DIFFERENT BRAIN MECHANISMS FOR SUBITIZING AND COUNTING REVEALED BY MEG

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INTRODUCTION

Enumeration is fast and accurate for four or fewer items (***subitizing***) but slow and error-prone thereafter (***counting***).

Functional brain imaging studies and neuropsychological case studies indicate an important role of parietal cortex in number processing (Piazza & Izard 2009). Especially horizontal part of intraparietal sulcus (**hIPS**) seems to be activated in various numerical tasks (Dehaene et al. 2003).

Studies comparing subitizing and counting usually detect brain areas activated by both subitizing and counting and by counting only. Areas activated solely by subitizing are rarely found.

We used magnetoencephalography (MEG) to furthter investigate the temporal and spatial pattern of subitizing and counting.

METHODS

- **Stimuli**: grey squares with 2-8 dots, 50 different dot positions / set size
- **Presentation:** display duration 400 ms, ISI 2500 ms
- **Task:** "Press the button with your right hand as soon as you know the number of dots"
- **Subjects**: 10 right-handed adults, 5 female, mean age 24 years

- **MEG-recordings:** 306-channel Elekta Neuromag device.

An overview of the data at the level of MEG sensors was obtained with areal mean signals (AMS). AMS signals were calculated over ten regions, each including the signal from 6-15 sensor pairs, and averaged across all ten participants. The sensor-level areal mean signals are calculated as a square root of sum of squared signals and they always have a positive value.

Minimum Current Estimates (MCE) were used for estimation of the spatial source locations in an average brain. MCEs were calculated across ten subjects during four time windows (230-270, 400-500, 500-600 and 800-900 ms).

BEHAVIORAL RESULTS

Response time grew by every dot added

- in subitizing range the growth was minor (37-90 ms)
- in counting range response time grew about 330 ms for one added dot

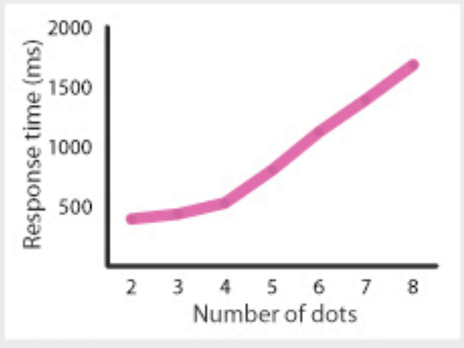


Fig. 1. Average of response time for 10 subjects

MEG RESULTS

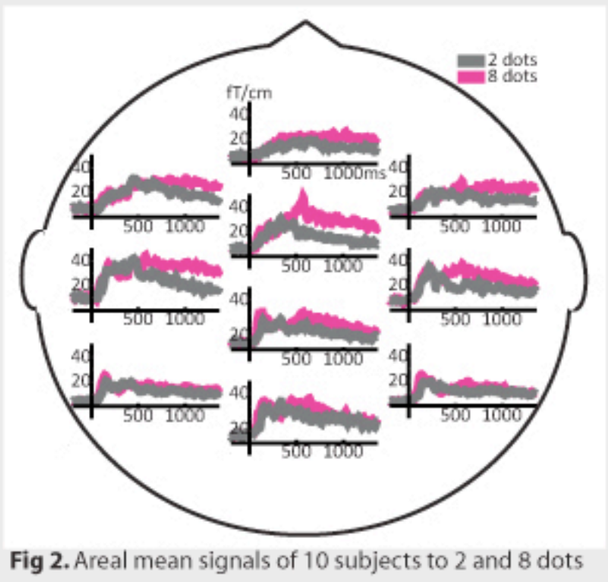


Fig 2. Areal mean signals of 10 subjects to 2 and 8 dots

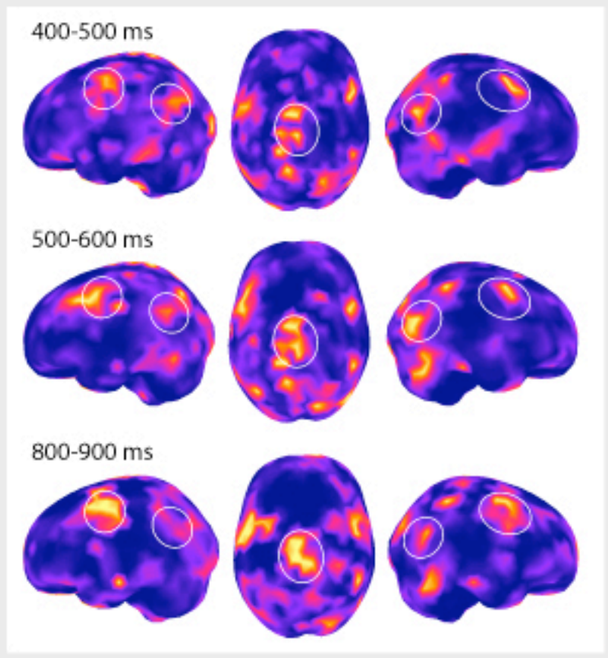
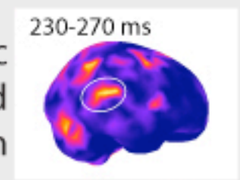


Fig 4. MCE for 8 dots

Subitizing: Slightly stronger signal at 250 ms over the right parietal channels for 2 dots than 8 dots.

Counting: 400 ms onwards, pronounced activation for larger sets detected above parietal channels followed by activation above vertex and frontal channels. At 700 ms activation culminated in the parietal channels but continued to grow in the vertex and frontal channels for 8 dots.

Activation on channels above vertex and frontal areas at 800-1100 ms correlated with response latency (vertex; $r = .50$, $p<.001$ and frontal; $r = .48$, $p<.001$).



At 250 ms, specific activation for 2 and 3 dots was found in temporal cortex.

Fig 3. MCE for 2 and 3 dots

At 400-500 ms onwards active areas could be identified in bilateral parietal, frontal and vertex areas.

CONCLUSIONS

Since enumeration had earlier been studied with fMRI, this MEG-study offers new valuable information about temporal and spatial pattern of subitizing and counting.

According to our results, an early peak at 250 ms in right temporal cortex seems to play an important role in subitizing. Based on its location and time of occurence, the activation might reflect the activation of the ventral visual stream.

The correlation between vertex and frontal activation and response latency suggests that vertex and frontal areas are involved in task guidance. Parietal areas activated earlier seem to posess a key role in numerical processing. These results suggest the engagement of a distributed parieto-frontal network during effortful counting.

REFERENCES

Dehaene, S., Piazza, M., Pinel, P., & Cohen, L. (2003). Three parietal circuits for number processing. Cognitive Neuropsychology, 20(3/4/5/6), 487-506.

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