The Destruction of Distraction?
Neural Mechanisms of Reduced Task-Related Analgesia with Aging

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Background

Although age has been associated with increased and prolonged experience of pain[1], little is known about potential age-related alterations in the 'top-down' control of pain, such as cognitive distraction from pain. Given that distraction relies on attentional resources, and is modulated by the prefrontal cortex, older adults may benefit less from the analgesic effects of distraction than young adults, showing more pain-related neural activity during distraction relative to young adults. In this study, we set out to investigate the influence of aging on task-related analgesia and the underpinning neural mechanisms, with a focus on the role of executive functions (EFs).

Methods

Participants:

- 25 young adults (**YA**: 8 male; *M* = 26.40, *SD* = 4.45 years old)
- 25 older adults (**OA**: 16 male; *M* = 69.12, *SD* = 6.39 years old)

were invited to a lab session and an fMRI session 1-2 weeks later.

In the lab session, we assessed different executive functions e.g. with the Stroop, Flanker and Trail Making Test (TMT).

In the fMRI session (1.5T MRI), participants completed a pain distraction paradigm while receiving warm and painful heat stimuli to their left forearm.

Pain stimulation:

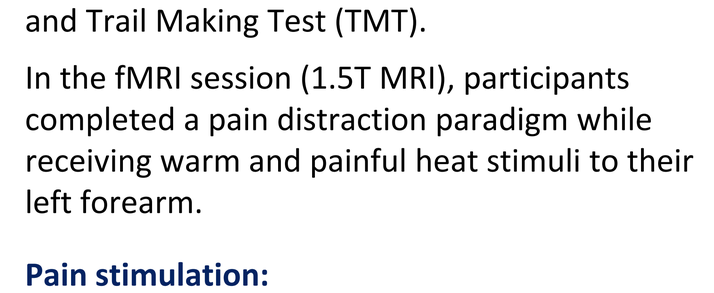
- Thermode (MSA, Somedic AB)
- Warm vs. painful heat stimuli (individually calibrated; warm: *M* = 43.19°C, *SD* = 1.50°C; painful: *M* = 46.89°C, *SD* = .83°C)

Pain ratings on 200-point VAS:

- Intensity
- Unpleasantness

Tasks:

- Distraction: Working memory task (2-back)
- Control: Target response task (0-back)



To maintain a similar level of task difficulty across participants, task speed was continuously adapted based on the participants' performance.

Pain distraction paradigm:

	Painful stimuli	Warm stimuli
2-back task	8 trials	8 trials
0-back task	8 trials	8 trials

Distraction effect size: Intensity (unpleasantness) rating for pain/0-back – pain/2-back.

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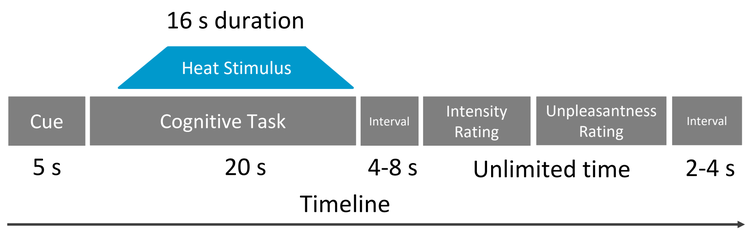
Procedure

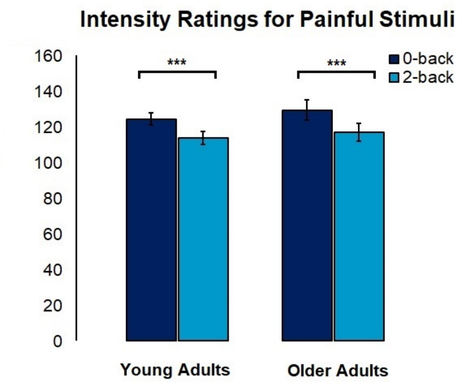
Trial



Participants completed 32 trials; 8 trials per condition. The experiment was split in 4 blocks, with short breaks in between.

Results

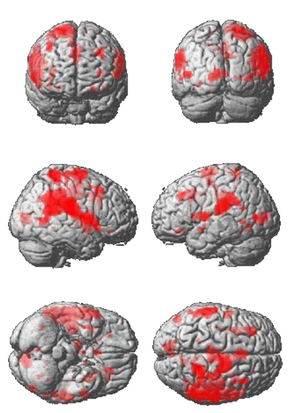
Behavioral distraction effect



*** corresponds to $p < .001$. Error bars represent the standard error of the mean. Mean difference (distraction effect size): **YA**: *M* = 10.57, *SD* = 9.77; **OA**: *M* = 12.42, *SD* = 9.38.

An ANOVA revealed significant main effects of task [$F(1,48) = 188.21$, $p < .001$] and temperature [$F(1,48) = 159.65$, $p < .001$] for intensity ratings, but no differences between age groups (YA vs. OA). The pattern of results was the same for unpleasantness ratings.

Pain-related neural activity



Contrasting painful with warm stimuli (p(unc) < .001, k = 20), yielded a network of regions involved in pain processing, including the

- Bilateral anterior and posterior insula
- Middle cingulate cortex
- Primary somatosensory cortex
- Thalamus

Neural distraction from pain

Young adults showed a sig. neural distraction effect in a network of regions involving the right anterior and posterior insula (p(unc) < .001, k = 20) in a 2-way interaction (pain > warm for control > distraction task; Fig. 1).

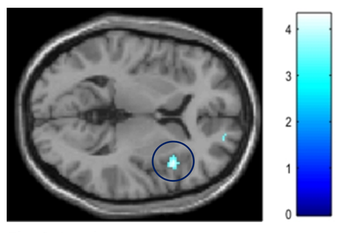


Fig. 1. Insula.

Older adults showed a sig. neural distraction effect in the left medial frontal gyrus and inferior parietal lobe (p(unc) < .001, k = 20) in a 2-way interaction (pain > warm for control > distraction task; Fig. 2).

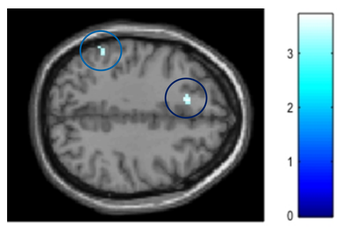


Fig. 2. Left medial frontal gyrus and inferior parietal lobe.

Age-related differences

Contrasting neural distraction activity patterns of YA > OA (Fig. 3), revealed that young adults showed, among others, more neural distraction in the

- Right anterior, middle, posterior insula
- Left posterior insula extending into the temporal lobe
- Left thalamus

The opposite contrast (OA > YA) did not yield any significant findings.

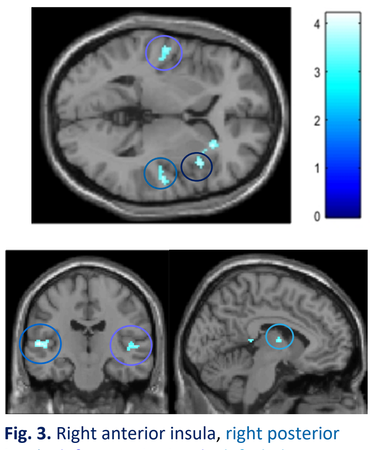


Fig. 3. Right anterior insula, right posterior insula, left posterior insula, left thalamus.

Neural distraction mechanism

Young adults showed more activation in the superior medial frontal gyrus (p(unc) < .001, k = 20) during distraction from pain (distraction > control task).

Older adults, on the other hand, showed more activation in the right superior temporal gyrus (STG) during distraction from pain (p(unc) < .001, k = 20).

Age-related differences

Contrasting neural activity for YA with OA at p(unc) < .001, did not reveal any sig. results. However, we found more activation in the PAG as well as in the superior left motor area and the left middle frontal gyrus at p(unc) < .01 for YA > OA. A one-tailed Pearson correlation across both groups (N = 50) revealed that activity in the PAG was significantly related to the behavioral distraction effect on the intensity VAS, r_{48} = .324, p = .011. The correlation remained, even when controlling for age and grey matter volume, r_{46} = .394, p = .003 (Fig. 4).

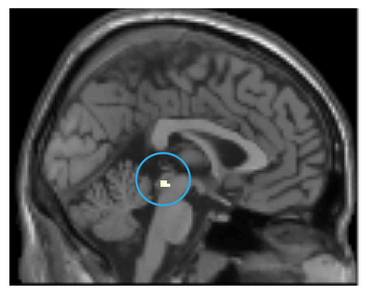
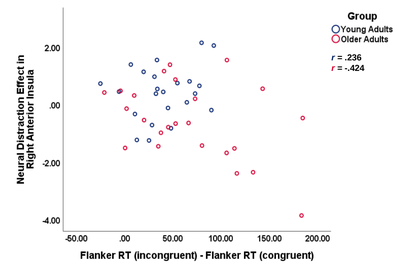


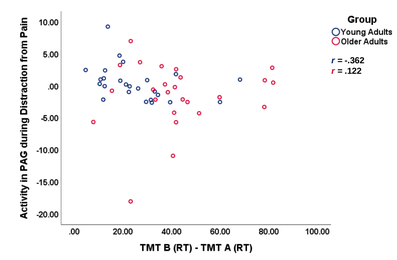
Fig. 4. Periaqueductal gray (PAG).

The role of executive functions

One-tailed Pearson correlations between the parameter estimates (from the clusters showing a group difference in the neural distraction effect) and the different neuro-cognitive measures revealed neg. corr. between a reduction in neural activity and the difference scores of the

- **Flanker** task (smaller effect - better selective attention abilities[2]) in the right IFG/insula and right anterior and posterior insula in OA
- **Stroop** task (smaller effect - better interference control abilities[3]) in the right anterior and posterior insula as well as the right STG in YA





Moreover, the **TMT** difference score (smaller effect – better executive functions[4]) correlated neg. with PAG activity in YA during distraction from pain.

The TMT difference score was also sig. correlated with the behavioral distraction effect in YA (intensity: r_{23} = -.377, p = .032; unpleasantness: r_{23} = -.452, p = .012; one-tailed Pearson correlation).

Discussion

Results suggest age-related differences in distraction from pain on the neural, but not behavioral level, with a smaller neural distraction effect for OA in a network of regions involved in pain processing. Distraction from pain was associated with more activity in the PAG in young adults, a region that forms part of the descending pain modulatory system.[5] Moreover, our results indicate that better EFs were associated with a larger neural distraction effect, although the strength of the association differed for test and age group and remains to be analyzed in more detail.

A reduced capacity in OA to activate descending pain control might have important consequences for how we treat pain in advanced age. Furthermore, our results suggest that EFs may play an important role in the 'top-down' modulation of pain, warranting further research.

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Acknowledgements

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