Archives of Clinical Neuropsychology, 2025, **40**, 993–1001
https://doi.org/10.1093/arclin/acaf008
Advance access publication date 3 February 2025
Original Empirical Article

OXFORD

The Effect of Body Expressions on the Learning Process and Facial Recognition among Healthy Participants and Individuals with Traumatic Brain Injury: Examination Using Eye Movements

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ABSTRACT

Objective: Context-dependent effect (CDE) is a process by which reinstating at test the original learning context enhances the recall ability of the material being studied. Although recognition by people with traumatic brain injury (TBI) is poorer than that of healthy controls, both groups show CDE equally. In the current study, we seek to test the effect of body emotional expressions as contextual information, on facial recognition, and eye movements.

Method: Twenty-four healthy individuals and 27 patients with moderate-to-severe TBI participated in the study. Participants were exposed to photos of people with neutral facial and body expressions and were asked to remember the people for a subsequent memory test. In the testing session, they were asked to determine whether the person presented to them had appeared before, under two conditions: (1) where the context remains constant (facial and body expressions remained neutral–Repeat condition) and (2) where the context changes (facial expression remained neutral but the body expression changed to angry or happy–Re-pair condition).

Results: While the memory of the individuals with TBI was poorer than that of the controls, both groups exhibited equal CDE. We found that both groups, controls more than TBI, spent most of their time looking at the head. Furthermore, longer dwell time was associated with better recognition in the study phase.

Conclusions: These findings are consistent with previous studies showing that despite impaired memory following TBI compared to a control group, CDE was preserved. The current study extends the context effect to body postures that express emotion.

Keywords: Facial expression; Memory; Eye tracking; TBI

The diffuse nature of injuries in traumatic brain injury (TBI) causes deficits in various domains, including emotional, behavioral, social, and cognitive. Among the most pronounced impaired cognitive domains are attention, processing speed, executive functions, and memory. Memory impairment influences a wide range of everyday activities, employability, and social interactions (for review, see Vakil, 2005, 2013, 2024). Thus, not surprisingly, memory impairment is the most frequent complaint by individuals with TBI, as well as by their families (Arcia & Gualtieri, 1993). In addition, when examining the recognition of facial expressions of basic emotions in emotional visual contexts, patients with TBI performed less accurately and more slowly in comparison to non-brain-damaged persons (Lancelot & Gilles, 2019). Facial expressions inform and convey information about others' emotions and social intentions and are, therefore, critical for social interactions. The predominant Basic Emotion Approach is based on a rapid, automatic perception of emotions in other people, based on universal facial expression categorization of prototypes. However, people's facial expressions are not perceived in isolation but within a context affected by other people, the environment, and information transmitted from the perceived person (Kelly et al., 2019). Several studies have demonstrated the effect of emotional context in general (Van den Stock & de Gelder, 2007) and facial expressions in particular on face recognition (Parag & Vakil, 2018; Vakil et al., 2019).

Aviezer et al., (2011) addressed the question as to whether the process of face-context integration is primarily a controlled or automatic process. The results suggest that face-context integration processes are automatic on two dimensions: intentionality and effort. Accordingly, the context of the body in facial recognition is processed and perceived in an unintentional,

Received: August 12, 2024. **Revised:** December 5, 2024. **Accepted:** January 9, 2025

uncontrolled, and relatively effortless manner, i.e. automatically. By contrast, Kelly et al., (2019) noted that the situational context may be processed by the perceiver in relation to the social information he/she has gained from life experiences, thus biasing processing based on these experiences. Perception of facial expressions is mostly influenced by contextual variables, such as verbal, visual, and auditory information perceived together with the face. These complex factors challenge the assumption of the existence of an automatic emotional mechanism that enables the prediction of basic emotions by facial expressions (Kelly et al., 2019). The term "vicarious responding" refers to body-related brain areas activated by another person's expressions or imagined situations, showing that conceptually related ideas rely on shared mirrored perceptions (Heberlein & Atkinson, 2009).

In their research, Chen et al., (2015) aimed to examine the effect of facial expression on face identification in the retrieval phase, so participants observed faces with neutral expressions, and at the test, two-thirds of the stimuli changed to angry or happy expressions, while one-third remained with neutral expression. The results of this study showed that facial expressions of happy faces were more successfully identified than angry faces. Bucher and Voss (2018) also found evidence for a selective perception of emotional faces and claimed the existence of faster processing of happy moods on happy faces than on neutral expressions. Bucher et al., (2020) also found that happy moods and happy faces were more often and more accurately identified than angry expressions. Their findings indicate that contextual effects reflect interpretive processes and induce changes in visual processing. Elias et al., (2017) noted that happy crowds' emotionality was more precisely judged in comparison with angry, fearful, or neutral crowds' emotions. In their study, participants had to define dynamically changing facial expressions and indicate the average mood of the crowd. Happiness showed superiority over other defined crowds' moods. Bucher et al., (2020) found a longer fixation on happiness compared with expressions of anger, which might indicate a preference for positive emotions.

Using eye-movement measures is considered a common research method for evaluating cognitive processes in general and memory in particular. This method does not require language skills; it can be used with children, the elderly, amnesics, and even with animals (Holm et al., 2008; Vakil et al., 2019, 2019). Aviezer et al., (2008) examined fixation patterns during face scanning and found that by monitoring eye movements, characteristic fixation patterns, previously regarded as solely determining facial expressions, are modulated by emotional context at the early stages of visual processing. The researchers also indicated that different facial regions are utilized while processing different expressions, such as disgust, which requires focusing on the mouth and nose, whereas anger requires focusing on the eyes and eyebrows. Studies in this field have found a connection between eye movement and memory (Hannula et al., 2007; Heisz et al., 2013; Kafkas & Montaldi, 2011; Parag & Vakil, 2018; Snow et al., 2011; Vakil et al., 2019). For example, Hannula et al. (2007) found that participants tended to spend more time looking at familiar than new stimuli, and this occurred more than one second before the explicit memory answer. It was also found that there is a tendency to make more fixations in the study phase toward stimuli that were eventually correctly remembered (Heisz et al., 2013; Kafkas & Montaldi, 2011). This connection was also found in the retrieval phase, as participants spent more time looking at a familiar stimulus than at a new one (Chanon & Hopfinger, 2008; Chen & Lee, 2015; Ryan et al., 2007). These studies were conducted on a healthy population, but there are also studies that compared neurotypical individuals to individuals with TBI. These studies indicated that although both groups showed an association between memory performance and eye movements, the pattern of people with TBI differed from that of the healthy group (Deitcher et al., 2020; Suh et al., 2006; Vakil et al., 2019).

The brain functions as a processing network of emotional observations and links the perceived action to emotional body language so that behavioral gestures are translated into emotional meanings (de Gelder, 2006; Tipper et al., 2015). Body expressions have strong contextual effects on facial emotional perception. Rajhans et al. (2016) demonstrated that neural mechanisms enable the integration of emotion across the body and face. It exists in human beings from an early developmental stage of childhood, reflecting a context-sensitive facial emotion perception. Body expressions are perceived as the most evolutionarily immediate means of conveying emotional information. They may provide contextual cues to viewing and perceiving facial expressions during social interactions. Sometimes, the body and face convey conflicting emotional information, so the context has an important role in their decoding (Rajhans et al., 2016). Contrary to Rajhans et al., recent research shows that body context may alter the categorization of facial expressions. Although unique patterns exist in faces and bodies, the emotional expressions of faces and bodies contextualize each other bidirectionally under context effects, so faces are influenced by bodies, and bodies are influenced by faces (Lecker et al., 2020).

Not only do people's faces reflect their emotions, but their body expressions as well. The Emotional Body Language theory claims the existence of a whole body's signal system, perceived and understood by people. It has a role in presenting emotional communication and impacts decision-making. An angry face followed by body signals such as a fist, a fearful face followed by body signals such as frightened movements, hand gestures, and other body actions may be indicators of emotions just like facial expressions (de Gelder, 2006; Van den Stock & de Gelder, 2007). Mortillaro and Dukes (2018) identified associations between body actions and facial emotions. They claimed that the inclusion of head and upper body movements makes emotions more distinguishable. For example, the authors state that facial expressions of pride and contentment cannot be differentiated from the body, as they are associated directly with the head's position.

People with TBI present reduced emotional expressiveness, which is perceived by others as being less interested. It seems that TBI reduces understanding of others' facial gestures as well. Spikman et al., (2013) found a significant deficit in affect recognition in patients with TBI, who were impaired in emotional recognition of Fear, Anger, Disgust, and Sadness, but not for Surprise and Happiness. As a result, they showed significant behavioral deficits toward others, impaired self-awareness, and limitations of social cognition.

The important role of context in memory processes has been recognized for many years. A context-dependent effect (CDE) is said to occur when memory performance is improved by the presence of the original contextual stimulus in the test phase as well as in the study phase. In a series of studies using a variety of paradigms and contextual information, Vakil and colleagues have consistently shown that although context memory is impaired when tested explicitly following moderate-to-severe TBI, it is, in fact, preserved when tested implicitly (i.e. CDE) (for review, see Vakil, 2024).

In a previous study (Lugasi et al., 2023), we demonstrated that individuals with TBI showed facilitation of face recognition when facial emotional expressions were consistent between study and test (i.e. CDE). This finding indicates that even though patients with TBI have difficulties recognizing facial emotional expressions when tested explicitly when tested implicitly, they nevertheless can benefit from a consistency of emotional expression, as reflected in CDE.

Based on all the above, the current study attempts to address the question of whether individuals with TBI, who have difficulties identifying emotional expressions when asked directly, would still be sensitive to changes of emotions expressed along with body posture, just as was found with facial emotional expressions (Lugasi et al., 2023). We expected to find CDE among both groups, even though the memory (i.e. facial recognition) of people with TBI would be poorer. Thus, facial recognition would be significantly better under the "Repeat" condition in which the body posture (i.e. context) remained the same at the test as in the study phase, compared to the "Re-pair" condition in which body posture was changed from the study to the test phase. In terms of eye movements, we hypothesized that participants of both groups would spend significantly more time looking at the head as a central part of detecting emotion and memory, as mentioned above (Mortillaro & Dukes, 2018).

METHOD

Participants

The neurotypical healthy control group consisted of 24 participants (11 males), whose ages ranged from 21 to 27 years ($M = 23.45$, $SD = 1.47$), and their years of education ranged from 12 to 13 years ($M = 12.29$, $SD = 0.46$). All of them were undergraduate students at Bar-Ilan University (Israel). The students took part in the experiment to fulfill academic requirements. None of the undergraduate students had a history of neurologic or psychiatric disorders, based on self-reports. The patients who were recruited from the Loewenstein Rehabilitation Hospital were diagnosed by the hospital's clinical staff with moderate-to-severe TBI and were hospitalized (up to 6 months) while participating in the study. The experimental group of patients with TBI consisted of 27 participants (17 males), whose ages ranged from 19 to 39 years ($M = 23.30$, $SD = 4.63$). Age was not significantly different between the groups ($t(49) = 2.23$, $p = .08$). The study was approved, as required, by the Helsinki Committee of Loewenstein Rehabilitation Hospital. Consent to take part in the study was obtained from all participants. All participants are Hebrew speakers.

Note that one individual from the TBI group was excluded from the behavioral analysis of sensitivity (d') due to extreme values on this measure (more than two *SD*s below the mean).

Instruments

Eye tracker

The stimuli were presented on a laptop with a 15.6-inch screen. A camera with an infrared source was located at the front of the laptop screen, 60 cm away from the participant, below the participant's eye level. The temporal parameter presentations of the stimuli were presented on E-PRIME 2.0 software, which also schedules the appearance of the stimuli with computer-recorded eye movements and automatically records the participant's reaction time (RT). A SensoMotoric Instrument (SMI) RED-M remote eye-tracker recorded the eye movements. This system has a sampling rate of 120 Hz and a high accuracy of 0.5 °. At the beginning of the experiment, a 9-point calibration cycle was presented, providing a spatial resolution of 0.1 °.

Visual Stimuli

In the current study, we used a total of 118 different colored facial photos of Caucasian males and females with neutral facial expressions. 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). The photos were selected based on a high inter-rater agreement on the facial emotional expression. In addition, we used six color photos of body postures (half male and half female), two neutral, two happy, and two angry. The pictures were based on the stimuli of (with the author's permission) Aviezer et al., (2008).

In order to ensure that attention was directed entirely at the face, the model's hair, ears, and neck were covered with a black oval frame. This method of framing was used in a previous study (Vakil et al., 2019). The selected photos were combined from neutral expression and body posture with the required emotions (see Appendix 1, a neutral, happy, and angry posture, from left to right, respectively).

Task and procedure

The participants were tested individually. Upon arrival, participants were informed that they would participate in a facial recognition experiment and were instructed to observe and try to remember the person who appeared on the screen for a future recognition test, regardless of their facial or body expression (the same instructions appeared on the computer screen). This instruction was deliberately given in order to create the dissociation between the "target" stimulus (which is the face) and the "context" stimulus (which is the body position) to test the CDE. They were also informed that their eye movements would be monitored. Calibration was conducted at the beginning of the task using a standard 9-point grid for both eyes. A 4-point grid was used for validation after each calibration trial. If the accuracy exceeded 0.8 °, calibration and validation were repeated.

In the study phase, 42 color photos of people (21 men and 21 women) were presented to participants consecutively, each photo for 5 s. The expression of all faces was neutral, and so was their body posture. During the test phase, 84 color photos of people were presented to participants, half of which had appeared in the study phase—old and half of which were new. The stimuli were presented in random order in both the learning and test phases. Participants were asked to press a key on the keyboard to signify whether the photo (regardless of whether the body posture was the same or not) was old (L) or new (A). Unlike the study phase, in the test phase, the photos remained on the screen until there was a response. One-third of the old photos (14) remained with the same neutral body posture as they had in the study phase (the Repeat condition), and two-thirds changed to another emotional body posture, the "Re-pair" condition (14 photos changed to angry expressions and 14 to happy body expressions). Regarding the new photos, one-third of them had a neutral body posture, one-third had a happy body posture, and one-third had an angry body posture. For all conditions, the facial expression remained neutral.

RESULTS

Behavioral results

In order to control for response bias, we used the sensitivity measure d' ($d' = z(H) - z(FA)$) (Snodgrass & Corwin, 1988) as the dependent measure. This measure was calculated by combining the Hits Rate (H) (the number of correct "Yes" responses for the 14 old faces in each condition) and the False Alarm (FA) rate (the number of incorrect "Yes" responses for the 14 new faces in each condition). With the purpose of testing the CDE, we compared the Repeat condition's performance (i.e. Neutral expression) with the two Re-pair conditions (i.e. Angry and Happy expressions).

Mixed-design Analysis of Variance (ANOVA) (2 × 2) was conducted to analyze the effect of Group (control versus TBI) and Context (Repeat vs. Re-pair, averaged happy and angry). The former is a between-subjects factor, and the latter is a within-subjects factor. Note that because we do not have specific predictions for the happy and angry conditions, those results were averaged for simplification of the data analyses.

Recognition (sensitivity–d')

Larger absolute values of d' mean that a person is more accurate and more sensitive in terms of signal-to-noise ratio. d' values near zero indicate chance performance. Consistent with our hypothesis, CDE was found so that the sensitivity measure was significantly higher under the Repeat condition compared to the averaged Re-pair conditions, $F(1, 49) = 8.69$ $p < .01$ $\eta_p^2 = 1.15$. Group effect was also significant, so groups performed differently on the sensitivity measure, in total $F(1, 49) = 5.96$, $p < .05$, $\eta_p^2 = 0.11$. Examination of the means shows that overall, the sensitivity measure of the control group was higher than the TBI group ($M = 1.17$, $SD = 0.16$; $M = 0.64$, $SD = 0.15$, respectively). The interaction between context and group was not significant $F(1, 49) = 0.01$, $p = .95$, $\eta_p^2 = 0.01$, so both groups exhibited CDE to the same extent (see Fig. 1).

Recognition (response bias–C)

In addition to the sensitivity d' measure, we calculated the measure C, $C = 0.5\,[z(H) + z(FA)]$ as a criterion of response bias. When C is negative, it reflects a liberal response bias (tendency to say "yes"), and when C is positive, it reflects a conservative response bias (tendency to say "no") (Snodgrass & Corwin, 1988). Mixed-design ANOVA was conducted to analyze the same factors as above. In general, the main effect for the group was not significant, so there was no overall difference between the control and the TBI groups, $F(1, 49) = 0.92$, $p = .34$, $\eta_p^2 = 0.02$. CDE effect was significant, so there was a difference between the context conditions, $F(1,49) = 7.62$, $p < .01$, $\eta_p^2 = 0.14$. As can be seen in Fig. 2, under the Repeat condition, response bias (C score) was more negative, which reflects a liberal response bias (tendency to say "yes"), compared to the Re-paired condition in which the responses tended to be more conservative (tendency to say "no"). The interaction between group and context was not significant, $F(1, 49) = 0.68$, $p = .41$, $\eta_p^2 = 0.01$. Thus, response bias for both groups was more conservative under the Re-pair condition than under the Repeat condition (see Fig. 2).

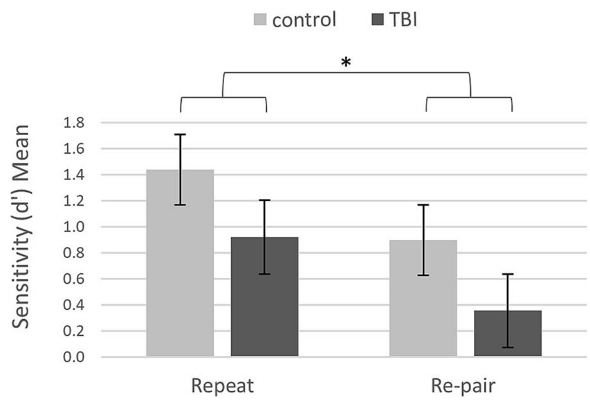

Fig. 1. Mean (SE) of sensitivity (d') of the two groups (control and TBI) under repeat and Re-pair conditions.

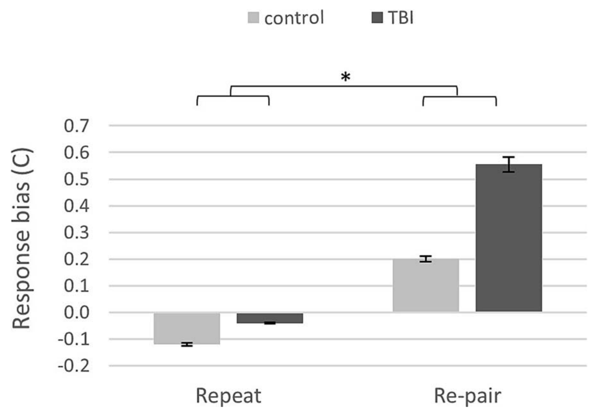

Fig. 2. Mean (SE) of response bias (C) of the two groups (control and TBI) under repeat and Re-pair conditions.

Response time

Finally, we conducted the same mixed-design ANOVA as described above, with RT as a dependent measure. CDE effect was significant, so there was a difference in RT under the Repeat condition compared to the Re-pair condition (on average), $F(1, 49) = 162.41$ $p < .001$, $\eta_p^2 = 0.77$, so the RT (in seconds)

Table 1. Group difference in DT toward each AOI—study phase

AOI	*t*-test	Control ($n = 21$)	TBI ($n = 26$)
Head	$t(45) = 2.75^{**}$	95.36	83.60
Body	$t(45) = -2.26^{*}$	0.45	1.57
WS	$t(45) = -2.51^{*}$	4.18	14.83

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

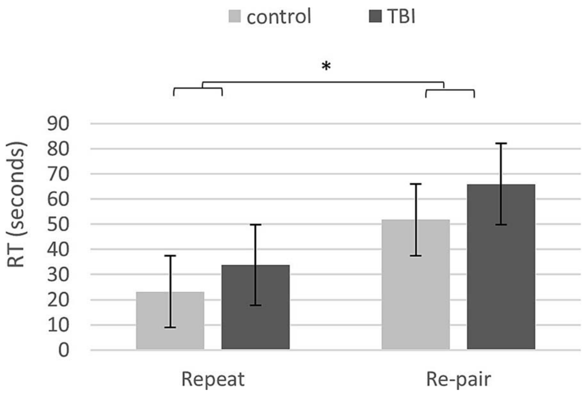

Fig. 3. Mean (*SE*) of Response time (RT) of the two groups (control and TBI) under repeat and Re-pair conditions.

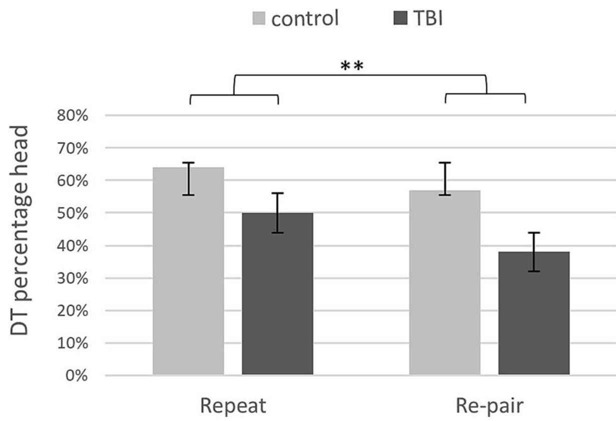

Fig. 4. Mean of DT for the head of the two groups (control and TBI) under repeat and Re-pair conditions in the study phase.

was faster in the Repeat condition ($M = 28.49$, $SD = 2.31$) compared to the Re-pair conditions combined ($M = 58.85$, $SD = 4.36$). Group effect was marginally significant, $F(1, 49) = 3.58$, $p = .06$, $\eta_p^2 = 0.07$. In other words, the control group tended to be faster than the group with TBI. The interaction between context and group was not significant $F(1, 49) = 0.57$, $p = .46$, $\eta_p^2 = 0.01$. Thus, both groups' RT were equally affected by the context condition (see Fig. 3).

Eye movement results

The eye movement measure used in this study is dwell time (DT), which is defined as the sum of durations of all fixations and saccades that hit the Area of Interest (AOI). We analyzed three AOIs: the head and the body (represented by two hands that were marked separately) (see Appendix 2). These areas were selected because they allowed us to examine the effect of body posture (context) on face recognition (target). We ensured that the size of each AOI was equal. We also measured the DT toward the background—White Space (WS) area that is not the person.

Study phase

As can be seen in Table 1, both groups (control significantly more than the TBI group) spent most of the time looking at the head. Much less DT was on the WS and the Body, but here the group with TBI had a longer DT than the controls. As a result of these findings, most of the DT was toward the head; thus, in our analysis, we focused upon only the DT on the head.

In order to test the hypothesis that longer DT in the study phase would be associated with better recognition, a Spearman correlation was computed separately for accuracy (*d'*) in the Repeat and Re-pair conditions, with DTs on the head. This analysis allows us to reflect the benefit of reinstating the original neutral facial expression more accurately. As can be seen in Table 2, in general, there is a significant correlation between the DT toward the head and recognition, so the longer DT on the total areas of the head in the study phase was positively correlated with higher *d'* (remembering the people that were presented in the study phase). This effect was found in both control and TBI groups, but among the TBI group, this effect was found only in the Re-pair condition (in the Repeat condition, it was marginally significant) (see Fig. 4).

Mixed-design ANOVA was performed to test the differences in DT toward the heads that were eventually remembered (Hits) in the two context conditions (Repeat and two Re-pair conditions averaged, within-subjects factor) and the two groups (control and TBI, between-subjects factor). We found a significant main effect for the group so that DT toward correctly recognized heads was higher among the control group ($M = 60.54$, $SD = 4.08$) than the TBI group ($M = 43.88$, $SD = 3.67$), $F(1, 45) = 9.22$, $p < .01$, $\eta_p^2 = 0.17$. Main effect of context was also significant, so DT toward heads in the Repeat condition was higher than toward heads in the Re-pair conditions, $F(1, 45) = 11.29$, $p < .01$, $\eta_p^2 = 0.20$. The interactions between context and group, $F(1, 45) = 0.59$, $p = .47$, $\eta_p^2 = 0.01$ was not significance.

Test phase

As in the study phase, DT in each AOI was analyzed. We found that the control group and the TBI group spent most of the time looking at the head, after that on the WS, and then on the body. In addition, the mean difference between the groups was not significant (see Table 3).

Table 2. Correlation between DT and *d'* in the study phase in the Repeat and the Re-pair conditions

Study phase	Control		TBI	
	d' Repeat ($n=21$)	*d'* Re-pair ($n=21$)	*d'* Repeat ($n=25$)	*d'* Re-pair ($n=25$)
DT – head	0.52*	0.49*	0.34	0.68*

* $p < .05$.

Table 3. Group difference in DT toward each AOI—test phase

AOI	*t*-test	Control ($n=21$)	TBI ($n=26$)
Head	$t(45)=1.20$	76.27	71.01
Body	$t(45)=-1.55$	1.03	2.44
WS	$t(45)=-0.93$	22.70	26.55

Table 4. Correlation between DT and *d'* in the study phase in the Repeat and the Re-pair conditions—test phase

Study phase	Control		TBI	
	d' Repeat ($n=21$)	*d'* Re-pair ($n=21$)	*d'* Repeat ($n=25$)	*d'* Re-pair ($n=25$)
DT – head	0.39	0.56**	0.41*	0.63**

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

As a result of the findings that most of the DT was toward the head, in our analysis we used only the DT toward the head. A Spearman correlation was computed separately under the Repeat and Re-pair conditions (average) between the accuracy measure *d'* and DTs on the head. As can be seen in Table 4, in general, there is a significant correlation between the DT toward the head and recognition, so the longer DT on the total areas of the head in the test phase was positively correlated with higher *d'* (remembering the people that were presented in the study phase). This effect was found in both the control and TBI groups, but among the control group, this effect was found only in the Re-pair condition (in the Repeat condition, it was marginally significant).

Mixed-design ANOVA was performed to test the differences in DT toward the faces that were remembered (Hits) in the two context conditions (Repeat and two conditions of Re-pair averaged, within-subjects factor) and the two groups (control and TBI, between-subjects factor). We found a significant main effect for the group so that DT toward correctly recognized faces was higher among the control group ($M = 46.54$, $SD = 2.82$) than the TBI group ($M = 37.33$, $SD = 2.42$), $F(1, 45) = 5.51$, $p < .05$, $\eta_p^2 = 0.11$. Main effect of context was also found significant, so DT toward people in the Repeat condition ($M = 46.54$, $SD = 2.82$) was higher than toward faces in the Re-pair condition ($M = 37.33$, $SD = 2.42$), $F(1, 45) = 10.85$, $p < .01$, $\eta_p^2 = 0.19$. The interaction between context and group, $F(1, 45) = 0.04$, $p = .84$, $\eta_p^2 = 0.001$ was not significant (see Fig. 5).

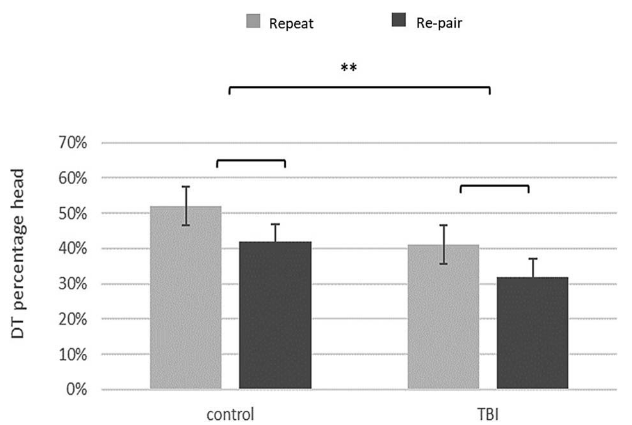

Fig. 5. Mean of DT for the head of the two groups (control and TBI) under repeat and Re-pair conditions in the test phase.

DISCUSSION

Consistent with our hypothesis, CDE found that face recognition (*d'*) was better under the Repeat condition when the person was presented with the original neutral body expression, compared to the Re-pair condition in which the body expression changed from neutral expression at the study phase to happy or angry expression. Interestingly, in the present study, we also found that the group with TBI showed CDE to the same extent as the control group. This CDE was found even though patients with TBI performed less accurately and more slowly in comparison to non-brain-damaged persons.

These findings concurred with previous findings demonstrating that while individuals with TBI have impaired memory when contextual information is tested explicitly, there is no impairment when tested implicitly (i.e. CDE) (Vakil, 2005; Vakil et al., 1996; Vakil et al., 1998). These results also suggested that although previous studies have shown that individuals with TBI have difficulty in perceiving and identifying emotions that were displayed in various modes (Mancuso et al., 2015; McDonald, 2008), the ability to implicitly identify emotions as expressed in body posture is preserved. This is evident from their sensitivity to the change from neutral to happy or angry body expressions yielding the CDE.

These findings are also consistent with a recent study (Lugasi et al., 2023) in which individuals with TBI showed facilitation of facial recognition when facial emotional expressions were consistent between study and test (i.e. CDE). However, we must admit that these results do not necessarily prove that the group with TBI identifies the emotions expressed in body posture. Perhaps the CDE observed simply reflects the fact that the groups noticed the changes in body postures between study and test phases without necessarily interpreting it as changes in emotional expressions. Future studies need to address this alternative interpretation by comparing changes in body postures expressing or not expressing emotions.

In addition, our study implies that expression recognition is influenced by body expression as well, as all the facial expressions in the current study were neutral, and only the body expression expressed happy or angry emotions in the Re-pair conditions. These results support studies that emphasize the interaction between facial and body expression (de Gelder, 2006; Lecker et al., 2020; Mortillaro & Dukes, 2018; Van den Stock & de Gelder, 2007).

Analysis of response bias as measured by the *C* index revealed that participants tended to have a more liberal response bias when the expression remained constant from study to test (i.e. Repeat condition) than when body expression was changed from study to test (i.e. Re-pair condition). A possible explanation for this result is that because under the Re-pair conditions, it is more difficult to recognize the face than under the Repeat condition, participants opted for a more conservative way and chose to say "No." Finally, as expected, participants spent less time before answering the question in the Repeat condition compared to the Re-pair conditions.

One of the aims of the current study was to test the influence of emotional expression by the body on recognition. By examining the DT with the eye tracker, we learned that participants tended to look most of the time at the head and barely looked at the body in the learning and test phases. At the same time, we found a CDE, which means that they definitely perceived the body expression. A possible explanation for these findings is that peripheral vision is sufficient for perceiving body expression. Thus, while participants focused on the head, they probably inferred the body expression.

Eye movement results of the current study support previous results that showed an association between eye movements (DT during the study) and memory performance during a subsequent test. This result was found among the control group and the TBI group, but among the latter, the effect was found only in the Re-pair condition. The results provide additional support for the connection between familiarity and eye movements, so that longer DT toward the stimuli is associated with better performance in recognition of those stimuli (Heisz et al., 2013; Kafkas & Montaldi, 2011; Snow et al., 2011). It is important to note that this association was found not only in the learning but in the test phase as well. In addition, a significant main effect for the group was found, so that DT toward correctly recognized faces was higher among the control group than the TBI group. That might explain the impaired facial recognition (d') of individuals with TBI. This finding probably reflects attentional impairment, which leads to memory deficit. We also found an eye movement reflection of the CDE, as DT toward people in the Repeat condition was higher than toward people in the Re-pair condition. These results indicate that eye movements are sensitive and reflect CDE.

Being the first study to test CDE with body expressions, we decided to keep facial expressions constant (i.e. neutral) in order to test more purely the effect of body expressions. This strategy, however, prevents us from making any conclusive statements about the interaction between facial and body emotional expressions on CDE. In previous studies, we have demonstrated the effect of facial expressions on CDE in neurotypical individuals (Vakil et al., 2019) as well as in individuals with TBI (Lugasi et al., 2023). In order to learn about the interaction between facial and body expressions on CDE, a follow-up study needs to be conducted in which faces with various facial expressions will be tested along with the various body expressions. One limitation of this study is that the group with TBI and the control group differed in some demographic respects, such as the ratio of males/females, which is higher in the group with TBI (17/27) compared to the control group (11/24). In addition, although the mean age does not significantly differ between the groups, there is a disparity in the age range: from 21 to 27 years for the controls and 19 to 39 years for the group with TBI. We posit that the fact that in the group with TBI, there were some older individuals did not affect the results since if anything, this fact led to more impaired performance of the patient group, and despite that, they demonstrated the CDE to the same extent as the controls. Also, unfortunately, years of education for individuals with TBI were not available to us.

In conclusion, the findings of the current study contribute to our knowledge about context effect among individuals with TBI who suffer from severe memory impairment, social interaction problems, and difficulty in understanding facial expressions (i.e. Deitcher et al., 2020; Suh et al., 2006; Vakil, 2005). The current study indicates that changing body expression had the same effect (i.e. CDE) on the group with TBI and the control group. The ability to recognize people and body expressions explicitly might be impaired among people with TBI, but the ability is preserved when using implicit measures. Thus, in addition to the theoretical contribution of the current study, the fact that individuals with TBI are sensitive implicitly to body expression of emotions could have clinical implications. Therefore, in future studies, it would be helpful to have more information about TBI patients and their performance on measures that tap both implicit and explicit memory.

SUPPLEMENTARY MATERIAL

Supplementary Data is available at *Archives of Clinical Neuropsychology* online.

FUNDING

This work was supported by the Israeli Ministry of Defense, Rehabilitation Department, under Grant number [203003–846].

CONFLICT OF INTEREST

The authors report no conflict of interest.

ACKNOWLEDGEMENTS

The authors wish to thank Professor Hillel Aviezer for permitting use of the pictures with body expressions.

AUTHOR CONTRIBUTIONS

Natalie Lugasi (Conceptualization, Data curation, Formal analysis, Investigation, Project administration, Writing—original draft), Yaron Sacher (Data curation, Methodology, Resources) and Eli Vakil (CRediT contribution not specified).

REFERENCES

Arcia, E., & Gualtieri, C. T. (1993). Association between patient report of symptoms after mild head injury and neurobehavioural performance. *Brain Injury*, 7(6), 481–489. https://doi.org/10.3109/02699059309008175.

Aviezer, H., Dudarev, V., Bentin, I. S., & Hassin, I. R. R. (2011). The automaticity of emotional face-context integration. *Emotion*, 11(6), 1406–1414. https://doi.org/10.1037/a0023578.

Aviezer, H., Hassin, R. R., Ryan, J., Grady, C., Susskind, J., Anderson, A., et al. (2008). Angry, disgusted, or afraid? Studies on the malleability of emotion perception. *Psychological Science*, 19(7), 724–732. https://doi.org/10.1111/j.1467-9280.2008.02148.x.

Bucher, A., & Voss, A. (2018). Judging the mood of the crowd: Attention is focused on happy faces. *Emotion*, 19(6), 1044–1059. https://doi.org/10.1037/emo0000507.

Bucher, A., Voss, A., Spaniol, J., Hische, A., & Sauer, N. (2020). Age differences in emotion perception in a multiple target setting: An eye-tracking study. *Emotion*, 20(8), 1423–1434. https://doi.org/10.1037/emo0000645.

Chanon, V. W., & Hopfinger, J. B. (2008). Memory's grip on attention: The influence of item memory on the allocation of attention. *Visual Cognition*, 16(2–3), 325–340. https://doi.org/10.1080/13506280701459026.

Chen, H. C., & Lee, Y. S. (2015). The eye movement measure of memory and its relationship with explicit measures. *Consciousness and Cognition*, 33, 354–363. https://doi.org/10.1016/j.concog.2015.02.003.

Chen, W., Liu, C. H., Li, H., Tong, K., Ren, N., & Fu, X. (2015). Facial expression at retrieval affects recognition of facial identity. *Frontiers on Psychology*, 6(780), 1–9. https://doi.org/10.3389/fpsyg.2015.00780.

Deitcher, Y., Sachar, Y., & Vakil, E. (2020). Effect of eye movement reactivation on visual memory among individuals with moderate-to-severe traumatic brain injury (TBI). *Journal of Clinical and Experimental Neuropsychology*, 42(2), 208–221. https://doi.org/10.1080/13803395.2019.1704223.

Elias, E., Dyer, M., & Sweeny, T. D. (2017). Ensemble perception of dynamic emotional groups. *Psychological Science*, 28(2), 193–203. https://doi.org/10.1177/0956797616678188.

de Gelder, B. (2006). Towards the neurobiology of emotional body language. *Nature Reviews Neuroscience*, 7(3), 242–249. https://doi.org/10.1038/nrn1872.

Hannula, D. E., Ryan, J. D., Tranel, D., & Cohen, N. J. (2007). Rapid onset relational memory effects are evident in eye movement behavior, but not in hippocampal amnesia. *Journal of Cognitive Neuroscience*, 19(10), 1690–1705. https://doi.org/10.1162/jocn.2007.19.10.1690.

Heberlein, A. S., & Atkinson, A. P. (2009). Neuroscientific evidence for simulation and shared substrates in emotion recognition: Beyond faces. *Emotion Review*, 1(2), 162–177. https://doi.org/10.1177/1754073908100441.

Heisz, J. J., Pottruff, M. M., & Shore, D. I. (2013). Females scan more than males: A potential mechanism for sex differences in recognition memory. *Psychological Science*, 24(7), 1157–1163. https://doi.org/10.1177/0956797612468281.

Holm, L., Eriksson, J., & Andersson, L. (2008). Looking as if you know: Systematic object inspection precedes object recognition. *Journal of Vision*, 8(4), 14–17. https://doi.org/10.1167/8.4.14.

Kafkas, A., & Montaldi, D. (2011). Recognition memory strength is predicted by pupillary responses at encoding while fixation patterns distinguish recollection from familiarity. *The Quarterly Journal of Experimental Psychology*, 64(10), 1971–1989. https://doi.org/10.1080/17470218.2011.588335.

Kelly, K. M., Kiderman, A., Akhavan, S., Quigley, M. R., Snell, E. D., Happ, E., et al. (2019). Oculomotor, vestibular, and reaction time effects of sports-related concussion: Video-oculography in assessing sports-related concussion. *Journal of Head Trauma Rehabilitation*, 34(3), 176–188. https://doi.org/10.1097/HTR.0000000000000437.

Lancelot, C., & Gilles, C. (2019). How does visual context influence recognition of facial emotion in people with traumatic brain injury? *Brain Injury*, 33(1), 4–11. https://doi.org/10.1080/02699052.2018.1531308.

Lecker, M., Dotsch, R., Bijlstra, G., & Aviezer, H. (2020). Bidirectional contextual influence between faces and bodies in emotion perception. *Emotion*, 20(7), 1154–1164. https://doi.org/10.1037/emo0000619.

Lugasi, N., Sachar, Y., & Vakil, E. (2023). The effect of facial expressions on the process of learning, and memory of face images among healthy participants and individuals with traumatic brain injury (TBI): Examination using eye movements. *Psychology*, 14(08), 1361–1380. https://doi.org/10.4236/psych.2023.148077.

Mancuso, M., Magnani, N., Cantagallo, A., Rossi, G., Capitani, D., Galletti, V., et al. (2015). Emotion recognition impairment in traumatic brain injury compared with schizophrenia spectrum: Similar deficits with different origins. *The Journal of Nervous and Mental Disease*, 203(2), 87–95. https://doi.org/10.1097/NMD.0000000000000245.

McDonald, S. B. (2008). Emotion perception deficits following traumatic brain injury: A review of the evidence and rationale for intervention. *Journal of the International Neuropsychological Society*, 14(4), 511–525. https://doi.org/10.1017/S1355617708080703.

Mortillaro, M., & Dukes, D. (2018). Jumping for joy: The importance of the body and of dynamics in the expression of positive emotion. *Frontiers in Psychology*, 9(763), 1–7. https://doi.org/10.3389/fpsyg.2018.00763.

Parag, O., & Vakil, E. (2018). Distinct eye movements for different cognitive processes as expressed in the face recognition task. *Memory*, 26(4), 524–534. https://doi.org/10.1080/09658211.2017.1381265.

Rajhans, P., Jessen, S., Missana, M., & Grossmann, T. (2016). Putting the face in context: Body expression impact face emotion processing in human infants. *Developmental Cognitive Neuroscience*, 19, 115–121. https://doi.org/10.1016/j.dcn.2016.01.004.

Ryan, J. D., Hannula, D. E., & Cohen, N. J. (2007). The obligatory effects of memory on eye movements. *Memory*, 15(5), 508–525. https://doi.org/10.1080/09658210701391022.

Snow, J., Ingeholm, J. E., Levy, I. F., Caravella, R. A., Case, L. K., Wallace, G. L., et al. (2011). Impaired visual scanning and memory for faces in high functioning autism Spectrum disorders: It's not just eyes. *Journal of the International Neuropsychological Society*, 17(6), 1021–1029. https://doi.org/10.1017/S1355617711000981.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology. General*, 117(1), 34–50.

Spikman, J. M., Milders, M. V., Visser-Keizer, A. C., Westerhof-Evers, H. J., Herben-Dekker, M., & van der Naalt, J. (2013). Deficits in facial emotion recognition indicate Behavioral changes and impaired self-awareness after moderate to severe traumatic brain injury. *PLoS One*, 8(6), 1–7. https://doi.org/10.1371/journal.pone.0065581.

Suh, M., Basu, S., Kolster, R., Sarkar, R., McCandliss, B., Ghajar, J., et al. (2006). Increased oculomotor deficits during target blanking as an indicator of mild traumatic brain injury. *Neuroscience Letters*, 410(3), 203–207. https://doi.org/10.1016/j.neulet.2006.10.001.

Tipper, C. M., Signorini, G., & Grafton, S. T. (2015). Body language in the brain: Constructing meaning from expressive movement. *Frontiers*

in Human Neuroscience, 9(450), 1–17. https://doi.org/10.3389/fnhum.2015.00450.
Vakil, E. (2005). The effect of moderate to severe traumatic brain injury (TBI) on different aspects of memory: A selective review. *Journal of Clinical and Experimental Neuropsychology*, 27(8), 977–1021. https://doi.org/10.1080/13803390490919245.
Vakil, E. (2013). Breakdowns in everyday memory functioning following moderate-to-severe Traumatic Brain Injury (TBI). In Perfect, T., & Lindsay, S. (Eds.), *Handbook of applied memory* (pp. 201–217). CA, USA: Sage Publications.
Vakil, E. (2024). The Mnemonic Consequences of Moderate-to-Severe Traumatic Brain Injury. In Kahana, M., & Wagner, A. (Eds.), *Handbook of human memory* (pp. 1830–1852). Oxford: University Press.
Vakil, E., Aviv, O., Mishael, M., Schwizer Ashkenazi, S., & Sacher, Y. (2019a). Direct and indirect measures of context in patients with mild-to-severe traumatic brain injury (TBI): The additive contribution of eye tracking. *Journal of Clinical and Experimental Neuropsychology*, 41(6), 644–652. https://doi.org/10.1080/13803395.2019.1604946.
Vakil, E., Golan, H., Grunbaum, E., Groswasser, Z., & Aberbuch, S. (1996). Direct and indirect measures of contextual information in brain-injured patients. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, 9, 176–181.
Vakil, E., McDonald, S., Allen, S. K., & Vardi-Shapiro, N. (2019b). Facial expressions yielding context-dependent effect: The additive contribution of eye movements. *Acta Psychologica*, 192, 138–145. https://doi.org/10.1016/j.actpsy.2018.11.008.
Vakil, E., Sherf, R., Hoffman, M., & Stern, M. (1998). Direct and indirect memory measures of temporal order and spatial location: Control versus closed-head injury participants. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology*, 11(4), 212–217.
Van den Stock, J., Righart, R., & de Gelder, B. (2007). Body expressions influence recognition of emotions in the face and voice. *Emotion*, 7(3), 487–494. https://doi.org/10.1037/1528-3542.7.3.487.

Archives of Clinical Neuropsychology, 2025, 40, 993–1001
https://doi.org/10.1093/arclin/acaf008
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