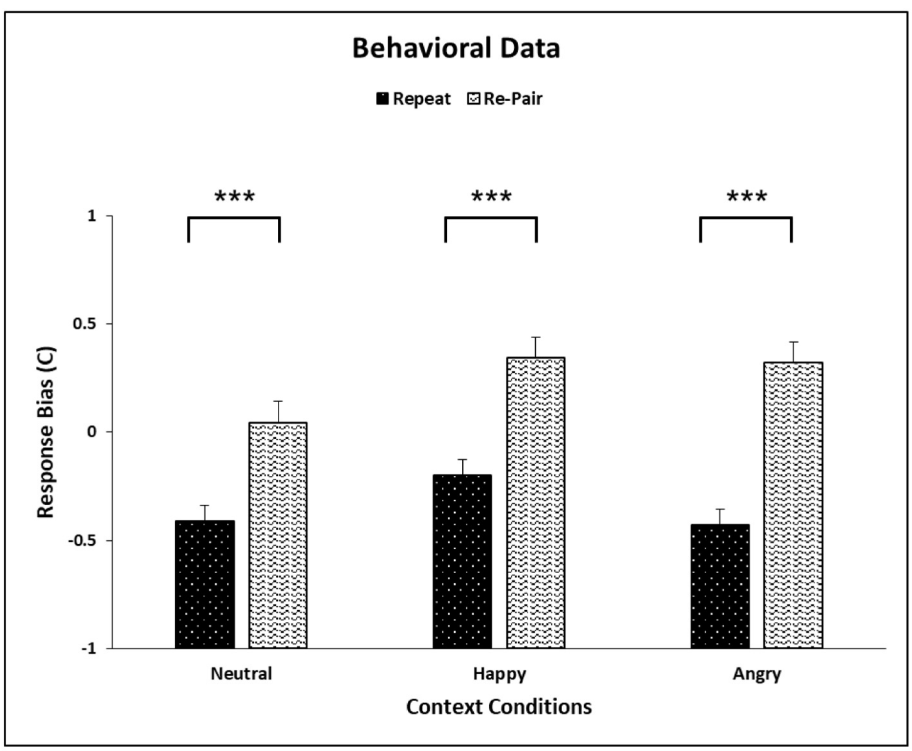
In addition to the sensitivity measure d', we also calculated the C index, $C = 0.5\,[z(H) + z(FA)]$, as a criterion or response bias measure. When C is negative, it reflects a liberal response bias (a tendency to say "Yes"), and when C is positive it reflects a conservative response bias (a tendency to say "No") (Snodgrass & Corwin, 1988). In order to test the effect of Group (Neutral, Happy, & Angry) and Context (Repeat vs. Re-pair - averaged) on response bias, the C index was submitted to a Mixed Analysis of Variance. The former is a between-subjects factor and the latter is a within-subjects factor.

Overall, the response bias was significantly more liberal under the Repeat condition than under the Re-pair - averaged condition, $F(1, 87) = 165.31.73$, $p < .001$, $\eta_p^2 = 0.66$. In other words, under the Repeat condition (with the original expression) participants tended to say "Yes" more often than under the Re-pair condition when the facial



***p < .001

Fig. 1. Mean (*SE*) of sensitivity (d′) of the three groups (neutral, happy & angry) under Repeat and Re-pair – averaged condition.



***p < .001

Fig. 2. Mean (*SE*) of Response bias (C) of the three groups (neutral, happy & angry) under Repeat and Re-pair – averaged condition.

expression was changed. Group main effect did not reach significance $F(2, 87) = 1.76$, $p = .178$, $\eta_p^2 = 0.04$. These findings should be interpreted cautiously because of the significant interaction, $F(2, 87) = 3.78$, $p < .05$, $\eta_p^2 = 0.08$. In order to detect the source of the interaction, two separate ANOVAs were conducted, one for the Repeat and one for the Re-pair condition. Response bias did not differ between the three groups under the Repeat condition, $F(2, 87) = 1.31$, $p = .28$. As can be seen in Fig. 2, the three groups tended to have a liberal response bias when the original faces were presented with the original facial expressions. This finding is understandable, because the stimuli looked very familiar and participants accordingly tended to respond more often “Yes, I have seen this picture”. However, under the Re-pair - averaged condition, the difference between the groups was marginally significant, $F(2, 87) = 3.00$, $p = .055$. LSD as a post-hoc procedure revealed that the Happy and Angry groups' response bias was more conservative than that of the Neutral group (see Fig. 2).

3.4. Eye movement results

The eye movement measure used in this study is DT, which is defined as the sum of durations of all fixations and saccades that hit the Area of Interest (AOI). Three AOIs were analyzed in the current study; the eyes (each eye is marked separately), the nose and the mouth (see Appendix 2). These areas were chosen based on previous studies that showed that these are the regions that are most frequently looked at during facial recognition (Barton, Radcliffe, Cherkasova, Edelman, & Intriligator, 2006).

3.4.1. Study phase

In order to test the prediction that longer DT at the study phase strengthens identity and expression of binding, we correlated the magnitude of CDE with DTs of the three AOI, eyes, nose and mouth, separately under the Repeat and Re-pair conditions. CDE was measured by subtracting the d' of the Re-pair condition from the d' of the Repeat condition, which reflects the benefit of reinstating the original facial expression. As can be seen in Table 2, longer DT on the face (primarily on the eyes) at the study phase was *positively* correlated with CDE under the Repeat condition. Interestingly, however, longer DT in each one of the AOIs was *negatively* correlated with CDE under the Re-pair condition.

3.4.2. Test phase

As in the study phase, correlations were conducted (separately for the Repeat and Re-pair conditions) in order to test the prediction that longer DT on the three AOI (eyes, nose and mouth) at the test phase is associated with the CDE magnitude. As can be seen in Table 3, the general pattern of correlations at the test phase is similar to that of the study phase, namely, a positive correlation under the Repeat condition and negative correlation under the Re-pair condition. However, it is interesting to note the differences between these two tables. At study, the positive correlation with CDE under the Repeat condition was primarily with DT on the eyes, while at test the positive correlation is primarily with DT on the nose. The negative correlation at the study phase under the Re-pair condition was with DT on all AOIs, but at test, it was only with DT on the eyes.

4. Discussion

The behavioral findings clearly indicate CDE, i.e., that face recognition is impacted by consistency of the facial expression. When the facial expression at the test phase remains the same as in the study phase (i.e., Repeat), correct recognition of the face is more likely than if the facial expression changes (i.e., Re-pair). It is important to note that the d' reflecting correct recognition under the Repeat condition was similar for the three groups. Furthermore, recognition of faces with angry expressions was found to be most sensitive to change of facial expression from study to test, compared with faces with happy expressions. That is the largest difference in d' between the Repeat and Re-pair conditions. The least sensitive category (although significantly affected as well) was faces with neutral expressions. This can be interpreted as an indication of binding between invariant and changeable facial features. Additionally, the strength of the binding as reflected by CDE is a function of the strength of the emotion expressed, that is angry > happy > neutral.

Table 2
Correlation between DT at study phase on eyes, mouth and nose with CDE (d′ under Repeat – d′ under Re-pair conditions) for the Repeat Re-pair conditions.

Study phase	CDE old faces Repeat condition ($n = 87$)	CDE old faces Re-pair condition ($n = 87$)
Dwell time - Eyes	0.31**	−0.23*
Dwell time - Mouth	0.12	−0.24*
Dwell time - Nose	0.10	−0.30**

* $p < .05$.
** $p < .01$.

Table 3
Correlation between DT at testing phase on eyes, mouth and nose of the old faces with CDE (d′ under Repeat – d′ under Re-pair conditions) for the Repeat Re-pair conditions.

Test phase	CDE old faces Repeat condition ($n = 87$)	CDE old faces Re-pair condition ($n = 87$)
Dwell time - Eyes	0.17	−0.33**
Dwell time - Mouth	0.02	−0.06
Dwell time - Nose	0.34**	−0.20

** $p < .01$.

Analysis of response bias as measured by C index showed that when facial expression remained constant from study to test (i.e., Repeat condition), participants tended to have a more liberal response bias (tended to say “Yes” more often) than when facial expression was changed from study to test (i.e., Re-pair condition). Moreover, the Happy and Angry groups showed a more conservative response bias than that of the Neutral group. Thus, a change in facial expression from happy or angry caused the participant to respond more hesitantly and more conservatively than a change from a neutral to a happy or angry expression. Such a change may possibly be perceived as less dramatic than a change from happy or angry.

These findings are contrary to Haxby et al. (2000) cited above, who claim that representation of identity must be relatively independent of representation of the changeable aspects of a face. Moreover, these results support the approach that suggests that identity recognition and facial recognition are interacting systems (Yankouskaya, Booth, & Humphreys, 2012). Though as was pointed out in the introduction, the relationship between facial identity and expression and CDE could be viewed as two orthogonal issues. CDE could emerge even if identity and expression are independent, because the definition of context can be very broad and flexible, including not only external visual similarity of the stimuli under the same expression category, but also internal feelings induced by the facial expression.

In a previous study, D'Argembeau and Van Der Linden (2007) found that faces were better recognized when presented at study with happy expressions than with angry ones. They attribute the advantage of faces with happy expressions over angry ones to the fact that happy expressions attract less attention than angry expressions, which allows more resources to process the facial identity. Our results may indicate an alternative explanation. In their paradigm, facial expression always changed from study (either happy or angry) to test (always neutral). To use our terminology, they only tested face recognition under the Re-pair condition, without a Repeat condition. Our findings showed that recognition of the identity of faces under the Repeat condition was equal for all faces. However, face identity recognition for angry expressions was more sensitive to changes than recognition of faces with happy (and neutral) expressions. This can explain their findings, as faces with angry expressions are recognized to a lower degree than faces with happy expressions.

Our results may also offer an alternative interpretation of the findings reported by Nomi et al. (2013). In their study, they presented faces with neutral, happy and angry expressions at the study phase. At the test phase, all faces were presented with neutral expressions and they found that the neutral faces were best recognized. Their conclusion was that “neutral expressions elicited better identity recognition”. However, they state that this is not a definitive conclusion because presentation angle and facial expressions were simultaneously manipulated. Based on our results, our interpretation would be that neutral faces were best remembered simply because their facial expression did not change from study to test (i.e., Repeat condition), unlike the faces with happy and angry expressions which changed to neutral during the test phase (i.e., Re-pair condition).

The finding that emotional salience and especially threat (anger) has a facilitating effect on contextual processing is consistent with other research that showed similar facilitation of attentional processes when angry or fearful faces were presented. These processes include diminution of repetition blindness (Mowszowski, McDonald, Wang, & Bornhofen, 2012) and attentional blinking (Milders, Sahraie, Logan, & Donnellon, 2006). The pattern seen in the results of the present study may reflect the influence of bottom-up subcortical, specifically amygdala, activation which provides rapid orientation to emotionally significant information and enhances perceptual sensitivity and post-encoding consolidation into memory (Anderson & Phelps, 2001).

The analyses of eye movements at the study and test phases offer several insights into the processes underlying the face recognition task. In general, longer DT on the face at the study and test phases was *positively* correlated with CDE under the Repeat condition. Interestingly, however, longer DT was *negatively* correlated with CDE under the Re-pair condition (see Tables 2 & 3). Thus, longer DT presents an advantage when the same facial expression is presented at study and test (i.e., Repeat condition), but it presents a disadvantage when participants viewed a different facial expression between study and test (i.e., Re-pair). Longer DT may enable stronger binding between the invariant facial features that determine face identity (i.e., Target) and changeable facial features such as facial expression (i.e., Context). Therefore, long DT becomes an advantage under the Repeat condition and a disadvantage under the Re-pair condition. On the other hand, shorter DT forms more flexible binding which is an advantage under the Re-pair condition.

Although the pattern of correlations at study (Table 2) and test (Table 3) is similar, it is also important to note two differences. First, at study under the Repeat condition, the positive correlation with CDE was primarily with DT on the eyes, while at test it is primarily with DT on the nose. Perhaps at the encoding phase the eyes are the best predictors of CDE, enabling better binding than other AOIs. However, at test focusing on the nose enables a more holistic processing of the face needed for recognition of familiar stimuli (i.e., Repeat condition). Second, the negative correlation at the study phase under the Re-pair condition was with DT on all AOIs but at test, it was only with DT on the eyes. These results might indicate that at study, longer DT, regardless of the region on the face, would harm recognition if the facial expression is changed (i.e., Re-pair condition). However, at test only longer DT on the eyes would harm recognition. The exact contribution of DT to recognition for each of the AOIs at study and test requires further research.

The exact same pattern of results emerged when DT was analyzed at the test phase (see the similarity between Tables 2 and 3). This similarity suggests that the scanning patterns at study and at test are associated in the same way with behavioral performance: namely, longer DT is an advantage for recognition under the Repeat condition and a disadvantage under the Re-pair condition.

It is interesting to note that out of the three AOIs in the face (i.e., eyes, nose, & mouth) DT on the mouth was the least informative (showing a significant correlation in only one case). This finding is consistent with previous reports showing that participants focus primarily on the nose (Hsiao & Cottrell, 2008) or just below the eyes (Peterson & Eckstein, 2012) during face recognition. These two studies concluded that fixations clustered around the middle of the face are optimal for face recognition. This strategy of focusing on the medial face is reasonable because as Farah, Wilson, Drain, and Tanaka (1995) claim, faces are represented and recognized holistically.

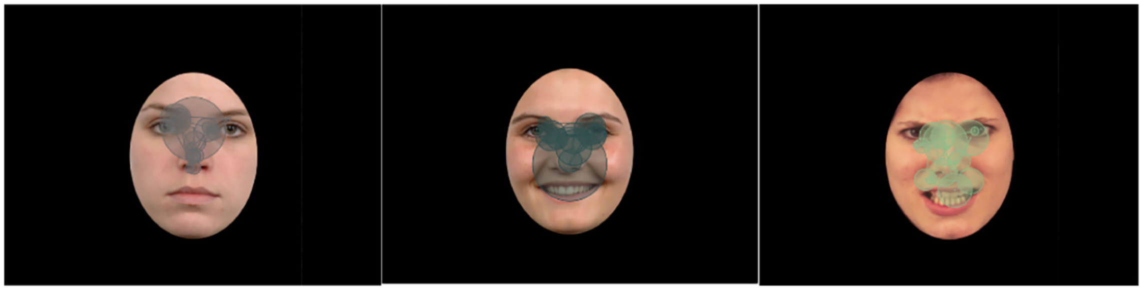
In summary, it was found that consistency of facial expressions between study and test facilitated face identity recognition. This finding can be viewed as memory CDE when face identity is the target (to be remembered) and facial expression is the context. The theoretical significance of these findings is that these two components of facial recognition interact with each other, which is consistent with Yankouskaya et al. (2012). Eye tracking provided further insights into the underlying processes of face recognition. In general, lengthier focus on the face at study and at test is an advantage when the same face and same expression is presented at study and test (i.e., Repeat condition), but is a disadvantage when the face is presented at test with a different expression than at study (i.e., Re-pair condition). Also, we found that there are two factors that determine the strength of binding between Target and Context, i.e., between facial identity and facial expression, respectively. One factor is DT - the longer the duration, the stronger the binding. The other factor is the type of facial expression - angry expressions lead to stronger target-context binding than happy and neutral expressions.

These findings also have implications for eyewitness memory literature. This study demonstrates that the facial expression of a suspect in either live or photo lineup could affect identification. The criminal's facial expression in the crime scene is probably negative, angry and threatening while at the lineup is probably neutral. Our findings demonstrate that such discrepancy of facial expression between encoding and retrieval could significantly harm the accuracy of identification (the strongest CDE was in angry expression). Furthermore, Christianson (1992) and Laney, Campbell, Heuer, and Reisberg (2004) show that under stress, attention is narrowed down leading the eyewitness to focus more on central details at the expense of peripheral details. As our eye movements' results show, longer DT is an advantage for the Repeat condition, but is a disadvantage to the Re-pair condition. Therefore, if there is a mismatch between facial expression between encoding and retrieval, the longer DT at encoding would impair identification. Thus, as concluded above, longer exposure at encoding at a negative expression would significantly impair identification. Therefore, in order to improve identification, it is recommended to present the suspect at either live or photo lineups with a negative facial expression, which presumably matches the expression at the crime scene better.

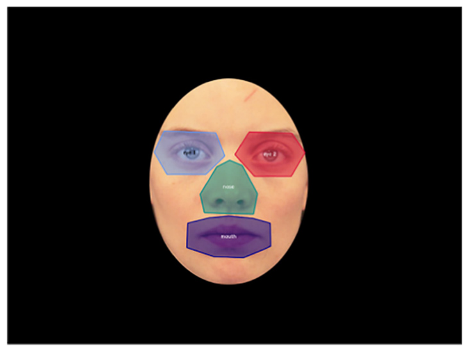
Author notes

The authors report no conflicts of interest.

Appendices



Appendix 1.



Appendix 2.

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