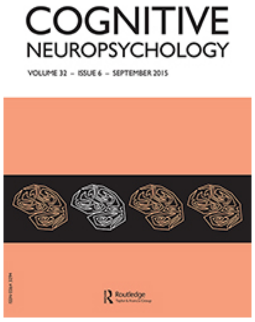

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# Interactions between the perception of age and ethnicity in faces: an event-related potential study

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Face perception models propose that different facial attributes are processed by anatomically distinct neural pathways that partially overlap. Whether these attributes interact functionally is an open question. Our goal was to determine if there are interactions between age and ethnicity processing and, if so, at what temporal epoch these interactions are evident. We monitored event-related potentials on electroencephalography while subjects categorized faces by age or ethnicity in two conditions: a baseline in which the other of these two properties not being categorized was held constant and an interference condition in which it also varied, as modelled after the Garner interference paradigm. We found that, when participants were categorizing faces by age, variations in ethnicity increased the amplitude of the right face-selective N170 component. When subjects were categorizing faces by ethnicity, variations in age did not alter the N170. We concluded that there is an asymmetric pattern of influence between age and ethnicity on early face-specific stages of visual processing, which has parallels with behavioural evidence of asymmetric interactions between identity and expression processing of faces.

**Keywords:** face perception; interference; age; ethnicity; Garner

## Introduction

Besides identity, faces contain a large variety of information, including, for example, emotion state, attractiveness, gender, ethnicity, and age. How these various attributes are processed has been the focus of a number of cognitive and neuro-anatomic models of face perception. In particular, distinctions between identity and expression processing are a feature of some cognitive models (Bruce & Young, 1986; Campanella & Belin, 2007; Young & Bruce, 2011), and this has been followed by proposed anatomic distinctions in identity and expression networks (Haxby, Hoffman, & Gobbini, 2000). Specifically, these propose a distinction between changeable and invariant facial attributes and suggest that after an early face representation is formed, possibly in the inferior occipital cortex, changeable aspects such as expression and direction of gaze are processed by the superior temporal sulcus, while invariant aspects such as identity are processed by the lateral fusiform gyrus (Haxby et al., 2000).

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Although there is considerable support for distinct streams of processing, including neuropsychological reports (Fox, Hanif, Iaria, Duchaine, & Barton, 2011), this does not exclude the possibility of functional interactions between networks involved in processing invariant and changeable facial properties (Young & Bruce, 2011). For example, many neuroimaging studies show that activity in the fusiform face area, a key identity-processing area, is also modulated by facial expression (Fox, Moon, Iaria, & Barton, 2009; Ganel, Valyear, Goshen-Gottstein, & Goodale, 2005; Ishai, Schmidt, & Boesiger, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001), while signals in the posterior superior temporal sulcus, a key region in processing expression, show influences of identity (Fox et al., 2009; Winston, Henson, Fine-Goulden, & Dolan, 2004), However, it has been behavioural studies that have proven to be critical in investigating whether and how different facial dimensions interact.

In particular, the Garner paradigm has achieved prominence for examining interactions between facial dimensions. The original method included three conditions (Garner, 1974, 1976). Subjects are given a discriminative task involving one of the dimensions. In the control condition, only that dimension varies in the trials of the block, while the irrelevant dimension is held constant. In the orthogonal condition, both dimensions vary independently in the stimuli, creating the possibility of interference from the irrelevant dimension. In the correlated condition, the irrelevant dimension co-varies with the relevant one, creating a redundancy that may facilitate responses. Importantly, this method can be done bi-directionally, first with one dimension as the task and the second as the irrelevant one, and then repeated with the role of the dimensions reversed.

The various combinations of results for the correlated and orthogonal conditions initially defined up to six types of dimensional interactions (Garner, 1976; Le Gal & Bruce, 2002). However, the utility of the correlated condition in distinguishing between parallel or shared processing has since been questioned (Kaufmann & Schweinberger, 2005; Le Gal & Bruce, 2002; Schweinberger & Soukup, 1998): hence most studies focus on the orthogonal—also known as the "filtering" (Ganel & Goshen-Gottstein, 2002, 2004; Kimchi, Behrmann, Avidan, & Amishav, 2012)—condition, which has come to be known as Garner-type interference (Pomerantz, 1983). This has three possible outcomes (Garner, 1974). If reaction times are slower in the orthogonal than the control conditions for both tasks, this would be evidence of inability to selectively attend to the relevant dimension alone, indicating that the processes involved are *integral*. Equivalent reaction times for orthogonal and control conditions would suggest that subjects can selectively attend to each dimension, implying that the two are processed by *separable*, independent pathways (Le Gal & Bruce, 2002). The final possibility is equivalent reaction times for one task but slower orthogonal reaction times for the second, termed *asymmetric separable* (or *asymmetric integral*).

The most frequently examined Garner interaction in face studies is the interaction between identity and expression (Table 1). Many studies have found that expression judgments are slowed by irrelevant variations in identity, but identity judgments are not affected by variations in expression, in both adults (Baudouin, Martin, Tiberghien, Verlut, & Franck, 2002; Schweinberger, Burton, & Kelly, 1999; Schweinberger & Soukup, 1998; Stoesz & Jakobson, 2013) and children (Krebs et al., 2011; Spangler, Schwarzer, Korell, & Maier-Karius, 2010). These have been given a neuro-anatomic interpretation, as an asymmetric interaction from a processing stream for invariant facial properties such as identity, to another stream that processes dynamic facial properties such as expression, but not vice versa (Atkinson, Tipples, Burt, & Young, 2005; Schweinberger & Soukup, 1998). Such an explanation may also account for similar asymmetries between identity and facial speech patterns (Kaufmann & Schweinberger, 2005; Schweinberger & Soukup, 1998; Spangler et al., 2010), and between ethnicity and expression (Karnadewi & Lipp, 2011).

While identity, gender, and ethnicity are clearly stable facial dimensions and speech patterns, gaze direction, and expression are changeable dimensions, the status of age is more ambiguous. While facial age lacks the moment-to-moment fluctuations that characterize expression, speech, and gaze, it does possess a long-term dynamic,

Table 1. Summary of the relevant papers for the study.

| Authors/Year | Dimensions tested | Type of paradigm and technique used | Pattern of interference found |
|---|---|---|---|
| Baudouin et al. (2002) | Identity/Expression | Garner | *Asymmetric:* Identity interferes with expression. |
| Schweinberger et al. (1999) | | Garner | *Asymmetric:* Identity interferes with expression. |
| Schweinberger and Soukup (1998) | | Garner | *Asymmetric:* Identity interferes with expression. |
| Stoesz and Jakobson (2013) | | Garner | *Symmetric* |
| Krebs et al. (2011) | | Garner | *Asymmetric:* Identity interferes with expression. |
| Spangler et al. (2010) | | Garner | *Asymmetric:* Identity interferes with expression. |
| Ganel and Goshen-Gottstein (2004) | | Garner | *Symmetric* |
| Fox, Oruç, and Barton (2008) | | Adaptation | *Asymmetric:* Identity interferes with expression |
| Fox et al. (2009) | | Same-Different Task/ fMRI | *Symmetric:* Inter-dependence of identity and expression analysis within the FFA and pSTS. |
| Ganel et al. (2005) | | Garner/fMRI | *Symmetric:* Inter-dependence of identity and expression analysis within the FFA, STS, and amygdala. |
| Ito and Urland (2005) | Ethnicity/Gender | Implicit and Explicit Categorization/ERP | *Asymmetric:* N170 varies with ethnicity but not gender. |
| Kubota and Ito (2007) | Ethnicity/ Expression | Categorization | Independent pattern |
| Wiese, Schweinberger, and Neumann (2008) | Age/Gender | Priming | Age is extracted irrespective of processing demands. Gender categorization may depend on whether subjects have to explicitly categorize gender. |
| Karnadewi and Lipp (2011) | Gender, Ethnicity, Age/Expression | | *Asymmetric:* Gender, ethnicity, and age interfere with expression. |
| Bestelmeyer et al. (2008) | Gender, Ethnicity/ Expression | Adaptation | Interdependent relation between expression and sex or race. |

with slowly evolving changes, such as loss of facial fullness, decreased tissue elasticity, deep wrinkling, and progressive bone resorption (Fedok, 1996), which human observers can use accurately to estimate age (Burt & Perrett, 1995; George & Hole, 1995) and can discount successfully when processing identity (Bahrick, Bahrick, & Wittlinger, 1975; Sergent & Poncet, 1990). Thus it is not settled whether facial age should be considered invariant or changeable. While one study of Garner interference considered age an invariant dimension and found that, like identity, it had an asymmetric interaction with expression (Karnadewi & Lipp, 2011), a study using the different approach of face adaptation found that age aftereffects resembled expression aftereffects, in that they were modulated by identity (Lai, Oruc, & Barton, 2010).

The first goal of this study was to explore the ambiguous status of facial age and its relation with other face-relevant processes by extending observations of Garner interference to the interaction between facial age and ethnicity, an invariant facial dimension. If age perception shows an asymmetric interaction with ethnicity, this would suggest a parallel between age and expression processing, as suggested by the study of face adaptation (Lai et al., 2010). If age and ethnicity show an integral pattern of interaction, in which Garner interference is found in both directions, as has been found for gender and identity (Ganel & Goshen-Gottstein, 2002), then age may behave as a stable dimension that shares processing resources with other invariant dimensions. If no interference is found in any direction, this would suggest that age and ethnicity are supported by strictly parallel mechanisms.

The neurophysiologic basis of Garner interference has rarely been investigated. The few reports that examined evoked potentials studied interactions in auditory processing (Caclin, McAdams, Smith, & Giard, 2008) or linguistic processing of auditory or visual stimuli (Boenke, Ohl, Nikolaev, Lachmann, & Leeuwen, 2009; Kaganovich, Francis, & Melara, 2006; Lew, Chmiel, Jerger, Pomerantz, & Jerger, 1997), with variable results, and there are no such studies for face perception. In the previous behavioural studies that used face stimuli, it has been asserted that Garner interference arises in interactions between perceptual processes (Atkinson et al., 2005; Le Gal & Bruce, 2002; Schweinberger et al., 1999; Schweinberger & Soukup, 1998). One key neurophysiologic marker of perceptual processing for faces is the N170 potential, which shows face-specific effects in occipitotemporal electrodes of the right hemisphere (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Botzel, Schulze, & Stodieck, 1995; Jeffreys, 1989), consistent with the known hemispheric asymmetry and location of regions of the face-processing network (Haxby et al., 2000). The second goal of this study was to implement the Garner interference paradigm in an electrophysiologic study. If interference between facial age and ethnicity arises in perceptual processes, we hypothesized that this should be evident in the N170 potential.

## Experimental procedure

### *Subjects*

A cohort of 15 subjects (7 males, mean age 30.6 ± 6.58 years) participated in the behavioural and EEG experiment, with normal or corrected-to-normal vision and without any neurological disorder. A second cohort of 15 subjects (8 males) was recruited to perform the behavioural study alone, to increase the sample size for these observations. For the total group of 30 subjects (mean age 27.6 ± 3.6 years, 16 males), fourteen subjects identified themselves as Caucasians, fourteen as south-Asian Indians and two as Latinos. All had more than four years of experience with both Caucasian and Asian faces, and all had lived for more than two years in Vancouver, where 43% of residents in the metropolitan area have Asian heritage.

The institutional review boards of Vancouver General Hospital and the University of British Columbia approved the protocol. All subjects were informed of the noninvasive recording technique and gave informed consent in accordance with the declaration of Helsinki.

### *Stimuli and procedure*

The stimulus set consisted of 40 non-famous faces with neutral expression, without facial hair, glasses or make up, selected from the Productive Aging Laboratory (PAL) Face Database (Minear & Park, 2004) and from the University of Utrecht (ECVP) Database (http://pics.psych.stir.ac.uk). These 40 faces were classified in binary fashion according to age (young being 20 to 35 years old and old being more than 60 years old), ethnicity (Asian and Caucasian), and gender (female and male) (Figure 1). All faces were converted to greyscale, resized to 476 pixels in width and 576 pixels in height with a resolution of 72 pixels per inch, and approximately equated for luminance and contrast using the SHINE toolbox (Willenbockel et al., 2010).

The experiment was programmed and carried out using MATLAB (Mathworks) and PsychToolbox (Brainard, 1997). A trial started with a fixation cross for 1.5 sec, which was replaced by a face that remained on the screen until the subject made a

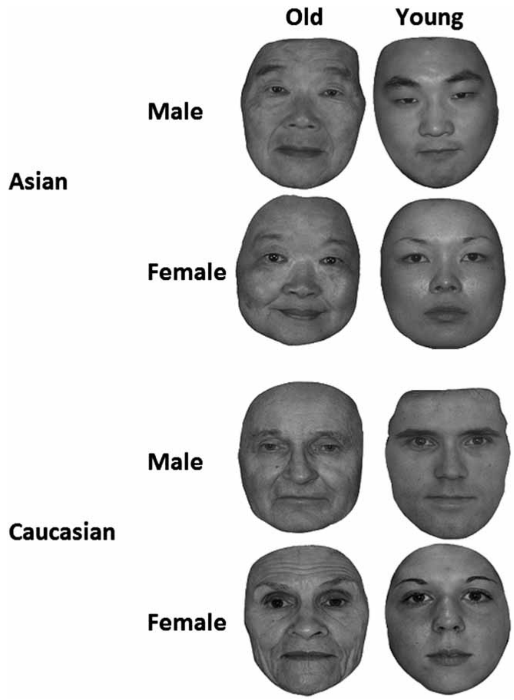


Figure 1. Example of the stimuli used.



response, after which the next trial began with the re-appearance of the fixation cross. There were two experimental sections: in the Age section, subjects classified faces as young or old by pressing a key, while in the Ethnicity section subjects classified faces as Asian or Caucasian. The response keys as well as the order of these sections were counterbalanced across subjects.

Each section included a baseline and an interference condition, administered in separate blocks that were applied in a counterbalanced order across subjects. Each block/condition had 460 trials. In the baseline condition, faces varied only in the dimension used for discrimination, while in the interference condition faces also varied in the irrelevant dimension. Thus, both conditions in the Age section depicted 5 old and 5 young faces. In the Age-baseline condition, half of the subjects saw only Caucasian faces, and the other half saw only Asian faces; while in the Age/ethnicity-interference condition for all subjects, 5 of the 10 faces were Asian, and the other 5 were Caucasian. To balance for any possible relation between the ethnicity of the face stimuli and that of the participant, which could have influenced the results in the Age-baseline condition, we matched the participants who saw Asian and Caucasian faces in terms of their ethnicity and gender. Thus in the behavioural experiment, 15 participants (3 female Caucasians, 3 female Asians, 4 male Caucasians, 4 male Asians, and 1 male Latino) saw all Asian faces. The remaining 15 participants (also 3 female Caucasians, 3 female Asians, 4 male Caucasians, 4 male Asians, and 1 male Latino) saw all Caucasian faces. In the EEG experiment 7 participants (2 male Caucasians, 3 female Caucasians, 1 female Asian, and 1 male Latino) saw only Asian faces, and 8 participants (3 male Caucasians, 3 female Caucasians, 1 female Asian, and 1 male Latino) saw only Caucasian faces in the Age-baseline condition.

The Ethnicity section showed 5 Asian and 5 Caucasian faces. The Ethnicity/baseline condition showed faces that corresponded to the participant's age, while in the Ethnicity/age-interference condition all subjects saw old and young faces. In all conditions, gender of the faces was kept uniform and corresponded to that of the participant.

This design resulted in the use of 10 different sets of pictures. To verify that our imaging processing had equated the 10 sets for low-level visual properties, we used ANOVA with factor of picture set (10 levels). There were no significant differences in mean luminance, $F(9) = 0.45$, $p = .66$, or contrast, $F(9) = 0.58$, $p = .81$, between the 10 sets.

### Electrophysiological recording

Subjects were seated in a sound-attenuated room, 100 cm from a 17″ computer monitor. Brain electrical activity was recorded using a standard 10/20 64-electrode cap (Biosemi ActiveTwo system) and 5 additional EXG electrodes (three eye movement channels plus the two mastoids: EX1 and EX2). All recordings were performed relative to two scalp electrodes located over medial parietal cortex (CMS/DRL), amplified with a gain of 0.5 and digitized on-line at a sampling rate of 256 samples per second. All electrode impedances were kept below 5 kΩ. Vertical eye movements were recorded using an electrode inferior to the right eye, while horizontal eye movements were recorded using electrodes on the right and left outer canthi.

Eye and movement artifact were removed from raw data manually by rejecting trials in which EEG or EOG exceeded ± 75 µV. Channels during which muscle potentials or amplifier blocking occurred during the entire experiment were interpolated using EEGLAB (Delorme & Makeig, 2004). No more than 10% of trials were rejected from each condition. Each subject's signal was then algebraically transformed to average reference and low pass filtered with a Butterworth filter (25.6-Hz half amplitude cut off) to eliminate high-frequency artifacts in the waveforms. Averages were computed from 100 ms before to 400 ms after stimulus onset for each condition separately.

### Data analysis

Participant's behavioural responses (accuracy and reaction time) were examined using repeated-measures analysis of variance (ANOVA) with two factors: section (Age versus Ethnicity categorization) and condition (Baseline, Interference), at an $\alpha$ level of .05.

ERPs waveforms were compared at all 64 electrodes using a repeated-measures t-test. This analysis was conducted at all time points between 80 and 27 ms (49 total time points) to include the P1, N170, and P2 components. To correct for multiple comparisons, we used the Bonferroni correction adjusted for inter-item correlations (Sankoh, Huque, & Dubey, 1997). This procedure adjusts the alpha level for significance by taking into account both the number of comparisons to be made (64 electrodes × 49 time points = 3136 comparisons) and the average correlation between both conditions, baseline and interference (Sankoh et al., 1997). With this procedure the alpha level for the Age task was .006 (inter-item correlation between Age/baseline and Age/ethnicity-interference conditions = .74) and for the Ethnicity task was .02 (inter-item correlation between Ethnicity/baseline and Ethnicity/Age-interference conditions = .88).

## Results

### Behaviour

Reaction times showed a main effect of section, $F(1, 29) = 5.44$, $p = .03$, with age judgments faster than ethnicity judgments. There were no effects of condition, $F(1, 29) = 0.23$, $p = .64$, or interaction between these factors, $F(1, 29) = 0.19$, $p = .66$ (Table 2). A post hoc analysis of effect size showed that the main effect of section, although significant, is minimal (Cohen's $d = 0.34$).

Regarding accuracy, there were no main effects of section, $F(1, 29) = 1.55$, $p = .22$, condition, $F(1, 29) = .64$, $p = .43$, or interaction between the two factors, $F(1, 29) = 0.23$, $p = .63$ (Table 2).[1]

### Event-related potentials

Based on visual inspection, three main components were detected in the waveforms of all participants. The first electrophysiological event was a prominent P1 component, which reached its peak at occipital electrodes between 80 and 120 ms (Figure 2). This was followed by the N170, which reached its

Table 2. Behavioural results.

| Conditions | Reaction Time (ms, Mean ± SD) | Accuracy (% correct responses, Mean ± SD) |
|---|---|---|
| Age/baseline | 536.00 ± 211.00 | 98.63 ± 1.47 |
| Age/ethnicity interference | 533.70 ± 226.90 | 98.00 ± 3.69 |
| Ethnicity/baseline | 623.00 ± 339.96 | 97.67 ± 3.36 |
| Ethnicity/age interference | 644.70 ± 262.36 | 97.47 ± 3.14 |

Note: In the Baseline conditions only the relevant dimension, age or ethnicity, respectively, varied. In the Interference conditions both the relevant and the irrelevant dimensions varied.



peak between 140 and 200 ms at occipito-temporal electrodes, in agreement with previous face perception studies (Bentin et al., 1996; Bentin & Deouell, 2000; Joyce & Rossion, 2005) (Figure 2). The P2 component followed the N170, reaching its peak between 200 and 270 ms at occipito-temporal and occipital electrodes (Figure 2). Our time-point-by-time-point amplitude analysis covered all three components by using a temporal window from 80 to 270 ms.

Compared to the Age/baseline waveform, the amplitude of the Age/ethnicity-interference waveform was significantly higher at right occipito-temporal electrodes PO8 (168–252 ms); P6 (176–192 ms) and PO4 (180–192 ms) as well as at occipital electrode O2 (180–208 ms) (Figure 3). Of note, there were no differences at earlier epochs corresponding to the P1 component. To determine the effect size of these results, we averaged the amplitude values over the significantly different time intervals for each electrode separately. Obtained means and standard deviations were used to calculate Cohen's *d*. The effect size (Cohen's *d*) of these results was 0.64 at P08, $d = 0.33$ at P6, and 0.79 at O2, which are within the zone of intermediate effects according to Cohen (1988) and the zone of desired effects according to Hattie (2009).

To determine whether the modulations in the N170 component (i.e. between 160 and 200 ms) in electrodes O2 and PO8 were responsible for later differences seen in the P2 component in those same electrodes (i.e. between 200 and 260 ms), we performed a peak-to-peak analysis. The N170 peak amplitude was subtracted from the P2 peak amplitude for each electrode separately and submitted to repeated-measures ANOVA with factors of electrode (PO8 and O2) and condition (Age/baseline and Age/ethnicity-interference). This showed an effect of electrode, $F(1, 14) = 13.29$, $p = .003$, due to higher peak-to-peak amplitude difference in electrode PO8 ($M = 10.9$, $SD = 26.97$ μV) than in electrode O2 ($M = 7.46$, $SD = 10.78$ μV), $t(14) = 2.14$, $p = .003$, but no main effect of condition, $F(1, 14) = 0.87$, $p = .37$, or interaction between condition and electrode, $F(1, 14) = 0.31$, $p = .59$. This result suggests that the later P2 differences merely reflected the changes generated in the earlier N170 component.

Our analysis did not show any differences between the Ethnicity/baseline and Ethnicity/age-interference conditions at any time point in any electrode (Figure 3).

## Discussion

Our study showed that variations in facial ethnicity when participants were categorizing faces by age were associated with increased amplitude of the N170 component in right occipito-temporal electrodes; however, no such differences were found when age varied during the categorization of faces by ethnicity. This would be classified as an asymmetric integral/separable type of interaction (Garner, 1974). The fact that Garner interference was evident in the epoch of the N170 potential over right occipitotemporal electrodes is consistent with the hypothesis that such interference arises in perceptual stages of face processing.

Before discussing the implications of our results, one technical issue deserves mention. It should be considered whether any amplitude modulations of the N170, such as we observed during age

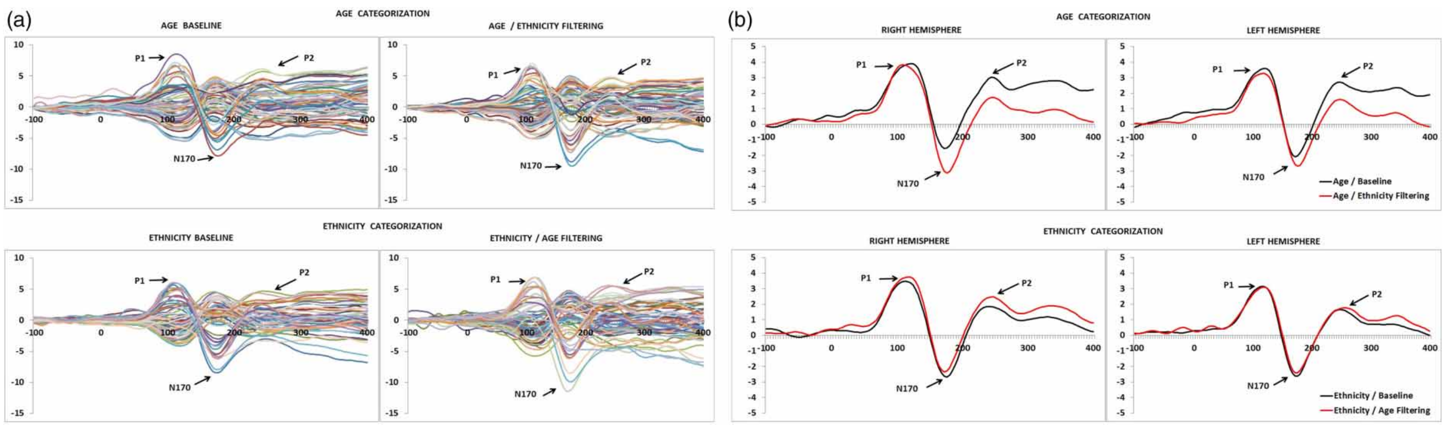


Figure 2. A) Overlaying waveforms of all electrodes for all four conditions B) Waveforms averaged over occipito-temporal electrodes of the right and left hemispheres (P1/2, P3/4, P5/6, P7/P8, P9/P10, PO3/PO4, PO7/PO8). The relevant components have been indicated. Note the amplitude difference between the Age/Baseline and Age/Interference conditions especially in the right hemisphere. [To view this figure in colour, please see the online version of this Journal.]

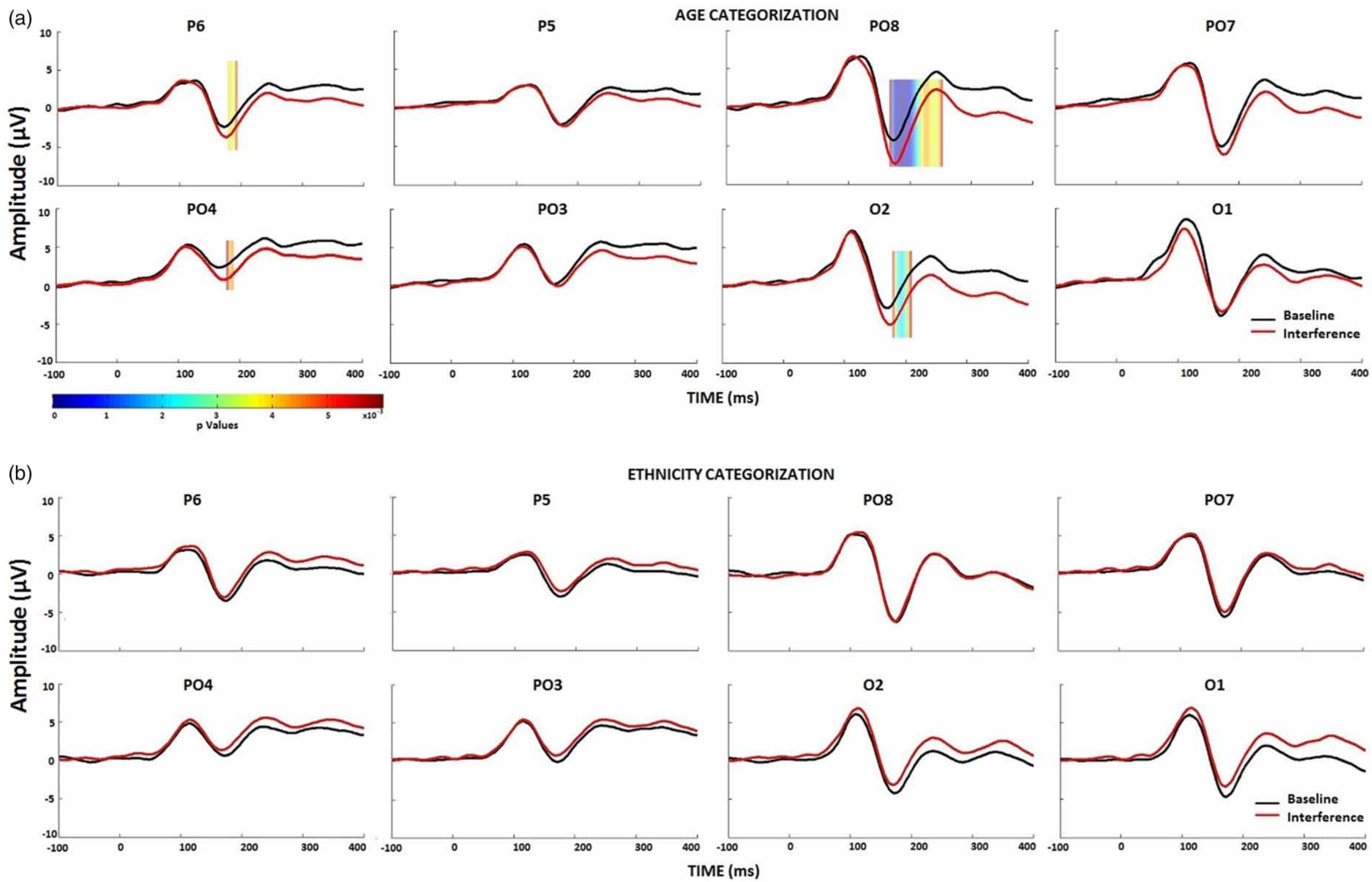


Figure 3. A) Grand-averaged ERPs obtained for the Age Block at the electrodes that exhibited significant differences between baseline and interference conditions (PO8, PO4, P6, O2) as well as for their left hemisphere counterparts (PO7, PO3, P5, O1). Periods during which statistically significant differences were obtained are indicated with a color coded bar. The color coding for p-values associated to significant differences is also shown ($p < .006$ corrected for multiple comparisons; see Data Analysis section for further details). B) The same electrodes are shown for the Ethnicity block. Note how there were no statistically significant differences between both experimental conditions. Positive amplitude values are plotted upward. [To view this figure in colour, please see the online version of this Journal.]

categorization, are inadvertently due to differences in low-level image properties of the stimuli. We believe this is not the case, for the following reasons. First, we equated all stimuli for luminance and contrast and statistically verified that stimulus sets did not differ in these two variables. Second, we did not observe differences between conditions during the P1 component, which is highly sensitive to changes in low level visual factors (Anllo-Vento & Hillyard, 1996; MacKay & Jeffreys, 1973; Shaw & Cant, 1980; Yiannikas & Walsh, 1983). Third, the fact that we found these differences in the N170 component on the right is consistent with the emergence of these effects during face-specific processing, given that face-object differences in event-related potentials have a right-hemispheric predominance and are most clearly seen in the N170 epoch (Bentin et al., 1996; Botzel et al., 1995; Jeffreys, 1989). Fourth, occurrence of such modulation at this epoch is also consistent with ERP studies reporting that both age and ethnicity information are available to the face perception system as early as 160 ms after stimulus onset (Ebner, He, Fichtenholtz, McCarthy, & Johnson, 2011; Ito & Urland, 2005; Mouchetant-Rostaing & Giard, 2003; Wiese, Schweinberger, & Neumann, 2008).

Our electrophysiological measures showed interference effects from Ethnicity to Age, while the behavioural measures did not. This suggests that the electrophysiologic signal may be even more sensitive to such interactions than behavioural methods. This is not necessarily surprising. It is widely accepted that behavioural measures may not be as sensitive as neurophysiologic measures to the timing and organization of cognitive processing, especially for complex tasks such as categorizing faces' age or ethnicity that probably entail several processing stages. In fact, ERPs have been used to assess the status of cognitive functions in healthy and abnormal populations in the absence of behavioural changes (Ciecko-Michalska et al., 2006; Key et al., 2014; Kotterba et al., 1998; Liu, Liu, He, & Zhou, 2007). A discrepancy between behavioural and electrophysiological measures may have been enhanced by our experimental design, in which facial age and ethnic differences were easy to discriminate (Figure 1). While large differences between stimuli in the interfering dimension were chosen to amplify interference effects in the electrophysiological signal, the same large differences when the dimension became the relevant one in the second task meant that behavioural performance was easy and near ceiling, making it difficult to discern interference effects behaviourally (Ganel & Goshen-Gottstein, 2004).

Our electrophysiologic results show an asymmetric integral/separable pattern of interaction, with ethnicity influencing age processing but not vice versa. Implications of such a pattern have been considered. It was initially proposed that this could stem from differences in the level of processing for the two dimensions (Garner, 1976). That is, effects arising at an earlier stage could interfere with later stages, but not vice versa.[2] In a related fashion, others have considered the possibility that asymmetries in task difficulty may lead to one being faster to complete, with the result that the output of the faster task would be available to influence processing of the second task, but the output of the slower task would not be ready in time in influence the first (Melara & Mounts, 1993). Thus an integral process would have the false appearance of asymmetric separability. For face perception studies, some have performed control studies using morphed stimuli to equate discriminability and reaction times for the two dimensions, and still found asymmetric interference between the two (Atkinson et al., 2005; Schweinberger et al., 1999). However, one study increased the difficulty of identity tasks by using images of brothers and found bi-directional interference supportive of integral processing and functional interdependence of expression and identity (Ganel & Goshen-Gottstein, 2004). Of note, in our study age judgments were faster than ethnicity judgments: if differences in the level of processing of age and ethnicity were responsible for our results, we should have observed interference from age to ethnicity but not vice versa, whereas we found the reverse.

A second interpretation of asymmetric separability is that this reflects "inherent logical relations between the two physical dimensions" (Garner, 1976). For example, some have argued that, while the invariant facial properties related to identity provide a useful reference for more precise extraction of speech and emotion from the face of a given individual, the changeable properties of the latter do not provide a stable basis for further computations about identity or gender (Atkinson et al., 2005). Following this reasoning, one might surmise from the asymmetric interaction we found that the ethnicity of a face may constrain the types of changes that reflect age, while age-related changes do not assist the identification of ethnicity. That is, features such as wrinkles and skin texture that convey the bulk of facial aging (Lai, Oruc, & Barton, 2013; Quinn & Macrae, 2005) may not convey much information about ethnicity and can be ignored during the ethnicity categorization task. In contrast, facial ethnicity may be derived from both featural and configural information (Harel & Bentin, 2009; Zhao & Bentin, 2011), especially when skin colour is not diagnostic, as in our task. Thus, extracting automatically those ethnic features could interfere with age categorization.

A third suggestion is that asymmetric interactions derive from dominance effects. If one type of information dominates processing, the stronger process will interfere with the weaker but not vice versa (Amishav & Kimchi, 2010). Thus in inverted faces, feature processing dominates and interferes with a configural discrimination task, while the feature discrimination task is unaffected by configural information (Amishav & Kimchi, 2010). Although there is a lack of data on the relative balance between age and ethnicity, it has been proposed that in children at least, age is less salient than ethnicity and gender (McGraw, Durm, & Durnam, 1989). Additionally, it has been shown that categorizing age creates fewer demands on the limited attentional capacity of the face perception system (Wiese, Kloth, Gullmar, Reichenbach, & Schweinberger, 2012; Wiese, Schweinberger, & Hansen, 2008), and it is performed with high accuracy over a wide age range (i.e. 20- to 60-year-old faces) (Burt & Perrett, 1995).

Finally, in addition to the perceptual and functional explanations above, a fourth, neuro-anatomic explanation offered by others is that asymmetric interactions reflect influences between processing streams for invariant and changeable facial properties (Atkinson et al., 2005). Thus, even though these may constitute parallel streams, the processing of changeable properties may be contingent upon information from the invariant stream, but not vice versa. This would be consistent with evidence from adaptation studies that the neural representations of identity are expression-invariant (but see Ganel & Goshen-Gottstein, 2004), while those of expression are partially dependent on identity (Fox & Barton, 2007; Fox et al., 2008; Mian & Mondloch, 2012; Vida & Mondloch, 2009). Similarly, age-invariance of identity and ethnic representations but partial dependence of age representations on identity and ethnicity could explain the current results and those of a recent study of the modulation of age aftereffects by identity (Lai et al., 2010). This could be consistent with age being processed as a changeable dimension. However, as we point out in the introduction, at least one study has found asymmetric interference between age and a changeable dimension, namely expression (Karnadewi & Lipp, 2011). This may imply that age retains a certain flexibility, sometimes behaving as a dynamic facial property, and sometimes as an invariant one. On the other hand, this might indicate that asymmetric interactions are not necessarily a signature of influences between the processing streams for invariant and changeable facial properties. Indeed, asymmetric patterns of interference may also be observed between two changeable dimensions (Graham & LaBar, 2007). Thus the behavioural patterns and inferences derived from them may not be reducible to such a simple neuro-anatomic dichotomy.

Nevertheless, the latency of the interference effects found, within the time window of the N170 component, may hint to its potential anatomic origin. Source localization studies point to right lateral inferior occipital cortex and/or the fusiform gyrus as the origin of the face-selective N170 (Botzel et al., 1995; Deffke et al., 2007; Rossion, Joyce, Cottrell, & Tarr, 2003). Simultaneous recordings show that the amplitude of the face-selective N170 is correlated with MRI signal in the fusiform face area and superior temporal sulcus (Sadeh, Podlipsky, Zhdanov, & Yovel, 2010). In prosopagnosic patients, damage to both the occipital face and fusiform face areas is associated with loss of face-selectivity in the N170 (Dalrymple et al., 2011), while loss of the occipital face area alone is not (Prieto, Caharel, Henson, & Rossion, 2011). Furthermore, there is complementary evidence that neural activity in these regions is modulated by age and ethnicity. Studies of task-related activation in fMRI show that age and gender categorization increase signal in the fusiform and inferior occipital gyri bilaterally (Wiese et al., 2012), while the fusiform gyri show changes in fMRI activity when faces share the ethnicity of the observer (Feng et al., 2011; Golby, Gabrieli, Chiao, & Eberhardt, 2001). Hence it is plausible that the age and ethnicity interactions we show occur in core components of the face-processing network, whose activity is reflected in the N170 potential.

In summary, we find that the facial dimensions of age and ethnicity, which are known to influence the face-selective N170 potential (Ebner et al., 2011; Ito & Urland, 2005; Mouchetant-Rostaing & Giard, 2003; Wiese, Schweinberger, & Neumann, 2008), show an asymmetric interaction in their electrophysiologic response in a Garner-interference paradigm. This is consistent with an effect arising in face-specific perceptual processes within the core components of the face-processing network. The interaction suggests that although age and ethnicity have distinct representations, which may be supported by different processing streams; these routes are interconnected with at least one direction of crosstalk (from ethnicity to age).

## Disclosure statement

No potential conflict of interest was reported by the authors.

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## Notes

1. To make sure that statistical effects were similar in both groups of 15 subjects (subjects in Group 1 participated in both the EEG and the behavioural experiments while subjects in Group 2 only participated in the behavioural experiment), the ANOVA analysis was also performed in each group separately. For reaction time, Group 1, showed no effect of section, $F(1, 14) = 2.24$, $p = .16$, condition, $F(1, 14) = 1.22$, $p = .29$, or interaction between the two, $F(1, 14) = .003$, $p = 0.96$. Likewise Group 2 showed no effect of section, $F(1, 14) = 3.06$, $p = .1$, condition, $F(1, 14) = 0.009$, $p = .93$, or interaction between the two, $F(1, 14) = 0.27$, $p = .61$. For accuracy, Group 1 showed no effect of section, $F(1, 14) = 0.77$, $p = .39$, condition, $F(1, 14) = 0.04$, $p = .85$, or interaction between the two, $F(1, 14) = 2.5$, $p = .14$, and Group 2 also showed no effect of section, $F(1, 14) = 1$, $p = .33$, condition, $F(1, 14) = 2.69$, $p = .12$, or interaction between the two, ($F(1, 14) = 1.89$, $p = .19$.
2. This would imply a simple feed-forward stage model, and may not be true of interactive models that incorporate feedback.

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