Neural reuse in the anterior insula? Disgusting smells selectively increase precision of visual looming perception

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Figure 1. Olfactory stimuli for expt. 1 (left) and 2 (right).

Introduction

- The **neural reuse** hypothesis postulates that brain regions are typically used and reused across multiple task domains (Anderson, 2014). Here, we performed a targeted behavioral test of this hypothesis.
- Ventral anterior insula (**vAI**) has been implicated in (1) time-to-collision (**TTC**) predictions of **looming but not receding** stimuli (Billington et al., 2011) and (2) during olfactory experience of **disgust** (e.g., Heining et al., 2005; *Fig. 2*), possibly indicating reuse of that region in visual perception of looms and olfactory disgust contexts.
- Prediction: **induction of disgust will selectively affect looming TTC judgments**

Results Experiment I

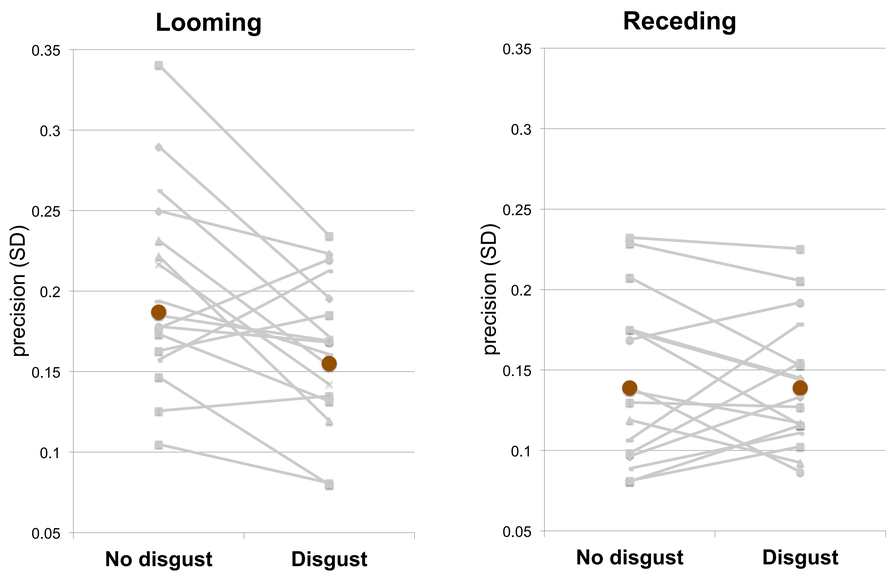

Figure 3. We observed an **increase in precision of TTC judgments for looming stimuli** (as indexed by a drop in standard deviation, SD) **during experience of disgust. No change** in precision was observed **for receding stimuli.** We did not observe effects of disgust on the accuracy of TTC judgments (RT relative to TTC=0). Interaction stimulus direction x odor presence: $F(1,19) = 4.87$, $p = .04$, $\eta_p^2 = .204$. *Large brown dots indicate estimated mean SDs.*

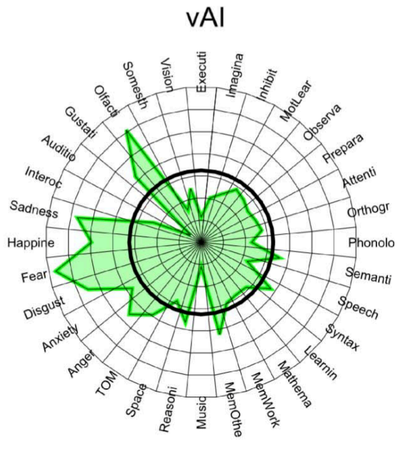

Figure 2. Spider plot showing activation of vAI during disgust-related tasks (adapted from Uddin et al., 2014).

Methods

- Experiment 1 and 2 were identical with the exception of the administered odor.
- **Sample:** 40 naive college-aged participants (20 in each experiment).
- **Stimuli: visual** - 25 looming and 25 receding 3D ball stimuli, randomly interspersed (*Fig. 4, top*) within each odor condition (100 trials total); **olfactory** - “Liquid Fart” (expt. 1) and lavender essential oil (expt. 2) (*Fig 1.*). Due to concern for lingering smell in testing room, no odor condition was always administered first.
- **Apparatus:** Visual looming and receding stimuli were presented using Vizard™ software and viewed monocularly, following Billington et al. (2011). Olfactory stimuli were presented using a cotton swab. See *Fig. 4*, bottom, for experimental set-up.
- **Participant instructions:** Press key when ball would “hit your face” (looming condition) and when ball would “pass through the green posts” (receding condition, see *Fig. 4*, top).
- **Manipulation check** via questionnaire: Odor in expt. 1 was perceived as disgusting; odor in expt. 2 was perceived as pleasant. Intensity ratings were identical between conditions.

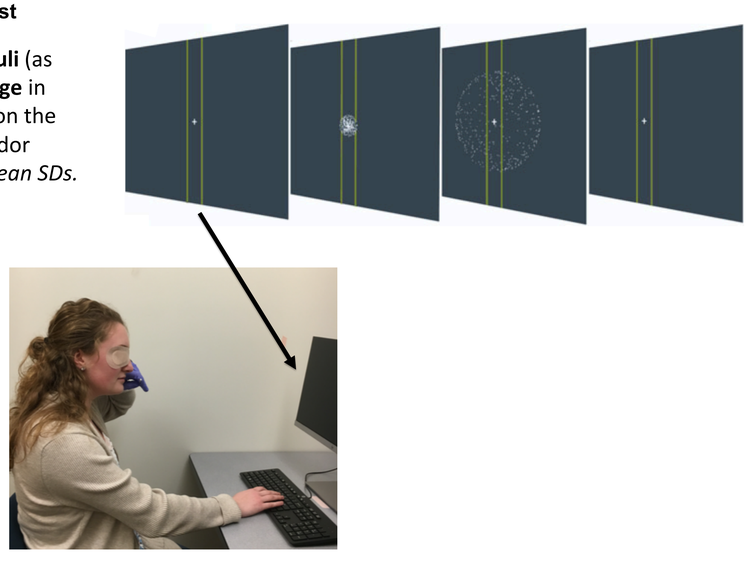

Figure 4. Experimental set-up (bottom) and looming stimulus (top, adapted from Billington et al., 2011).

Experiment II

- Uddin et al. (2014) also identified olfaction more generally as a source of AI activation (*Fig. 2*). In Experiment 2 we used a pleasant, non-disgusting stimulus to assess whether the effect of Expt. 1 was due to the experience of disgust specifically, or to the presence of an olfactory stimulus more generally.

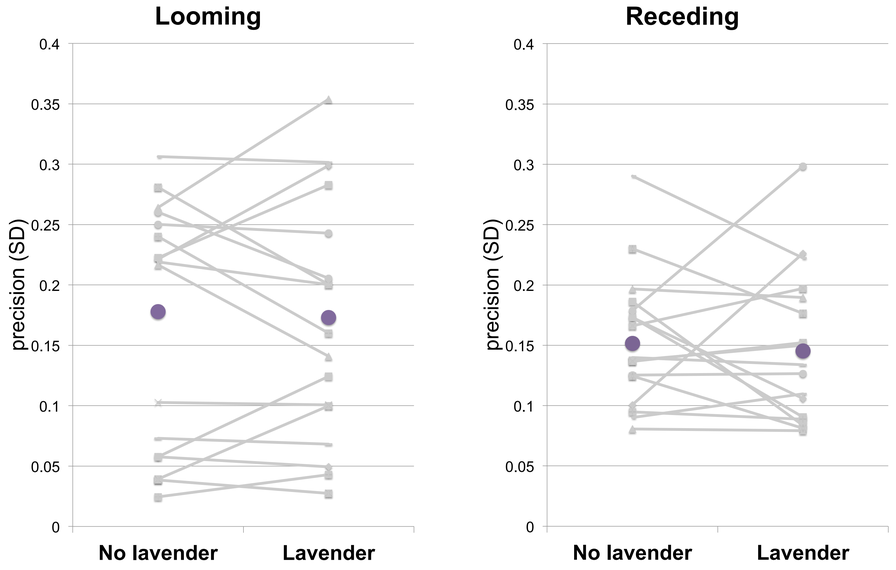

Figure 5. Results of Experiment 2. Unlike in Experiment 1, **no change in precision of TTC judgments** was observed as a function of odor presence in either the looming or receding conditions. We again did not observe effects of odor on accuracy of TTC judgments. Interaction stimulus direction x odor presence: $F(1,19) = .006$, $p = .938$, $\eta_p^2 = .000$. *Large purple dots indicate estimated mean SDs.*

Discussion

- **Summary of results**: Exposure to a disgusting odor led to increased precision for looming but not receding TTC judgments (Expt. 1, *Fig. 3*), while a pleasant odor did not show any effect on precision (Expt. 2, *Fig. 5*).
  - Expt. 2 suggests that the increase in TTC judgment precision for looming stimuli seen in Expt. 1 was specifically related to the presence of a disgusting stimulus.
- **Speculation:** the presence of a disgusting stimulus resulted in **facilitation** of looming TTC judgments due to overlap in neural activation patterns (Billington et al., 2011; Heining et al., 2006; Uddin et al., 2014). This overlap may have caused an increase in activation levels in vAI, readying the region for its involvement in the looming TTC judgments, akin to a **“priming” effect**.
- We argue that the **neural reuse** perspective (Anderson, 2014) aligns more closely with these results than **functional specialization**/modularity perspectives (e.g., Kanwisher, 2010), which would presumably have to postulate the presence of spreading activation (e.g., Mahon & Caramazza, 2008) to account for the current selective effect.
- **Future** neuroimaging **studies** are needed to verify our priming hypothesis. A further future direction is to assess whether the lack of an effect in Expt. 2 was due to the anxiolytic properties of lavender (Malcolm & Tallian, 2017), for example by using a non-disgusting, yet arousing, olfactory stimulus such as mint or eucalyptus.

References: Anderson, M. L. (2014). *After Phrenology: Neural reuse and the Interactive Brain*. Cambridge, MA: The MIT Press. Billington, J., Wilkie, R. M., Field, D. T., & Wann, J. P. (2011). Neural processing of imminent collision in humans. *Proceedings of the Royal Society of London B: Biological Sciences, 278*(1711), 1476–1481; Heining, M., Young, A. W., Ioannou, G., Andrew, C. M., Brammer, M. J., Gray, J. A., & Phillips, M. L. (2006). Disgusting smells activate human anterior insula and ventral striatum. *Annals of the New York Academy of Sciences, 1000*(1), 380–384. Kanwisher, N. (2010). Functional specificity in the human brain: A window into the functional architecture of the mind. *PNAS, 107*(25), 11163–70. Mahon, B. Z., & Caramazza, A. (2008). A critical look at the embodied cognition hypothesis and a new proposal for grounding conceptual content. *Journal of Physiology-Paris, 102*, 59e70. Malcolm, B. J., & Tallian, K. (2017). Essential oil of lavender in anxiety disorders: Ready for prime time? *Mental Health Clinician, 7*(4), 147–155. Uddin, L. Q., Kinnison, J., Pessoa, L., & Anderson, M. L. (2014). Beyond the Tripartite Cognition—Emotion—Interoception Model of the Human Insular Cortex. *Journal of Cognitive Neuroscience*, *26*(1), 16–27.

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