The M170 Is Not Size-Invariant

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Abstract

The M170, a neuro-magnetic correlate of face perception, is known to respond to several high-level facial attributes such as personal familiarity. However, the M170 response to low-level image properties, other than image degradation and mean luminance, are largely unknown. Characterizing the extent to which basic image manipulations modulate the M170 provides important constraints on the computations that it can potentially be implementing. Here, we investigate the low-level image property of size. Previous M170 studies have used a variety of image sizes, making such an analysis an important way to calibrate different results. Also, we were motivated by the observation that image size may have a direct effect on the M170 due to it signaling a closer (larger) or further (smaller) face, an ecologically relevant property. In accordance with this prediction, we observed that M170 latency was affected by image size, although indiscriminately of image type (face versus non-face). In particular, we observed that the M170 occurs earlier for larger images, perhaps signaling the importance of closer objects, in particular faces. In contrast, M170 amplitude was invariant to image size, and always larger for faces, underscoring the resiliency of M170 amplitude selectivity for faces.

Introduction

Roughly 170 milliseconds after viewing an image, neural activity in occipitotemporal cortex generates an electrical current and an associated magnetic field peak, referred to as the M170. The M170, detected with magnetoencephalography (MEG), is similar but not identical to the face-specific N170, detected with electroencephalography (EEG) (Harris et al., 2005; Taylor et al., 2001). Like the N170, the M170 is noticeably larger, and sometimes earlier for images of faces than other stimuli, which has led researchers to posit that it is an important marker of face processing (Taylor et al., 2001; Barrie et al., 2006; Liu et al., 2000; Lu et al., 1991; Watanabe et al., 1999). Specifically, it is believed that the M170 reflects a stage of face processing between face detection ("Is this a face?") and face recognition ("Is this face familiar?") (Liu et al., 2002).

The M170 is known to respond to several high-level facial attributes (those not achieved with simple pixel-based manipulations). For example, the M170 can be modulated by gaze direction (Taylor et al., 2001), can discriminate between human cartoon faces, human Mooney faces, and animal faces (Liu et al., 2000; Marinkovic et al., 1995) and may be larger for personally familiar (but not familiar celebrity) faces (Kloth et al., 2006). Additionally, it is known that the M170 is affected by the low-level image property of degradation (Cherian et al., 2008; Tanskanen et al., 2005; Tarkiainen et al., 2002), but is invariant to the low-level image properties of luminance and stimulus duration (Lu et al., 1991).

In an effort to uncover which face-processing stage the M170 reflects, several researchers have investigated high-level facial attributes, like familiarity (Kloth et al., 2006) and gaze direction (Taylor et al., 2001). However, the M170 seems to reflect an early stage of face processing, and is therefore likely to be modulated by some low-level image properties. These low-level properties could confound research on high-level attributes if they are not considered. Therefore, it is prudent to precisely characterize the effects of low-level image properties on the M170.

The low-level image property that we examined was image size. Previous M170 studies have used a range of image sizes, from under 3° x 3° visual angle (Linkenkaer-Hansen et al., 1998) to 24° x 24° visual angle (Lueschow et al., 2004). A priori, it is hard to predict how size might affect the M170. A larger image could conceivably yield a smaller and later M170, because a larger image would be more degraded by encroaching into the retinal periphery and becoming less foveal (Cherian et al., 2008). The idea that larger faces might disrupt facial processing is supported by the anecdotal evidence that large images of faces, such as those by artist Chuck Close, can be difficult to recognize (Greenberg and Jordan, 1998). Alternatively, a larger face image might be more ecologically significant, signaling a nearer person, potentially leading to a larger and earlier M170. Lastly, image size might not affect the M170 at all, because image size is a low-level property like luminance; and the M170, to the extent that it codes for high level properties, might be invariant to a size change. Given the competition of these scenarios, it is clear that knowing how image size affects the M170 will not only inform the design of future experiments, but will also further general understanding of the M170 and the properties of neural face processing 170 milliseconds after image presentation

Methods

To examine the effects of image size on the M170, we recorded the M170 in response to images of faces and buildings in small, medium, and large sizes.

Participants

Behavioral data were collected from 9 paid participants with normal or corrected-to-normal vision. Informed consent was obtained from all of the participants and the MIT Committee on the Use of Humans as Experimental Subjects (COUHES) approved the study.

Stimuli

(a) (b)

Figure 1: Example face (a) and building (b) stimuli used in the experiment to elicit the M170 response.

Stimuli consisted of 50 building images and 50 unfamiliar face images, each in 3 different sizes (19°, 11°, and 6° square). Building images were compiled from images of houses, skyscrapers, and lighthouses. All images had their backgrounds removed, were converted to grayscale, and centered on a white background (Figure 1).

Procedure

Images were displayed above the MEG machine via a projector. Each trial consisted of a 300 ms fixation cross, 300 ms image, 1500 ms fixation cross, and a 200 ms blank screen. Participants were instructed to keep their eyes at the location of the fixation cross and to not blink, except during the blank screen.

To ensure that participants were attending to the images, participants performed a one-back task. They were instructed to push a button with their left index finger if an image was identical to the one immediately before it, which had a 5% probability of happening. Response trials were excluded from analysis.

MEG Data Acquisition and Analysis

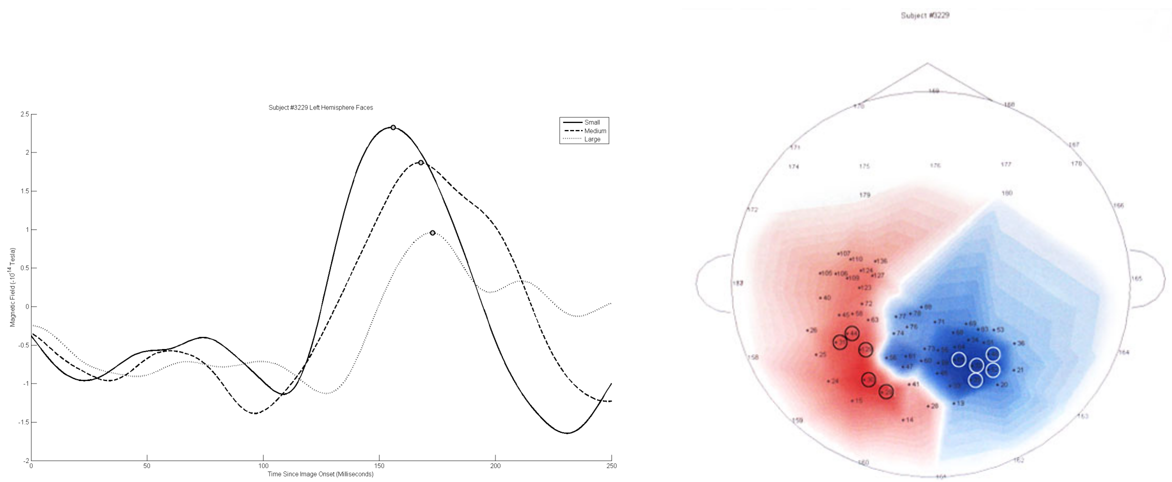
Data were collected at the MIT/KIT MEG joint research laboratory on the MIT campus. MEG recordings were done using a 157 sensor whole-head system with first-order gradiometer sensors (Kanazawa Institute of Technology, Japan). An additional 3 magnetometers recorded local noise for reference. Participants were supine in the MEG machine, which was inside an actively shielded room (Vacuumschmelze, Germany). The M160 software was used to record all MEG data and automatically remove environmental noise from the data using the Continuously Adjusted Least-Squares Method (CALM) (Yokogawa Electric Corporation and Eagle Technology Corporation, Japan) (Adachi et al., 2001).

MEG data from each trial (from 200 ms before to 600 ms after image presentation) were automatically inspected for artifacts due to eye blinks or muscle movement, using a ± 2 pT threshold. Each trial was removed if data from any sensor surpassed this threshold, and if a particular sensor had more than 15 bad trials, it was excluded from analysis (sensor exclusion was done before trial exclusion).

The remaining data were 35 Hz lowpass filtered (48 order Hamming-window based, linear-phase filter) using zero-phase digital filtering (Lueschow et al., 2004). Averaged MEG waveforms were created for each condition, for each sensor, and for each participant by averaging MEG trial data from 0 ms to 400 ms after image presentation with a 100 ms baseline correction. As has been done previously in M170 studies, these averaged waveforms were used to identify sensors that displayed an M170, hereafter referred to as M170 sensors (Taylor et al., 2001; Linkenkaer-Hansen et al., 1998). We identified M170 sensors using the waveforms belonging to the 11° sized face images. We later confirmed that results were not changed by using different image conditions to pick the M170 sensors. A sensor was classified as an M170 sensor if it had a prominent peak between 140ms 230ms after image presentation.

Only a subset of these M170 sensors, hereafter referred to as sensors of interest (SOIs), were used for analysis. To select the SOIs, we found the M170 peak amplitudes and latencies for every M170 sensor over the right and left temporal cortex. The five sensors with the largest M170 amplitudes for faces were selected as SOIs. Similarly, we confirmed that using other image conditions for SOI selection did not change our results. Sensors containing an M170 were generally located over the whole of occipitotemporal cortex, and SOIs were the most posterior of these sensors (Figure 2).

We multiplied the right hemisphere M170 amplitudes by 1, so that M170 amplitudes were positive in both hemispheres (right temporal cortex produces negative M170s, left temporal cortex produces positive M170s). Then, the MEG waveforms from the five SOIs on each hemisphere were averaged together, for image size, image type (face or building), hemisphere, and participant separately (Figure 2). Using these



(a) (b)

Figure 2: Example from a single subject of sensor of interest (SOI) selection, for the right and left hemispheres (a) and the associated M170 waveforms for the left hemisphere response to face images (b).

averages, the M170 peak amplitudes and latencies were identified for each condition and compared.

Results

M170 latencies (reported in milliseconds) were not significantly affected by image condition (face $M = 178.4$, $SE = 4.7$; building $M = 181.0$, $SE = 4.9$) (ANOVA $F_{1,8} = 0.690$, $P = 0.430$), and were marginally earlier in the left hemisphere than the right (left $M = 175.9$, $SE = 4.6$; right $M = 183.4$, $SE = 5.3$) (ANOVA $F_{1,8} = 3.554$, $P = 0.096$). There was a main effect of image size on M170 latency, (small $M = 186.4$, $SE = 5.0$; medium $M = 177.1$, $SE = 5.0$; large $M = 175.5$, $SE = 4.2$)(ANOVA $F_{2,16} = 10.499$, $P = 0.001$), with no significant difference between medium and large (t-test $P = 1.000$), a marginally significant difference between small and medium (t-test $P = 0.071$), and a significant difference between small and large (t-test $P = 0.001$). There were no significant factor interactions. Therefore, for both face and building images, large images elicited a faster M170 than small images.

M170 amplitudes (reported in 10-13 Tesla) were not significantly affected by hemisphere (left $M = 1.8$, $SE = 0.3$; right $M = 1.6$, $SE = 0.2$) (ANOVA $F_{1,8} = 0.655$, $P = 0.442$) or image size (small $M = 1.6$, $SE = 0.1$; medium $M = 1.7$, $SE = 0.2$; large $M = 1.8$, $SE = 0.2$) (ANOVA $F_{2,16} = 2.608$, $P = 0.105$), but were significantly affected by image condition (face $M = 2.0$, $SE = 0.2$; building $M = 1.4$, $SE = 0.2$) (ANOVA $F_{1,8} = 13.065$, $P = 0.007$). There were no significant factor interactions. Therefore, for all image sizes, faces elicited larger M170s than buildings.

Effects on M170 latency and amplitude were each revealed with a Greenhouse-Geisser corrected repeated measures ANOVA. Paired comparisons were made with Bonferroni correction. Results are displayed in Figure 3.

Discussion

In agreement with previous results, we found that face M170s were larger than building M170s. However, we did not observe that face M170s were earlier than building M170s. Similarly, we found no effect of

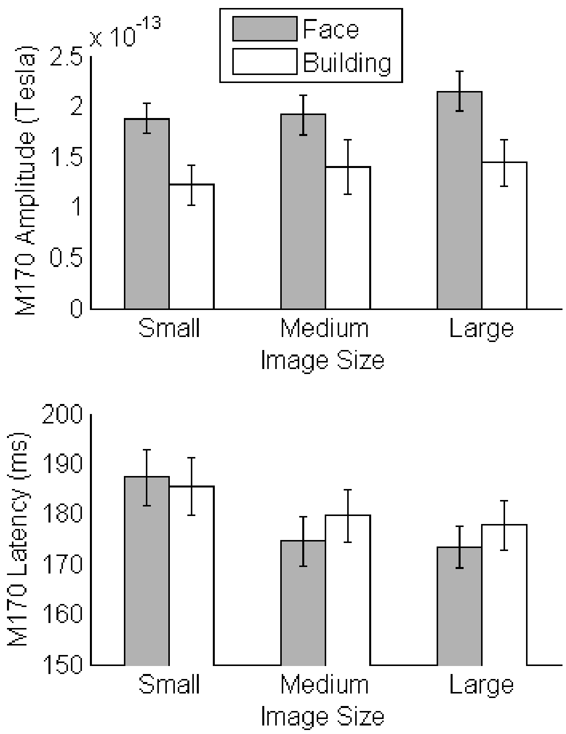


Figure 3: M170 amplitudes were larger for faces than buildings, and earlier for larger images ($P < 0.01$). Error bars indicate standard error.

hemisphere on M170 amplitude, and only a marginal effect of hemisphere on M170 latency. Our investigation of hemispheric effects was motivated by the lack of agreement in the literature on whether there is laterality in M170 properties (Harris et al., 2005; Liu et al., 2000, 2002; Kloth et al., 2006; Itier et al., 2006), and here we found no significant hemispheric effect on the M170.

In regards to image size, we observed that it did not affect M170 amplitude. This is good news for previous studies that may not have equated the image sizes across different image conditions. It also allows for easier comparison of results across studies. In contrast, we did observe an effect of image size on M170 latency, with larger images eliciting an earlier M170. This result may complicate previous reports of an earlier M170 for faces than for other stimuli; especially because it may be difficult to equate the image sizes of such radically different shapes as faces and objects. Therefore, future studies, especially those examining M170 latency, should take care to equate image sizes across experimental conditions.

The fact that the M170 was earlier for larger images, rather than smaller images, is surprising. Perhaps the face processing pathway is designed to work faster with faces that are closer. Our image sizes corresponded to viewing faces that were roughly 2, 3.5, and 6.5 feet away. Therefore, our results imply that the M170 face processing pathway proceeds faster when processing a face that is 2 feet away than when processing a face that is 6.5 feet away. In contrast, M170 amplitude was unaffected by image size; indicating that the strength and duration of neural recruitment responsible for the M170 is invariant to object and face proximity as indicated by image size.

Lastly, the effect of image size on M170 latency was independent of image type (face or building). Larger images elicited earlier M170s, and M170 latencies were the same for face and building images. Therefore, it appears that M170 latency may be more susceptible to low-level image properties like image size; and is not as face-specific as M170 amplitude. Unlike latency, M170 amplitude is face-specific, because it is larger for faces than buildings, and is invariant to the low-level property of image size. From this, we extrapolate that by the time of 170 milliseconds, the M170's face processing pathway can be delayed, but is otherwise unaffected by small image size.

Conclusion

We observed that M170 amplitude was modulated by image type (M170s were larger for faces than buildings), but not image size. In contrast, M170 latency was modulated by image size (M170s were earlier for larger images), but not by image type. The effect of image size must be taken into account in future studies examining latency effects on the M170. Additionally, our results imply that M170 latency, but not amplitude, is affected by the low-level image property of size. Therefore, we observed that by 170 milliseconds the M170's face processing pathway could be delayed, but not otherwise significantly affected by image size.

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