Distraction from Pain: An fMRI Study on the Role of Age-related Changes in Executive Functions

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Background

Recent studies suggest that descending pain inhibition is affected in older adults. Aging is also associated with pronounced atrophy of the prefrontal cortex, a key region for cognitive pain modulation as well as executive functions (EFs)[1,2]. We aimed to investigate if cognitive distraction from pain is altered by aging, and if executive functions modulate this distraction effect. Altered cognitive pain modulation in older adults could be a potential mechanism contributing to the increased risk of older adults to develop chronic pain.

Methods

Participants

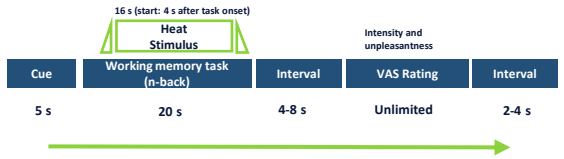
- 30 young adults (YA: 11 male; M_{age} = 26.70, SD_{age} = 4.20)
- 30 older adults (OA: 16 male; M_{age} = 67.73, SD_{age}= 6.50)

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

Lab session: Participants completed a neuropsychological test battery, including a Stroop test (inhibition), flanker test (selective attention, interference control), the Trail Making Test (TMT; general executive functions) and a digit span test (working memory).

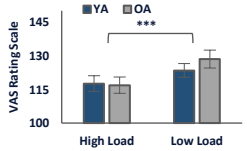
fMRI session: Participants completed n-back task trials with two levels of task load (low load: 0-back; high load: 2-back) while receiving warm or painful heat stimuli to their left forearm, resulting in the following 4 conditions: low load/warm, low load/pain, high load/warm, high load/pain.

FIGURE 1. Trial timeline of the distraction paradigm.



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

FIGURE 2. Intensity ratings for painful stimuli for YA and OA.



*** corresponds to p < .001. Error bars represent the SEM.

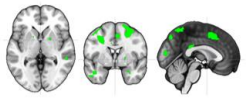
Behavioral distraction effect

An ANOVA revealed significant main effects of task load [F(1,58) = 12.310, p = .001] and temperature level [F(1,58) = 217.309, p < .001] for intensity ratings, but no differences between age groups (YA vs. OA) (see **Fig 2**).

Neural distraction effect

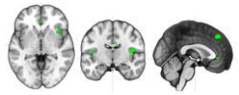
To search for pain-related regions that showed a distraction effect (i.e., less activation during the high load than during the low load task), we created the contrast **low load (pain > warm) > high load (pain > warm)**. This contrast (at p(unc) = .005, k>10) revealed several clusters across groups (**Fig 3**), but importantly, when comparing groups, YA showed a larger neural distraction effect than OA (**Fig 4**).

FIGURE 3. Neural distraction effect across age groups.



Brain activity was reduced in the right and left parietal lobe, the left pre- and right postcentral gyri, the right mid cingulate cortex and the left insula when simultaneously completing a high load task.

FIGURE 4. Neural distraction effect for YA > OA.



YA showed, among others, a stronger neural distraction effect in the right superior medial gyrus, right insula and right mid cingulate cortex than OA.

Neural distraction mechanism

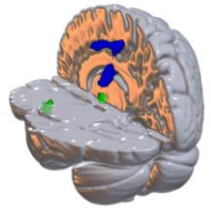
To search for areas that may be driving the distraction effect (i.e., showing more activation during the high load than during the low load task), we created the contrast **high load (pain > warm) > low load (pain > warm)**. This contrast (at (p(unc) = .005, k>10) revealed a cluster in the perigenual anterior cingulate cortex (pACC) across age groups. Group comparisons revealed that this cluster was significantly more active for OA than for YA.

Executive functions and the neural distraction effect and mechanism

To examine the role of executive functions in modulating the neural distraction effect and mechanism, we entered executive functioning scores, i.e., the TMT difference score, the Flanker effect, the Stroop interference effect and the total digit span, as covariates to the contrasts (p(unc) = .001, k >20).

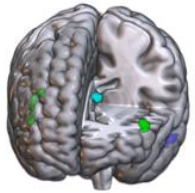
While executive functions in YA were not correlated to the neural distraction effect, better performance in the flanker and Stroop test correlated with a larger neural distraction effect in the left insula, right thalamus, left postcentral gyrus and left precuneus in OA (**Fig 5**).

FIGURE 5. EFs and the neural distraction effect in OA.



Better performance in the **flanker** and **Stroop** tests correlated with a larger neural distraction effect in OA.

FIGURE 6. EFs and the neural distraction mechanism in OA.



Better performance in the **flanker**, **TMT** and **digit span** tests correlated with a larger neural distraction mechanism in several frontal regions in OA.

In YA, better performance on the flanker task and TMT correlated positively with activity in the cingulate gyrus while in OA a better performance in the flanker task, TMT and digit span test correlated with more activity in the left middle temporal and inferior temporal gyri as well as in the left and right inferior, right middle and left superior frontal gyri (**Fig 6**).

Discussion and Conclusion

Our results show clear age-related changes in the underlying neural effects and mechanisms of cognitive distraction from pain. OA showed increased activation of the pACC during distraction, compared to YA. This region is a key structure in descending pain control[1,3]. This increased recruitment may be the result of a compensatory mechanism following age-related atrophy in the PFC, but without success: OA exhibited a smaller neural distraction effect in several areas related to pain processing than YA.

This interpretation is supported by the correlations with executive functions. OA with worse executive functions showed a smaller distraction effect in pain-related regions, and less recruitment of prefrontal regions during distraction.

In sum, our findings demonstrate that the top-down control of pain is altered by age and could explain the higher vulnerability of older adults to developing chronic pain. Moreover, our results suggest that the assessment of executive functions may be a useful tool for predicting the efficacy of cognitive pain modulation strategies in older adults.

References

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Acknowledgments

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