The visual representation of pain facial expressions: a high-definition transcranial direct current stimulation study

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Context

- Pain and empathy neural signatures share a great deal of resemblance, and this social competence has been linked to the adequacy of pain estimation, a highly adaptive yet frequently inaccurate perceptual skill[1].
- It was recently shown that the neurostimulation of the right inferior frontal gyrus (rIFG) could temporarily alter cognitive empathy as measured by the Multifaceted empathy test (MET)[2,3]. Such an intervention could in turn modulate the perception of pain facial expressions. Diminished empathic resources could lead to a greater tendency to underestimate pain in others without necessarily affecting the sensitivity to the expression's fine variations, but this has yet to be explored[1,4].
- We tested this hypothesis using a similar experimental design, but with special attention to observers' visual representations (VRs) of pain facial expressions, or more simply put, their expectations of what the face of a person in pain should look like.

Method

N= 25 (13 males; M_{age}= 24.38)

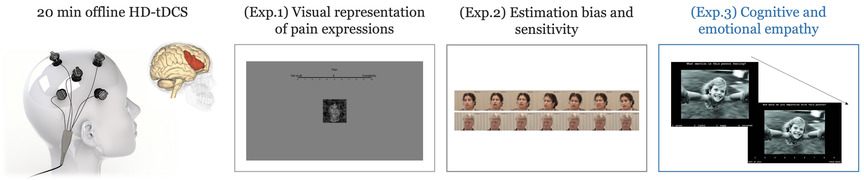

Figure 1. Experimental protocol. Participants received 20 minutes of stimulation, they then completed (Exp.1) a reverse correlation task[5], (Exp.2) a pain estimation task[6], (Exp.3) and the MET (replication of previous experimental design)[2,3].

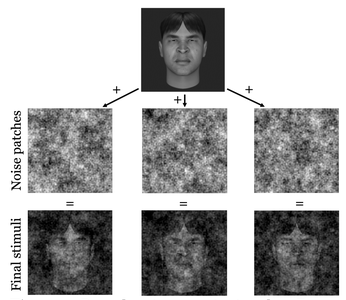

Figure 2. Procedure to generate stimuli in Exp.1 .

Analyses and results

Measuring the visual representation of pain (Exp.1)

An average classification image (CI) was created for each stimulation condition by calculating the average weighted sum of the noise patches presented during experiment 1, using the pain ratings as weights. A pixel-by-pixel ANOVA and Cluster test showed no effect of stimulation [F_{crit}= 5.2, k_{crit}= 284, p's> .05, k_{max}= 150] (see Figure 3)[7]. The average CI of the three conditions, however, reveals typical pain features in VRs [T_{crit}= 2.3, k= 452, p< .05] (see Figure 4)[8,9,10]. Pain action units were more strongly activated in the CI with high correspondence to observers' expectations, in comparison to its mathematical inverse, as detected by Openface (see Table 1)[11].

Table 1. *Action units detection with Openface[11]*

CIs	AU04	AU06	AU07	AU09	AU10
High correspondence	0%	15%	7%	42.2%	25.8%
Low correspondence	0%	0%	0%	24%	0%

Online evaluation of VRs

An average CI of the three conditions was then created for each participant (total of 25, see examples in Figure 5). CIs were rated by an independent group (N= 30) on the emotions they most importantly conveyed (see Table 2).

Table 2. *Emotional representations*

Emotions	disgust (9) > sadness (7) > anger (5) > pain (4*)

∗ When VRs were judged as being more pain-forward, at least one of the other 3 negative valence emotions followed very closely.

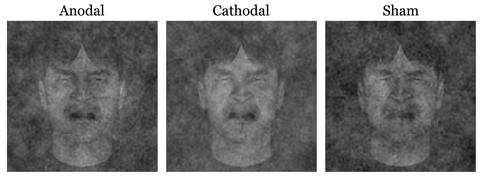

Figure 3. Average CIs overlaid on the base face for each stimulation condition.

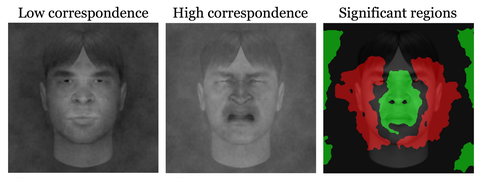

Figure 4. *A*verage CIs of the three stimulation conditions combined, overlaid on the base face. The low correspondence CI is simply the mathematical inverse of the high correspondence CI. When the regions in red were paler, and those in green darker, the presented face was rated as expressing more pain.

Figure 5. Examples of CIs, averaged across stimulation conditions for each participant. Those CIs are all overlaid on the same base face but seem to express wildly different emotional expressions.

Measuring the pain estimation bias and sensitivity (Exp.2)

Ratings provided by our participants in experiment 2 were compared to pain ratings reported by the demonstrators. The estimation bias was calculated from the mean difference of the estimates, and the sensitivity was obtained by calculating the mean absolute difference of the scores' slopes (see Figure 6). Measures of estimation bias and sensitivity were not correlated [r= -.22, p= .30].

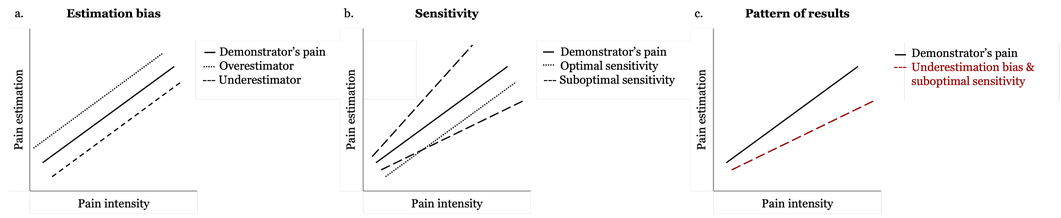

Figure 6. Fictitious illustration of (*6a*) bias and (*6b*) sensitivity. The black line represents the pain intensity reported by the demonstrator. (*6c*) All participants exhibited an underestimation bias and a suboptimal sensitivity [M_{bias} = -1.57, $M_{sensitivity}$ = -.40].

Measuring the effect of HD-tDCS on estimation bias and sensitivity (Exp.2), cognitive and emotional empathy (Exp.3)

Repeated measures ANOVAs revealed no effect of stimulation on (*7a*) bias [F(2, 48)= .59, p = .56], (*7b*) sensitivity [F(2, 48)= .39 , p=.68], (*7c*) cognitive empathy [F(2, 48)= .50, p=.61], or (*7d*) emotional empathy [F(2, 48)= .50 , p = .61].

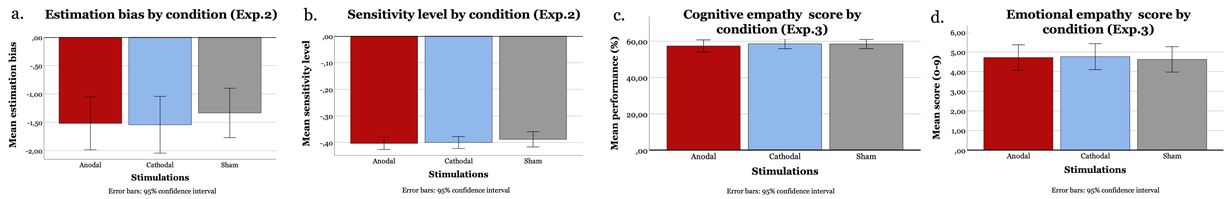

Figure 7. Average results for experiment 2 and 3, by stimulation condition.

Discussion and conclusion

- The effect of the rIFG stimulation on cognitive empathy was not replicated in the present study[3]. However, several other results replicate earlier findings;
  - An underestimation bias and a suboptimal sensitivity were found in all participants, which is consistent with previous studies[1,4,9].
  - At least partially distinct mechanisms underlie these two perceptual parameters; a sensitive individual could either overestimate, underestimate, or have no bias.
  - Facial features classically associated with pain percept (eye narrowing, nose wrinkling, and upper lip raising) were revealed in VRs[8,9,10]. This was later confirmed by the Openface facial recognition algorithm[11].
- Notably, the finding that our participants' VRs were rated primarily as expressing disgust, followed by sadness and anger may reflect some overlap in the emotional representation's space. Despite their distinctive properties, pain is frequently confounded with other negative valence emotions[12,13] .
- This confusion should be investigated as a function of individuals' empathetic profiles. This could provide valuable insight as to why different people mistake pain for different emotions.

References
[1] Prkachin, K. M., & Berzins, S. (1994). *Pain*, *58*(2), 253-259. **[2]** Wu, X., Xu, F., Chen, X., Wang, L., Huang, W., Wan, K., ... & Wang, K. (2018). *Front. hum neurosci*, *12*, 446. **[3]** Dziobek, I., Rogers, K., Fleck, S., Bahnemann, M., Heekeren, H. R., Wolf, O. T., & Convit, A. (2008). *J. Autism Dev. Disord.*, *38*(3), 464-473. **[4]** Green, A. D., Tripp, D. A., Sullivan, M. J. L., & Davidson, M. (2009). *Pain Med*, *10*(2), 381- 392. **[5]** Mangini, M. C., & Biederman, I. (2004). *Cognitive Sci*, *28*(2), 209-226. **[6]** Lucey, P., Cohn, J. F., Prkachin, K. M., Solomon, P. E., & Matthews, I. (2011, March). In Face and Gesture 2011, 57-64, IEEE. **[7]** Chauvin, A., Worsley, K. J., Schyns, P. G., Arguin, M., & Gosselin, F. (2005). *J. Vis*, *5*, 659-667. **[8]** Blais, C., Fiset, D., Furumoto-Deshaies, H., Kunz, M., Seuss, D., & Cormier, S. (2019). *J Pain*, *20*(6), 728-738. **[9]** Blais, C., Lévesque-Lacasse, A., Charbonneau, C., Desjardins, M-C., Fiset, D., & Cormier, S. (2020). *J. Vis*, *20*(11), 1550. **[10]** Roy, C., Blais, C., Fiset, D., Rainville, P., & Gosselin, F. (2015). *Eur J Pain*, *19*(6), 852-860. **[11]** Baltrušaitis, T., Robinson, P., & Morency, L. P. (2016, March). *WACV*, pp. 1-10. IEEE. **[12]** Kappesser, J., & de C Williams, A. C. (2002). *Pain*, 99(1-2), 197-206. **[13]** Kunz, M., Peter, J., Huster, S., & Lautenbacher, S. (2013). *PloS one*, 8(12), e83277.

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