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The interaction between embodiment and empathy in facial expression recognition

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Abstract

Previous research has demonstrated that the Action-Observation Network (AON) is involved in both emotional-embodiment (empathy) and action-embodiment mechanisms. In this study, we hypothesized that interfering with the AON will impair action recognition and that this impairment will be modulated by empathy levels. In Experiment 1 ($n = 90$), participants were asked to recognize facial expressions while their facial motion was restricted. In Experiment 2 ($n = 50$), we interfered with the AON by applying transcranial Direct Current Stimulation to the motor cortex. In both experiments, we found that interfering with the AON impaired the performance of participants with high empathy levels; however, for the first time, we demonstrated that the interference *enhanced* the performance of participants with low empathy. This novel finding suggests that the embodiment module may be flexible, and that it can be enhanced in individuals with low empathy by simple manipulation of motor activation.

Key words: embodiment; empathy; tDCS; facial expression

Introduction

The ability to understand the intentions and actions of others is a basic human need. For non-verbal communication, understanding is enabled by automatic mimicry of the other's feelings or actions (Knafo *et al.*, 2008; Shamay-Tsoory, 2011). Understanding feelings refers to empathy which has two main aspects, cognitive and affective. Hawk *et al.*, (2011) labeled the cognitive aspect of empathy as "perspective-taking" or the attempt of the observer to put himself "in the other one's shoes" and create a theory about his or her mental state. It appears that this process involves cognitive functions that require cognitive and affective theory of mind (ToM), as well as mentalizing by using autobiographical memory.

The cognitive aspect of empathy and ToM developed in parallel timeframes, with a link between ToM and the process of automatic mimicry in empathy being supported for decades by psychologists like Harris (1991, 1992) and by philosophers like Goldman (1989) and Gordon (1986). Recently, in a study involving preschoolers, Bensalah *et al.*, (2016) found that levels of affective empathy did not change with age, whereas levels of cognitive empathy increased with age and were positively correlated to ToM. This finding is compatible with a line of studies that have observed a dysfunction in cognitive empathy in individuals with autism spectrum disorder, while similar findings have not been reported for affective empathy (Dziobek *et al.*, 2008; Baron-Cohen, 2011; Mazza *et al.*, 2014; Koehne *et al.*, 2016). A connection between mimicry and empathy was also reported in relation to both facial expression recognition (FER) and observed pain (Decety *et al.*, 2010; Richter and Kunzmann, 2011).

The phenomenon of automatic mimicry is also regarded as grounded cognitive understanding, or "embodiment" (Barsalou, 2008). Murata *et al.*, (2016) found that mimicry increased when

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participants were explicitly asked to infer the emotional state of a facial expression, suggesting that mimicry contributes to the comprehension process of observed emotions. Strong evidence for mimicry involvement during tasks that involve emotional empathy are demonstrated in imaging studies of the inferior frontal gyrus (Niedenthal, 2007; Uono *et al.*, 2017). Dimberg (1982) found a connection between exposure to facial expressions and the facial muscle activity of the observer as early as 1982. He exposed participants to happy and angry facial expressions, and was able to distinguish between the two emotions by the different muscle activity patterns. In a later study, he found the same results even though the exposure to the facial expressions was unconscious (Dimberg *et al.*, 2000).

Interest in the neural mechanism of mimicry and imitation started in 1981 with the discovery of what was later known as the Mirror Neurons System (MNS) (see Rizzolatti *et al.*, 1981, 1988). While some question the existence of the MNS in humans (Hickok, 2014), others found activity supporting this claim via transcranial magnetic stimulation (TMS) and ECOG recordings. (Fadiga *et al.*, 1995; Mukamel *et al.*, 2010, respectively). Additional research suggests that mimicry and imitation are crucial to understanding perceived action (Barsalou *et al,*. 2003; Parzuchowski *et al.*, 2014). Various brain imaging studies show that motor and premotor cortices are activated while processing motion and effector-specific verbs (Pulvermüller *et al.*, 2001; Buccino *et al.*, 2005; Tettamanti *et al.*, 2005; Ong *et al.*, 2014). These findings provide evidence of the Action-Observation Network (AON) in humans that generates similar activity patterns to selective observed and acted gestures. A connection between the AON and ToM was made by Gallese and Goldman (1998) where they discussed the ability of “theory–theory of mind” *vs* “simulation–theory of mind” to explain the role of the AON in humans.

Involvement of the AON in both the understanding of emotions and the understanding of actions can account for the individual differences found in cognitive understanding relative to empathy scores. For example, Aziz-Zadeh *et al.*, (2010) found that individual differences in empathy scores were correlated with cognitive performance of prosody comprehension. Williams *et al.*, (2013) also noted that participants with high empathy scores made fewer errors when asked to imitate facial expressions.

The mechanism of mimicry and its involvement in expression or action comprehension has been also explored through the modulation of the mimicry process. Reports from Chiavarino *et al.* (2013), Davis *et al.* (2015, 2017), Oberman *et al.* (2007), Strack *et al.* (1988) and Rychlowska *et al.* (2014) all employed paradigms of facial restrictions and implied that restricting the ability to imitate observed situations changes the way we comprehend the situations even though the imitation is not visibly executed. Neal and Chartrand (2011) found that dampening facial feedback signals, and conversely, amplifying facial feedback signals, affected the ability to read others’ facial emotions. Hence, in order to understand the emotion associated with an other’s facial expression, the observer simulates the sensorimotor response needed to generate the perceived expression (Bastiaansen *et al.*, 2009; Keysers and Gazzola, 2009). Further understanding of the role of the AON and mimicry in empathy was suggested by Gallese (2003). In his Shared Manifold Hypothesis, he argues that our capacity to understand others’ intentions cannot be exclusively dependent on mentalistic or linguistic abilities, but it is rather deeply grounded in our interactions with the world. This shared manifold makes it is possible for us to relate to other human beings as similar to us and makes intersubjective communication possible. He also argues that the AON originally discovered in the domain of action appears in a whole range of different ‘mirror matching mechanisms’.

Despite years of research, none of the studies that modulated mimicry correlated the effect of the modulation with the empathy scores of the participants. In this study, we therefore aimed to explore the effect of mimicry modulation on participants with varying empathy scores. First, we hypothesized that interfering with the imitation process of one action (e.g. facial movement) will affect how fast participants recognize only the related action (e.g. facial expression comprehension), but not how fast they recognize an unrelated action (e.g. gesture comprehension). This prediction follows Thomas *et al.*’s (2013) findings, where perceptual enhancement was reported only when the observed action and the stimulated body part were congruent.

Second, we hypothesized that the effect of interfering with mimicry will be modulated by participants’ empathy levels. Specifically, we hypothesized that the effect will be more pronounced in individuals with high empathy levels compared to individuals with lower empathy levels. This follows studies like Williams *et al.*’s (2013) that suggested that empathetic participants tend to use the mechanism of mimicry to a greater extent than less empathetic participants.

Experiment 1

We adapted the facial movement restriction paradigm from Strack *et al.*’s study (1988), as an interference in the action–observation process by having participants hold chopsticks between their lips with a closed mouth, limiting their facial movements.

Stimuli

Facial expression recognition. As we chose to restrict facial movement, the primary task we selected for the experiment was FER. The database of expressions consisted of 89 pictures taken from Ekman and Friesen (1978) which was compiled from pictures of six males and eight females acting out six different facial expressions: happy, sad, angry, fear, surprise and disgust. Examples of all six facial expressions are shown in Figure 1.

Hand gesture comprehension (HGC). To assure our manipulation affected only a relevant cognitive task we added a control task which was unrelated to the face. The control task included 40 video clips, 1500 ms long, of right-hand gestures all performed by a single actor seated behind a table. His face was concealed, and he was wearing a dark long-sleeved shirt. These video clips were created in our lab (Cohen-Maximov *et al.*, 2015) (see screenshot example in Figure 2).

Empathy questionnaire—empathy quotient (EQ). The vast majority of tools for the assessment of empathy are self-reporting questionnaires. We used the empathy questionnaire “Empathy Quotient” (EQ) written by Baron-Cohen and Wheelwright (2004) which consists of 40 questions tapping empathy and 20 filter/distracter questions. Participants respond to each item on a 4-point scale running from “definitely disagree” to “definitely agree”. The items in the questionnaire describe a reaction to, or an understanding of a situation, for example: “I find it hard to know what to do in a social situation” (Baron-Cohen and

Fig. 1. An example of all six facial expressions from the top left picture: happy, sad, angry, neutral, surprise and disgust, of both female and male actors.

Wheelwright, 2004). Initially, the authors attempted to separate items into affective and cognitive empathy categories. This attempt was abandoned claiming that in most instances of empathy, the affective and cognitive components co-occur and cannot be easily separated. Other works claim that the EQ by Baron-Cohen and Wheelwright emphasize only the cognitive aspect of empathy (Batchelder *et al.*, 2017). Considering the strong link found between the cognitive aspect of empathy and other embodiment aspects (Zahavi, 2010), we found this questionnaire best suited for our purposes.

Fig. 2. Example gesture stimuli (screen shot from video). In this video clip, the congruent description was/LO SHOME'A/("Can't hear") and the incongruent description was/NOSE'A LE'AT/("driving slowly").

Materials and methods

Participants

Ninety participants (65 females, 25 males) took part in the study (mean age = 24.48, s.d. = 4.87). All participants were healthy, right-handed (as measured by the Edinburgh Handedness Inventory, Oldfield, 1971), with normal/corrected to normal vision and native Hebrew speakers. Participants provided informed consent to participate in the study.

Procedure

The experiment was constructed of the above experimental tasks and the EQ.

Participants' EQ scores ranged between 21 and 70 with a mean and median of 47. Participants were assigned to one of the two facial restriction conditions (unrestricted or restricted mouth movements by using chopsticks) in a pseudo-random order, provided that the average and mean EQ score in each group remained around 47, in order to later create a group with high empathy and a group with low empathy.

Each participant was tested individually in a quiet room in front of a computer monitor that presented in random order a block of the FER and a block of the HGC.

In the FER block, stimuli were presented in a random order, each picture was presented for 400 ms and followed by a correct or incorrect written description of the facial expression. Half of the pictures were followed by a correct description and half by an incorrect description. Participants were asked to judge whether the description matched, or did not match, the facial expression.

In the HGC block, each video lasted 1500 ms and was followed by a correct or incorrect written description of the performed gesture. Half of the video clips were followed by a correct description and half by an incorrect description. Participants were asked to judge whether the description following the video was, or was not, correct.

Table 1. Mean RTs, SE and accuracy for FER and gesture comprehension tasks according to facial movement restriction condition and EQ group

Experimental condition	EQ group	Facial-expression recognition		Gesture comprehension		N
		RT (SE) ms	Accuracy (%)	RT (SE) ms	Accuracy (%)	
Unrestricted	High	772 (33)	92	763 (27)	97	21
	Low	1002 (31)	89	1014 (25)	95	24
	Total	895 (22)	90	897 (19)	96	45
Restricted	High	929 (31)	92	805 (26)	97	23
	Low	816 (32)	92	922 (27)	96	22
	Total	874 (22)	92	862 (19)	96	45
Total	High	854 (23)	92	785 (19)	97	44
	Low	913 (22)	90	970 (18)	95	46

Note: EQ, empathy quotient; RT, reaction time; SE, standard error (in parentheses); N, number of subjects.

Results and discussion

Before the analysis we took the following steps: first we excluded correct responses that exceeded the average reaction time (RT) by more than three s.d. Then, we calculated a mean RT (of correct responses) of all six facial expressions, thus creating one variable for the FER task. Analyses were performed on two dependent variables (RT for the HGC task and RT for the FER task). Finally, we divided the participants in each condition into two groups by their median empathy score, creating a high empathy group and a low empathy group in each of the conditions. This allowed us to enter the empathy variable either as a continuous factor or a group factor, depending on the specific analysis.

Overall, accuracy levels were higher than 93% consistent with the findings in a previous study that used the same materials (Cohen-Maximov *et al.*, 2015). Analysis of accuracy yielded no significant affects. Mean RT of correct responses and accuracy in both tasks as a function of facial movement restriction condition and empathy group are presented in Table 1. No main effect or interactions were found for gender, which was tested as a background variable.

To test our hypothesis that the effect of interfering with mimicry will be modulated by participants' empathy scores, we correlated RT and EQ scores in each task under each condition. For the HGC task, we found a negative correlation under both restricted and unrestricted conditions ($r = -0.753$, $n = 45$, $P < 0.001$; $r = -0.622$, $n = 45$, $P < 0.001$, respectively). The higher the EQ score the faster the RT (see Figure 3).

For the FER task, we found a negative correlation for the unrestricted condition ($r = -.585$, $n = 45$, $P < 0.001$), i.e. the higher the EQ score the faster the RT. But most interestingly, this correlation was reversed under the restricted condition ($r = 0.313$, $n = 45$, $P = 0.037$). Under this condition we found that the lower the EQ the faster the RT (see Figure 4).

This pattern of results affirms our first hypothesis that interfering with the imitation process of one action will only affect the understanding of a related action. It also supports our second hypothesis that interfering with mimicry will be modulated by participants' empathy scores.

To further assess the effect of the experimental condition and empathy level on the RT of both tasks, a pair of two-step

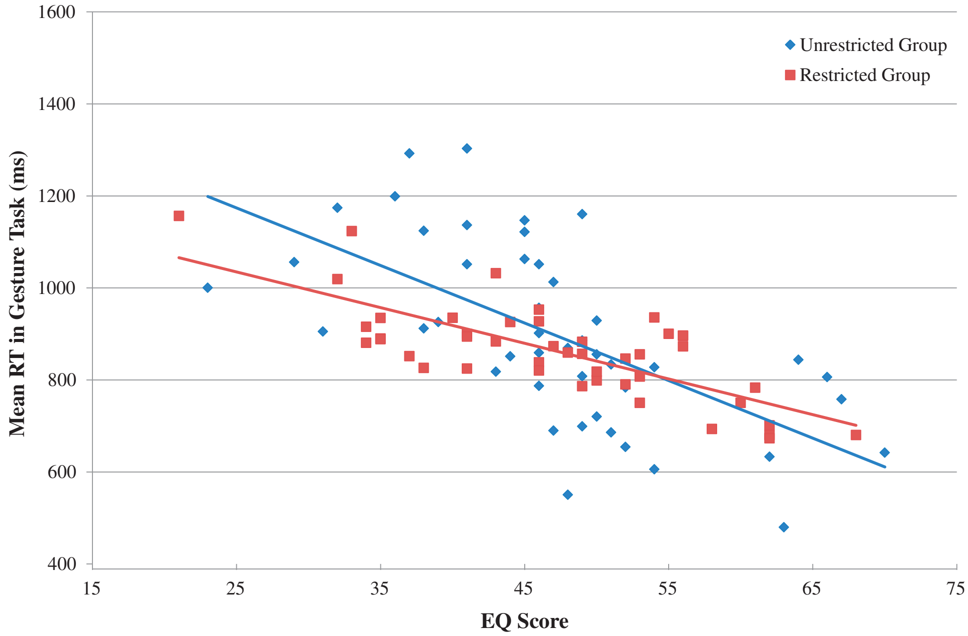

Fig. 3. Scatter-plots and linear correlations between EQ scores and RT (in ms) in the gesture comprehension task under each restriction condition.

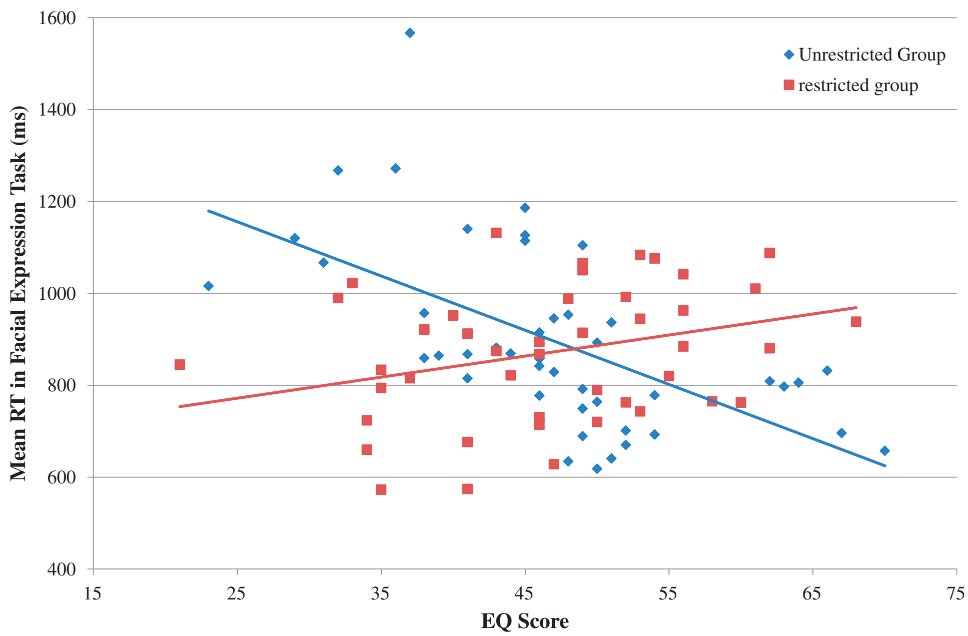

Fig. 4. Scatter-plots and linear correlations between EQ scores and RT (in ms) in the FER task under each restriction condition.

hierarchical linear regressions were performed; one for the FER task and the other for the HGC task. At the first step, the EQ scores and condition were entered to test for main effects. At the second step, the interaction variable of EQ score and facial movement restriction condition was added. The hierarchical approach was chosen to enable us to test the model containing our main effects, and analyzing the effects of the interaction between them. The results of the regressions can be found in Table 2.

In the FER task regression, the model for the first step was not significant, $R^2 = 0.043$, $P = 0.150$, showing that neither EQ score nor conditions are effective predictors by themselves. However adding the interaction variable to the model in the second step produced a significant model, $F_{(3,\ 86)} = 10.010$, $P < 0.001$, $R^2 = 0.259$, $\Delta R^2 = 0.216$. This indicates that the effect of restriction was modulated by the participants' EQ scores.

In the HGC task regression, we found that the first model was significant, $F_{(2,\ 87)} = 30.203$, $P < 0.001$, $R^2 = 0.410$. But only the EQ Score was found as a significant predictor, as shown in Table 2. The second model was also significant, but the interaction variable did not add to the prediction power of the regression, as we can see from the very small delta in the R^2, $F_{(3,\ 86)} = 21.793$, $P < 0.001$, $R^2 = 0.432$, $\Delta R^2 = .022$.

These results also affirm our hypothesis that interfering with the imitation process of one action will significantly only affect the understanding of a related action. However, in our second hypothesis we predicted that this impairment will be more pronounced in individuals with high empathy levels compared with individuals with lower empathy levels, as found in previous studies of mimicry restriction (Strack *et al.*, 1988; Chiavarino *et al.*, 2013; Rychlowska *et al.*, 2014). However, what we found was that the interference was modulated by the empathy level in a way that created a dis-ordinal interaction, where the direction of the correlation of the experimental condition was reversed to the correlation of the control group (see Figure 4).

To better understand the dis-ordinal interaction between EQ Scores and restriction condition for the FER task, we performed a two-way MANOVA, using the correct RT of each task as the dependent variables, and using the experimental condition and EQ groups as factors.

A main effect for empathy group was found significant ($F_{(2, 85)} = 26.878$, $P < 0.001$, partial $\eta^2 = 0.387$). A two way ANOVA revealed a significant main effect for empathy group only for the HGC task ($F_{(1, 86)} = 49.086$, $P < 0.001$, $\eta^2 = 0.363$); high empathy participants were significantly faster in their RT than low empathy participants (mean = 785, SE = 19; mean = 970, SE = 18, respectively). Crucially, the general MANOVA also revealed a significant multivariate interaction between the experimental condition and EQ groups ($F_{(2, 85)} = 14.592$, $P < 0.001$, partial $\eta^2 = 0.256$). The following two way ANOVA revealed a significant interaction in both tasks; ($F_{(1, 86)} = 6.433$, $P = 0.013$, partial $\eta^2 = 0.070$) in the HGC task with a small effect size, and ($F_{(1, 86)} = 29.313$, $P < 0.001$, partial $\eta^2 = 0.254$) in the FER task with a much larger effect size. As shown in Figure 5, post hoc analyses with Bonferroni adjustment revealed that under the unrestricted condition, participants in the high empathy group were significantly faster than the participants in the low empathy group in both tasks: ($F_{(1, 86)} = 26.335$, $P < 0.001$, partial $\eta^2 = 0.234$) in the FER task, and ($F_{(1, 86)} = 45.441$, $P < 0.001$, partial $\eta^2 = 0.346$) in the HGC task. The effect sizes in these analyses suggest a meaningful difference between high and low empathy participants in both tasks. The same pattern was found under the restricted condition in the HGC task ($F_{(1, 86)} = 10.009$, $P = 0.002$, partial $\eta^2 = 0.104$). In contrast, for the restricted condition in the FER task, post hoc analyses revealed a reversed situation. Here, we found that participants in the high empathy group were significantly slower than the participants in the low empathy group ($F_{(1, 86)} = 6.362$, $P = 0.013$, partial $\eta^2 = 0.069$). Finally, we found that in the FER task, participants in the low empathy group were significantly faster under the restricted condition than the unrestricted condition ($F_{(1, 86)} = 17.637$, $P < 0.001$, partial $\eta^2 = 0.170$), while participants in the high empathy group were significantly faster under the unrestricted condition that

Table 2. Summary of the two two-step hierarchical analysis for predicting performance in the FER and gesture comprehension tasks with facial movement restriction manipulation condition and EQ scores as predictors ($N = 90$)

Variable	R^2	B	P
FER			
Step 1	0.043		0.150
EQ score		−0.198	0.063
Facial restriction condition		−0.059	0.573
Step 2	0.259		0.000**
EQ score		−0.670	0.000**
Facial restriction condition		−2.296	0.000**
EQ score × restriction condition		2.336	0.000**
Gesture comprehension			
Step 1	0.410		0.000**
EQ score		−0.631	0.000**
Facial restriction condition		−0.106	0.200
Step 2	0.432		0.000**
EQ score × restrictioncondition		0.747	0.071

Note: EQ, empathy quotient.
**P < 0.01.

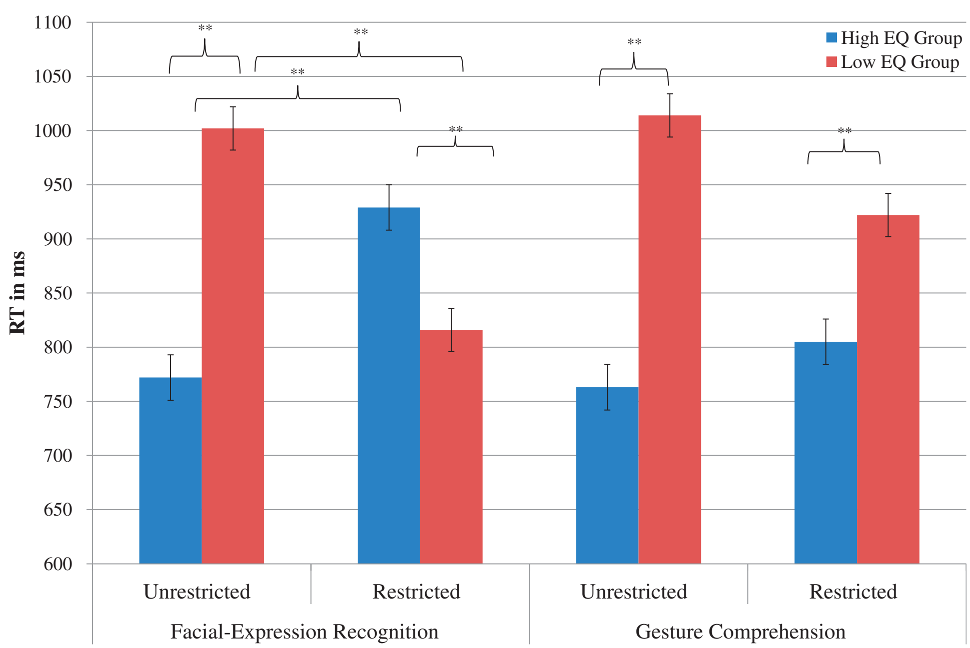

Fig. 5. Mean RTs and SE for gesture comprehension and FER according to restriction manipulation and EQ group. *P <0.05.

the restricted condition ($F_{(1,\ 86)} = 12.012$, $P = 0.001$, partial $\eta^2 = 0.123$). This last finding, confirmed both in the regression model and the ANOVA, is a novel finding that was not previously reported.

Our finding that under natural conditions (where facial expressions are not restricted) people with higher empathy perform better compared with people with lower empathy scores, is in line with other findings in the literature like Aziz-Zadeh *et al.* (2010) and Williams *et al.* (2013). However, when we hypothesized that the interference effect of mimicry modulation will change with regards to the participants empathy scores, we thought that the effect will be more pronounced in individuals with high empathy levels compared with individuals with lower empathy levels. What we actually found was that when facial movement was restricted, high empathy individuals took longer to recognize facial expressions. This too is in line with previous studies (Strack *et al.*, 1988; Chiavarino *et al.*, 2013; Rychlowska *et al.*, 2014), however, unexpectedly, low empathy individuals were faster in recognizing facial expression. The latter is a surprising and novel finding that to the best of our knowledge has not been reported yet.

These findings suggest individual differences in FER that rely on both empathy levels and mimicry. Previous studies like Neal and Chartrand (2011), Strack *et al.* (1988) and Davis *et al.* (2010) explained the connection between mimicry and recognition using the facial feedback hypothesis (Goldman and Sripada, 2005). The facial feedback hypothesis refers to three stages that aim to aid emotion perception. The first, a subtle and unconscious mimicry of an observed facial expression; in the second, these subtle muscle contractions in the perceiver's face generate an afferent muscular feedback signal from the face to the brain; and in the third stage, the perceiver uses this feedback to reproduce, and thus understand, the observed expression's emotional meaning.

In Experiment 1, we saw that when the ability to mimic is restricted, the ability to recognize facial expression breaks down when empathy levels are high, but improves when empathy levels are low. We argue that the ability to comprehend facial expressions relies on mimicry, as suggested by the feedback hypothesis, but at least one of the three stages of the feedback process is utilized or is manifested differently than hypothesized in people with low empathy levels.

What mechanisms can explain this difference in the feedback process? Kaplan and Iacoboni (2006) found that participants' empathy levels were correlated with the intensity of the activity in the premotor areas while observing people carrying out an action. Gazzola *et al.* (2006) also found correlations between the activity in brain areas involved in the AON and participants' empathy scores. We argue that under natural conditions, people with high empathy levels rely on the ability to mimic, and the freedom to do so seems to give them an advantage in comprehending others. This is the use of the facial feedback in the hypothesis. Braadbaart *et al.* (2014) found that brain activity in the premotor and motor cortices was correlated with EQ scores during imitation of facial expressions. This could indicate a better use of the second stage of the feedback hypothesis (generating an afferent muscular feedback signal from the face to the brain) by individuals with higher EQ.

Unlike Strack *et al.* (1988), the restriction of facial movement did not produce a general detrimental effect on the performance of a related task, but rather, the restriction significantly assisted participants with low empathy scores. In fact, they were able to match the performance levels of empathetic participants under natural conditions (without any restriction).

These findings suggest that individuals with low empathy may have difficulties relying on grounded imitation or facial feedback; however, their performance in understanding facial expressions improved when asked to hold chopsticks with their lips. Possibly, restricting their lips while performing the task increased the activation of the facial area of the sensory-motor cortex, thus boosting the feedback from the face to the brain. This enhanced activation may have enabled or facilitated the embodiment mechanism, which resulted in an outcome of faster (observed) FER. At the same time, participants with high empathy scores may have an optimized use of the embodiment process under natural conditions, and interfering with this process only reduces its effectivity. The interference did not prevent feedback from the face to the brain, but rather disturbed their optimal feedback process.

To test this hypothesis, we repeated the experiment, but this time applied transcranial direct current stimulation (tDCS) over the facial area of the motor cortex, instead of using movement restriction. This area was chosen to test the effect of enhanced activation of the motor cortex on the embodiment process (see also Watkin *et al.*, 2003; Tseng *et al.*, 2014). tDCS is a non-invasive brain stimulation technique using weak direct electrical currents. Experiments by Nitsche and Paulus (2000, 2001), demonstrated modulation effects of anodal tDCS over the primary motor cortex (increases cortical excitability) and cathodal tDCS (decreases cortical excitability) on brain tissue in which the effects outlasted the duration of stimulation.

Experiment 2

Design

Experiment 2 replicated Experiment 1 but the interference of the action–observation process was achieved by tDCS rather than restriction of movement.

Participants

Fifty participants (41 females, 9 males) took part in the study (mean age = 23.66, s.d. = 4.81). All participants were healthy, right-handed (as measured by the Edinburgh Handedness Inventory, Oldfield, 1971), with normal/corrected to normal vision and native Hebrew speakers. Participants provided informed consent to participate in the study.

Participants' EQ scores ranged from 27 to 70 with a mean of 46.8 and a median of 46. Participants were divided in to one of the two conditions (anodal or sham stimulation) in a pseudo-random order, providing that the average EQ score in each group remained around 46.8. We did this to allow proper comparison of both experiment conditions and empathy levels of the participants by later dividing each group into a high empathy and a low empathy sub-group for statistical analysis.

Transcranial direct current stimulation

We used a double anodal/cathodal montage of two 3 cm×3 cm electrodes over the facial area of the motor cortex of both hemispheres (between the C3 and C5 of the 10–20 EEG map in the left hemisphere and between the C4 and C6 in the right hemisphere) and a 5 cm×7 cm return electrode over the FZ, with a 1.25 mA current. Participants in the anodal and the cathodal conditions received stimulation for 15 min; in the sham condition, stimulation lasted only 30 s. To individually locate the motor cortex, we used TMS placing the coil over the motor cortex. The coil was positioned tangentially to the scalp.

The intensity of the magnetic stimulation was slowly increased until a clear contraction was observed in the contralateral hand, then the optimal position for eliciting the muscle contraction was determined and marked. This marker represented the hand area (C1 and C2 of the 10–20 EEG map).

We first conducted a pilot trial with six participants in each condition, and compared their mean RT with the sham group. We found that the cathodal condition had no effect on the RT, and therefore continued only with anodal stimulation and sham condition (see Jacobson *et al.*, 2012 for discussion of the weak cathodal effect on cognitive tasks).

Procedure

The procedure and tasks were similar to Experiment 1, except that the participants conducted the tasks 5 min after stimulation commenced.

Results and discussion

As in Experiment 1, we excluded correct responses that exceeded the average RT by more than three s.d. Then, we calculated a mean RT (of correct responses) of all six facial expressions, thus creating one variable for the FER task. This resulted in two dependent variables (RT for the HGC task and RT for the FER task). Finally, we divided the participants in each condition into two groups by their median empathy score, creating a high empathy group and a low empathy group. This allowed us to enter the empathy variable either as a continuous factor or a group factor, depending on the specific analysis.

Accuracy levels were very high (92–96%). Analysis of accuracy yielded no significant effects. Mean RT of correct responses and accuracy in both tasks as a function of stimulation condition and empathy group are presented in Table 3. No main effect or interactions were found for gender which was tested as a background variable.

We correlated RT and EQ scores in each task under each condition. For the HGC task, we found a negative correlation under both the stimulation and sham conditions ($r = -0.431$, $n = 25$, $P = 0.031$; $r = -0.766$, $n = 25$, $P < 0.001$, respectively). The higher the EQ score the faster the RT (see Figure 6).

For the FER task, we found a negative correlation for the sham condition ($r = -0.741$, $n = 25$, $P < 0.001$): the higher the EQ score the faster the RT. But just like in the behavioral experiment's results, under the experimental condition (anodal stimulation, in this case) the correlation was positive ($r = 0.455$, $n = 25$, $P = 0.022$). Under this condition we found that the lower the EQ the faster the RT (see Figure 7).

Table 3. Mean RTs, SE and accuracy for FER and gesture comprehension tasks according to stimulation condition and EQ group

Experimental condition	EQ group	Facial-expression recognition		Gesture comprehension (SE), in ms		*N*
		RT (SE) ms	Accuracy (%)	RT (SE) ms	Accuracy (%)	
Sham	High	734 (36)	93	701 (43)	97	12
	Low	977 (35)	88	970 (41)	94	13
	Total	856 (25)	90	835 (30)	96	25
Stimulation	High	817 (38)	90	817 (45)	94	11
	Low	701 (34)	89	960 (40)	90	14
	Total	759 (25)	90	888 (30)	92	25
Total	High	775 (26)	92	759 (31)	96	23
	Low	839 (24)	89	965 (29)	92	27

Note: EQ, empathy quotient; RT, reaction time; SE, standard error (in parentheses); N, number of subjects.

Here too, we performed a pair of two-step hierarchical linear regressions to check the interaction. The EQ scores and condition were entered at the first step to test for main effects, and the interaction variable of EQ score and stimulation condition added at the second step. This analysis showed similar affects as the behavioral experiment. The results from the regressions can be found in Table 4.

In the FER task regression, the model for the first step was significant but only accounted for just under 20% of the variance in RT, $F_{(2, 47)} = 5.829$, $R^2 = 0.199$, $P = 0.005$. Adding the interaction variable to the model in the second step produced a model that accounts for over 50% of the variance in the RT, $F_{(3, 46)} = 15.673$, $P < 0.001$, $R^2 = 0.505$, $\Delta R^2 = 0.307$. This indicates that the effect of the stimulation on performance was modulated by the participants' EQ scores.

In the HGC task regression, we found that the first model was significant and accounted for almost 38% of the variance, $F_{(2, 47)} = 14.162$, $P < 0.001$, $R^2 = 0.376$. And only the EQ score was found as a significant predictor, as shown in Table 3. The second model was also significant, $F_{(3, 46)} = 10.192$, $P < 0.001$, $R^2 = 0.399$, but the interaction variable did not add to the prediction power of the regression, as we can see from the insignificant *F* change, $\Delta R^2 = 0.022$, $F_{change} = 1.782$, $P = 0.188$.

These results affirm our hypothesis that interfering in the imitation process by stimulating the motor cortex affects the understanding of a related action in the same way physical restriction does.

Next, we performed a two-way MANOVA consisted of correct RT of the FER and the HGC tasks as the dependent variables, and the experimental condition and EQ groups as factors.

A main effect for empathy group was found significant ($F_{(2, 45)} = 12.514$, $P < 0.001$, partial $\eta^2 = 0.357$). A two-way ANOVA revealed a significant main effect for the empathy groups only for the HGC task ($F_{(1, 46)} = 23.589$, $P < 0.001$, $\eta^2 = 0.339$) with high empathy participants significantly faster in their RT than low empathy participants (mean = 775, SE = 26; mean = 839, SE = 24, respectively). Effect size suggests a strong and meaningful difference in performance. There was also a significant main effect of the experimental condition in the MANOVA ($F_{(2, 45)} = 9.860$, $P < 0.001$, partial $\eta^2 = 0.305$). A two-way ANOVA revealed a significant main affect only in the FER task ($F_{(1, 46)} = 7.325$, $P = 0.010$, $\eta^2 = 0.137$) overall, participants in the sham group were slower than participants in the anodal tDCS group, effect size suggests that the differences in RT were not very strong.

Crucially, and the main objective of this analysis, the general MANOVA revealed a significant multivariate interaction between the stimulation condition and EQ groups ($F_{(2, 45)} = 14.048$, $P < 0.001$, partial $\eta^2 = 0.384$). The following two-way ANOVA revealed a significant interaction only in the FER task ($F_{(1, 46)} = 25.131$, $P < 0.001$, partial $\eta^2 = 0.353$). As shown in Figure 8, post hoc analyses with Bonferroni adjustment revealed that under the sham condition, participants in the high empathy group were significantly faster than the participants in the low empathy group ($F_{(1, 46)} = 23.226$, $P < 0.001$, partial $\eta^2 = 0.336$) and the large effect size indicated a noteworthy difference. However, participants under the stimulation condition expressed the opposite effect, with low empathy participants significantly faster than participants with high empathy ($F_{(1, 46)} = 5.192$, $P = 0.027$, partial $\eta^2 = 0.101$). Last, we found that participants in the low empathy group were significantly faster under the stimulation condition than the sham condition ($F_{(1, 46)} = 32.396$, $P < 0.001$,

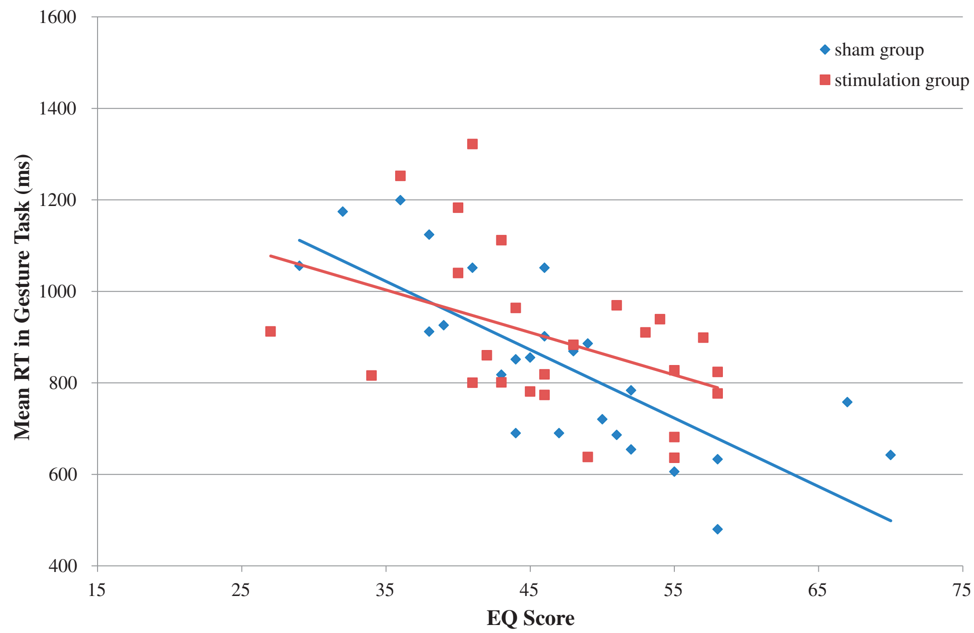

Fig. 6. Scatter-plots and linear correlations between EQ scores and RT (in ms) in the gesture comprehension task under each stimulation condition.

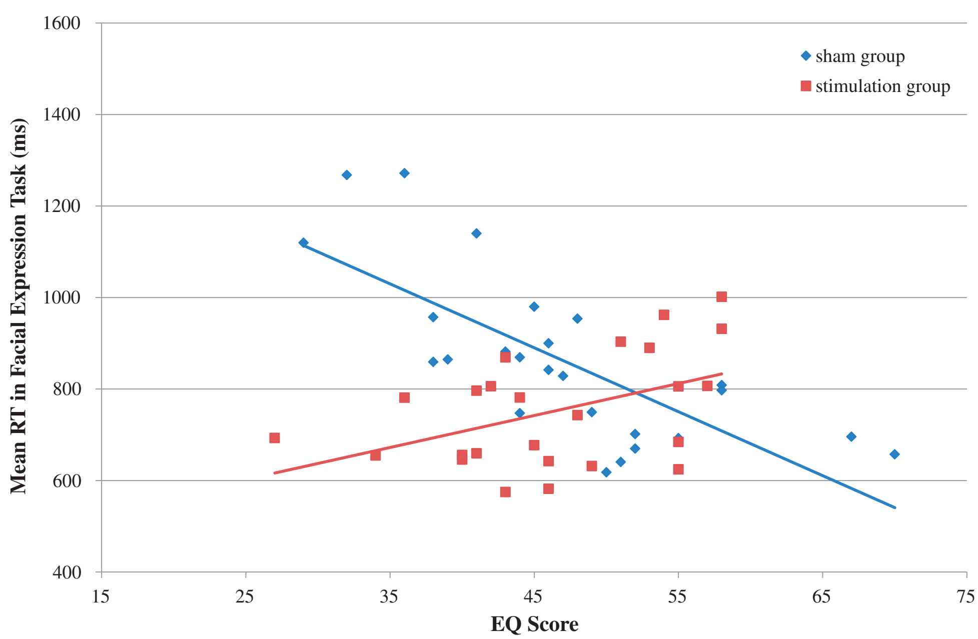

Fig. 7. Scatter-plots and linear correlations between EQ scores and RT (in ms) in the FER task under each stimulation condition.

partial $\eta^2 = 0.413$), again with a noteworthy effect size. These findings are similar to the behavioral findings of Experiment 1, and further affirmed our hypothesis.

Both experiments were designed as between-subject experiments, meaning we had eight groups all together, comprised of four conditions (restricted, unrestricted, sham and anodal tDCS) and within each condition we had two sub-groups (high EQ and low EQ). To make sure our groups were comparable, we performed two more two-way MANOVA analyses, the first to compare the control conditions, and the second to compare the experimental conditions.

The first MANOVA consisted of correct RT of the FER and the HGC tasks as the dependent variables, and the two control conditions (sham and unrestricted) as well as EQ groups (high EQ and low EQ) as factors. We only found a main effect for EQ group ($F_{(2, 65)} = 26.55$, $P < 0.001$, $\mu = 0.45$) with both high EQ groups significantly faster than the low EQ groups in both tasks, ($F_{(1, 66)} = 49.66$, $P < 0.001$, $\mu = 0.43$, for the FER task, and $F_{(1, 66)} = 37.33$, $P < 0.001$, $\mu = 0.36$, for the HGC task). There was no main effect for condition (sham *vs* unrestricted) or an interaction effect. The second MANOVA was between the two experimental conditions. Here too, the dependent variables were the correct RT of the FER and the HGC tasks, and the two experimental conditions (restricted and anodal tDCS) as well as EQ groups were factors. In this analysis we found a main effect for EQ group ($F_{(2, 65)} = 26.87$, $P < 0.001$, $\mu = 0.45$). Further ANOVA analysis revealed that in the FER task high EQ group was significantly slower than the low EQ group ($F_{(1, 66)} = 12.65$, $P = 0.001$, $\mu = 0.16$) and in the HGC task high the EQ group was significantly slower than the low EQ group ($F_{(1, 66)} = 19.36$, $P < 0.001$, $\mu = 0.22$). We also found a main effect for condition ($F_{(2, 65)} = 9.34$, $P < 0.001$, $\mu = 0.22$). Further ANOVA analysis revealed no main effect in the HGC task, meaning participants in both condition performed similarly, but conversely, revealed a main effect in the FER task ($F_{(1, 66)} = 12.53$, $P = 0.001$, $\mu = 0.16$), where participants in the restricted condition were slower than the participants in the anodal tDCS condition (874 and 752 ms, respectively). The difference was significant; however, as can be seen by the partial-eta, the effect size was inconsequential. We find that these results indicate that the different groups in this study are comparable.

Table 4. Summary of the two two-step hierarchical analysis for predicting performance in the FER and gesture comprehension tasks with stimulation condition and EQ scores as predictors ($N = 90$)

Variable	R^2	B	P	ΔR^2
FER				
Step 1	0.199		0.005**	
EQ score		−0.296	0.028*	
Stimulation condition		−0.344	0.011*	
Step 2	0.505		0.000**	0.307
EQ score×stimulation condition		5.342	0.000**	
Gesture comprehension				
Step 1	0.376		0.000**	
EQ score		−0.588	0.000**	
Stimulation condition		0.153	0.191	
Step 2	0.399		0.000**	0.023
EQ score×stimulation condition		0.846	0.188	

Note: EQ, empathy quotient.
**P <0.01.

General discussion

In both experiments, we demonstrated that under natural conditions (i.e. no interference in the action–observation process), people with higher empathy perform faster in recognition tasks, compared to people with lower empathy levels.

Our main finding refers to the dis-ordinal interaction between individual differences in empathy levels and interference, or lack of interference, with the action–observation process. Focusing on our main task for FER, we showed that when interfering with the action–observation process of facial expressions, high empathy individuals deteriorated in their recognition speed while low empathy individuals performed faster. This indicates that people with lower empathy actually benefit from the manipulation of this process.

Looking at the gesture comprehension control task, we can see that the effect of the interference is specific to the relevant action. While the gesture comprehension task was not completely clean of effect, the interference did not modulate it in the same dis-ordinal fashion as the main facial expression comprehension task.

We suggest that people with low-empathy utilize the embodiment process poorly, and that interfering with the relevant body part may boost the feedback from the face to the brain, which in turn, facilitates the embodiment mechanism, leading to better comprehension. At the same time, participants with high empathy scores appear to utilize the embodiment process in an optimized fashion, and therefore, interference over-stimulates and disturbs the naturally well-balanced feedback high empathy individuals usually have.

The connection between brain activity in the motor area and the ability to understand the actions of others is well established (see a review by Avenanti *et al.*, 2013). Initially, the explanations of action simulation and emotional simulation developed separately, with action simulation theories developing in the discipline of physiology (Gallese *et al.*, 1996; Rizzolatti *et al.*, 1988, 1996; Umilta *et al.*, 2001), however, with the advancement of imaging technology, theories of emotion simulation have also become supported in the neurological/physiological

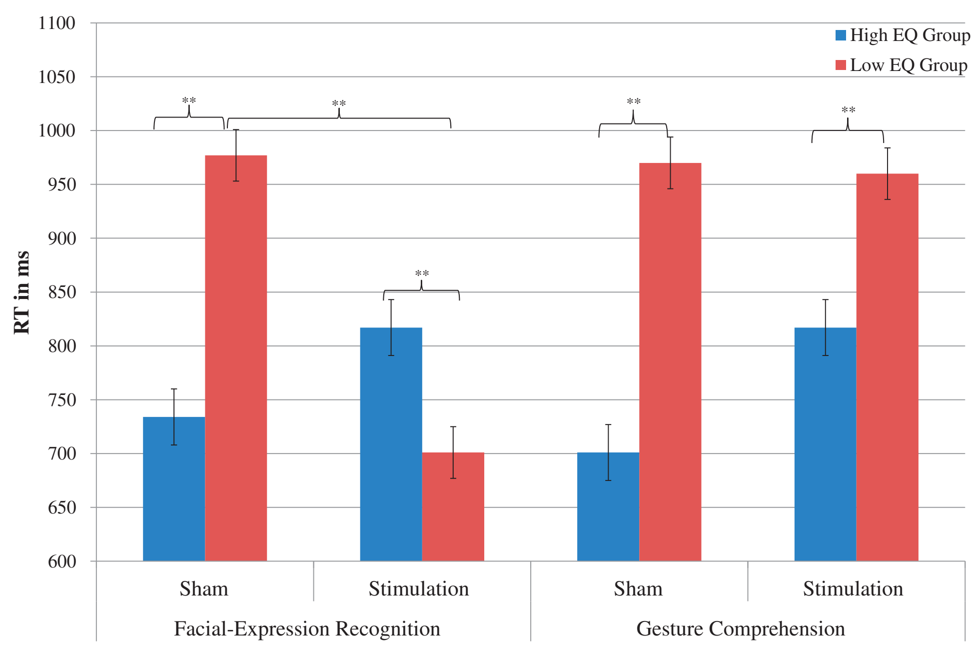

Fig. 8. Mean RTs and SE for gesture comprehension and FER according to stimulation manipulation and EQ group. *P <0.05.

realm (Phillips *et al.*, 1997, 1998; Schienle *et al.*, 2002) (see review by Gallese *et al.*, 2004).

The results of the first experiment might have been explained by the emotion–simulation theory as we achieved the results by behavioral manipulation without collecting information about the motor cortex activity. However, similar findings obtained in the tDCS experiment (Experiment 2) provided evidence of the involvement of the motor cortex. Specifically, activation of the AON facilitated FER of participants with low empathy and disturbed the performance of the high empathy participants. This finding reinforced our hypothesis that physical intervention would increase the activation of the motor cortex.

It seems that participants with low empathy utilize the embodiment process fundamentally differently than high empathy participants (see also Gazzola *et al.*, 2006 Kaplan and Iacoboni, 2006; Aziz-Zadeh *et al.*, 2010). The natural activation in the AON for low empathy individuals is most likely sub-optimal. This sub-optimal activation results in a deficit of the second stage of the facial feedback hypothesis, and therefore, prevents the use of feedback at the neural level to reproduce, and thus to understand, the observed expression. In other words, compared with high empathy individuals, low empathy individuals' use of action or emotion simulation is decreased due to lower levels of neural activity in the motor cortex. To explain the results of the stimulation condition of low empathy participants, we argue that stimulating areas of the motor cortex facilitated the facial feedback process and thus the simulation process.

The inhibitory effect of anodal stimulation in high empathy participants was also reported in a study by Bortoletto *et al.* (2015). They found that while performing a task that increases cortical excitability, anodal stimulation of the motor cortex hindered motor learning. Conversely, the same stimulation enhanced performance when combined with a neutral task.

This study makes a unique contribution to embodiment theories. While the most widely held theory states that embodiment is an automatic process, we demonstrated that its utilization is subject to individual differences, with empathetic individuals capable of a more efficient utilization. We believe that individual levels of empathy could provide a crucial link between the theories of action simulation and emotion simulation contributing to a unified simulation theory.

From a clinical perspective, it is encouraging that the embodiment module is flexible, and that it can be activated more efficiently following simple manipulations of motor cortex excitability via external (tDCS) or internal (focusing of attention) means.

Further study utilizing neuroimaging is required to shed light on the use of the AON and other mechanisms, which underlie the performance of participants with varying empathy levels. Importantly though, these findings open the exciting possibility that for individuals with low empathy levels, known to have deficits in social cognition (Baron-Cohen and Wheelwright, 2004), behavioral interventions like embodiment training may help to improve empathetic abilities. By focusing attention to different body parts and activating the relevant areas in the motor cortex, individuals with low empathy may be able to improve their understanding of the people around them, with profound implications for social interaction.

Limitations

It is fair to acknowledge a few limitations to this study. Our first limitation is the difference between the two tasks. The "Hand Gesture Comprehension Task" was created in the author's lab and is different from the Facial expression task taken from Ekman's studies. They differed in presentation duration (400 *vs* 1000 ms) and in details (just faces *vs* whole upper torso and a mask). The results could be also reflecting these differences. However, we feel that these two aspects of non- verbal communication are naturally very different, and at the same time, very important for understanding of others.

Our second limitation is the low spatial resolution of the tDCS. Reviewing different tDCS methods out today, one can find more high-density system, however these are fairly new. We preferred using the traditional tDCS system, with the smallest available electrodes that allow reasonable spatial resolution.

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Conflict of interest. None declared.

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