Supplementary Material 1: Full comparison of threshold and suprathreshold data

The main purpose of the threshold data was to demonstrate that at threshold there were no differences between classification accuracies and ERPs associated with different contrast combinations. Threshold data therefore serves as a form of control. In this supplementary material we include a full analysis of the data, i.e., an additional repeated measures ANOVA level (*contrast level*) was added to the levels of *contrast combination* and *stimulus type* employed in the Results section. Below we present our analysis of threshold and suprathreshold data together, firstly the behavioural data, followed by the ERPs. The results section presents only a brief analysis of changes in latencies and amplitudes that occur due to the transition from threshold to suprathreshold contrast, and the full analysis of the suprathreshold data, for the sake of brevity. The full analysis here presented is fully consistent with the analysis given in Results and provides more detail for the interested reader.

Behavioural data

A 2x3x3 (*contrast level* by *contrast combination* by *stimulus type*) repeated measures ANOVA analysis of accuracies (plotted in figure A, top row) revealed that all the main effects and interactions were significant (all ps<.02), most notably the 3-way interaction was significant $(F(4,68)=3.53,p=.01,\eta_p2=.17)$. A 3x3 ANOVA at threshold indicated both main effects and an interaction $(F(4,68)=3.07,p=.02, \eta_p2=.15)$, and a 3x3 ANOVA at suprathreshold indicated the same $(F(4,68)=3.62,p=.01, \eta_p2=.18)$. Due to the complex nature of these interactions, Tukey's HSD was used to follow them up. At threshold, performance for luminance-only objects did not differ significantly from objects defined by the two types of contrast combination or from full-information non-objects. It was significantly lower than all other non-objects and all random patches. For L-M/luminance and full-information defined objects, performance did not differ from each other but was otherwise reduced compared to all non-objects and random patches. For luminance-only non-objects, performance did not differ significantly from any other non-object or random patch stimuli. However, for L-M/luminance and full-information non-objects, performance was significantly lower than that for full-information random patches. Finally, performance for random patches did not differ significantly between the three signal types either, although similar performance was reached for L-M/luminance random patches and full-information non-objects. At suprathreshold, luminance-only objects still had the same performance as L-

M/luminance objects, but both were more accurately identified than full-information objects. For luminance-only non-objects, performance was still better than for luminance-only objects, but these non-objects were now similar in performance to all other stimulus classes except full-information objects (the class with lowest performance overall). Within each contrast combination, non-objects and random patches led to similar performance. However, performance was again lower for full-information stimuli, with its non-objects classified more poorly than luminance only and L-M/luminance random patches, in addition to its random patches being classified more poorly than the random patches from the other two combinations.
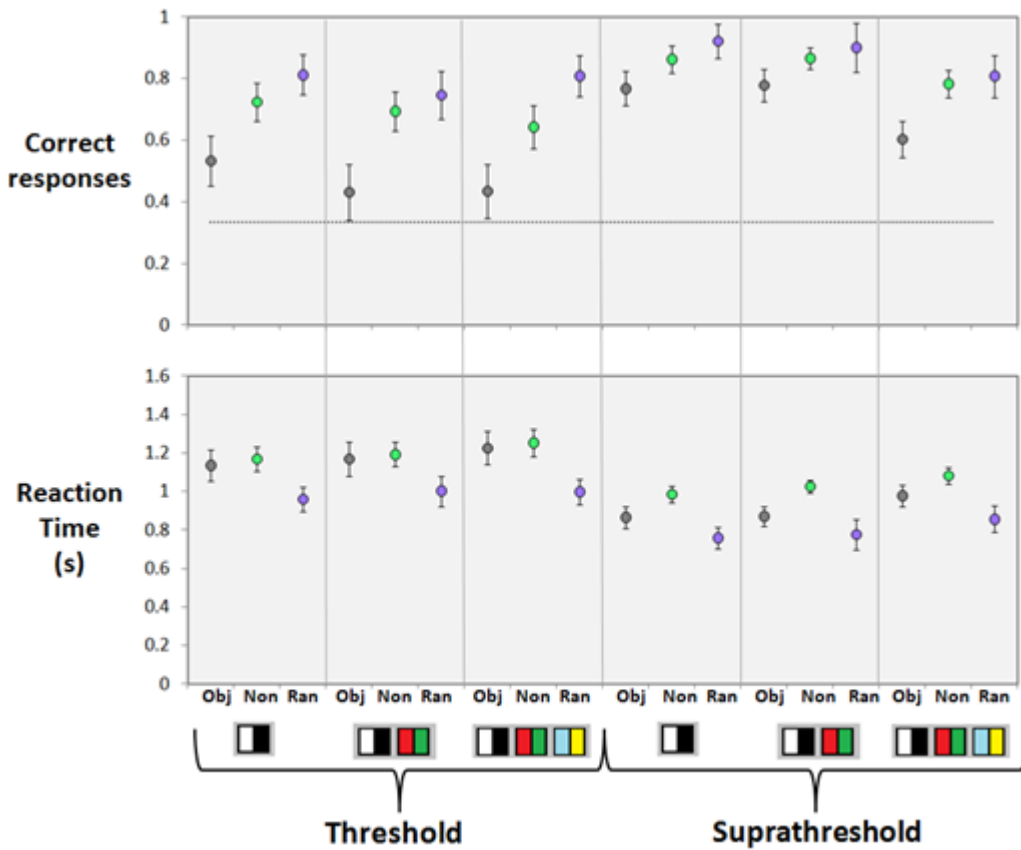
Figure A. *Correct responses (top) and reaction times for each stimulus type below (objects (grey), non-objects (green) and random patches (purple)), at each contrast combination (luminance only, luminance combined with L-M and the full combination) at both contrast levels (threshold (left hand side) and suprathreshold (right hand side)).*

In terms of reaction times (plotted in figure A, bottom row), there was a main effect of contrast level (F(1,17)=116.27,p<.001, η_p^2=.87), contrast combination (F(2,34)=16.95,p<.001, η_p^2=.50), stimulus type (F(2,34)=52.19,p<.001, η_p^2=.75) and an interaction between contrast level and stimulus type (F(2,34)=20.61,p<.001, η_p^2=.55). Interactions between contrast level and contrast combination (F(2,34)=2.81,p=.07) and contrast combination and stimulus type showed a trend towards significance (F(4,68)=2.37,p=.06). There was no three-way interaction (F(4,68)=1.39,p=.25). The effect of contrast combination was simple: full-information stimuli were responded to more slowly than both luminance only (p<.001) and L-M/luminance combined (p<.001), which on their own did not differ from each other (p=.42). To decompose the contrast level by stimulus type interaction, we used Tukey's HSD. Objects and non-objects did not differ in terms of their performance at threshold, but did differ at suprathreshold. All other differences between conditions were also significant, apart from random patches at threshold which did not differ from suprathreshold non-objects. Overall, performance was faster for suprathreshold stimuli, and fastest for random patches, followed by objects, and with non-objects being responded to most slowly overall (all ps<.001). See Supplementary Material 2 for a full breakdown of responses biases.

As a last step, accuracies and RTs were correlated across all subjects to determine if any speed-accuracy tradeoffs were present. A Bonferroni-corrected correlation analysis of 18 accuracy-reaction time combinations revealed no speed-accuracy trade-offs (Range of Pearson's *r*: -.62 ≤ *r* ≤ .12, all ps>0.05).

Event-related potentials: N1

The threshold and suprathreshold N1 waveforms and topographies are depicted in Figure B, while the bar plots of their amplitudes are presented in the top panel of Figure C. Again, due to the complexity of the results (amplitudes, threshold/suprathreshold amplitude ratios and latencies) we will give an overview of the main findings before going into details of the statistical analysis. Differences between contrast combinations in terms of N1 emerged at suprathreshold contrast levels, with amplitude being 1.64x higher than at threshold for luminance alone and 1.69x higher for luminance combined with L-M colour contrast, while no differences in amplitude were found for the full-combination, which only improved in terms of response latency. There was a weak effect of stimulus

type, with less negativity for random patches, which was further qualified by enhanced amplitudes for objects when defined by the full-information contrast.

There was a large main effect of contrast level ($F(1,17)=35.49, p<.001, \eta_p^2=.68$), with N1 amplitudes at suprathreshold being more negative. There was also a strong effect of contrast combination ($F(2,34)=13.36, p<.001, \eta_p^2=.44$), with post-hoc tests indicating that N1 elicited by combination of luminance and L-M was more negative than for the full-information stimulus ($p<.001$). There was also a trend for the luminance only stimulus to be more negative than the full-information stimulus ($p=.061$). The final main effect is that of stimulus type, although it is only just significant ($F(2,34)=3.36, p=.047, \eta_p^2=.17$). Post-hoc tests indicated that this was due to less negativity elicited by random patches than by objects ($p=.032$) and that there was not an overall difference between non-objects and random patches or objects and non-objects.
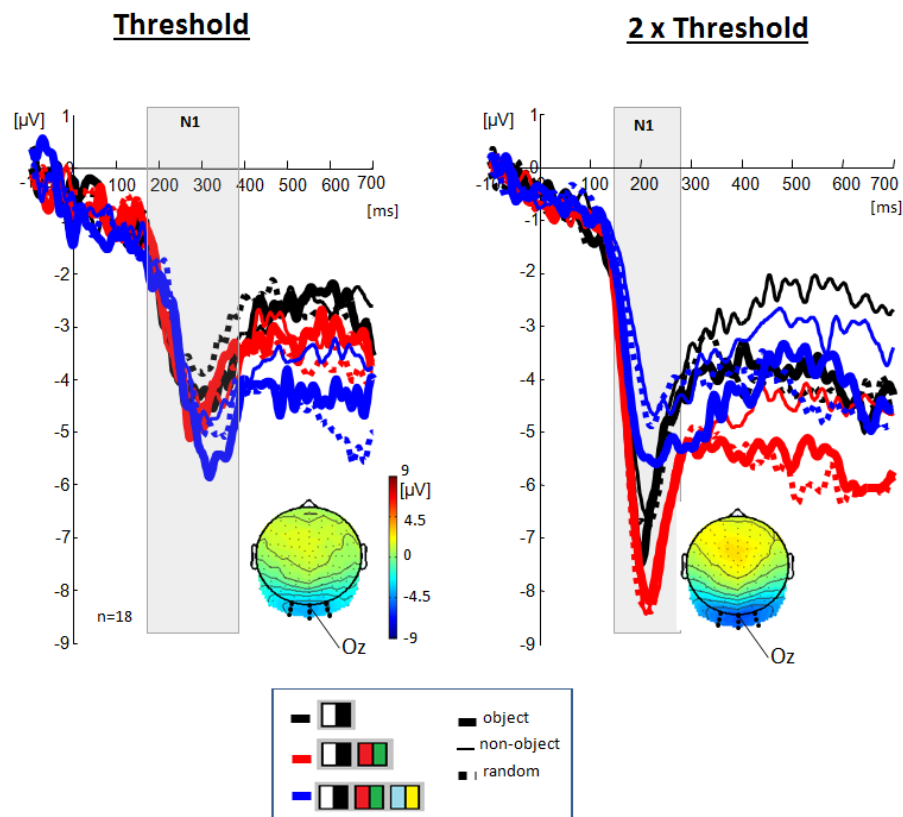

Figure B. *N1 component of the event related potential. Waveforms at occipital sites and topographies during the N1 window (indicated by the grey box) are depicted for threshold (left panel) and suprathreshold (right panel) stimuli. Topographies were calculated after data were collapsed across all conditions. Note: the suprathreshold data presented here (right hand side) is identical to that presented in the Results section.*

However, some of these differences are further qualified through observed interactions between the factors. Contrast level by contrast combination interaction ($F(2,34)=22.20, p<.001, \eta p^2=.57$) was found, indicating that differences in amplitude across threshold and suprathreshold contrasts were not similar between channel combinations. Post-hoc Bonferroni-corrected paired t-tests were conducted to decompose the interaction, with the p value reduced from .05 to .0056 to account for the fact that 9 comparisons were made. Tests indicated that while the N1 was enhanced by contrast increases for luminance only ($t(17)=4.66$, $p<.001$) and luminance combined with L-M ($t(17)=7.51, p<.001$), there was no difference for the full-information stimulus ($t(17)=0.63, p=.54$). While at threshold there were no differences between N1 amplitudes elicited by any of the channel combinations (all $ps>.1$), differences emerged at suprathreshold levels, with most activity elicited by luminance and L-M combination (t-test against luminance only: $t(17)=3.72, p=.002$; t test against full-information: $t(17)=7.10, p<.001$). Luminance only also produced a stronger N1 than the full-information stimulus at suprathreshold ($t(17)=4.62, p<.001$). No interaction was found between contrast level and stimulus type ($F(2,34)=1.30, p=.29$) meaning that different image classes resulted in similar N1s both at threshold and suprathreshold. However, a contrast combination by stimulus type interaction ($F(4,68)=3.70, p=.009, \eta p^2=.18$) means that the differences in N1 between images were not the same across the three combinations. Bonferroni-corrected paired t-tests were used to assess differences between activity elicited by different images for each channel combination, with the p value reduced from .05 to .0056. Post-hoc tests revealed that the differences between the three stimulus classes only existed for the full stimulus, with objects being more negative (t-test for objects vs. non-objects $t(17)=-3.54, p=.003$; objects vs. random $t(17)=-3.12, p=.006$). No other differences were significant (all $ps>.1$). Finally, there was no three way interaction ($F(4,68)=.84, p=.51$).

We also analysed latencies of the N1 peak using the same ANOVA model. There was a main effect of contrast level ($F(1,17)=24.31, p<.001, \eta p2=.59$): latencies were around 20 ms faster for suprathreshold contrasts. There was also a main effect of contrast combination ($F(2,34)=6.57, p=.004, \eta p^2=.28$). This effect was driven by slower latencies for the full combination, when compared both to the luminance only ($p=.009$) and to luminance with L-M ($p=.02$). Stimulus type did not affect latency on its own ($F(2,34)=1.51, p=.23$), but there was an interaction between contrast level and stimulus type ($F(2,34)=4.69, p=.02, \eta p^2=.22$). Tukey's HSD revealed that the interaction was driven by the fact that there was no difference in threshold and suprathreshold latency for non-objects, while all the other

latencies shortened when going suprathreshold. No other interactions reached significance (contrast level by channel combination: $F(2,34)=0.95, p=.40$; channel combination by stimulus type, $F(4,68)=0.66, p=.63$; three-way interaction: $F(4,68)=0.77, p=.55$).
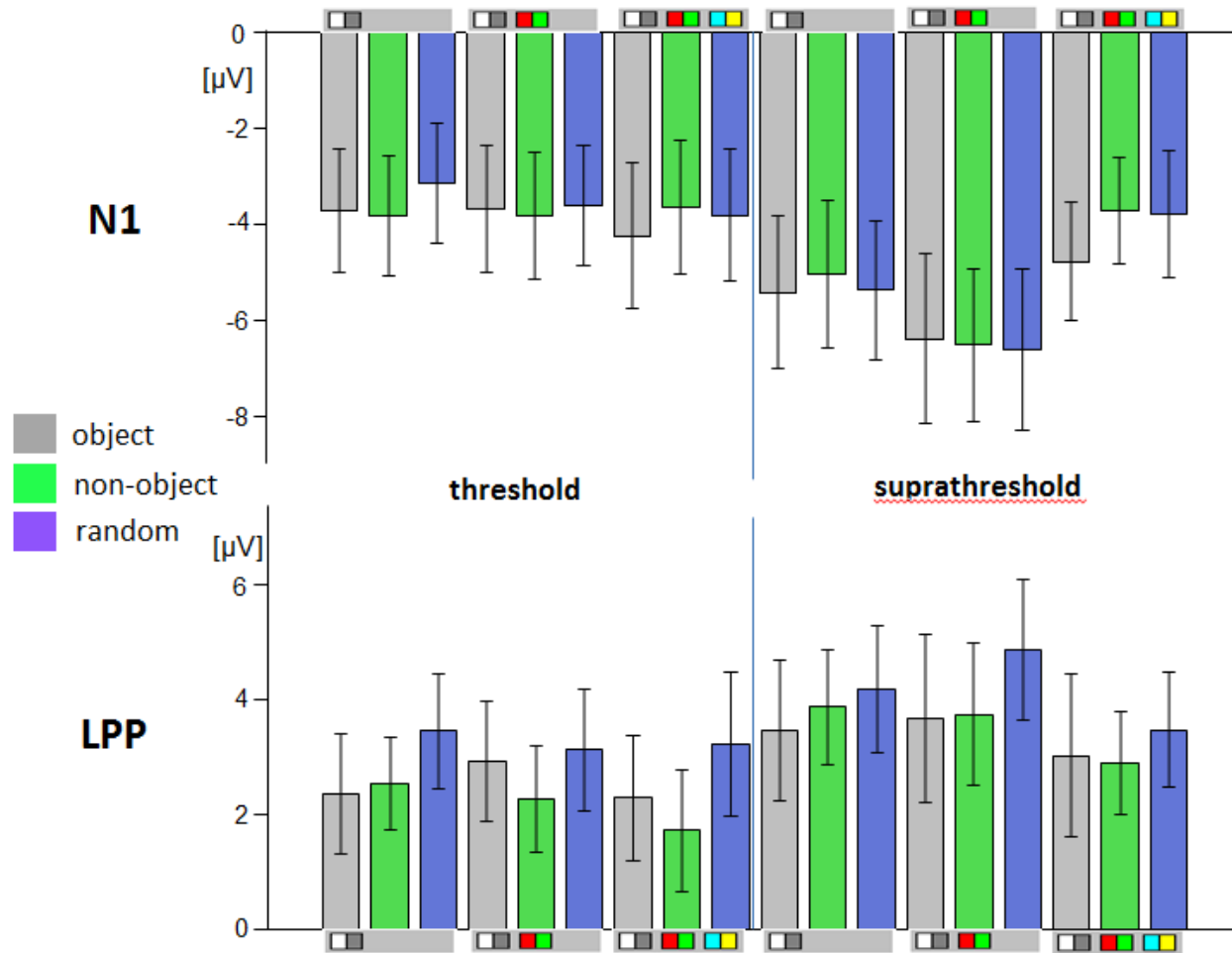

Figure C. *Bar plot of ERP amplitudes. N1 is depicted in the top panel, LPP in the bottom panel. The stimulus types are colour coded - objects: grey, non-objects: green and random patches: purple. Error bars depict +/- 2 SE.*

Event-related potentials: LPP

The late positive potential (LPP) can be seen in Figure D, while the bar plot of its amplitudes is presented in the bottom panel of Figure C. In the LPP, only main effects were observed and they were independent of each other. The main effect of contrast level ($F(1,17)=18.13, p=.001, \eta p2=.52$) was due to larger amplitudes for suprathreshold stimuli. Main effect of contrast combination

(F(2,34)=8.52,p=.001, Ɲp2=.33) was due to the positivity elicited by full-information stimuli being lower than both luminance only and luminance and L-M combined (ps<.01). Luminance only and combination of luminance and L-M did not differ (p=1). Main effect of image type (F(2,34)=9.18,p=.001, Ɲp2=.35) was observed, with random patches eliciting more positive activity than both objects (p=.03) and non-objects (p=.003). As noted, none of the interactions were significant (*contrast level* by *contrast combination*: F(2,34)=1.28,p=.29, *contrast level* by *stimulus type* F(2,34)=0.89,p=.42, *contrast combination* by *stimulus type* F(4,68)=0.62,p=.65, three-way interaction F(4,68)=1.38,p=.25).
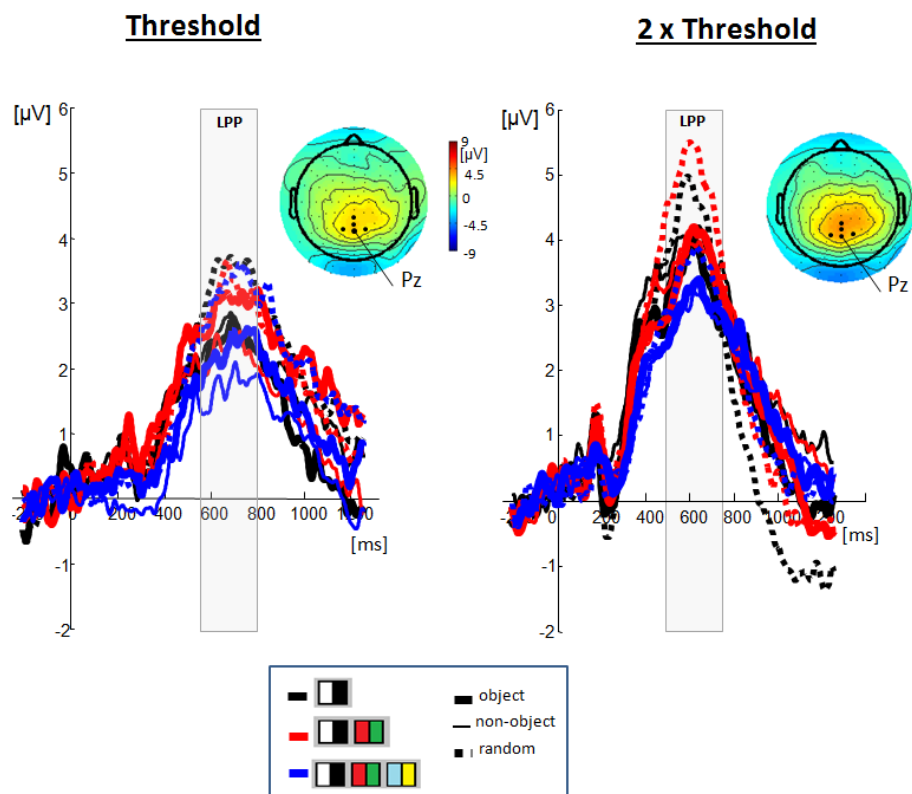
Figure D. *LPP component of the Event Related Potential. Waveforms at centro-parietal sites and topographies during the LPP window (indicated by the grey box) are depicted for threshold (left panel) and suprathreshold (right panel) stimuli. Topographies were calculated after data were collapsed across stimulus type and contrast combination conditions.*