Anuario de Psicología (2017) **47**, 107–114

anuario de
psicología
The UB Journal of Psychology
www.elsevier.es/anpsic

ORIGINAL RESEARCH PAPERS

Dissociating attentional effects on the N170 event-related potential of faces and body parts

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Received 24 April 2017; accepted 6 October 2017
Available online 24 November 2017

KEYWORDS
Attention;
Perceptual load theory;
Face;
Body parts;
Event-related potentials;
N170;
LNC

Abstract Attention was manipulated sensu Lavie's perceptual load theory to short time presentations (200 ms) of task-irrelevant unfamiliar unaltered faces, hands, and houses. Participants performed a letter detection task (X vs. N) under high (6 different letters) or low (6 identical letters) attentional load conditions. Letter strings were superimposed on task-irrelevant stimuli. Replicating and extending previous findings, while the typical pattern of face selectivity (faces > hands > houses) was observed under low load, N170 to faces, houses, and hands converged under high load. High load reduced N170 to faces, increased N170 to houses, and did not affect N170 to hands. These findings demonstrate that the category selectivity of N170 strongly depends on selective attention for faces and objects, while body parts and human bodies insensitive to selective attention.

PALABRAS CLAVE
Atención;
Teoría de la carga perceptiva;
Rostro;
Partes del cuerpo;
Potenciales relacionados con eventos;
N170;
LNC

Disociación de los efectos de la atención sobre el potencial relacionado con eventos N170 de rostros y partes del cuerpo

Resumen Se manipuló la atención, en el sentido de la teoría de la carga perceptiva de Lavie, a presentaciones de poco tiempo (200 ms) de rostros, manos y casas inalterados y desconocidos, irrelevantes para la tarea. Los participantes realizaron una tarea de detección de letras (X frente a N) en condiciones de carga de atención alta (6 letras diferentes) o baja (6 letras idénticas). Las cadenas de letras se superponían a estímulos irrelevantes para la tarea. Se reprodujeron y ampliaron los hallazgos anteriores, mientras que el típico patrón de selectividad de rostro (rostros > manos > casas) se observó con una carga baja, N170 a rostros, casas y manos confluyeron con una carga alta. La carga alta redujo el N170

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https://doi.org/10.1016/j.anpsic.2017.10.004
0066-5126/© 2017 Published by Elsevier España, S.L.U. on behalf of Universitat de Barcelona.

a los rostros, aumentó el N170 a las casas y no afectó al N170 a las manos. Estos hallazgos demuestran que la selectividad de categoría del N170 depende en gran medida de la atención selectiva de rostros y objetos, mientras que las partes del cuerpo y los cuerpos humanos son insensibles a la atención selectiva.

Introduction

ERPs studies showed that faces elicited a larger event related potentials (ERPs) component of negative polarity. However, this component was seen at occipital temporal area between 100 and 200 ms after stimulus onset and peaks around N170 ms. Accordingly, it has been termed N170 (Bentin, Allison, Puce, Perez, & McCarthy, 1996). Faces elicited larger N170 component compared to other visual objects (Eimer, 2011). Schweinberger and Burton (2003) suggested that face sensitive N170 is linked to the structure encoding stage of face processing.

Forgoing studies showed that faces capture attention to a larger extend than other objects do (Langton, Law, Burton, & Schweinberger, 2008). While a substantial body of evidence exists concerning the specialty of faces, little is known about the influence of selective attention on the early processing of faces and objects. In the study of Holmes, Vuilleumier, and Eimer (2003), authors presented face pairs concurrently with house pairs and investigated the influence of attention allocation to cued faces vs. houses on the N170 response. Results of the N170 showed an enhancement of negativity when attention was allocated to faces compared to when attention was allocated to houses. The authors concluded that spatial attention modulated the face-sensitive N170 (see also, Lueschow et al., 2004). In Mohamed, Neumann, and Schweinberger (2009) study, authors manipulated attention, by superimposed letter strings on faces and houses. Participants were instructed to detect X vs. N among identical (low load) or different (high load) letters. Results showed decreasing of the N170 ERP component of faces under high attentional load, suggesting that face sensitive N170 was affected by selective attention.

Conversely, Cauquil, Edmonds, and Taylor (2000) claimed that N170 is unaffected by selective attention. In that study, the N170 to different stimulus categories was recorded (i.e. upright and inverted faces with opened or closed eyes, phase scrambled faces, eyes, lips and flowers). Participants responded to either isolated eyes or to faces with closed eyes. The N170 was unaffected by selective attention (see also, Carmel & Bentin, 2002).

It is controversial in the literature whether faces are the sole category affected by selective attention. Prior studies showed that faces are not the sole category of interest, but bodies and body parts are special too. Forgoing studies showed that faces and bodies have been considered to recruit specialized visual processing mechanisms (Minnebusch & Daum, 2009). However, faces and bodies have been considered to be processed configurally (Minnebusch & Daum, 2009). While other objects are thought to be processed in a part based manner (Biederman, 1987; Tanaka & Farah, 1993). Moreover, there are regions in the human brain responding selectivity and strongly to bodies such as extrastraite body area (EBA), and fusiform body area (FBA) (Downing, Jiang, Shuman, & Kanwisher, 2001). However, these areas analogues to face selective areas in the human brain.

Interestingly, ERPs studies on Body processing showed that bodies produce ERP component which occurs in the time between 100 and 200 ms and peaks around 190 (Thierry et al., 2006). However, this component is larger for bodies than other visual objects. Studies in body processing showed that there is evidence that body parts might be engaged attention similar to faces (Ro, Friggel, & Lavie, 2007). It has been shown that human body is special category compared to other objects. Nevertheless, little is known about the effect of selective attention on the processing of bodies and body parts. Mohamed, Neumann, and Schweinberger (2011) claimed that bodies unaffected by selective attention, in contrast to faces which affected by selective attention. Participants performed letter detection task which superimposed on faces and human bodies. Attention was manipulated by detecting letters among different (high load) or identical letters (low load). Results showed that N170 for faces was diminished under high load condition compared to low load. In contrast body selective N170 does not affected by selective attention.

The current study investigated the effect of attentional load on the early and late processing of faces and human body parts, regarding to perceptual load theory. In this theory, visual perception is capacity limited, but task irrelevant distractor processing occurs obligatorily, unless all capacity is run out by task-relevant target stimuli. An established behavioural finding is that perceptual load to letter target stimuli determines the degree of processing of simultaneously presented distractor faces or body parts. Although irrelevant distractor faces are processed under low load in a letter detection task, explicit distractor processing is significantly reduced or abolished under high load (Jenkins, Burton, & Ellis, 2002; Jenkins, Lavie, & Driver, 2005).

Overall there is long-term argument about faces and body parts processing. Therefore, I aimed to reassessing the potential sensitivity of the N170 to attention, using different distractors types, faces, hands and houses. I test if hands similar to faces and affected by selective attention. I presented either faces or body parts (e.g., hands) as distractors. While houses category was used as a control object. Participants were instructed to detect letter strings which were superimposed in all categories (faces, hands, houses) for detect identical letters (low load) or identify specific

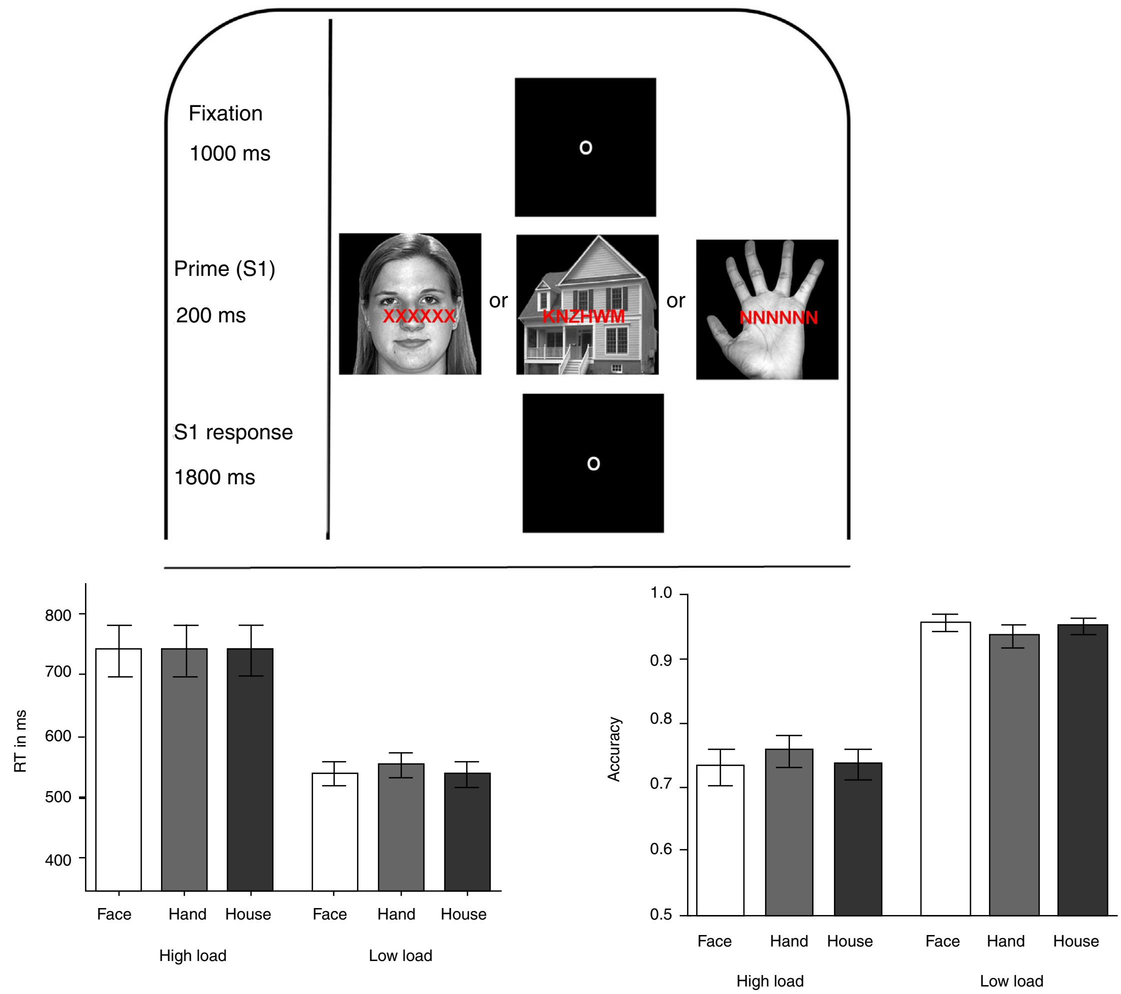

Figure 1 (A) Examples for the stimuli. Participants had to perform two-alternate choice responses (''X'' or ''N'') to letter strings superimposed on distractors. Note that letter strings were actually presented in red colour. (B) Effects of attentional load on reaction time in the letter judgement task (left). Same for response accuracy. Note equivalent effects of load for distracters (right).

letters among different letters (high load). I assumed that a face selective N170 response (faces > hands > houses) under low load, similar what was observed for faces and houses in Mohamed et al. (2009) study. In the current study, I focus on the effect of load manipulation on body parts distractor processing. In addition, I aimed to replicate the findings of faces and houses which have been observed in Mohamed et al. (2009) study. I would expect that N170 for faces and hands and houses amplitude may be influenced under high load as compared to low load.

Methods

Participants

18 students (9 males), aged between 19 and 30 years (*M* = 22.5, *SD* = 2.54) contributed data. All of participants are given a written informed consent, and had normal or corrected-to-normal visual acuity, and right-handed, which specified by Edinburgh Handedness Inventory. The study was conducted in accordance with the Declaration of Helsinki.

Stimuli

80 pictures of each group (faces, houses and hands) were used. Faces pictures obtained from CAL PAL_database (Minear & Park, 2004). Houses pictures were obtained from a set of stimuli used in a previous study of Mohamed et al. (2009). Hands were obtained from different sources, and adjusted due to contrast and luminance, using Microsoft Photoshop. All images were converted to grayscale and placed in front of a black background. Images were adjusted in size (400 × 400 pixels) and orientated in such that both eyes were horizontally aligned. Letter-strings consisted of 6 upper-case letters in red colour (cf. Fig. 1), and included target ''X'' or ''N'' and non-target letters ''H'', ''K'', ''W'', ''M'', and ''Z'', which were presented in Arial 26 bold. In high load condition participants were instructed to detect X or N among different letter. While as, under low load, participants were instructed to detect X or N among Identical Letters. In half of the displays each, the target letter was an ''X'' or an ''N'', respectively. High and low load displays occurred in equal frequency and in randomized order.

Procedure

Participants were seated in front of computer monitor at a viewing distance of 90 cm, which was kept constant by a chin rest. During each experimental trial, white fixation circle was presented for 1000 ms, and replaced by the blended display for 200 ms. Note that the blended display was replaced by another fixation circle for 1800 ms, which a repeated (from the blended display) or non-repeated face, hand, house, or butterflies in order to investigate ERP repetition priming effects (for an analogous design, cf. reference Neumann & Schweinberger, 2008). The current study focused on the first blended display for 200 ms. Participants responded by button press (left index finger for ''N'', right index finger for ''X''). Speed and accuracy were emphasized. The experimental design included two variables ''Load'' (high vs. low) and ''Distractors type'' (faces vs. houses vs. hands), resulting in six conditions of interest. A total of 540 trials were presented in randomized order; breaks were allowed after every 90 trials (~9 min).

Apparatus

An electroencephalogram (EEG) with 144-channels Biosemi Active II system (Biosemi, Amsterdam, Netherlands) was used. Electrode positions included 128 standard sites plus 16 inferior temporal, occipital–temporal and occipital sites. EEG (DC to 120 Hz) was sampled at 512 Hz. Data were re-referenced offline to a common average reference. Trials with incorrect behavioural response were removed, as well trials with amplitudes exceeded 100 μV using automatic artefact detection implemented in Besa 5.1.8.10 (Berg & Scherg, 1994). ERP epochs were quantified for 1400 ms (−200 ms pre-stimulus baseline). Eye movement artefacts were excluded by a specific algorithm. Data were filtered with a band pass at of 0.3–40 Hz.

Data analysis

Repeated measure analyses of variance were calculated for analysing Load and Distractors Type. For statistical analysis of ERPs, I pooled average ERPs within each of 14 regions of interest (ROIs). ROIs were frontal medial (FM)/frontal right/left (FR/FL), central medial/central right/central left (CM/CR/CL), parietal medial/parietal right/parietal left (PM/PR/PL), temporal right/temporal left (TR/TL), occipital–temporal right/occipito-temporal left (OTR, OTL), and occipital medial (OM). I am interested about N170 in Occipital temporal regions for all distractors in the time segment 120–200 ms and also Late negative component (LNC) in the time intervals between 350 and 750 ms in occipital temporal regions. Additionally, I focus on the effect of P100 (80–120 ms) in occipital medial region. However, face and body researches have shown that neurons activated for faces and bodies were focused in these areas (Perrett, Chitty, Mistlin, & Potter, 1986).

Behavioural results

Perceptual load was successfully manipulated: mean correct response times (RTs) were slower (mean = 747.25 vs. 561.33 ms), and accuracies were reduced (mean = 73% vs. 93%) under high vs. low load. ANOVAs showed a main effect of load on both RTs, $F(1,17) = 74.19$, $p < 0.001$, and accuracies, $F(1,17) = 169.64$; $p < 0.0001$. No other effects or interactions were reported (all $ps > 0.10$).

Event-related potential results

The analysis of P100 mean amplitude on ''OM'' revealed main effect of Distractors $F(2,34) = 10.38$; $p < 0.01$, and interaction Load by Distractors $F(2,34) = 16.17$, $p < 0.01$. which reflects the effect of distractors under low load conditions $F(2,34) = 16.57$; $p < 0.01$ than high load condition $F(2,34) < 1$. I performed pair-wise ''*t*-test'' (uncorrected so far) for low load conditions between distractors which revealed that face distractors caused largest P100 compared to either house $t(17) = 5.74$, $p < 0.001$, or hand $t(17) = 4.34$, $p < 0.001$. Whilst, no reliable difference between houses and hands $t(17) = -0.47$; $p = 0.7$ was reported.

For P100 latency, analysis showed main effect of Distractor Type $F(2,34) = 6.95$, $p < 0.01$, and interaction of Distractors by Load $F(2,34) = 10.03$, $p < 0.01$. However, this effect appears under low $F(2,34) = 11.14$, $p < 0.01$ than high load $F(2,34) = 0.93$, $p < 1$. Pair-wise *t*-test showed longest P100 for face ($M = 101$ ms) vs. hands ($M = 97$ ms) vs. houses ($M = 91$ ms), $t(17) = 3.02$, $p < 0.01$; $t(17) = 4.26$, $p < 0.01$; $t(17) = 2.39$, $p < 0.05$ respectively (Fig. 2).

For mean N170 amplitude, on OTR and OTL showed that there was a main effect of Distractor Type $F(2,34) = 33.46$; $p < 0.001$, and interaction of Load by Distractors $F(2,34) = 19.05$; $p < 0.001$. However, Distractors effect appears under high $F(2,34) = 21.32$; $p < 0.001$ and low load $F(2,34) = 32.34$; $p < 0.001$. Pair-wise *t*-test, showed larger N170 under high load for hands ($M = -4.29\,\mu$V) vs. houses ($M = -2.60\,\mu$V), $t(17) = 5.28$, $p < 0.01$ and faces ($M = -2.92\,\mu$V), $t(17) = -4.29$, $p < 0.01$, whilst there are no differences between houses and faces. Under low load there is larger N170 for faces ($M = -4.15\,\mu$V), and hands ($M = -4.35\,\mu$V), than houses ($M = -1.42\,\mu$V), $t(17) = 5.81$, $p < 0.01$. Moreover, there is no differences between faces and hands $t(17) = 0.56$, $p = 0.58$. Additionally, there is a load effect in terms of larger N170 amplitudes under low than high load for faces $F(1,17) = 13.79$; $p < 0.01$ and the opposite pattern, i.e. larger N170 amplitudes under high load than under low load, for houses $F(1,17) = 21.67$; $p < 0.001$. No load effects whatsoever were seen for hands $F(1,17) > 0.78$. For N170 latency there is no effects were reported, all $ps > 0.10$ (Fig. 3).

For the late posterior negativity, I observed main effects of Distractors $F(2,34) = 18.49$; $p < 0.001$, Load $F(1,17) = 72.29$; $p < 0.01$, and interaction of Load by Distractors Type $F(2,34) = 4.30$; $p < 0.01$ on OTR & OTL. However, this effect of distractor appears under high load $F(2,34) = 8.07$; $p < 0.01$, and low load condition $F(2,34) = 11.88$; $p < 0.001$. In high load condition Largest LNC for hands ($M = -2.28\,\mu$V) vs. houses ($M = -1.61\,\mu$V), $t(17) = -3.45$, $p < 0.01$ or faces

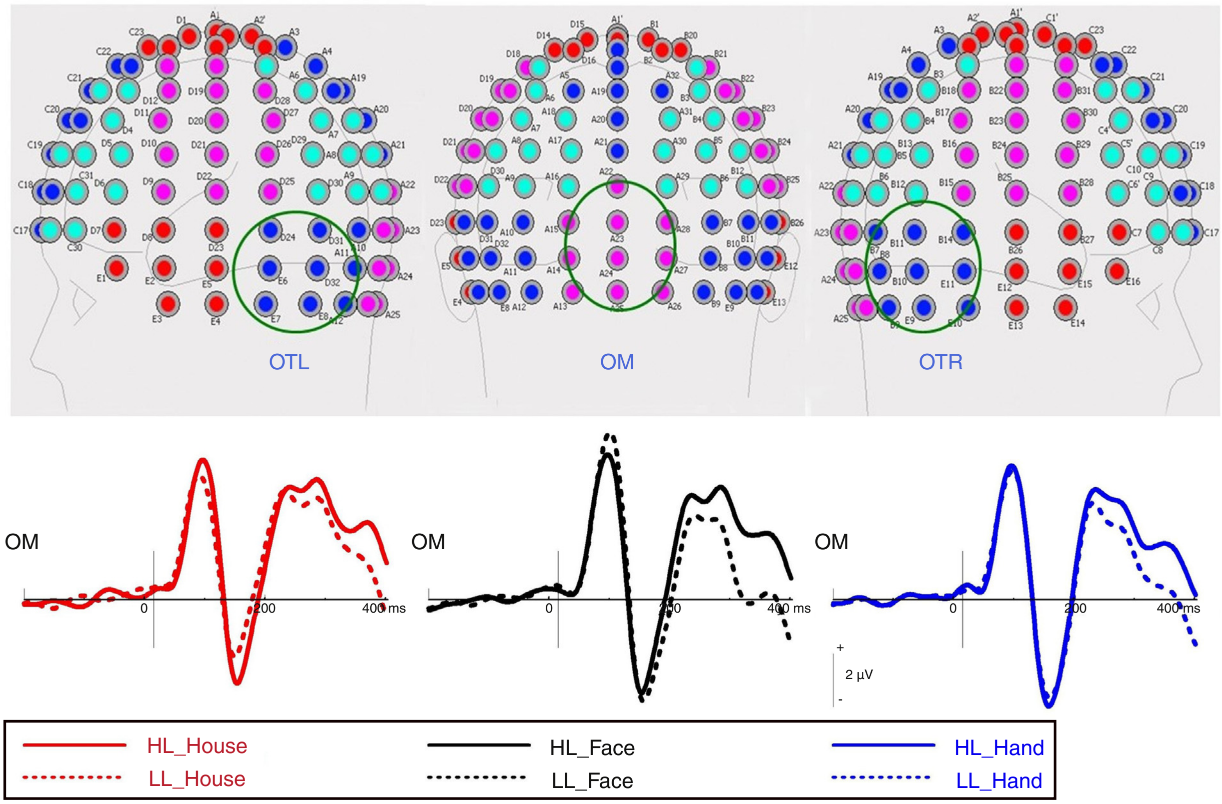

Figure 2 Grand average event-related potentials (ERPs) for occipital-medial site of interest, across all observers. Note that P100 was larger to faces than other categories under low load condition.

($M = -1.95\,\mu V$), $t(17) = -2.43$, $p < 0.01$. In contrast, in low load LNC mean amplitudes were larger for either faces ($M = -4.93\,\mu V$) or hands (Mean $= -4.66\,\mu V$), than houses (Mean $= -3.64\,\mu V$), $t(17) = -3.88$, $p < 0.01$ for faces, $t(17) = -486$, $p < 0.01$ for hands, but no differences was observed between faces and hands $t(17) = 0.97$, $p = 0.35$. For LNC latency there is no effects were reported, all $ps > 0.10$) (Fig. 4).

General discussion

The results of the current study showed that the early processing stage of faces and houses, as indexed by N170 is strongly depending on selective attention, in contrast to hands. Findings on hands showed that there is no effect of selective attention. When these stimuli were presented in a letter identification task, the effect of selective attention was completely inconsistent, and depends on stimulus type. For instance, face-elicited N170 was dramatically reduced if letters were presented under high load conditions. Interestingly, an opposite pattern was reported for object, in that object N170 was increased under high load conditions. Nevertheless, the N170 of body parts (i.e., hands) is insensitive to selective attention.

However, these findings in line with the findings of Holmes, Vuilleumier, and Eimer (2003) and Lueschow et al. (2004), which investigated the effect of selective attention on faces. Findings showed that face sensitive N170 is affected by selective attention. In contrast, Cauquil et al. (2000) claimed that face-sensitive N170 does not influence by selective attention. In particular, in this study attention was manipulated by instructing participants to respond to one specific category (eithers eyes only, or faces with eyes closed).

One possible explanation of the face sensitive N170 reduction under high load, could due to that the task was consumed all of the available capacity in the attentional system. Thus, there is no capacity left to perceive faces in this short time interval (200 ms). So, I assume in this short time, the number of brain's cells activated in the brain will be reduced, causing this effect on face sensitive N170. Evidence for this has come from studies of Perret and Co-workers which showed activation on brain cells when faces were perceived (Perrett, Chitty, Mistlin, & Potter, 1986; Perrett, Hietanen, Oram, & Benson, 1992; Perrett, Oram, Lorincz, Emery, & Baker, 1997).

Another possible explanation of face sensitive N170 reduction could be due to the competition effects between faces and letters. when face and letters strings compete each other, in the absence of available attentional capacity it leads to decrease the activation of cells neurons in face area and increase the activation of cells neurons in letter areas ''Word Areas'' (Puce, Allison, Asgari, Gore, & McCarthy, 1996), causing reduced N170 under high load condition. In contrast, under low load identical letter strings does not consume the whole attentional capacity, given a chance to distractors to be perceived (e.g., faces), and leads to increase N170. In the study of Jacques and Rossion (2004), which reported reduction of face-sensitive N170 when a face

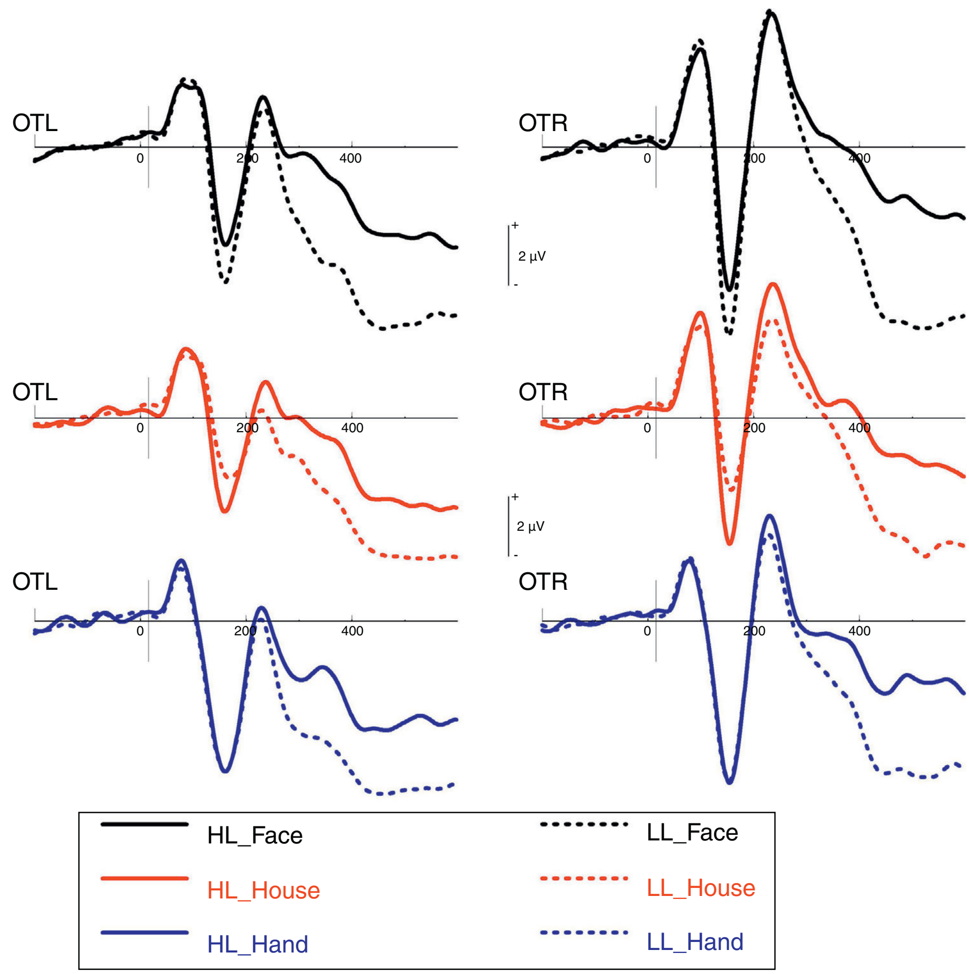

Figure 3 Grand average event-related potentials (ERPs) for sites OTL and OTR in the time range between −100 and 800 ms, for all distracters types. Note that N170 for faces was diminished under high load and an opposite pattern for houses, while no effect of load on hands.

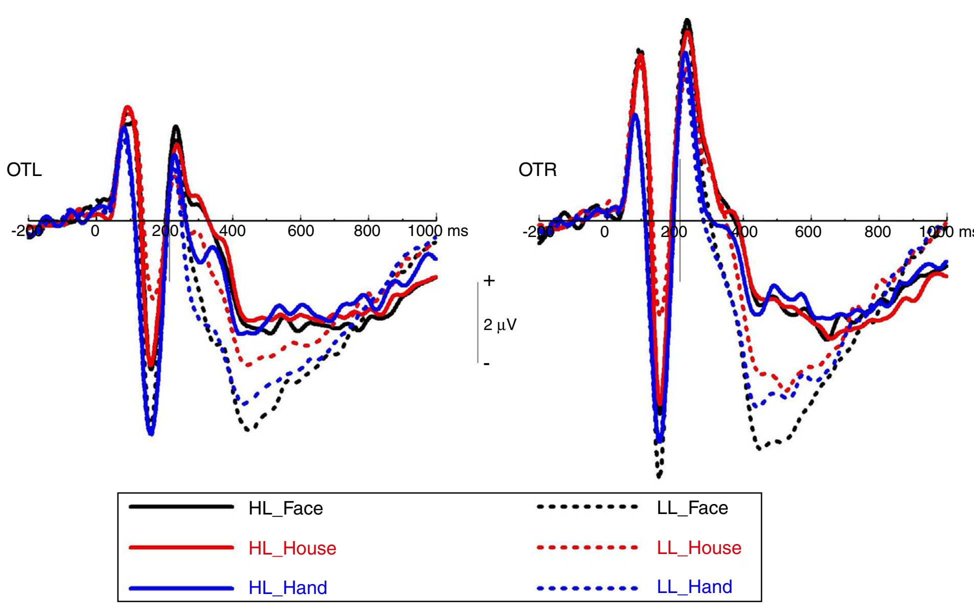

Figure 4 Grand average event-related potentials (ERPs) for sites OTL and OTR in the time range between −100 and 800 ms for all load conditions. Note that N170 for faces was diminished under high load and an opposite pattern for houses, while no effect of load on hands.

compete another face. A similar observation was reported by Gauthier, Skudlarski, Gore, and Anderson (2000), which showed reduced face sensitive N170 when face compete a familiar objects. These findings supported my idea why face sensitive N170 was reduced under high load condition.

Interestingly, object elicited N170 was increased under high-load conditions versus low load conditions. However, these findings in line with the findings of Mohamed et al. (2009), that used a typical load manipulation that I used in the current study. Results showed that house elicited N170 is increased under high load conditions, under low load condition I assume that house has available capacity in the attentional system to be perceived as objects, and no competition might be occurred between houses and letters. Thus, human brain perceives houses clearly under low load conditions, and houses succeeded to activate objects selective areas. Nevertheless, under high load, in this short time (200 ms) there is no available capacity in the attentional system to ignore the competition effects between unfamiliar houses and familiar letters which lead to increase house selective N170. I assume that effect was shown under high load condition is not the effect of houses stimuli, but it could be the effect of letter strings which leads to increase N170. It seems that letters have a superiority effect. I realize that my interpretation is speculative and further experiments should be conducted to support this explanation.

For hands findings, hands selective-N170 does not affected by attentional manipulations. The mean amplitude and latency of the N170 did not differ depending on perceptual load types. It is well noted that all hands have the same features, in contrast to either faces or houses. One can argue that participants succeeded to encode all of them such as one hand, with no significant discrimination about them. Consequently, no attentional effects could be evoked. However, these findings in line with the findings of Mohamed et al. (2011), which showed that there is no effect of load manipulations on either human bodies or headless bodies (*Note that I masked the face part in human bodies stimuli, and the clothes were controlled*). Combined findings showed that bodies and body parts were unaffected by selective attention.

Results of late posterior negativity ''LNC'' is in line with perceptual load theory. In that enhancement of late negativity under low load suggests more extensive processing of all distracters type under low attentional load. However, these findings in line with the findings of Engell and McCarthy (2010), suggesting that there is a link between similar negative slow waves to extended or more efficient processing in short-term memory (Schweinberger, Sommer, & Stiller, 1994).

Conclusion

Using an attentional load manipulation in the context of Lavie Perceptual load theory, the Present study investigated the N170 to task-irrelevant unfamiliar faces, hands, and houses. In low load conditions, I observed strongly face and body selective N170 response. Under high load, the N170 to the same unfamiliar faces was clearly reduced, while no changes were reported for the N170 for hands, and was only marginally larger than the N170 for houses. I conclude that the early stages of unfamiliar face processing, and object processing as indexed by the N170 strongly depend on selective attention, while body sensitive N170 insensitive to selective attention. However, these findings suggested that body structural encoding has different effects compared to faces structural encoding stages. I concluded that the effect of selective attention has a different pattern on faces and human bodies.

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