Comparison of visual working memory maintenance and associative memory retrieval in ageing and synaesthesia.

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Abstract

We compare young, older and synaesthetic adults during the performance of a visual associative memory task and a visual working memory task. During the working memory task, we find a main effect of group in the inferior occipital gyrus, the superior parietal lobule (SPL), and dorsolateral prefrontal cortex. In all three areas, the synaesthetes show less signal change, compared to young and older adults, indicating a more efficient use of relevant neural networks. The older participants show higher levels of activity in the SPL compared to the other two groups, indicating increased use of relevant resources to achieve a similar level of performance. This finding supports the compensation-related utilization of neural circuits hypothesis (CRUNCH). During the delay period of the associative memory task, we also find a main effect of group in the SPL, the inferior temporal cortex, and the anterior prefrontal cortex. Additionally, we find an effect in the middle temporal gyrus and the perirhinal cortex, an area known to support higher-order conceptual associations. The prefrontal activations (BA10), consistent with monitoring and verification of retrieved information, were significantly lower in the synaesthetes compared to young and older adults. Our data are consistent with the view that visual representations are activated both during sensory stimulation and maintenance of visual information. Despite functioning at similar performance levels, synaesthetes and older adults show higher and lower neural efficiency respectively, reflected in reduced or enhanced activations within the same brain networks.

Methods

Participants

19 young adults (8♀, 21-32 years; *M* = 24.3), 19 older adults (11♀, 59-81 years; *M* = 66.2), 19 young synaesthetes (15♀, 19-33 years; M=23.0)

Stimuli

- 8 black-and-white fractal pair associates (Fig. 1), and 8 different fractals used in delayed-match-to-sample (DMS) task (Fig. 2).

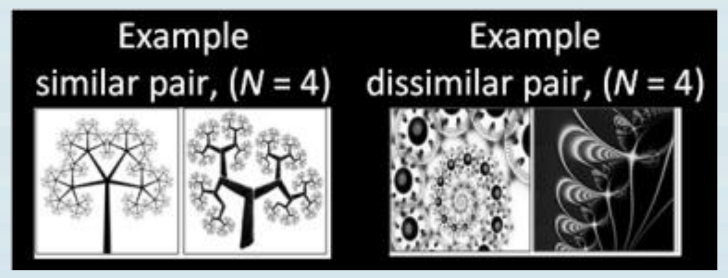

Fig 1. Example stimuli. Similar pairs (low memory load) on the left, dissimilar pairs (high memory load) on the right.

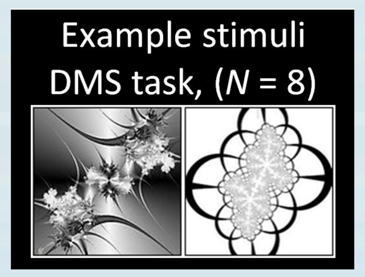

Fig 2. Example stimuli for DMS task.

Data aqcuisition

Data were collected on a 1.5 T Siemens Magnetom Avanto MRI Scanner with a 32-channel head coil. 644 volumes were obtained using a T2* weighted EPI sequence; TR=2.62s, TE=42ms, flip angle=90 degrees

Acknowledgements

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Methods

Tasks

1. Self-paced learning (prescan) (Fig. 3)
Participants learned the 8 pair-associates to 87% performance criterion by trial and error before the fMRI scan.
2. Delayed Pair-Associative (DPA) Retrieval (Fig. 4)
3. Delayed Match-to-Sample (DMS) (Fig. 5)

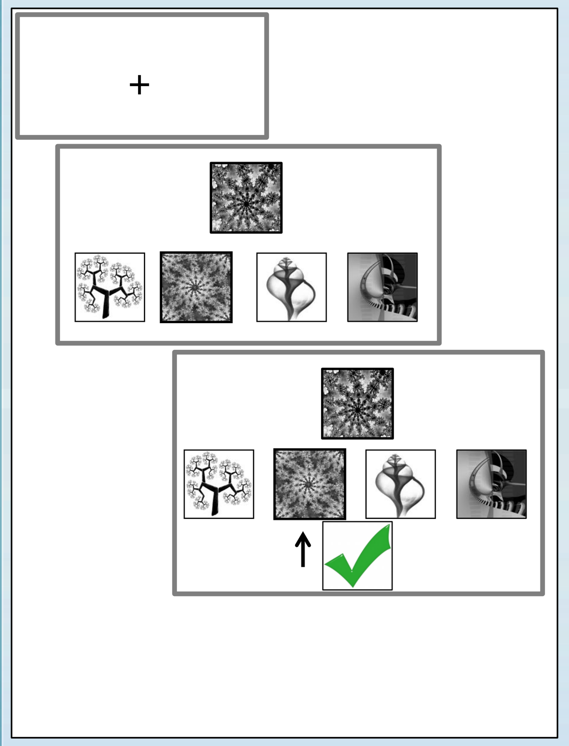


Fig 3. Pair-Associative Learning example trial

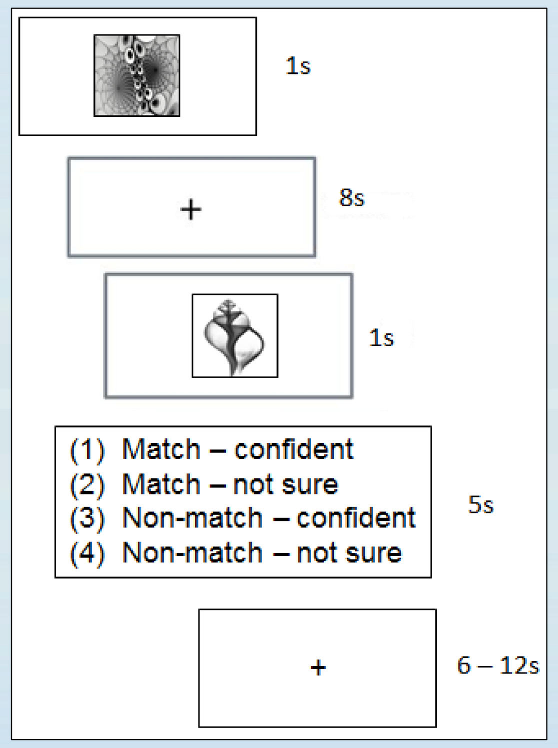


Fig 4. Delayed Pair-Associative (DPA) Retrieval example trial

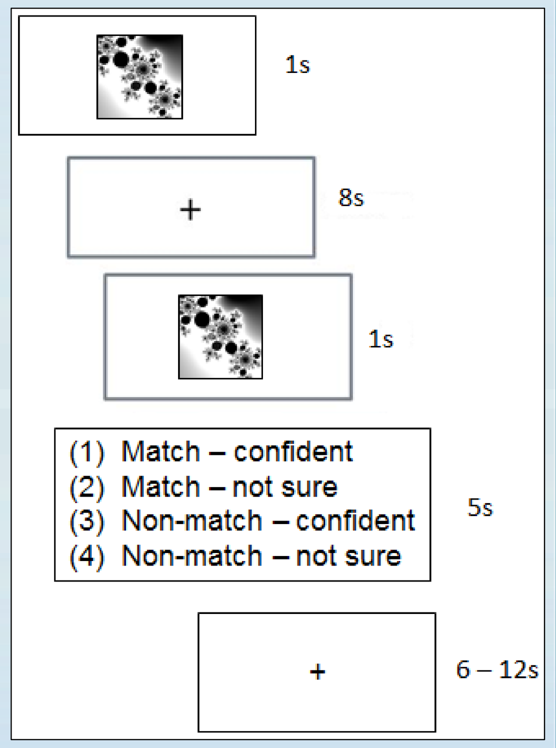
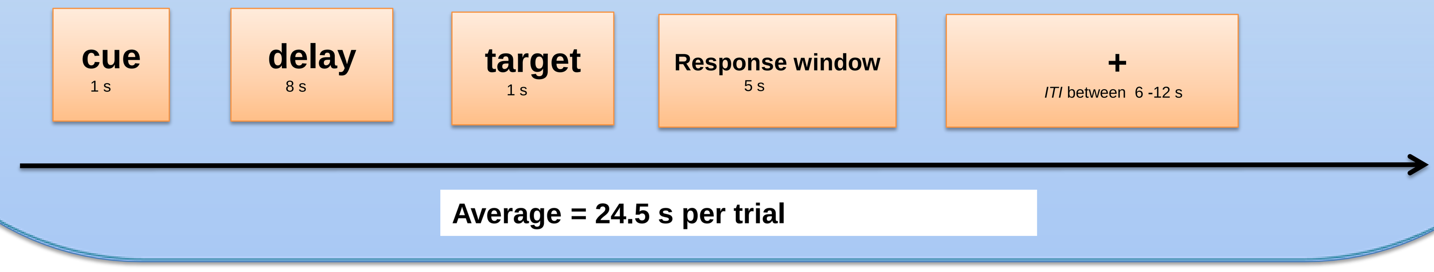


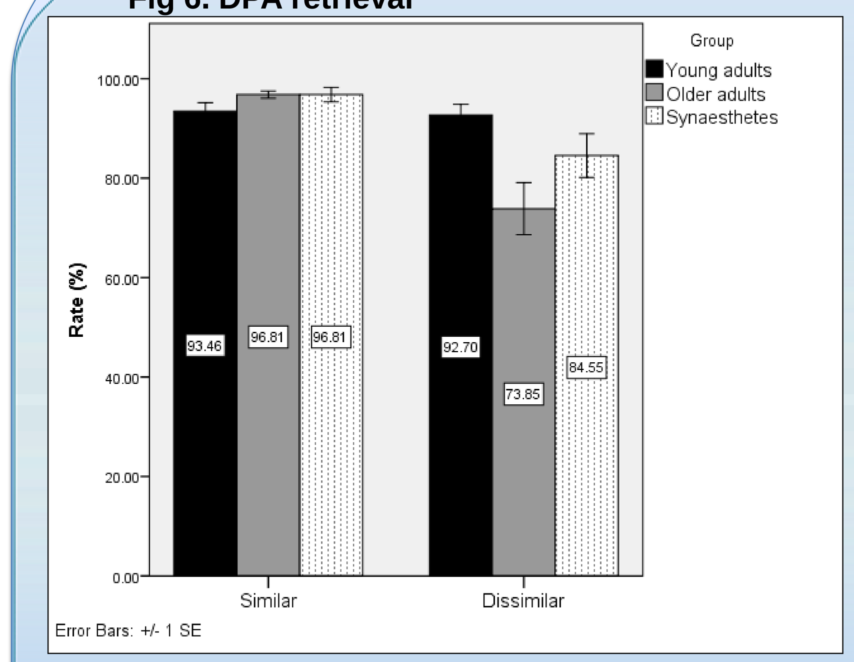
Fig 5. Delayed-Match-To-Sample (DMS) example trial

fMRI Event-related design, including 32 similar and 32 dissimilar pair trials
Trial structure:



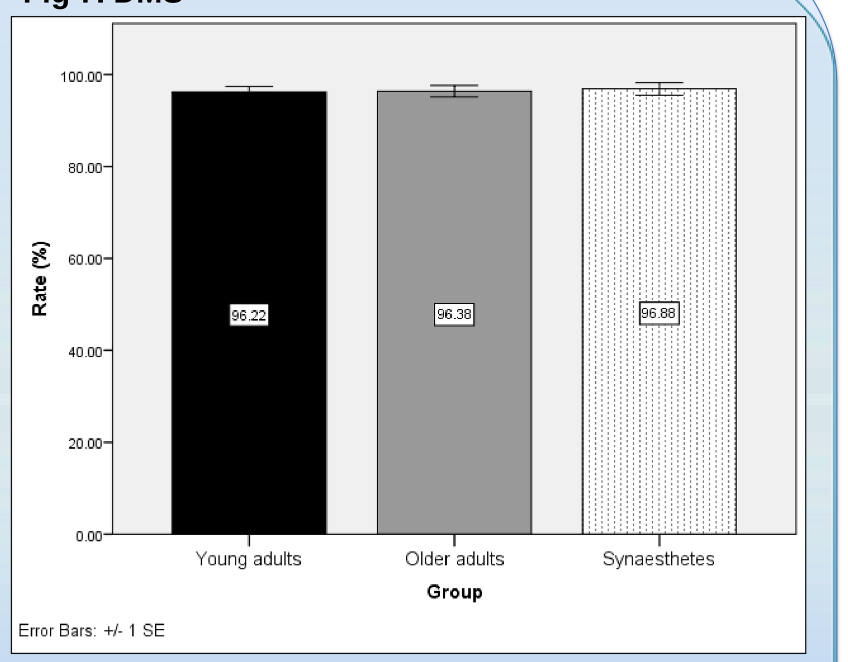
Behavioural Results

Fig 6. DPA retrieval



A 3 (group) x 2 (condition) mixed ANOVA showed a main effect of condition (p<0.001) and significant interaction between group and condition (p=0.001) (Fig. 6).

Fig 7. DMS

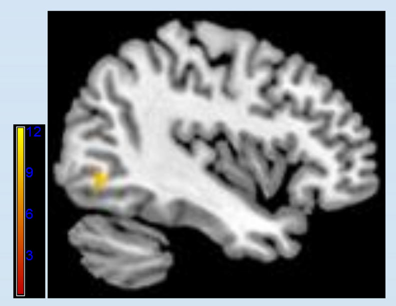


A one-way ANOVA showed no main effect of group in DMS (p=0.931) (Fig. 7).

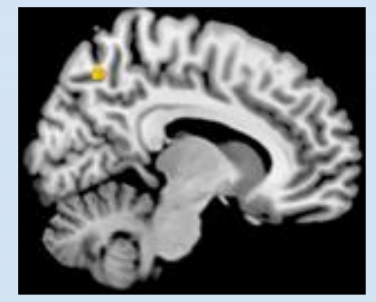
fMRI Results

DMS delay, main effect of group

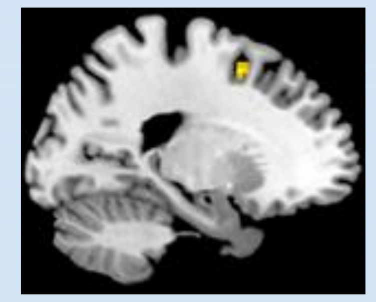
P<0.001 (uncorrected)



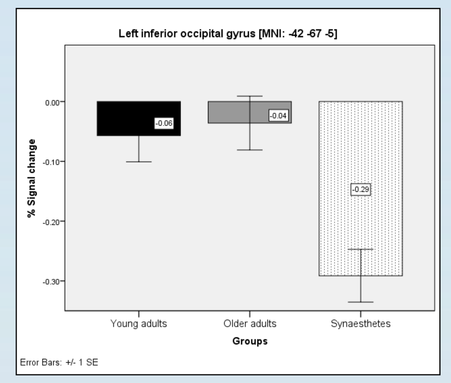
L inf Occipital Gyrus
MNI -42 -67 -5

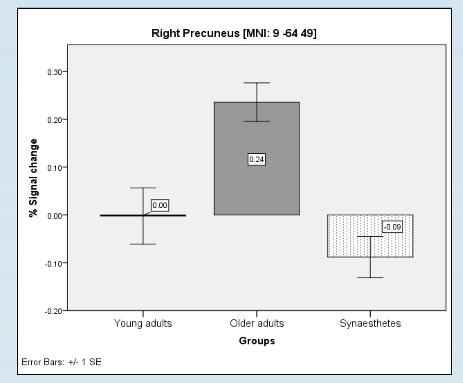


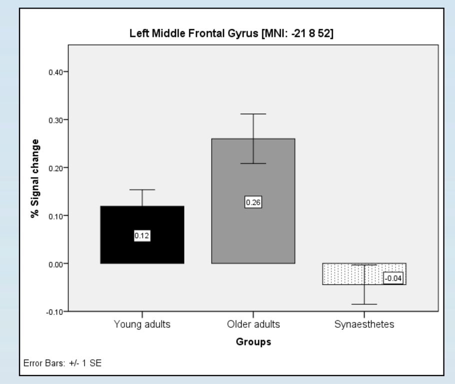
R SPL (7A)
MNI 9 -64 49



L middle Frontal Gyrus
MNI -21 8 -52

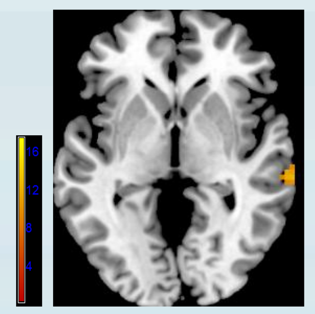






DPA delay, main effect of group

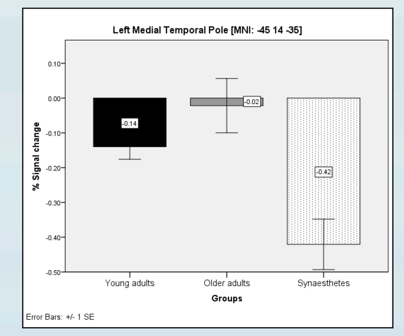
P<0.001 (uncorrected)
In : L BA 18 (-6 -88 22), R middle temporal gyrus (69 -28 -2),
R inf Temporal Gyrus (48 -73 -11), L medial Temporal Pole (-45 14 -35)
L SPL (-3 -67 46), R middle Frontal Sulcus (30 14 37), L middle Frontal Gyrus (-30 62 4)



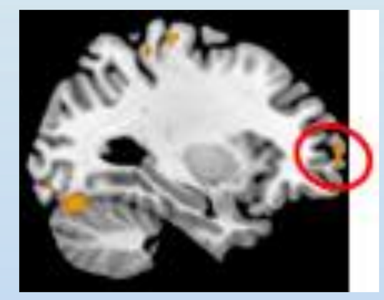
R middle Temp Gyrus
MNI 69 -28 -2

R inf Temp Gyrus
MNI 48 -73 -11

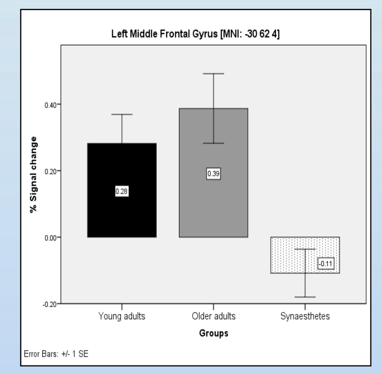
L medial Temp Pole
MNI -45 14 -35

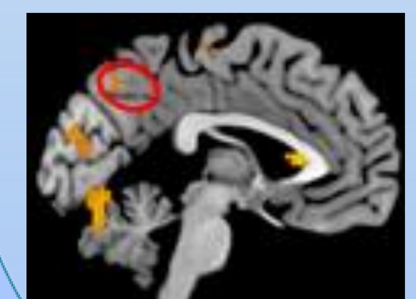


R middle Frontal Sulcus
MNI 30 14 37

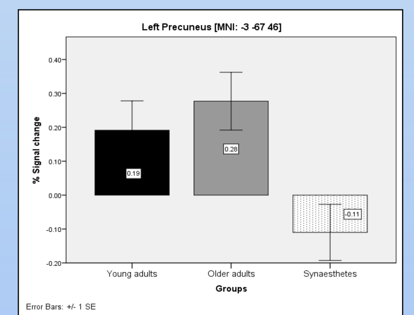


L middle Frontal Gyrus
MNI -30 62 4

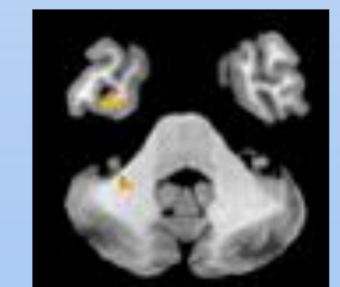




L SPL
MNI -3 -67 46



DPA delay, t-contrast
old > synaesthetes
L PRH – 36 -7 -38



Conclusions

- Representations for the abstract stimuli remain active during the delay period in the occipital and temporal areas, particularly in the high memory load DPA condition.
- Parietal (SPL) and prefrontal activations are higher in the older adults, indicating more intense use of resources to achieve the same level of behavioural performance to young adults.
- Activations in occipital, parietal and temporal areas are consistently lower in the synaesthetes, compared to the two other groups.
- Activity in the fusiform gyrus and the hippocampus of the synaesthetes during working memory maintenance predicted subjective visual imagery (data not shown).