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Cultural differences in the visual processing of meaning: Detecting incongruities between background and foreground objects using the N400

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East Asians have been found to allocate relatively greater attention to background objects, whereas European Americans have been found to allocate relatively greater attention to foreground objects. This is well documented across a variety of cognitive measures. We used a modification of the Ganis and Kutas (2003) N400 event-related potential design to measure the degree to which Asian Americans and European Americans responded to semantic incongruity between target objects and background scenes. As predicted, Asian Americans showed a greater negativity to incongruent trials than to congruent trials. In contrast, European Americans showed no difference in amplitude across the two conditions. Furthermore, smaller magnitude N400 incongruity effects were associated with higher independent self-construal scores. These data suggest that Asian Americans are processing the relationship between foreground and background objects to a greater degree than European Americans, which is consistent with hypothesized greater holistic processing among East Asians. Implications for using neural measures, the role of semantic processing to understand cultural differences in cognition, and the relationship between self construal and neural measures of cognition are discussed.

Keywords: context; culture; event-related potential; N400; self-construal; visual semantic processing

Individuals are either oriented more toward independent or interdependent self-construal based on cultural experiences (Kitayama *et al.*, 2007; Markus and Kitayama, 1991). For example, with respect to differences in behavior or 'style of action', research suggests that East Asian behaviors, when compared to Western behaviors, are more sensitive to knowledge held by others (Haberstroh *et al.*, 2002) and to ingroup/outgroup status of the other (Leung and Bond, 1984). East Asians tend to have interdependent self-construals, and thus emphasize sociability and in-group harmony, and see their behavior in relation to others' thoughts, attitudes, feelings and actions. In contrast, individuals with an independent self-construal emphasize self-reliance, competition, and uniqueness, and see their behavior as resulting from their own internal thoughts, attitudes, and feelings rather than stemming from relations to others. In fact, the self has been conceptualized as a modus operandi through which behaviors are oriented (Kitayama *et al.*, 2007).

A range of cognitive tasks has demonstrated the comparative bias or emphasis that East Asians *vs* North Americans place on stimuli when evaluating their environment. For example, Ishii *et al.* (2003) found that Japanese showed greater difficulty ignoring vocal tone, whereas North Americans showed greater difficulty ignoring verbal content on a verbal content-tone Stroop-type task. On a spatial reasoning task, Kim (2002) found that East Asian American performance deteriorated when asked to 'talk aloud' compared to European Americans. This interference suggests more integrated processing of information for East Asian Americans, at least with respect to certain cognitive domains.

Much of the recent literature on cultural differences in cognition has focused on differences in attention to foreground objects *vs* the background field. In one of the first of these studies, Masuda and Nisbett (2001) found that Japanese made more statements about background contextual features, and that their recall was more influenced by the background context when viewing complex scenes compared to Americans. The general finding that East Asians attend to the background context more than Westerners, who attend to the foreground and focal objects, has been replicated across several paradigms such as change blindness (Masuda and Nisbett, 2006), visual change detection (Boduroglu *et al.*, 2009), eye movement patterns (Chua *et al.*, 2005), the Framed Line Test (Kitayama *et al.*, 2003), and the Rod and Frame Test (Ji *et al.*, 2000). Masuda and Nisbett (2006) have argued that cultural differences in

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attention may be sufficient to explain cultural differences in other aspects of cognition (Choi and Nisbett, 1998; Masuda and Kitayama, 2004; Miyamoto and Kitayama, 2002; Morris and Peng, 1994).

Attempting to summarize the differences in cognition between East Asians and North Americans, Nisbett and colleagues characterized East Asian cognitive styles as more holistic and North American cognitive styles as more analytic (Nisbett *et al.*, 2001). Thus, East Asian cognitions are thought to orient more towards the context, and attend to the relationship between the foreground and the background. Other holistic tendencies include placing a greater emphasis on change, finding the 'middle way', and multiple perspectives taking (Norenzayan *et al.*, 2007). North American cognitive styles are considered analytic with more focus on the foreground, detachment of the object from context, and stronger reliance on rules and categories. These differences are thought to emerge due to differences in social systems (Kuhnen *et al.*, 2001; Nisbett *et al.*, 2001), differences in voluntary immigration (Kitayama *et al.*, 2006) and perhaps differences in environmental landscapes (Miyamoto *et al.*, 2006). Indeed, if particular cognitive styles are associated with self-construal, then analytic styles would be more strongly associated with independent self-construal and holistic styles would be more strongly associated with interdependent self-construal.

Recently, neuroscientific methods have been used to further investigate cultural differences in cognition, and particularly visual perception of focal objects. For example, European Americans have been shown to have increased hemodynamic activity in object processing regions of the occipital lobe when viewing objects (Goh *et al.*, 2007; Gutchess *et al.*, 2006). Using Kitayama's Framed Line Test, Hedden *et al.*, (2008) found that North Americans displayed increased activation of frontal and parietal attentional areas when performing relative (i.e. context dependent) judgments of line length compared to absolute (i.e. context independent) judgments. In contrast, East Asians showed the opposite pattern. Hedden *et al.* (2008) interpreted their findings as reflecting greater activation of attentional areas for culturally non-preferred tasks. Furthermore, activation of these attentional areas decreased when making absolute (context independent) judgments as a function of independent self-construal for North Americans, and decreased for East Asians residing in the US as a function of their level of acculturation. In other words, the ability to ignore the contextual frame when making absolute judgments about line length was associated with utilization of fewer attentional resources as a function of increased independent self-construal and acculturation to the US.

Using the novelty P3 event-related potential paradigm, Lewis *et al.* (2008) found electrophysiological evidence consistent with increased context sensitivity in Asian Americans compared to European Americans. These data suggested that Asian Americans might be allocating greater anterior executive attention processing of contextually novel events compared to European Americans. In contrast, European Americans tended to allocate relatively more attention to classifying target stimuli, associated with posterior areas involved in memory and categorization. Furthermore, self-construal mediated the relationship between ethnicity of the subject and the magnitude of the novelty P3 ERP.

The use of neuroscience methods has yielded data that are consistent with the analytic and holistic characterization of the 'culture and cognition' literature. Across these studies evidence is accumulating that European Americans show greater neural activity, or more efficient neural processing, of focal and target objects. In contrast, there is evidence that East Asians show greater neural activity, or more efficient processing, associated with analysis of contextual information. Furthermore, in a couple of studies neural processing has been associated with self-construal, suggesting that this aspect of culture, in particular, may be associated with culture-specific neural processing of the environment.

Since the existence of cultural differences in attention to foreground *vs* background objects has been established, we begin to explore the process or mechanisms behind the cultural differences. Heine and Norenzayan (2006) argue that whereas stage 1 cultural psychological research establishes cultural difference, stage 2 research is invaluable in discovering mechanisms underlying these differences. For example, how do East Asians utilize the information accumulated from greater attention to background scenes? It seems unlikely that East Asians are merely looking for additional information to process, as this would be cognitively costly. Rather, East Asians are likely selecting for information that is useful to them. Indeed, if East Asians are engaged in greater holistic processing of information, then presumably background and foreground information are integrated in some manner. Understanding the neural mechanisms involved in synthesizing foreground and background information should provide us with a better understanding of cultural differences in cognition. To this end, we investigated the role of semantic processing between the foreground and background.

One neural measure that may be particularly well suited to studying the processing of information between foreground and background objects is the N400. The N400 is an event-related potential that has been shown to be sensitive to processing semantic relationships (Kutas and Hillyard, 1980). The magnitude of the N400 is inversely related to semantic relatedness (Holcomb and Neville, 1991) and cloze probability (Kutas and Hillyard, 1984), and may therefore serve as an index of semantic expectancy. The increased magnitude of the N400 associated with unexpected semantic events may reflect increased cognitive processing necessary to integrate anomalous semantic information (e.g. Holcomb, 1993). In addition to the extensive research on the N400 and linguistic processing, the N400 has also been used effectively in studies of semantic processing of visually presented complex scenes (West and Holcomb, 2002). For example, Ganis and Kutas (2003) presented participants with a background scene such as a soccer game. Then, they 'popped' a central object onto the background image. On half of the trials, the object was congruent with the background (e.g. a soccer ball), and on half of the trials the object was incongruent (e.g. a roll of toilet paper). They found that the magnitude of the N400 was greater when an incongruent object was superimposed upon the background image, than when the object was congruent.

We propose to use a modification of the Ganis and Kutas (2003) design to measure the degree to which participants process the semantic relationship between focal objects and background scenes. If, as hypothesized by Nisbett *et al.* (2001), East Asians disperse their attention across the field and process relationships among events in their environment to a greater degree than do European Americans, then they would display greater N400s than European Americans when processing semantically incongruent objects and backgrounds. In addition, we investigated the relationship between the N400 and self-construal, hypothesizing that greater independence and lower interdependence would be associated with greater N400s.

METHODS

Participants

Participants were 58 undergraduate students, aged 18–21 years, from the Claremont Colleges, a consortium of West Coast liberal arts colleges. All participants were right-handed, monoracial and had normal or corrected to normal vision. Four Asian Americans and six European Americans were eliminated due to excessive ocular and muscle artifacts during the event-related potential session (see below). Remaining in the study were 24 Asian Americans and 24 European Americans. Half of the participants were self-identified European American (10 women and 14 men) and half were self-identified East Asian American (18 women and 6 men). European American students were born and raised in USA. We required all East Asian American students to be 1.5 generation or greater (1.5 generation was defined as immigrating to USA before the age of 8). Eligibility and group categorization were determined using a preliminary online survey that included questions about ethnicity and handedness, as well as two distractor questions. Participants were also asked to fill out a demographics survey at the end of the experiment. The data from this survey was used to further characterize our subject pool. Participants were recruited from introductory psychology courses, Asian American psychology courses, and advertisements. They were compensated $15 or given subject pool credit for the session.

Materials and apparatus

Self-construal survey. To measure self-construal, participants were administered a 30-item version of the Self-Construal Scale (SCS) developed by Singelis (1994). This scale consists of 15 independent items, such as 'I enjoy being unique and different from others in many respects' and 15 interdependent items, such as 'I do my own thing regardless of what others think'. Each item was rated on a Likert scale from 1 (Strongly Disagree) to 7 (Strongly Agree). Treating self-construals as orthogonal constructs, independent and interdependent self-construal were measured by calculating the average response to items from each subscale separately. Although often used in cross-national comparisons, measures like the SCS have been successfully used to discriminate populations within a country (see Oyserman *et al.*, 2002).

Visual stimuli. Stimuli consisted of 100 unique background scenes and 50 unique focal objects superimposed on the center of the background scenes (see Figure 1). Each focal object was superimposed upon one congruent background and one incongruent background (i.e. each focal object was presented twice). Objects and backgrounds were selected to maximize congruity and incongruity by selecting objects and background pairings that are commonly (e.g. crab on beach) or rarely (e.g. crab on parking lot) seen or associated together. Stimuli were selected by four judges, two of whom were Asian American. Visual images were obtained from various Internet image databases.

The stimuli were presented on a Dell 22 inch computer monitor centrally positioned at eye level 75 cm from the observer's eyes. The background scenes subtended 95 square degrees of visual angle. The superimposed focal objects were presented in the center of the background scenes and subtended an average of 4.2×4.2 degrees of visual angle. E-Prime (Psychology Software Tools Inc., Pittsburgh, PA) was used to program the presentation of the stimuli.

Procedure

Five practice trials were followed by four sets of 25 stimuli. Between each set, subjects were allowed to take a break for as long as they felt necessary. Participants were presented with a fixation point ('+') in the center of the computer screen for an interval between 500 and 1500 ms. Then, a background picture was presented for 300 ms. This was followed by the presentation of a focal object that was superimposed on the same background for 300 ms. The object was either congruent or incongruent with the background pictures. The sequence of trials was randomized for each subject.

The orienting task for participants was to determine whether the center focal object was either animate or inanimate. Participants were given two response boxes, one for each hand. If the focal object was animate, they were instructed to press '1' simultaneously with both hands. If the focal object was inanimate, they were instructed to press '2'. If they were undecided, then they were instructed to press '3'. Reaction time and accuracy were recorded. After the experimental procedure, all participants completed the Singelis SCS, followed by demographic questions.

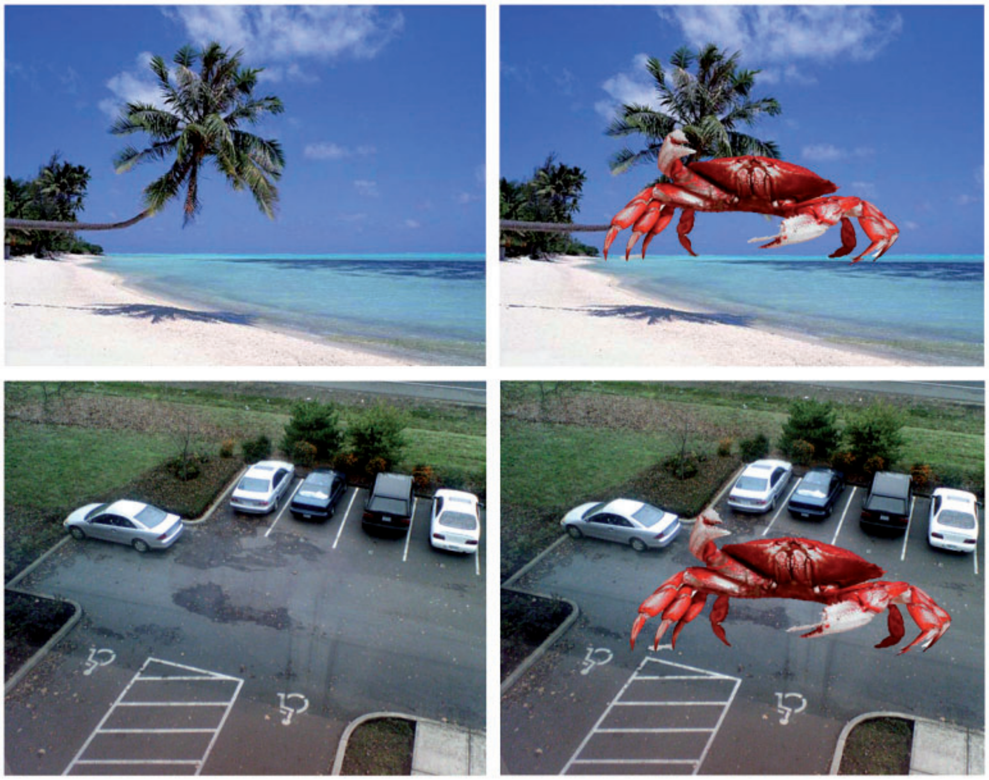

Fig. 1 (**A**) Sample congruent visual stimuli. First, the background picture is presented (left). Then, a semantically congruent object is shown superimposed upon the background image (right). (**B**) Sample incongruent stimuli. First the background picture is presented (left). Then, a semantically incongruent object is shown superimposed upon the background image (right).

EEG acquisition

EEG was recorded using the Electrical Geodesics Inc. 256-channel Hydrocel Geodesic Sensor Net soaked in a potassium chloride saline surfactant solution (Electrical Geodesics Inc., Eugene, OR). Each electrode of the net used an Ag/AgCl-plated carbon-fiber pellet connected to a gold pin by a lead-shielded wire. The net was connected to a DC-coupled high impedance (200 MΩ) Net Amps 300 amplifier. Electrodes were adjusted to impedances below 50 kΩ, which preserves the signal integrity (<0.1% error) for a system of this design (Ferree *et al.*, 2001). The analog voltages were amplified by a factor of 1000 and a lowpass 100 Hz filter was used during recording. Voltages were digitized with a 16-bit A/D converter at 250 Hz. Recording electrodes were referenced to the subject's vertex electrode.

ERP analysis

NetStation 4.2 software was used to process the raw EEG data (Geodesics Inc., Eugene, OR). Raw data were filtered using a 0.3–30 Hz bandpass filter. For ERPs in response to the background stimuli, trials were epoched from 200 ms before the onset of the background scene to 300 ms after its onset. For ERPs in response to the focal object superimposed upon the background scene, the trials were epoched from 200 ms before the onset of the focal stimulus to 1000 ms after its onset. Trials were rejected if they contained remaining ocular artifacts (>70 μV difference between eye channels) or more than five bad channels (100 μV difference between successive samples or reaching amplitudes of 200 μV). Subjects with fewer than 25 artifact free trials in either the congruent or incongruent conditions were eliminated from analyses in the study (as mentioned above, this resulted in elimination of four Asian Americans and six European Americans from the study). For the Asian Americans, there remained, on average, 43 trials (out of 50) for ERP analyses in the congruent condition and 42 (out of 50) for the incongruent condition per subject. For the European Americans, there remained on average 44 trials (out of 50) for ERP analyses in the congruent condition and 45 (out of 50) for the incongruent condition per subject. For the ERPs in response to the background scene, all trials were averaged together, re-referenced to the average reference, and baseline corrected to the 200 ms period preceding the background stimulus. For ERPs in response to the object superimposed upon the background scene, trials for each condition (congruent and incongruent) were averaged separately, re-referenced to the average reference, and baseline corrected to the 200 ms preceding the onset of the background stimulus.

RESULTS

Self-construal orientation surveys

Based on previous studies that found strong correlations between culture and self-construal (see Oyserman *et al.*, 2002), we predicted that European American participants would display greater independent self-construal, whereas Asian American participants would display greater interdependent self-construal. Retaining all items of the Singelis SCS resulted in a Cronbach alpha's of 0.75 for the independent subscale, and 0.72 for the interdependent subscale, suggesting moderately high reliability for both scales.

There were no significant differences in self-construal scores between males and females for either the interdependent subscale, $t(46) = 0.22$, NS or the independent subscale, $t(46) = 0.88$, NS. Therefore, the remaining analyses were collapsed across sex. European Americans ($M = 4.8$; s.d. = 0.69) were significantly more independent than Asian Americans ($M = 4.3$; s.d. = 0.51), [$t(46) = 2.6$, $P = 0.01$]. However, Asian Americans ($M = 4.7$; s.d. = 0.62) did not differ from the European Americans ($M = 4.6$; s.d. = 0.55) on the interdependent subscale of the SCS, $t(46) = 0.9$, NS.

Behavioral performance

In order to orient attention during the N400 task, subjects performed an incidental animacy judgment of the objects that were superimposed on the background scenes. For the animate objects, there was no difference in accuracy between the Asian Americans ($M = 96.5\%$; s.d. = 2.1) and European Americans ($M = 97.5\%$; s.d. = 2.0), $t(46) = 1.7$, NS. Mean reaction times were log transformed in order to normalize the data (Ratcliff, 1993), and subsequent statistical analyses were conducted using the transformed data. However, raw means and standard deviations are presented parenthetically for ease of interpretation. There was no difference in log transformed reaction times between Asian Americans ($M = 963$ ms; s.d. = 356) and European Americans ($M = 935$ ms; s.d. = 278 ms), $t(46) < 0.01$, NS. Similarly, for the inanimate judgments, no difference emerged between the two groups in accuracy (Asian Americans: $M = 91\%$; s.d. = 5.2; European Americans: $M = 92\%$; s.d. = 4.5; $t(24) = 1.1$, NS, or log transformed reaction time (Asian Americans: $M = 931$ ms; s.d. = 334 ms; European Americans: $M = 867$ ms; s.d. = 230 ms), $t(46) = 0.52$, NS.

In addition, there were no differences in log transformed reaction times between the two groups for the congruent object-background pairings (Asian Americans: $M = 684$ ms; s.d. = 117 ms; European Americans: $M = 726$ ms; s.d. = 134 ms), $t(46) = 1.11$, NS, or the incongruent object-background pairings (Asian Americans = 682 ms; s.d. = 114 ms; European Americans: $M = 736$; s.d. = 151), $t(46) = 1.40$, NS, $t(46)$.

Furthermore, the Asian Americans did not show a significant difference in log transformed reaction times between the congruent ($M = 683$; s.d. = 117) and incongruent object-background pairings ($M = 682$; s.d. = 114), $t(23) = 0.18$, NS. Similarly, the European Americans did not show a significant difference in log transformed reaction times between the congruent ($M = 726$; s.d. = 134) and incongruent ($M = 736$; s.d. = 151) object-background pairings, $t(23) = 0.13$, NS. Furthermore, there were no correlations between the behavioral responses and the self-construal scores.

Finally, data capturing possible cultural differences in perception of the stimuli were collected post-hoc. A separate sample of 20 European Americans and 20 Asian Americans, drawn from the original pool, viewed the stimuli and made judgments regarding the in/congruity of the focal object superimposed upon the background scenes. Trials were presented at the rate of 1 per 5 s and each stimulus was presented for 1 s. No group differences in perception of in/congruity emerged for any one object/background pairing [all $\chi^2(1) > 0.05$], or when responses across stimuli were aggregated; $t(38) = 0.29$, NS.

The behavioral results suggest no obvious differences in the degree to which the Asian Americans and European Americans behaviorally responded to the object-background stimuli.

Electrophysiological analyses

In order to determine any group differences in processing the background scenes, ERPs were created for the period from 200 ms before the onset of the background through the 300 ms duration of the background scene (see Figure 2). Repeated measures ANOVAs were conducted on the mean amplitude for 70 electrodes spanning the extent of the electrode net coverage for three temporal windows (0–100 ms, 100–200 ms and 200–300 ms). Ethnicity was entered as a between-subject variable and a Greenhouse-Geisser correction was used for violation of sphericity. For each of the temporal windows there was no main effect of ethnicity [0–100 ms: $F(1) = 0.03$, NS; 100–200 ms: $F(1) = 0.0$, NS; 200–300 ms: $F(1) = 0.67$, NS], nor was there an ethnicity by electrode interaction, [0–100 ms: $F(5.0) = 1.8$, NS; 100–200 ms: $F(3.3) = 0.61$, NS; $F(2.7) = 0.83$, NS]. These data suggest that there were no obvious differences in how the two groups processed the background scene alone.

In order to investigate electrophysiological responses to incongruent object-background pairings, ERPs were created for 200 ms before the onset of the focal object superimposed upon the background through 1000 ms after its onset. The shape of the resulting ERPs was very similar to those reported by Ganis and Kutas (2003) (see Figures 3 and 4). There was a peak negativity occurring around the time the object was superimposed upon the background. The ERP became increasingly positive, except for a brief negative deflection occurring around 400 ms post object onset. This negativity characterized the N400. The scalp topography of

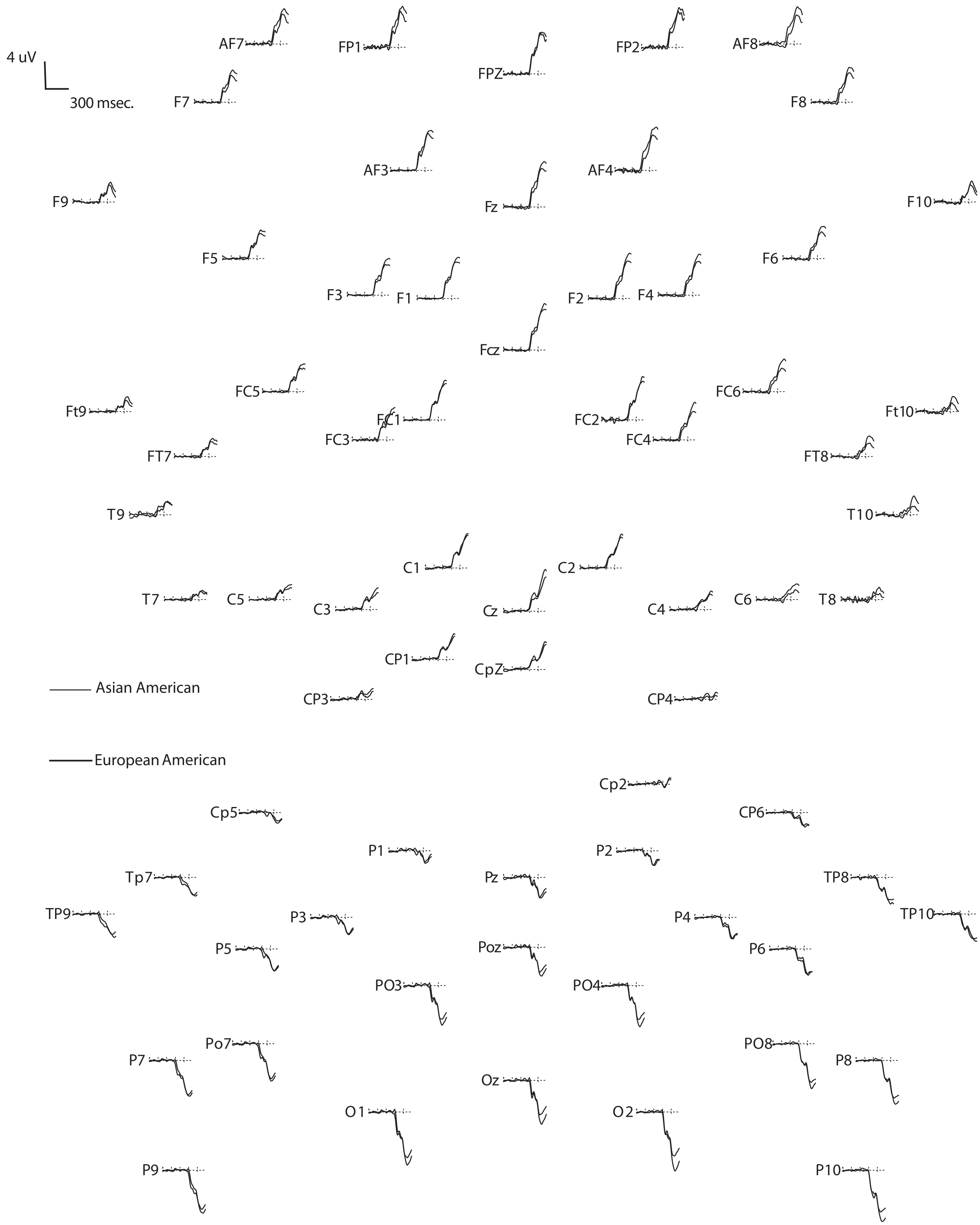

Fig. 2 Event-related potentials for Asian Americans and European Americans in response to the presentation of the background scene alone. Voltage is plotted as a function of time, 200 ms pre-stimulus onset to 300 ms post-stimulus onset.

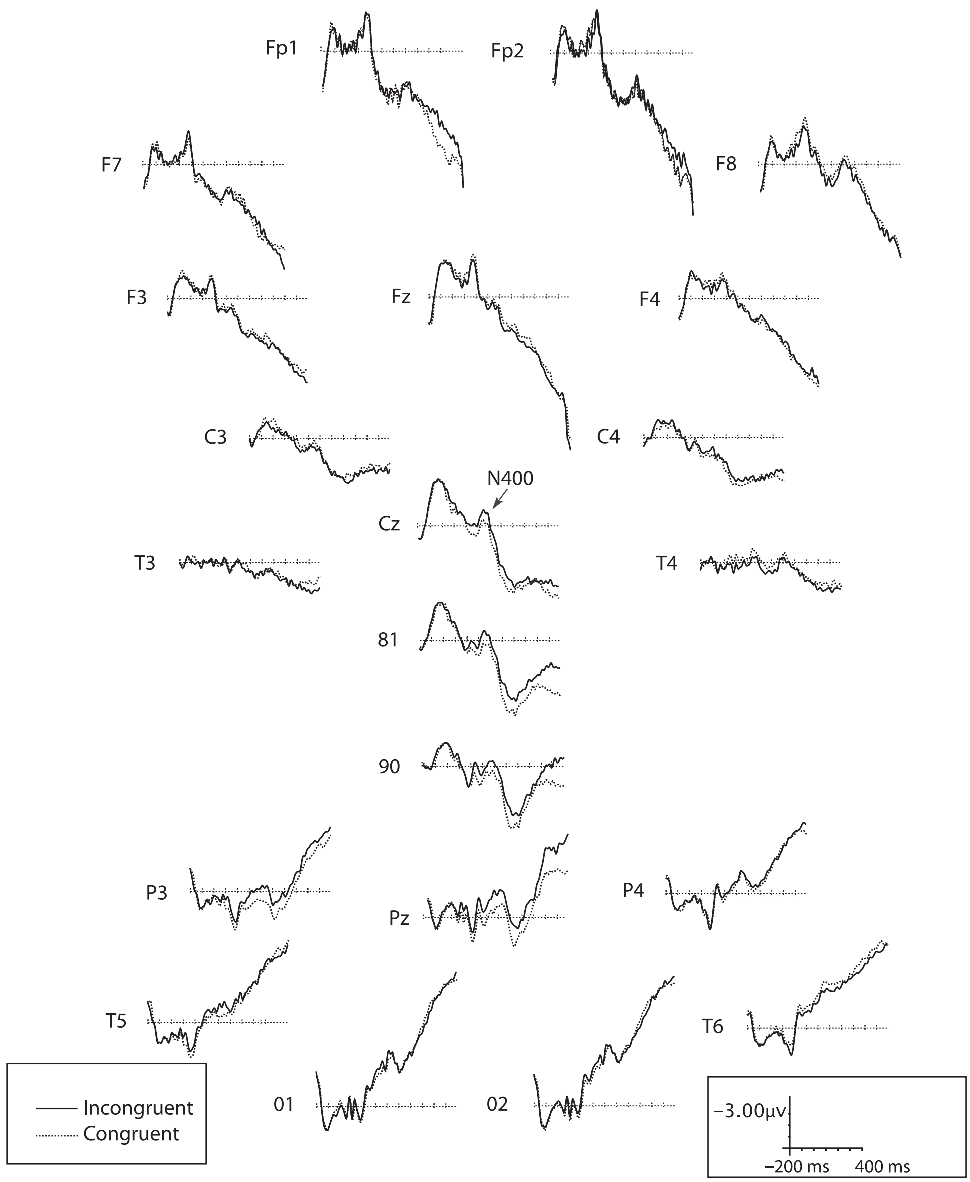

Fig. 3 Event-related potentials for Asian Americans during the congruent and incongruent conditions. The N400 is designated for Cz. Asian Americans showed greater N400 negativity during the incongruent than the congruent conditions at the centroparietal electrodes. Voltage is plotted as a function of time 200 ms pre-stimulus onset to 1000 ms post-stimulus onset.

the N400 was also similar to that reported by Ganis and Kutas (see Figure 5). The N400 was maximal at midline centroposterior electrodes, and largely symmetrical.

In order to quantify the N400, we measured the mean amplitude of the vertex (Cz) and two immediately posterior electrodes (number 81 and 90) across a 350–450 ms latency window. The amplitudes of the three electrodes were averaged and entered into the following repeated measures ANOVA analyses. The Asian Americans showed greater negativity to incongruent trials than congruent trials, $F(1, 23) = 4.5$, $P = 0.045$. In contrast, the European Americans did not show a difference in amplitude across the two conditions, $F(1, 23) < 1$, NS. Furthermore, and not surprisingly, subtracting the amplitude during the congruent trials from the amplitude during the incongruent trials resulted in significantly larger N400 difference wave amplitude for the Asian Americans than for the European Americans, $t(48) = 2.3$, $P = 0.026$ (see Figure 6).

Relationship between self-construal and ERPs

Correlational analyses were conducted between the Singelis SCS independent and interdependent subscales and the N400 amplitude of the difference wave. The greater the magnitude of the N400 incongruity effect, the lower the independent self-construal score ($r = 0.32$, $P = 0.03$)

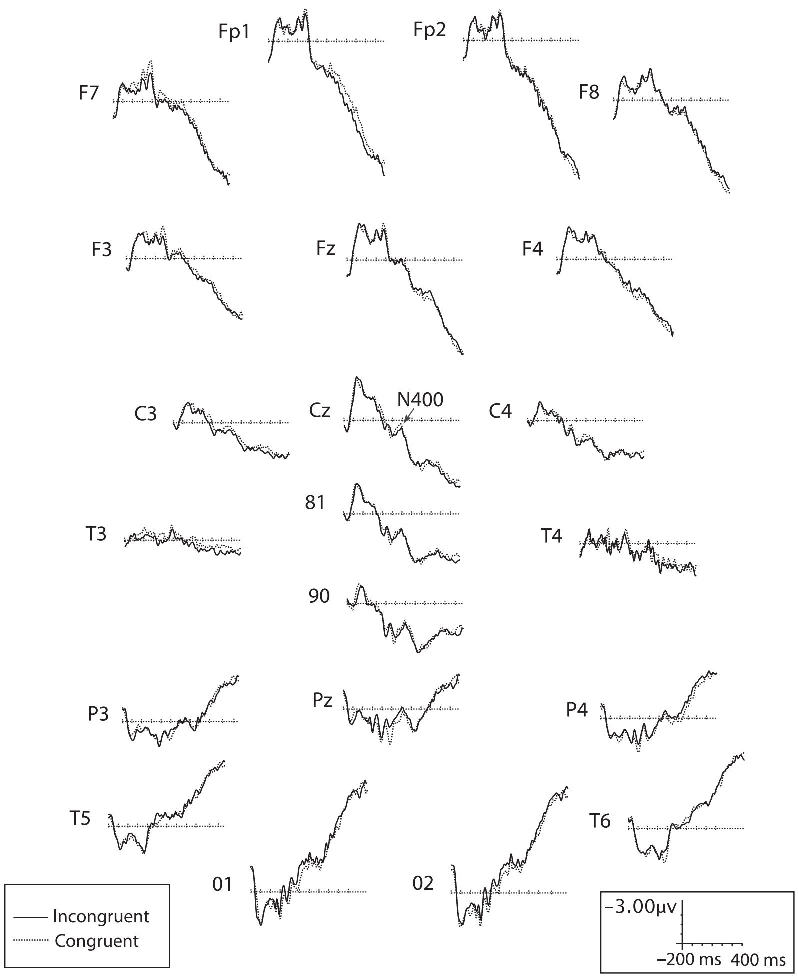

Fig. 4 Event-related potentials for European Americans during the congruent and incongruent conditions. The N400 is designated for Cz. In contrast to the Asian Americans, the European Americans did not show greater N400 negativity during the incongruent than the congruent conditions at the centroparietal electrodes. Voltage is plotted as a function of time 200 ms pre-stimulus onset to 1000 ms post-stimulus onset.

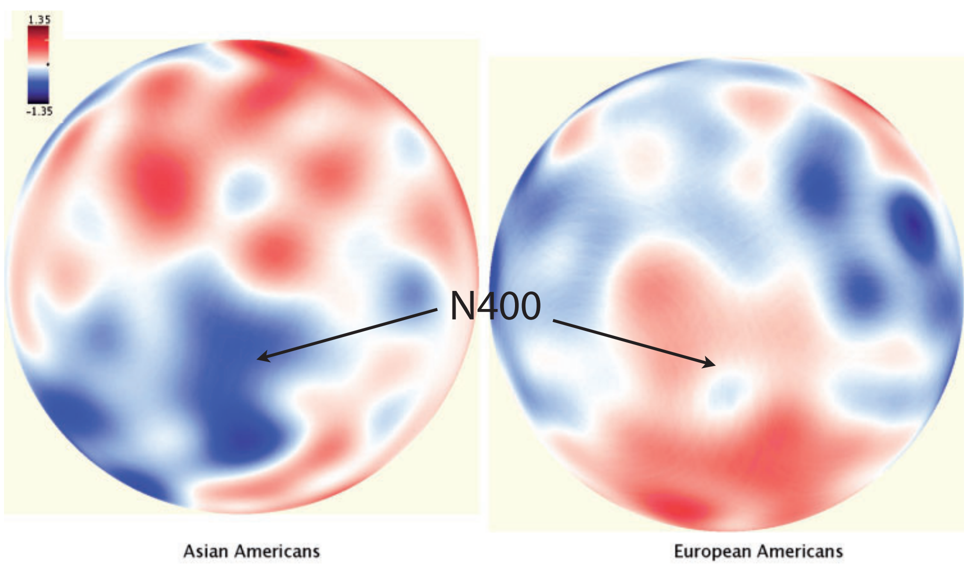

Fig. 5 Scalp topography of voltage difference between the incongruent and congruent conditions for the Asian Americans (left scalp topography) and the European Americans (right scalp topography). Greater negativity for the incongruent condition is indicated by blue coloring. Notice the greater negativity during the incongruent condition for Asian Americans along the centroposterior midline electrode sites.

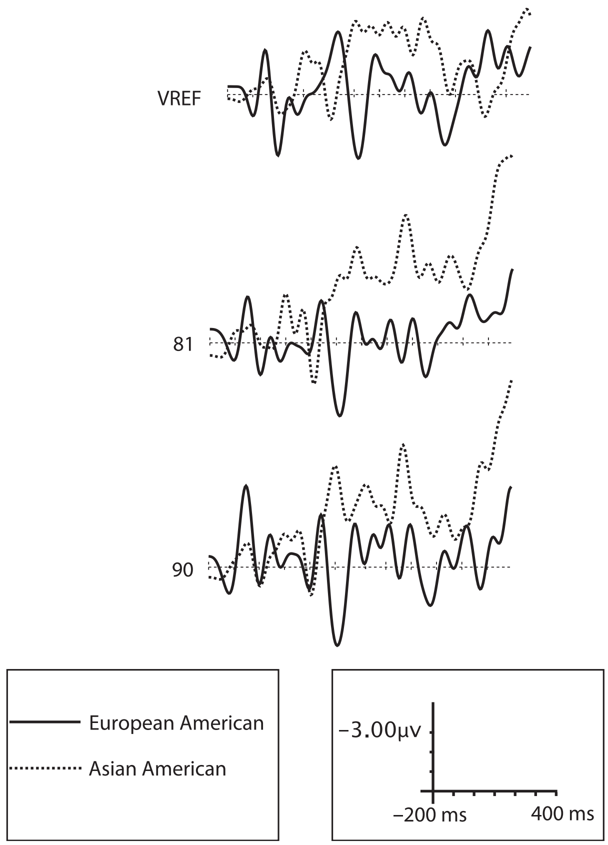

Fig. 6 Difference ERP waves (incongruent minus congruent conditions) for Asian American and European American groups. Asian Americans show greater negativity for the difference waves for the centroposterior midline electrodes. Voltage for the midline electrodes is plotted as a function of time from 200 ms pre-stimulus onset to 1000 ms post-stimulus onset.

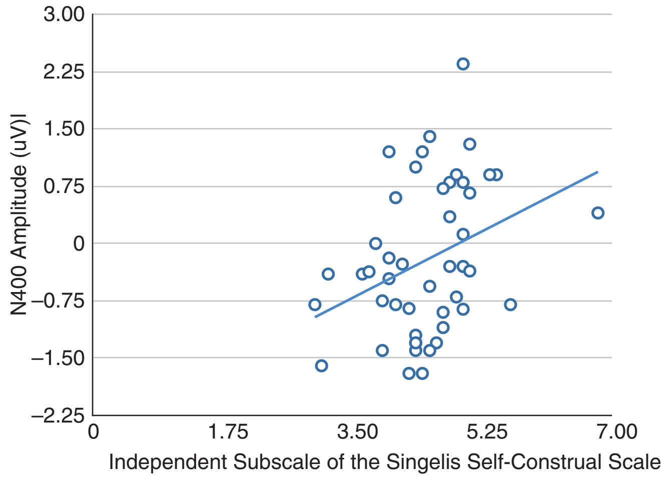

Fig. 7 Scatterplot of the relationship between independent self-construal, as measured by the Individualism subscale of the Singelis Self-Construal Scale, and the N400 amplitude (difference between congruent and incongruent conditions at electrode Cz electrode). The scatterplot shows that as independent self-construal increases there is an associated decrease in the magnitude of the N400 incongruity effect.

(see Figure 7 for a scatterplot of this relationship). No relationship was found between the N400 and the interdependent self-construal score ($r = -0.02$, NS).

DISCUSSION

We investigated the extent to which Asian and European Americans would incidentally process background information when making animacy judgments about a focal object. Since there has been converging evidence that Asians process contextual information to a greater degree than European Americans, we reasoned that the Asian Americans would be more sensitive to background scenes that were incongruent with focal objects than would be the case with European Americans. Consequently, we investigated whether East Asian Americans would show a relatively greater N400 to incongruent foreground-background pairings when compared to European Americans. We also investigated the relationship between the N400 and self-reports of interdependent and independent self-construal.

As expected, East Asian Americans showed a larger N400 to incongruous pairings of background scenes and foreground objects compared to congruous pairings, and showed a greater N400 incongruity effect than European Americans. These findings suggest that Asian Americans are processing or incorporating the context to a greater degree than European Americans when making judgments about focal objects. Therefore, Asian Americans may be particularly sensitive to semantic discrepancies when processing the visual field. This semantic processing evidence importantly suggests a cognitive mechanism associated with cultural differences in foreground and background attention.

Our finding is consistent with other literature using electrophysiological measures. Lewis *et al.* (2008) found that East Asian Americans were more influenced by the context compared to European Americans using a Novelty P3 measure. There, subjects' expectation of particular alphanumeric stimuli comprised the context, and cultural differences emerged when contextually novel events occurred. East Asian Americans in the present study also responded more strongly to contextually influenced information. Since the present stimuli are markedly more similar to the stimuli or operational definition of context used in the 'culture and cognition' literature, this provides consistent, yet more compelling support for electrophysiological differences associated with culture and context.

It is interesting that the European Americans in this experiment did not show a significant incongruity effect on the N400 which might appear to be at odds with Ganis and Kutas (2002). However, the ethnic make-up of the subjects in that study was not specified and therefore comparisons with the Asian American and European American findings in our study are difficult to make. Furthermore, in Experiment 2 of Ganis and Kutas subjects explicitly judged the semantic congruity between the object and background, whereas our study required only an animacy judgment of the object. That is, the analysis of semantic congruity between object and background was explicit in one of Ganis and Kutas' studies, whereas it was incidental in our experiment. In Experiment 3 of Ganis and Kutas, however, subjects only identified the object, thus making processing of semantic congruity incidental to task demands of the experiment. In that case a less clear picture emerged as they found a non-significant trend for a congruency N400 effect among midline centroposterior electrodes. This is consistent with our findings. Together, it appears that the centroposterior N400 incongruity effect for visually presented stimuli may be due at least in part to the explicitness of the semantic congruity task. Testing this variability was not the focus of our study, but future studies should investigate the origin of the effect.

Another explanation for the lack of an N400 might be that the European Americans processed the background scenes differently or less fully than the Asian Americans. If they did not process semantic elements of the background scenes, then they would not have processed the semantic incongruity when shown anomalous object/background pairings. While we cannot rule out this explanation, we attempted to control for differences in background processing since all subjects were first presented the background alone. Indeed, we did not find cultural differences in the ERPs when subjects were presented with the background scenes alone. Interestingly, Gutchess *et al.* (2006) did not find greater functional magnetic resonance imaging activity among East Asians, relative to European Americans, when processing background scenes, a finding consistent with our ERP results.

A lack of an N400 in European Americans could also be due to cultural differences in the perception of incongruity. Again, while we cannot rule out this possibility, we did not find any evidence to support this explanation when we subsequently measured explicit judgments of congruity of stimuli used in this study.

Chua *et al.* (2005) argued that an underlying mechanism of the cultural differences in attending to foreground *vs* background objects is related to eye movements. They found that Americans fixated more on the objects in the foreground than Chinese participants, and Chinese looked more toward the background. In our study, though, differences in eye movements are an unlikely explanation for the electrophysiological findings since ocular movements tend to result in measurable electrical artifacts. Trials with such artifacts were eliminated from ERP analyses. Furthermore, Chua *et al.* did not find that cultural differences in scanning complex figures occurred until 400 ms after viewing the pictures, which was less than the duration of our stimuli.

One alternative explanation for differences in group performance would be covert attentional shifts. These are well documented (e.g. Posner *et al.*, 1984) and would not result in ocular artifacts. However, cultural differences in covert attention seem unlikely to fully explain the group differences. The background image was presented for 300 ms alone before the focal object appeared superimposed upon the background. This would seem sufficient for subjects to 'overtly' process the content of the background before the object-background stimulus, thus reducing the potential influence of covert attentional shifts.

The remaining, best explanation of the group differences in this study is the degree to which subjects incorporate or ignore the background scene when performing the animacy judgment. In this light, the Asian Americans' increased N400 may be seen as a neural index of the effort to incorporate semantically anomalous information when making their decisions about animacy. Rather than simply exerting more effort to attend to both foreground and background, or choosing background to the exclusion of foreground (or vice versa), East Asian Americans may quickly detect information discrepancies perhaps minimizing subsequent cognitive overload. This 'incorporate or ignore' interpretation is consistent with cultural differences found on the Rod-And-Frame (Ji *et al.*, 2000) and the Framed Line Test (Kitayama *et al.*, 2003). When making judgments about the verticality or the length of a line, East Asians tend to take into account the frame to a greater degree than North Americans. Therefore, the N400 in this study may reflect a neural index of a cultural difference in incorporating *vs* ignoring the relationship between object and the contextual field. Importantly, we believe this is consistent with greater holistic processing by Asians as advocated by Nisbett *et al.* (2001).

Seemingly contradictory support for this interpretation stems from the behavioral data. One might expect that subjects who deeply process the background would show facilitation in their reaction times when the superimposed object was semantically related and inhibition when semantically unrelated. However, no differences in reaction time as a function of semantic relatedness emerged for either group in our study. The failure to find reaction time varying as a function of semantic relatedness might be accounted for by the orientating task being one of animacy judgment rather than object identification. Future studies might extend this method to object identification. We view an incidental task as representative of processing objects in daily life, where explicit naming of objects one encounters is less relevant than recognizing potential relevance for the situation. It could also be that additional processing required for congruency judgments are minimal, so as not to affect reaction time. Indeed, since reaction times may be less sensitive than ERPs, this may account for apparent inconsistency between the reaction time and ERP data, and thus underscores the utility of using electrophysiological measures.

We also found that the N400 was negatively correlated with independent self-construal. That is, individuals with higher independent self-construal seemed to use contextual visual cues less than those with lower independent self-construals, at least as indexed by the N400. This finding is consistent with the hypothesized relationship between context and self-construal, and importantly suggests that differences in independent self-construal may in part determine the way contexts are processed.

However, the N400 was not related to interdependent self-construal. This was unexpected, although not surprising given a growing evidence for an orthogonal relationship between interdependence and independence (e.g. see Oyserman *et al.*, 2002; Schimmack *et al.*, 2005). Thus, low independence is not equivalent to high interdependence. Perhaps the current task as performed in solitude and using non-social objects primes independence (see Kitayama *et al.*, 2004). It would therefore make sense and be consistent with other studies (i.e. Hedden *et al.*, 2008) that found independence to be predictive of culturally-related differences in neural processing, even if this is somewhat inconsistent with finding of Lewis *et al.* that interdependence not independence mediated the relation between ethnic group and greater contextual influence. Also, we used an equally well established, but different self-report measure of self-construal, perhaps contributing to the different results. At this time, several studies have found relationships between neural indices of context and self-construal. We believe clarity in the specific relation between self-construal and contextual processing will ultimately help integrate the cognitive, behavioral and neuroscience literatures of cultural psychology.

One limitation of the current study is that we focused on a sample of East Asian Americans in contrast to European Americans. This differs from the general reliance on East Asians as often found in some of the literature, but we believe this speaks to the generalizability of the findings. Furthermore, our measurement of self-construal through attitudinal items is imperfect and subject to self-report biases like the referencing effects (Heine *et al.*, 2002).

Furthermore, ERP measures, although providing temporal precision in the sequencing of brain activity, lack the spatial resolution necessary to identify the neural generators in the current study. A convergence of methods have emphasized left temporal lobe generators during semantic incongruity tasks, especially in the anterior temporal lobe areas (e.g. Helenius *et al.*, 1998; McCarthy *et al.*, 1995; Newman *et al.*, 2001; Nobre *et al.*, 1995). Other areas that may contribute to semantic processing include the right temporal lobe, left frontal lobe and the cingulate gyrus. Therefore, it is difficult to know which of these brain areas contribute to cultural differences in semantic processing identified in our study.

In looking at the present study, evidence for the utility of electrophysiological measures to study culture is mounting. By applying these methods to understand culture and visual processing of context, we can better understand the neuro-cognitive processes involved in the use of context. Secondly, by adding neural methodologies, this project adds more refined techniques that are better able to uncover dynamic, subtle, and automatic aspects of cognition that vary by culture where behavioral differences are not revealed. In sum, this study furthers our understanding of the processes behind cultural differences in the use of context and foreground information by suggesting semantic processing as a possible mechanism to understand *how* and *why* this information is differentially used. It takes another step toward an integrated understanding of how neural mechanisms, cognition, and behavior work together toward a more systematic understanding of culture.

Conflict of Interest

None declared.

REFERENCES

Boduroglu, A., Shah, P., Nisbett, R.E. (2009). Cultural differences in allocation of attention in visual information processing. *Journal of Cross-Cultural Psychology*, *40*, 349–60.

Choi, I., Nisbett, R.E. (1998). The cultural psychology of surprise: Holistic theories and recognition of contradiction. *Journal of Personality and Social Psychology*, *79*, 890–905.

Chua, H.F., Boland, J.E., Nisbett, R.E. (2005). Cultural variation in eye movements during scene perception. *Proceedings of the National Academy of Sciences of the United States of America*, *102*, 12629–33.

Ferree, T.C., Luu, P., Russell, G.S., Tucker, D.M. (2001). Scalp electrode impedance, infection risk, and EEG data quality. *Clinical Neurophysiology*, *112*, 536–44.

Ganis, G., Kutas, M. (2003). An electrophysiological study of scene effects on object identification. *Cognitive Brain Research*, *16*, 123–44.

Goh, J.O., Chee, M.W., Tan, J.C., et al. (2007). Age and culture modulate object processing and object-scene binding in the ventral visual area. *Cognitive, Affective & Behavioral Neueroscience*, *7*, 44–52.

Gutchess, A.H., Welsh, R.C., Boduroglu, A., Park, D.C. (2006). Cultural differences in neural function associated with object processing. *Cognitive, Affective & Behavioral Neuroscience*, *6*, 102–9.

Haberstroh, S., Oyserman, D., Schwarz, N., Kuhnen, U., Ji, L.J. (2002). Is the interdependent self more sensitive to question context than the independent self?: self-construal and the observation of conversational norms. *Journal of Experimental Social Psychology*, *38*, 323–9.

Hedden, T., Ketay, S., Aron, A., Markus, H.R., Gabrieli, J.D.E. (2008). Cultural influences on neural substrates of attentional control. *Psychological Science*, *19*, 12–7.

Heine, S.J., Lehman, D.R., Peng, K., Greenholtz, J. (2002). What's wrong with cross-cultural comparisons of subjective likert scales? The reference-group effect. *Journal of Personality and Social Psychology*, *82*, 903–18.

Heine, S.J., Norenzayan, A. (2006). Toward a psychological science for a cultural species. *Perspectives on Psychological Science*, *1*, 251–69.

Helenius, P., Salmelin, R., Service, E., Connolly, J.F. (1998). Distinct time courses of word and context comprehension in the left temporal cortex. *Brain*, *121*, 1133–42.

Holcomb, P.J. (1993). Semantic priming and stimulus degradation: implications for the role of the N400 in language processing. *Psychophysiology*, *30*, 47–61.

Holcomb, P.J., Neville, H.J. (1991). The electrophysiology of spoken sentence processing. *Psychobiology*, *19*, 286–300.

Ishii, K., Reyes, J.A., Kitayama, S. (2003). Spontaneious attention to word content versus emotional tone: Differences among three cultures. *Psychological Science*, *14*, 39–46.

Ji, L.J., Peng, K.P., Nisbett, R.E. (2000). Culture, control, and perception of relationships in the environment. *Journal of personality and social psychology*, *78*, 943–55.

Kim, H.S. (2002). We talk? Therefore we think. A cultural analysis of the effect of talking on thinking. *Journal of Personality and Social Psychology*, *83*, 828–42.

Kitayama, S., Duffy, S., Kawamura, T., Larsen, J.T. (2003). Perceiving an object and its context in different cultures: a cultural look at new look. *Psychological Science*, *14(3)*, 201–6.

Kitayama, S., Duffy, S., Uchida, Y. (2007). Self as cultural mode of being. In: Kitayama, S., Cohen, D., editors. Handbook of Cultural Psychology. New York: Guilford Press, pp. 136–74.

Kitayama, S., Ishii, K., Imada, T., Takemura, K., Ramaswamy, J. (2006). Voluntary settlement and the spirit of independence: evidence from Japan's "Northern Frontier". *Journal of Personality and Social Psychology*, *91*, 369–84.

Kitayama, S., Snibbe, A.Cl, Markus, H.R., Suzuki, T. (2004). Is there any "free" choice? Self and dissonance in two cultures. *Psychological Science*, *15*, 527–33.

Kuhnen, U., Hannover, B., Schubert, B. (2001). The semantic-procedural interface model of the self: The role of self-knowledge for context-dependent versus context-independent modes of thinking. *Journal of Personality and Social Psychology*, *80*, 397–409.

Kutas, M., Hillyard, S.A. (1980). Reading senseless sentences: brain potentials reflect semantic incongruity. *Science*, *201*, 203–5.

Kutas, M., Hillyard, S.A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, *307*, 161–3.

Leung, K., Bond, M.H. (1984). The impact of cultural collectivism on reward allocation. *Journal of Personality and Social Psychology*, *47(4)*, 793–804.

Lewis, R.S., Goto, S.G., Kong, L. (2008). Culture and context: East Asian American and European American differences in P3 event-related potentials. *Personality and Social Psychology Bulletin*, *34*, 623–34.

Markus, H.R., Kitayama, S. (1991). Culture and the self: implications for cognition, emotion, and motivation. *Psychological Review*, *98*, 224–53.

Masuda, T., Kitayama, S. (2004). Perceiver-induced constraint and attitude attribution in japan and the US: a case for the cultural dependence of the correspondence bias. *Journal of Experimental Social Psychology*, *40*, 409–16.

Masuda, T., Nisbett, R.E. (2001). Attending holistically versus analytically: comparing the context sensitivity of Japanese and Americans. *Journal of Personality and Social Psychology*, *81*, 922–34.

Masuda, T., Nisbett, R.E. (2006). Culture and change blindness. *Cognitive Science*, *30*, 381–99.

McCarthy, G., Nobre, A.C., Bentin, S., Spencer, D.D. (1995). Language-related field potentials in the anterior-medial temporal lobe: I. Intracranial distribution and neural generators. *Journal of Neuroscience*, *15*, 1080–9.

Miyamoto, Y., Kitayama, S. (2002). Cultural variation in correspondence bias: The critical role of attitude diagnosticity of socially constrained behavior. *Journal of Personality and Social Psychology*, *83*, 1239–48.

Miyamoto, Y., Nisbett, R. E., Masuda, T. (2006). Culture and the physical environment—holistic versus analytic perceptual affordances. *Psychological Science*, *17*, 113–9.

Morris, M.W., Peng, K. (1994). Culture and cause—American and Chinese attributions for social and physical events. *Journal of Personality and Social Psychology*, *67*, 949–71.

Newman, A.J., Pancheva, R., Ozawa, K., Neville, H.J., Ullman, M.T. (2001). An event-related fMRI study of syntactic and semantic violations. *Journal of Psycholinguistic Research*, *30*, 339–64.

Nobre, A.C., McCarthy, G. (1995). Language-related field potentials in the anterior-medial temporal lobe: II. Effects of word type and semantic priming. *Journal of Neuroscience*, *15*, 1090–8.

Norenzayan, A., Choi, I., Peng, K. (2007). Perception and cognition. In: Kitayama, S., Cohen, D., editors. *Handbook of Cultural Psychology*. New York: Guilford Press, pp. 569–94.

Nisbett, R.E., Peng, K.P., Choi, I., Norenzayan, A. (2001). Culture and systems of thought: Holistic versus analytic cognition. *Psychological Review*, *108*, 291–310.

Oyserman, D., Coon, H.M., Kemmelmeier, M. (2002). Rethinking individualism and collectivism: Evaluation of theoretical assumptions and meta-analyses. *Psychological Bulletin*, *128*, 3–72.

Posner, M.I., Walker, J.A., Friedrich, F.J., Rafal, R.D. (1984). Effects of parietal injury on covert orienting of attention. *Journal of Neuroscience*, *4*, 1863–74.

Ratcliff, R. (1993). Methods for dealing with reaction time outliers. *Psychological Bulletin*, *114*, 510–32.

Schimmack, U., Oishi, S., Diener, E. (2005). Individualism: A valid and important dimension of cultural differences between nations. *Personality and Social Psychology Review*, *9*, 17–31.

Singelis, T.M. (1994). The measurement of independent and interdependent self-construals. *Personality and Social Psychology Bulletin*, *20*, 580–91.

West, W.C., Holcomb, P.J. (2002). Event-related potentials during discourse-level semantic integration of complex pictures. *Cognitive Brain Research*, *13*, 363–75.