

Early spatial attentional modulation of inputs to the fovea

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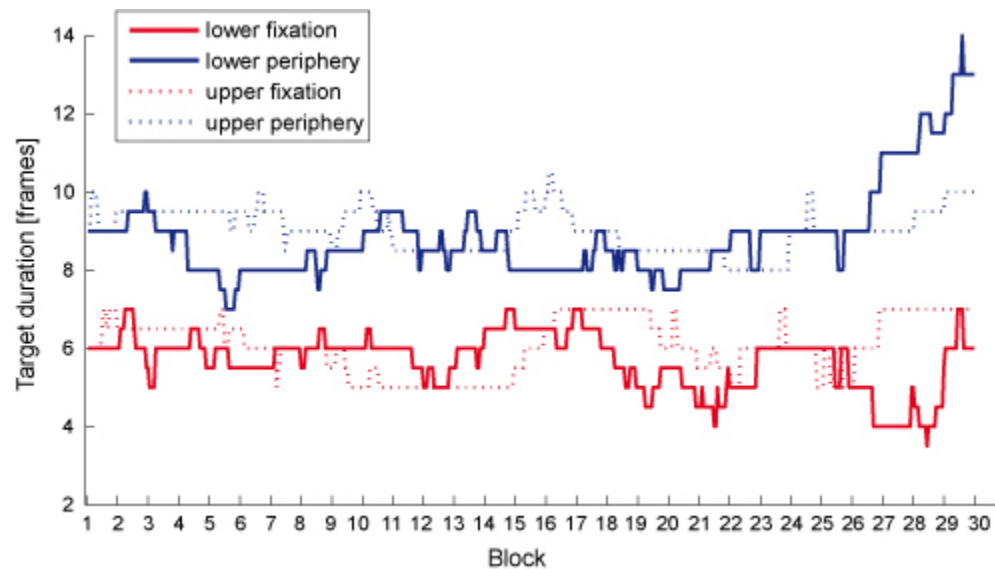
Supplementary Material

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Behavioral results

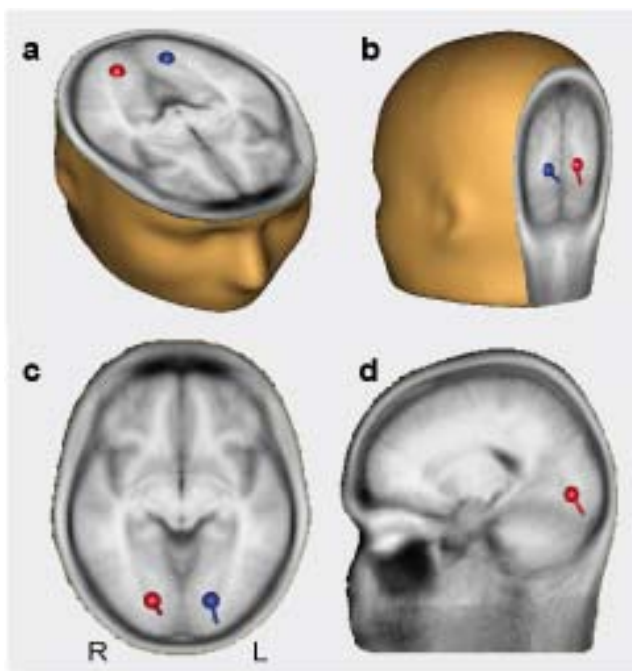
During the experiment the duration of targets was continuously adjusted on an individual basis to the behavioural performance of the participants. The initial target-duration was set to a level considered difficult to detect, based on behavioural pilot testing. If subjects had not engaged in the task, then the target duration would have increased rapidly above this level. However, we found that target duration shortened after a few blocks, was then maintained across most of the experimental blocks at this shortened duration, with a tendency to rise again to the starting level during the last 3 or 4 blocks (Supplementary Figure 1). This indicates that participants were able to perform the task and were engaged in it.



Supplementary Figure 1. Median target duration (in frames) plotted for each trial. Red traces represent target duration at fixated locations, blue traces at peripheral locations. Solid lines represent durations for fixation on lower, dotted lines for fixation on upper stimulus.

Cortical sources of attentional modulation

The cortical generators of the attentional effect for the upper fixation were found more ventral and medial than those for the lower fixation (Supplementary Figure 2). This result is in line with previous results on EEG source localization showing more ventral locations for upper-field stimuli (Heinze et al, 1994; Martinez et al, 1999; Woldorff et al, 1997), likely due to the retinotopic organization of early visual cortices (Woldorff et al, 1997).



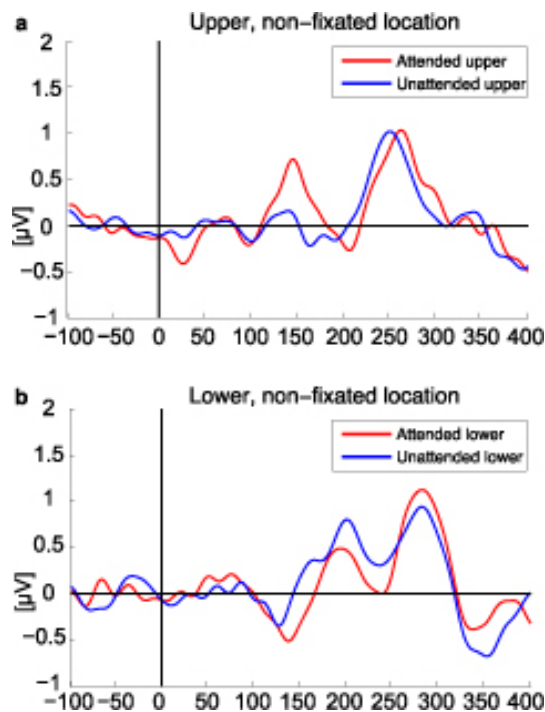
Supplementary Figure 2. Dipole representations of sources of attentional modulation when subjects fixated on the upper stimulus. **a,c**, Transversal sections at $z = -5$. **b**, Coronal section at $y = -78$. **d**, Sagittal section at $x = -19$.

For the lower fixation location, fitting a third dipole resulted in an additional 9% explained variance. The location of this third dipole was in the vicinity of the right superior frontal gyrus (Talairach coordinates: $x=20$, $y=59$, $z=14$). In a recent study, Wei and colleagues (2009) reported that this brain area might be involved in maintaining suppression of distracter locations.

In the current study, participants were required to ignore the non-attended location (which contained another stimulus sequence), and as such, a VESPA response in this brain area is conceivable. Clearly, further experiments would be required to test this hypothesis.

Attentional modulation at non-fixated location

Consistent with the findings at fixation, there is clear attentional modulation of the first major peak for both the upper and lower field conditions (Supplementary Figure 3). Interestingly, this first major peak reverses polarity based on upper versus lower field stimulation indicating that the main contributions are likely from retinotopically mapped areas. Also, the peak latency of this initial response at non-foveal locations is delayed relative to that of the fixated response.



Supplementary Figure 3. Temporal properties of attentional modulation at non-fixated location. **a**, Modulation of grand average VESPA at lateral parietal electrodes with attention for the non-fixated upper visual stimulus. **b**, Modulation of grand average VESPA at central parietal electrodes with attention for the non-fixated lower visual stimulus.

Rejection based on eye-movements

In order to calculate accurate VESPA's for the two stimulus locations, which were only 1.8 x 1.8 degrees in size and marginally more than 2 degrees apart, it was necessary to take a very strict approach to restricting the range of eye-movements allowed. Otherwise, the calculation of the response to the fixated location could have included periods where participants were fixating the surround, or indeed the other stimulus location, during the trial. All of the participants who were rejected due to eye-movements produced eye-blinks at the end of trials (end of the 5s stimulus). Since we use a 500ms window for the estimation of the VESPA, which extends into the time after the stimulus, these subjects had a great number of rejected trials. We therefore calculated the VESPA for these subjects removing the last 500ms of the stimulus.

Using this approach we were able to obtain VESPA's for 3 out of 5 bad participants (B1-B3). For the other 2 participants we were not able to obtain a regular VESPA, even though the number of trials was well within the acceptable range. Including subjects B1-B3 in the statistical analysis resulted in $p = 0.018$ for the lower and $p = 0.004$ for the upper fixation location. As such, the inclusion of these subjects did not affect significance levels of the statistical comparisons, but in fact, p -values were even more robust. Nonetheless, these subjects did not reach our established criteria for acceptance and were not included in the main analysis.

References

Heinze HJ, Mangun GR, Burchert W, Hinrichs H, Scholz M, Munte TF, Gos A, Scherg M, Johannes S, Hundeshagen H, et al. (1994) Combined spatial and temporal imaging of brain activity during visual selective attention in humans. *Nature* 372:543-546.

Martinez A, Anllo-Vento L, Sereno MI, Frank LR, Buxton RB, Dubowitz DJ, Wong EC, Hinrichs H, Heinze HJ, Hillyard SA (1999) Involvement of striate and extrastriate visual cortical areas in spatial attention. *Nat Neurosci* 2:364-369.

Wei P, Müller HJ, Pollmann S, Zhou X (2009) Neural basis of interaction between target presence and display homogeneity in visual search: an fMRI study. *Neuroimage* 45:993-1001.

Woldorff MG, Fox PT, Matzke M, Lancaster JL, Veeraswamy S, Zamarripa F, Seabolt M, Glass T, Gao JH, Martin CC, Jerabek P (1997) Retinotopic organization of early visual spatial attention effects as revealed by PET and ERPs. *Hum Brain Mapp* 5:280-286.

Supplementary Video

Supplementary Video. Presentation of one experimental trial. During the depicted trial, subjects were asked to fixate on the upper stimulus and, while keeping fixation, perform the experimental task on the lower stimulus. There are 2 targets in the attended lower stream and 1 distracter in the unattended upper stream. The modulation of stimuli's luminance lasts for 5s. Please note that for presentation the two stimuli were placed slightly further apart than in the original study.