Exploring the Relationship between Empathy and the Perceptual Evaluation of Pain Facial Expressions: Insights from a High-Definition Transcranial Direct Current Stimulation Research

Marie-Claude Desjardins[1], Daniel Fiset[1], Daphnée Sénécal[1], Arthur R. Chaves[2, 3], Sara Tremblay[1, 3, 4, 5] & Caroline Blais[1]

[1]Department of Psychoeducation and Psychology, University of Québec in Outaouais, [2]Faculty of Health Sciences, University of Ottawa, [3]University of Ottawa Institute of Mental Health Research at The Royal, [4]Department of Neuroscience, Carleton University, [5]Department of Cellular and Molecular Medicine, University of Ottawa

Introduction and aim

Efficient pain communication is crucial to humans' survival, yet individuals often underestimate others' pain and struggle to detect the expressions' subtle variations (called sensitivity)[1, 2]. As empathy and pain rely on shared neural processes, this social competence is proposed to mediate pain evaluation through its specific effect on the estimation bias[2]. Recent work suggests that the neurostimulation of the right inferior frontal gyrus (rIFG), a critical region of both networks, could temporarily alter cognitive empathy as measured by the Multifaceted empathy test (MET)[3, 4]. However, the impact of such manipulation on the parameters that underlie the evaluation of pain facial expressions remains unclear. Disrupting the rIFG could selectively affect the bias without interfering with one's sensitivity to pain variation. We tested this hypothesis using a similar experimental design. We additionally measured observers' visual representations (VRs) of pain facial expressions or their expectations of how a person's face should look when experiencing pain. VRs have been linked to evaluation inaccuracies and were, therefore, included as a third perceptual parameter [5, 6].

Methods

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

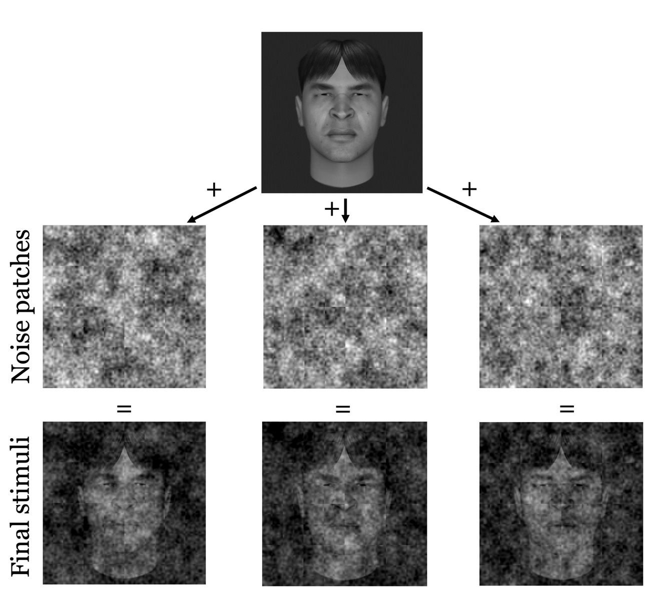

Figure 2. Procedure to generate stimuli in Exp.1 .

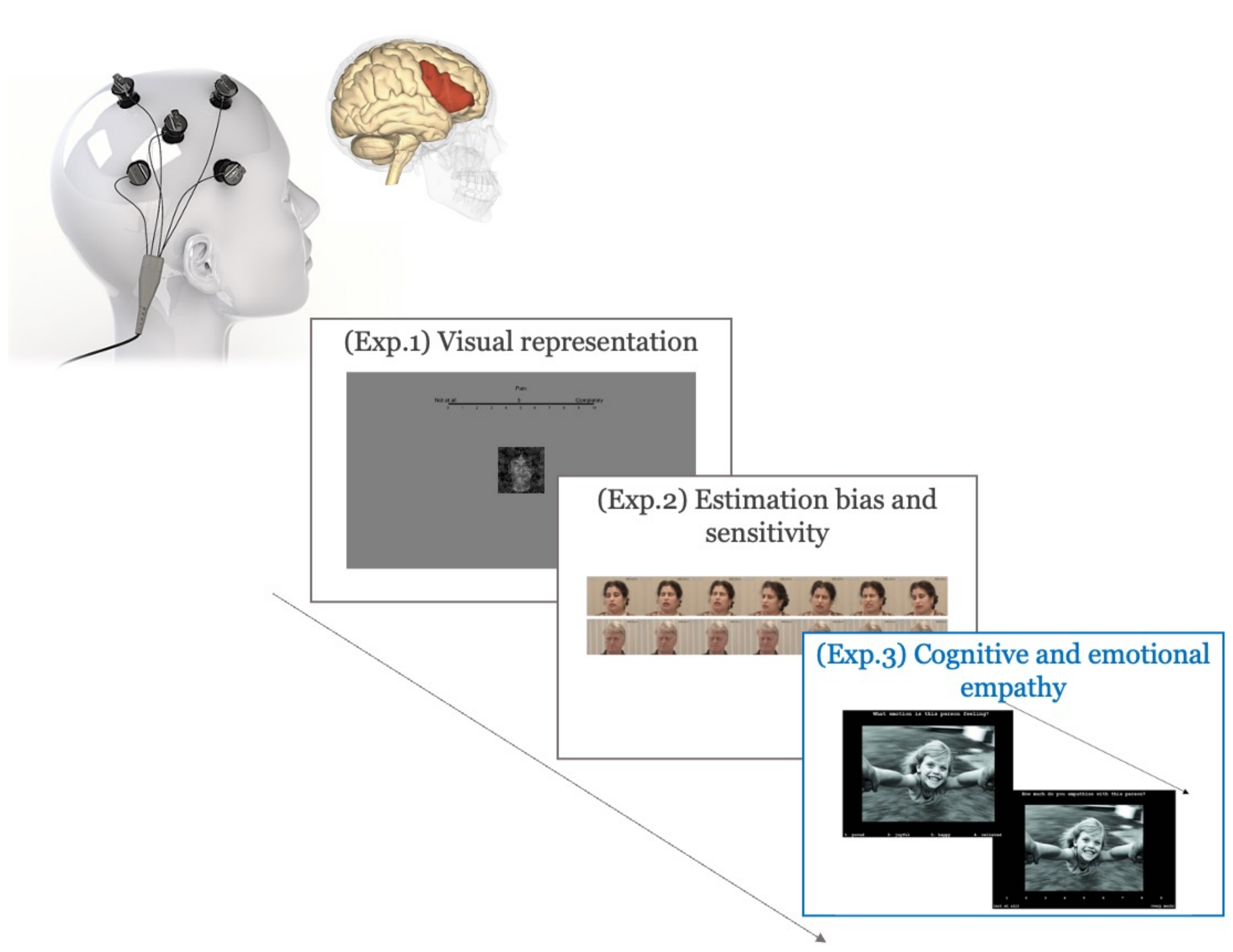

Figure 1. Experimental protocol. Participants received 20 minutes of stimulation, then completed (Exp.1) a reverse correlation task[7], (Exp.2) a pain estimation task[8], (Exp.3) and the MET (replication of previous experimental design)[3, 4].

Analyses and results

Measuring the visual representation (VR) 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)[9]. 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)[5, 6, 10].

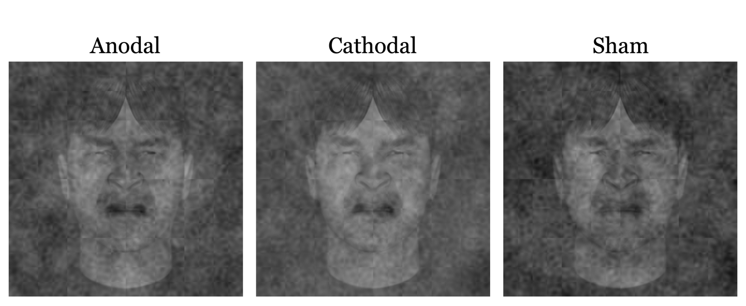

Figure 3. Average CIs overlaid on the base face for each stimulation condition.

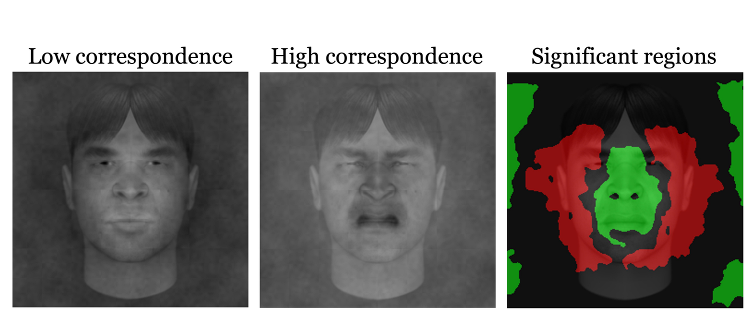

Figure 4. Average CIs of the three stimulation conditions combined, overlaid on the base face. The low correspondence CI is simply the mathematical inverse of the high correspondence CI. When the regions in red were paler, and those in green darker, the presented face was rated as expressing more pain.

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 5). Measures of estimation bias and sensitivity were not correlated [r= -.22, p= .30].

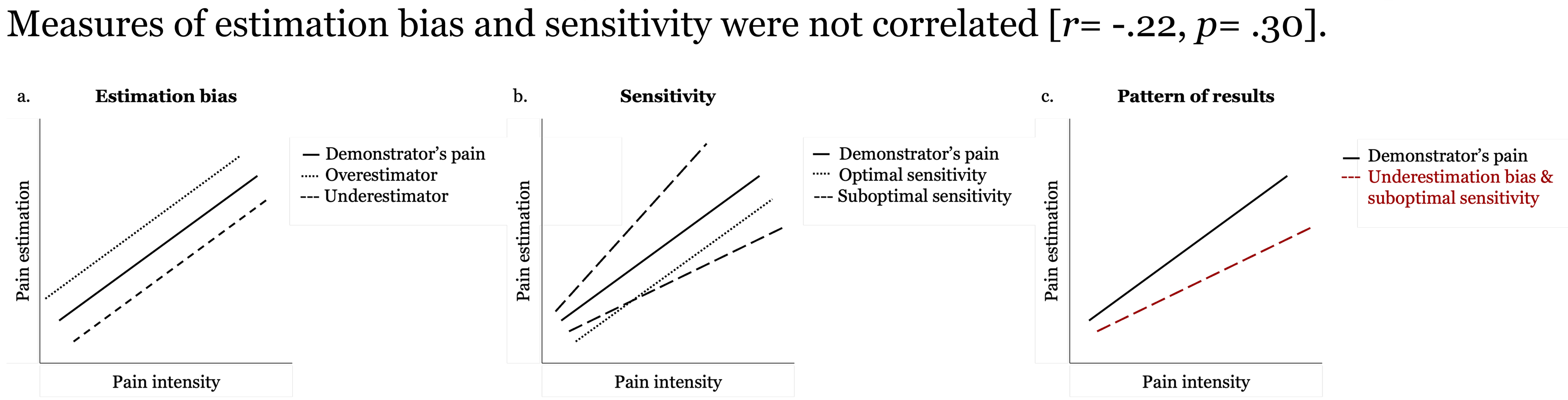

Figure 5. Fictitious illustration of (*5a*) bias and (*5b*) sensitivity. The black line represents the pain intensity reported by the demonstrator. (*5c*) All participants exhibited an underestimation bias and a suboptimal sensitivity [M_{bias} = -1.47, $M_{sensitivity}$ = -.40].

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 (*6a*) the bias [F(2, 48)= .59, p= .56], (*6b*) sensitivity [F(2, 48)= .39 , p=.68], (*6c*) cognitive empathy [F(2, 48)= .50, p=.61], or (*6d*) emotional empathy [F(2, 48)= .50 , p= .61].

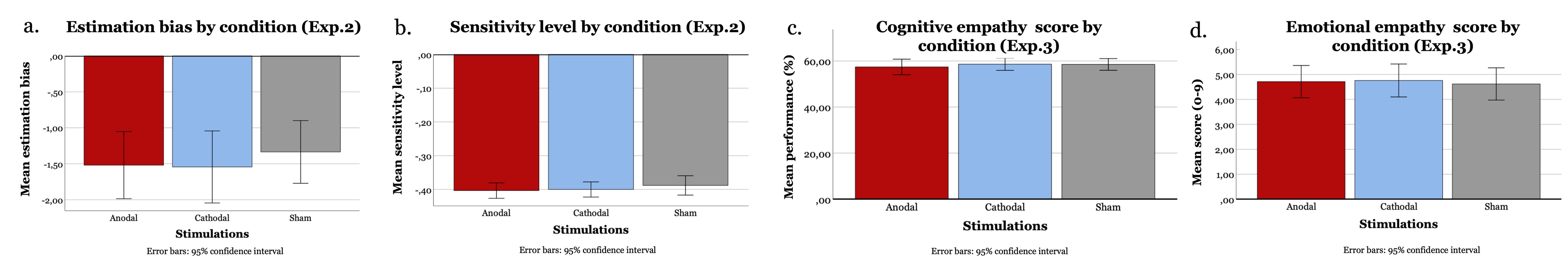

Figure 6. Average results for experiment 2 and 3, by stimulation condition.

Reanalysing data using the clustering approach

Contrast scores of polarities (anodal vs. sham and cathodal vs. sham) derived from pain and empathy measures were submitted to a k-means model that yielded three subgroups (Descriptive statistics are provided in Table 1). Mixed-design ANOVAs, Polarity (anodal-sham, cathodal-sham) x Groups (clusters), were conducted for each measure of interest. A main effect of clusters was found for the bias [F(2,22)= 21.32, p<.001, n^2=.68] and emotional empathy [F(2,22)= 8.83, p=.002, n^2=.72] but not for sensitivity or cognitive empathy (all ps> .05). Clusters 1 and 3 responded oppositely, whereby stimulating the rIFG either enhanced or diminished both the bias and emotional empathy, regardless of polarity type, while Cluster 2 remained unresponsive (see Figure 7).

Table 1
Means (M) and Standard deviations (SD) by clusters, and one-way ANOVAs' level of significance for contrast scores of pain and empathy components.

Contrast measures	Cluster 1 (n= 8)		Cluster 2 (n= 11)		Cluster 3 (n= 6)		p
	M	*SD*	*M*	*SD*	*M*	*SD*	
Cathodal vs. Sham							
Bias	-1.24	.48	-.04	.61	.85	.62	**<.001**
Sensitivity	-.03	.10	-.02	.11	.03	.11	.529
Cognitive	-.02	0	0	0	-.02	0	.529
Emotional	.34	.74	-.24	.63	.56	.56	*.047*
Anodal vs. Sham							
Bias	-.78	1.01	-.23	.82	-.70	.93	**.021**
Sensitivity	-.05	.11	-.02	.10	.04	.11	.354
Cognitive	.01	.06	.01	.07	-.06	.04	.087
Emotional	.15	.69	-.32	.52	.78	.17	**.002**

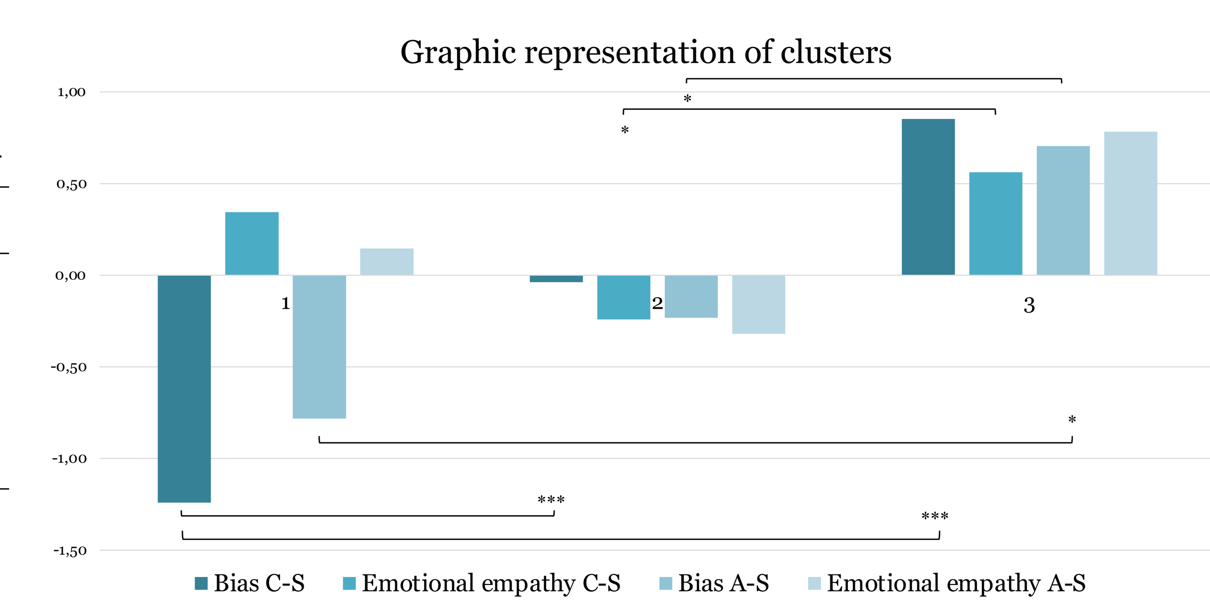

Figure 7. Results of One-way ANOVAs for contrast measures of stimulation polarities [C-S: *cathodal vs. sham*, A-S: *anodal vs. sham*], by cluster [1, 2 and 3], for the estimation bias and emotional empathy. Cluster 1 differed from cluster 2, and 3 for the bias [C-S] and from cluster 3 for the bias [A-S]. Cluster 3 differed from cluster 2 on emotional empathy [C-S and A-S]. *Non-significant results of sensitivity and cognitive empathy were not included for clarity purposes.*

Discussion and conclusion

- ❖ The previous claim of rIFG stimulation effects on cognitive empathy was not supported[3].
- ❖ However, using the clustering method, we revealed three distinctive response patterns to HD-tDCS for emotional empathy and estimation bias, highlighting the importance of considering the interindividual variability in response to stimulation[11, 12].
  - ❖ Once again, only the bias, as opposed to the sensitivity, appeared malleable.
  - ❖ It is worth noting that the pattern of alterations observed in emotional empathy was similar to that of the estimation bias.
- ❖ Several other results of the present study replicate earlier findings;
  - ❖ Extracted VRs depicted traditional pain features: the area associated with the brow lowering, lids tightening, nose wrinkling, and upper lip raising[5, 6, 10].
  - ❖ With no exception, participants tended to underestimate pain and showed a suboptimal sensitivity [2, 5].
  - ❖ At least partially distinct mechanisms underlie the two latter perceptual parameters of pain evaluation; a sensitive individual could either overestimate, underestimate, or have no bias.
- ❖ Despite its seemingly mundane nature, adequately evaluating pain from others' facial expressions remains a challenging perceptual skill. Implementing strategies that target the estimation bias could be a promising first step in addressing the issue of pain mismanagement.

References
[1] Prkachin, K. M., & Berzins, S. (1994). *Pain, 58*(2), 253-259. **[2]** Green, A. D., Tripp, D. A., Sullivan, M. J. L., & Davidson, M. (2009). *Pain Med, 10*(2), 381- 392. **[3]** Wu, X., Xu, F., Chen, X., Wang, L., Huang, W., Wan, K., ... & Wang, K. (2018). *Front. hum neurosci, 12*, 446. **[4]** 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. **[5]** Blais, C., Fiset, D., Furumoto-Deshaies, H., Kunz, M., Seuss, D., & Cormier, S. (2019). *J Pain, 20*(6), 728-738. **[6]** Lévesque-Lacasse, A., Desjardins, M.-C., Fiset, D., Charbonneau, C., Cormier, S., & Blais, C. (2023). *J Pain*, 25(1), 250-264. **[7]** Mangini, M. C., & Biederman, I. (2004). *Cognitive Sci, 28*(2), 209-226. **[8]** Lucey, P., Cohn, J. F., Prkachin, K. M., Solomon, P. E., & Matthews, I. (2011, March). In Face and Gesture 2011, 57-64, IEEE. **[9]** Chauvin, A., Worsley, K. J., Schyns, P. G., Arguin, M., & Gosselin, F. (2005). *J. Vis, 5*, 659-667. **[10]** Roy, C., Blais, C., Fiset, D., Rainville, P., & Gosselin, F. (2015). *Eur J Pain, 19*(6), 852-860. **[11]** Guerra, A., López-Alonso, V., Cheeran, B., & Suppa, A. (2020). *Neuroscience Letters, 719*, 133330. **[12]** Tremblay, S., Larochelle-Brunet, F., Lafleur, L.-P., El Mouderrib, S., Lepage, J.-F., & Théoret, H. (2016). *Eur J Neuroscience*, 44(5), 2184–2190.

NSERC CRSNG
Chaires de recherche du Canada
Canada Research Chairs
UQO
GNS SNG
NEST LAB
LPVS-UQO
lpvs-uqo.ca