Supplementary Data: Experimental Group 4 - MEG SFG with Letter Search Load Task

We conducted a further MEG experiment identical in design to Experiment 2, but using a different load task, based on letter search (Figure S1). This task has been successfully used for manipulating load in previous work (e.g.[1]) including in experiments focused on inattentional-deafness (psychophysics[2], MEG[3]). The results are shown in Figure S2 and are broadly consistent with the results reported in the main text (Experiment 2).

Materials and Methods

Participants

Sixteen paid participants (9 male; mean age of 24.9 years, SD = 5.1 years) took part in the MEG experiment. All were right handed, had normal or corrected to normal vision and reported normal hearing and no history of neurological disorders.

Apparatus, Stimuli and Procedure

The apparatus, recording methods and auditory stimuli were identical to those used in Experiment 2.

The visual task used was a letter search task, similar to the one in Molloy et al.[3] (Figure S1a). The search array comprised six letters spaced equally around a (non-visible) circle centred at fixation and subtending 1.9° viewing angle. The background of the display was dark grey (RGB: 77 77 77); the letters and fixation cross appeared in white. The target letters were X or Z (present in equal proportion) both measuring 0.6° x 0.6°. The non-target letters in the low load condition were smaller Os (0.2° x 0.2°), and those in the high load were the letters K, W, V, N and M (all the same size as the target letters). The positions of the letters were randomised on each trial so that the target had an equal probability of occurring in each position. The low load non-target letters were chosen to be easily distinguishable from the targets based on low-level visual features such as line curvature and orientation – resulting in target pop-out. For the high load condition, to distinguish non-targets from targets requires binding together the low-level features of line orientation with spatial location.

We have previously used these stimuli with 100ms duration, but pilot testing indicated that increasing the duration to 200 ms (which was necessary in order to accommodate the 200 ms SFG signals used) made the high load task too easy. The task was therefore modified to include a 100 ms mask, which immediately followed the 100 ms search display (Figure S1a). The response period was 1800 ms (during which the screen was blank). The experiment consisted of 8 blocks of 120 trials each, and the order of blocks (low or high load) was counterbalanced between subjects.

Analysis

The data were processed and analysed identically to those from Experiment 2.

Results

Visual Task

Participants showed a significant effect of load on performance in the visual task - increased load led to lower accuracy (Mean: LL = 97.9%, HL = 89.3%; SD: LL = 3.7, HL = 6.7; $t(15) = 5.5$, $p < .001$) and longer RTs (Mean: LL = 597ms, HL = 761ms; SD: LL = 83, HL = 79; $t(15) = -9.1$, $p < .001$) confirming that the load manipulation was successful (Figure S1b).

Auditory processing

Figure S2 parallels Figure 3 in the main text, showing broadly similar effects, albeit noisier in general than in Experiment 2, and with an overall smaller figure-related negativity (compare the LL responses in Figure S2a with that in Figure 3a).

Effect of perceptual load on figure ground segregation

Under low load there was a significant figure-related negativity from 120-140 and 175-280ms (Figure S2a), characteristic of the effect shown in Experiments 1 and 2. Also paralleling the results seen in Experiment 2, under high load the FRN response was significantly reduced; in fact, in this experiment the FRN was totally abolished - there was no significant difference between the FA and FP responses at any point in the trial (Figure S2b). This difference between load conditions was substantiated by a significant interaction between load and figure from 70-115, 220-260, 700-725 ms, and 760-845ms post stimulus onset (Figure S2c). These data are qualitatively consistent with the results seen in Experiment 2, and confirm that a different visual load manipulation also led to reduced processing capacity in the auditory system.

Effect of perceptual load on overall response to ignored sound

The instantaneous power (RMS) of the auditory responses when collapsed over FP and FA trials (Figure S2d) show the same peaks and topographies seen in Experiments 1 and 2. There were significant differences in amplitude of the responses between high and low load from 195-260 ms (P2 response) and 430-450 ms (during the P3). In both cases the low load responses had higher amplitudes, indicating that high visual load reduced both the later onset response to the auditory stimuli and the P3 awareness response. Again, these results are consistent with the pattern seen in Experiment 2.

Visual Evoked Responses

For Experiment 3 and Supp Experiment 1, visual ERPs were calculated to explore the dynamics of the visual load. Both are displayed in figure S3. In both cases, since the data are comprised of several DSS components, the activity is expressed as the instantaneous power (RMS; see methods) across channels.

The evoked responses from the visual only trials in the feature vs combination search (Experiment 2, Figure S3a) exhibit a clear onset peak, and subsequently a relatively flat sustained response, both with topographies (inset) consistent with activity in occipital cortex. Topographies through the apparently sustained response indicate that there were in fact reversals in polarity of the overall response, and individual data (not shown) revealed that there was relatively large variability in peak latencies between subjects, which would result in the broad, flat response seen in the average data. When contrasted between low and high load, a larger amplitude for the low load trials is seen throughout most of the response from 115-190ms and 330-420ms post onset.

The evoked responses from the visual only trials of the letter search task (Supplementary Experiment, Figure S3b) show two clear onset peaks about 100 ms apart, which represent the M135 onset response to the search array (which appears at 0 ms), and to the mask (appearing at 100 ms). The topography plots are consistent with activity in occipital areas.

High load responses were significantly higher than those in the low load task during the M135 onset peak (65-125 ms), but later in the trial the pattern reversed such that low load trials produced higher amplitudes from 640-660 ms.

The effects in the latter portion of the trial are consistent between visual tasks, and likely reflect that under low load, responses such as the N2pc and P3 (which occur in response to target selection) are stronger, reflecting better task performance[3, 7]. The different patterns exhibited during the onset responses of the two tasks appear to reflect different demands on very early visual processing: from ~0-120 ms the ERFs reflect the information in the stimulus displays (identical in the feature-conjunction search, more information in the high load letter search than the low). The effect on early responses in the feature-conjunction search from 115-190ms occurs during the time window associated with the P1-N1 complex in EEG, and is consistent with multiple reports from EEG of one or both of these peaks being stronger during feature search than combination[4-6]. The effect on early responses in the letter search is also consistent with previous MEG responses to the letter search stimuli[3] where the high load display evoked a stronger M100 response. These differences indicate that the pattern of visual evoked activity depends heavily on the task stimuli and requirements, and may reflect that the two tasks place different demands on resources.

The differences in the dynamics of load between the two visual tasks is also evident in the timing of the effect of load on auditory evoked responses, and the interaction between load and figure processing. While both visual tasks reduce responses to the auditory stimuli in conditions of high load, the letter search induces this effect earlier than the feature-combination search. Similarly, the interaction between load and figure processing was evident earlier using the letter search than the feature-combination search. Since the behavioural performance data suggest that the feature-combination search was harder overall than the letter search, this may relate to the fact that there was a salient visual event (the onset of the mask at 100ms) in the letter search paradigm that did not occur in the feature-conjunction search, which may have drawn attention and processing resources back to the visual system at a crucial time for auditory processing (~100-200ms).

FIGURE S1: VISUAL LOAD TASK

Companion to Figure 2 in the main text. **A**. **Load Task Paradigm used in Supplementary Experiment.** Letter search task of low load (a; target dissimilar from distractors) or high load (b; target similar to distractors). Subjects were instructed to identify which of two target letters (X or Z) had been present in the display. Search arrays were presented for 100ms, followed by a 100ms mask. Auditory stimuli (which occurred on 50% of trials; no auditory task) were presented at precisely the same time as the visual stimuli, covering the 200ms during which the search array and mask were displayed on screen. **B. Behavioural data from the Supplementary Experiment.** Mean values for accuracy (percentage correct) and reaction times are plotted for low load (blue bars) and high load (red bars). Error bars reflect the standard error of the sample mean, corrected to reflect the within-subjects contrast. Individual data are plotted and connected by grey lines to illustrate change in performance for each participant between low and high load conditions. The scales are set to match those used in Figure 2B from the main text.

FIGURE S2: EFFECT OF LOAD ON FIGURE-GROUND SEGREGATION

Companion to Figure 3 in the main text. **A. Figure Present/Absent responses as a function of visual load** Evoked fields illustrating responses for Figure-present (FP) vs. Figure-absent (FA) signals under Low Load (LL; left) and High Load (HL; right) conditions. The spatial filter used to calculate the responses (see methods) is inset. Black horizontal bars at the bottom of the plots indicate periods when there was a significant difference between conditions. **B. Interaction between load and figure present/absent**. Difference timeseries, LL(FP-FA) – HL(FP-FA), quantifying the interaction between load and figure. **C. Overall response to the SFG stimuli (collapsed over FA/FP conditions) as a function of load.** Mean RMS (instantaneous power) of responses to auditory stimuli (collapsed over FP and FA trials) under LL and HL, with scalp maps of peak topographies. Black horizontal bars at the bottom of the plots indicate periods when there was a significant difference between conditions.

FIGURE S3: EFFECT OF LOAD ON VISUAL EVOKED RESPONSES

A. Visual evoked responses in Experiment 2 (feature-combination search task). Mean RMS (instantaneous power) of activity in visual-only trials from Experiment 2 contrasting responses in LL and HL, with scalp topographies to illustrate polarity reversals. **B**. **Visual evoked responses in Supplementary Experiment (letter search task)**. Mean RMS (instantaneous power) of activity in visual-only trials from Supplementary, contrasting responses in LL and HL, with scalp topographies to illustrate polarity at major peaks.

References

1. Forster S, Lavie N. Failures to ignore entirely irrelevant distractors: The role of load. *J Exp Psychol-Appl* **14**, 73-83 (2008).

2. Raveh D, Lavie N. Load-induced inattentional deafness. *Atten Percept Psycho* **77**, 483-492 (2015).

3. Molloy K, Griffiths TD, Chait M, Lavie N. Inattentional Deafness: Visual Load Leads to Time-Specific Suppression of Auditory Evoked Responses. *The Journal of neuroscience : the official journal of the Society for Neuroscience* **35**, 16046-16054 (2015).

4. Handy TC, Soltani M, Mangun GR. Perceptual load and visuocortical processing: event-related potentials reveal sensory-level selection. *Psychological science* **12**, 213-218 (2001).

5. Rorden C, Guerrini C, Swainson R, Lazzeri M, Baylis GC. Event related potentials reveal that increasing perceptual load leads to increased responses for target stimuli and decreased responses for irrelevant stimuli. *Frontiers in human neuroscience* **2**, 4 (2008).

6. Wolber M, Wascher E. Visual search strategies are indexed by event-related lateralizations of the EEG. *Biological psychology* **63**, 79-100 (2003).

7. Hopf JM*, et al.* Neural sources of focused attention in visual search. *Cereb Cortex* **10**, 1233-1241 (2000).

FIGURE 1

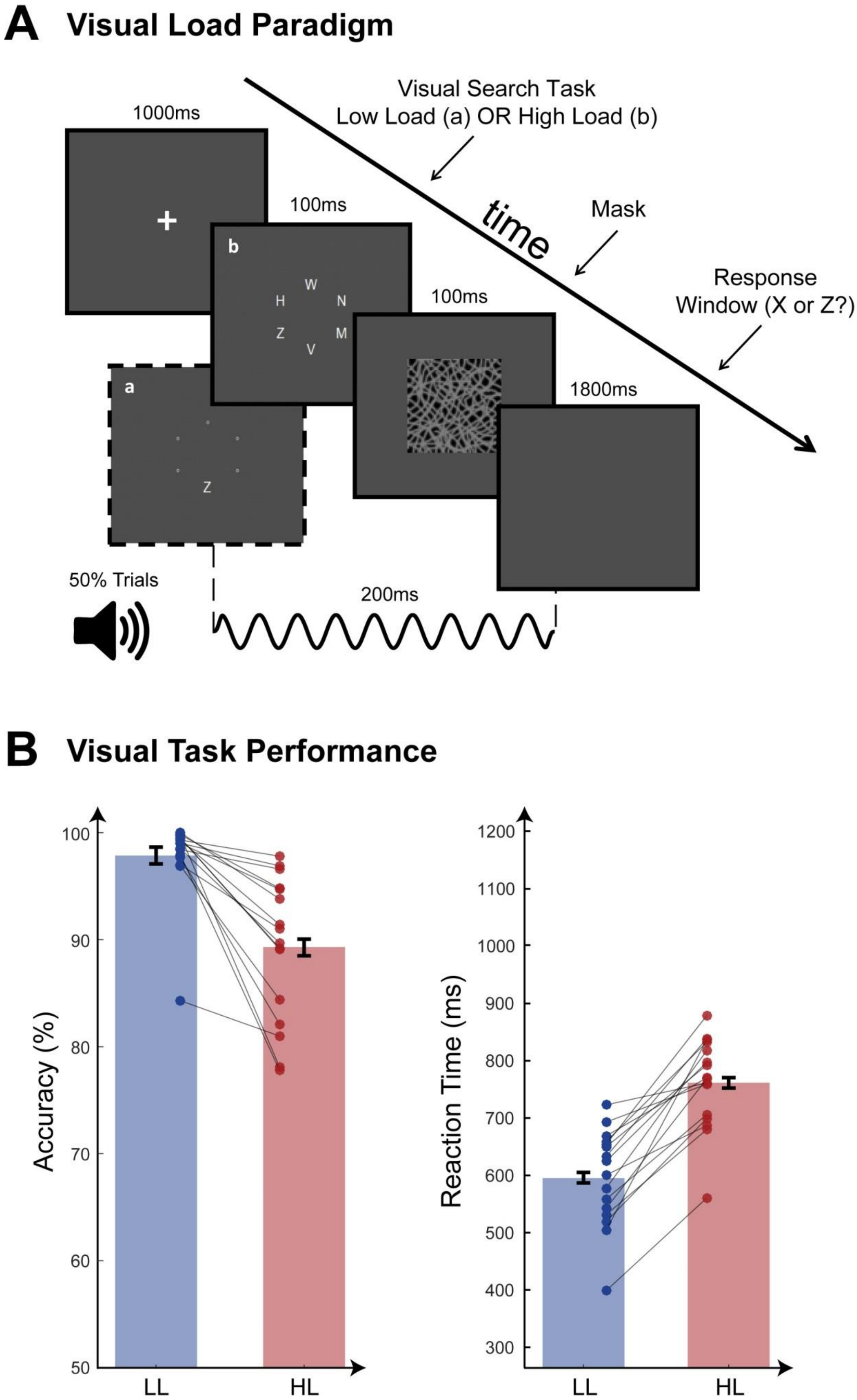
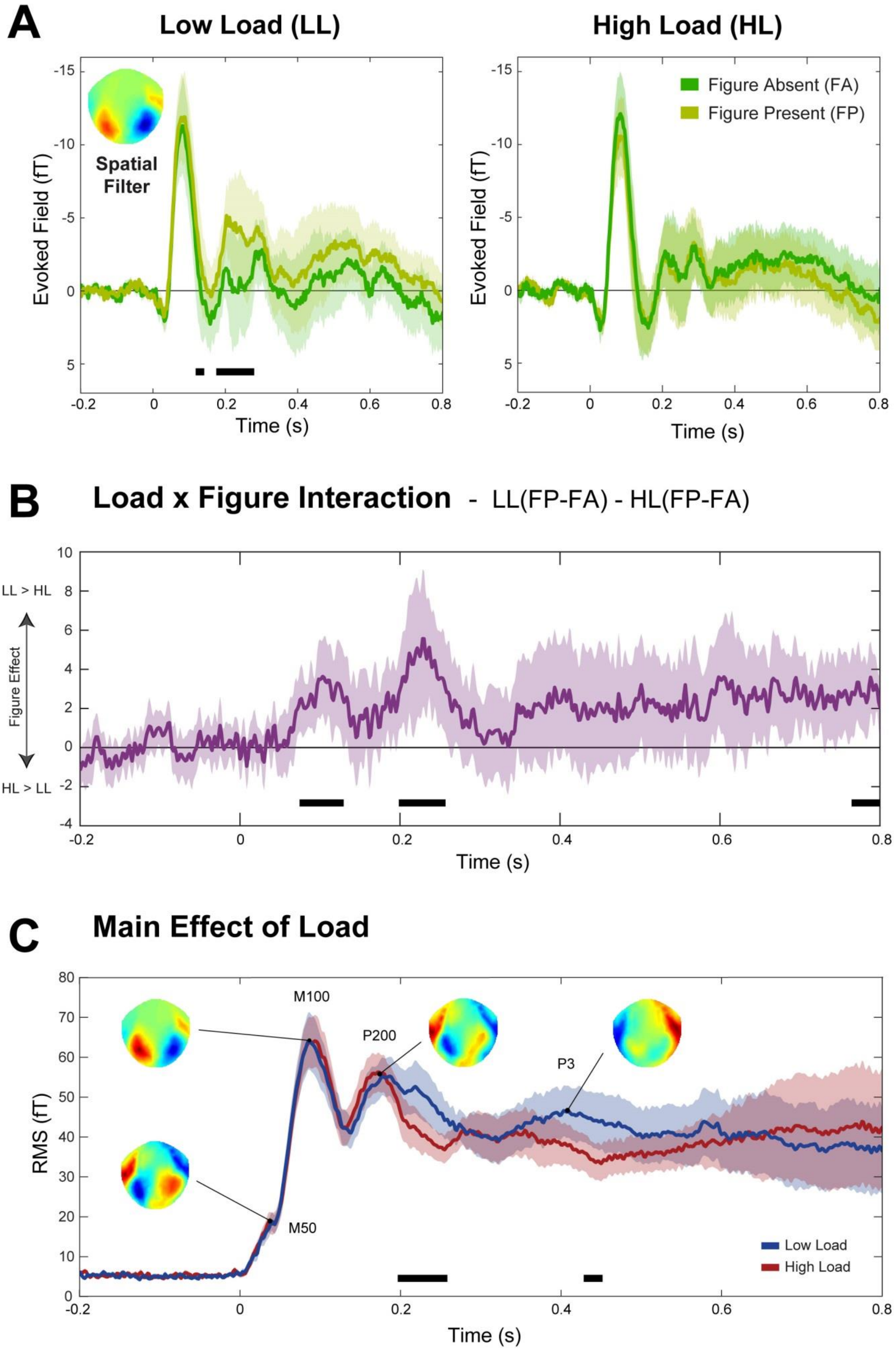
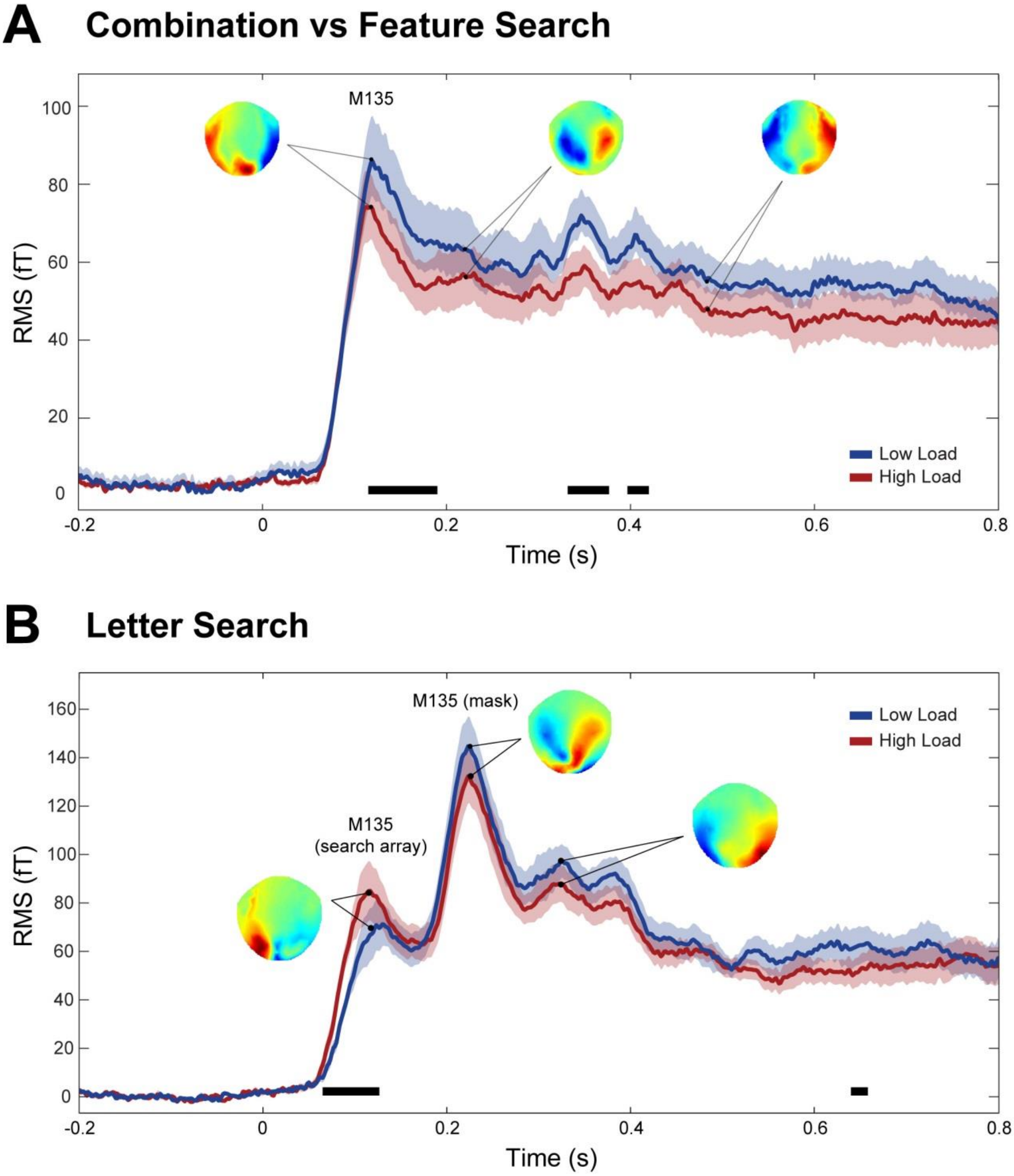

A
Visual Load Paradigm
Visual Search Task
Low Load (a) OR High Load (b)
1000ms
100ms
time
Mask
100ms
Response
Window (X or Z?)
1800ms
b
W
H
N
Z
M
V
a
Z
50% Trials
200ms
B
Visual Task Performance
Accuracy (%)
100
90
80
70
60
50
LL
HL
Reaction Time (ms)
1200
1100
1000
900
800
700
600
500
400
300
LL
HL

FIGURE 2



A
Low Load (LL)
High Load (HL)
Spatial Filter
Evoked Field (fT)
Time (s)
Figure Absent (FA)
Figure Present (FP)
B
Load x Figure Interaction - LL(FP-FA) - HL(FP-FA)
LL > HL
Figure Effect
HL > LL
Time (s)
C
Main Effect of Load
RMS (fT)
M100
P200
P3
M50
Low Load
High Load
Time (s)

Figure 3



A
Combination vs Feature Search
M135
RMS (fT)
Time (s)
Low Load
High Load
0
20
40
60
80
100
-0.2
0
0.2
0.4
0.6
0.8
B
Letter Search
M135 (mask)
M135
(search array)
RMS (fT)
Time (s)
Low Load
High Load
0
20
40
60
80
100
120
140
160
-0.2
0
0.2
0.4
0.6
0.8