Cultural differences in sensitivity to the relationship between objects and contexts: evidence from P3

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Cross-cultural differences in Easterners and Westerners have been observed in different cognitive domains. Differential sensitivity to the relationship between objects and contexts might be an underlying cognitive mechanism for these differences. Twenty-one Chinese and 22 Germans participated in a three-stimulus event-related potential oddball task. They were instructed to monitor geometrical forms filled in black (targets) that were presented among a series of blank geometrical forms (standards). Novel stimuli were colored images of common objects. Robust novelty P3 and target P3 over the entire scalp were observed in both groups. As compared with the German group, Chinese participants showed larger amplitudes of novelty P3 and target P3 over frontal regions and earlier peak latency for target P3. This indicates a higher sensitivity to the relationship between contexts and objects in the Chinese as compared with the German group, which might be an underlying mechanism for cross-cultural differences reported in many cognitive domains. *NeuroReport* **25:656–660** © **2014 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Traditionally, cognition has been assumed to be universal. However, marked cross-cultural differences in cognitive processing have been observed between individuals in Eastern and Western cultures [1–3]. For example, when being asked to copy lines [4], Japanese participants are more accurate at copying the relative as compared with the absolute length of the lines, whereas American participants show the opposite effect. Similar differences have been observed with the Rod and Frame test [5], in scene perception [6], and categorization [7], and have led some researchers to question whether there are cross-cultural differences in object-specific and context-specific attentional processes that could account for these effects.

Indeed, a number of cross-cultural cognition studies have focused on selective attention to objects versus their contexts. For example, eye-tracking techniques have been used to test whether individuals in different cultures have a systematic fixation bias for objects or contexts. Usually, participants were presented with images of real-world scenes [8,9], photos [8,10,11], or scenes with anomalies [12]. Some studies found that participants in different cultures had different fixation patterns to contexts and objects [8,10], but other studies did not [9,11,12]. This inconsistency possibly indicates that comparison of object and context-selective attentional processes might not target the underlying cognitive mechanisms of the cross-cultural differences observed. Also, a functional MRI study [13] and an event-related potential (ERP) study [14] did not find any cultural differences in context processing. One line of research thus started to focus on the attentional processing of the relationship between objects and contexts rather than assuming differential preferences for objects or contexts as such [14].

Goto *et al.* [14] presented background images that were then followed by objects superimposed on them to Asian Americans and European Americans. The relationship between the background and the object could be congruent (e.g. a beach and a crab) or incongruent (e.g. a parking lot and a crab). The incongruent object–background images elicited a significantly larger N400 than the congruent ones only in the Asian American group, indicating that Asian Americans attend to the relationship between objects and contexts to a greater extent than European Americans. This is an impressive finding; however, the N400 is considered an index of semantic incongruency rather than a measure of attention [15]. The component that is most frequently used to address attentional processes is the P3 in the oddball paradigm [16,17].

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In a two-stimulus oddball paradigm, participants are usually presented with infrequent targets (e.g. a high-frequency pure tone) among a series of frequent standards (e.g. low-frequency pure tones). Targets typically generate a large positivity peaking at 250–600 ms after stimulus onset, which is most prominent over posterior regions. This positivity has been labeled the 'target P3'. Unexpected, infrequent, nontarget deviant stimuli (e.g. barking) can also elicit a P3 response, which is referred to as the 'novelty P3' [17]. Features of the novelty P3 are influenced by the features of the infrequent stimuli that elicit it. Unrecognizable infrequent stimuli sometimes elicit a novelty P3 with an anterior distribution [16], whereas recognizable infrequent stimuli produce a novelty P3 with similar latency and posterior distribution as the target P3, albeit with a reduced amplitude [16,18]. An anteriorly distributed novelty P3 may be related to orienting [16,17]. Given the similar scalp topography and latency, posteriorly distributed novelty P3 and target P3 may have more similarities than differences, and are sometimes referred to by the same label 'posterior P3 waves' [16]. So far, the most prominent account to explain the target P3 effects has been the context-updating theory, which posits that environmental events are automatically represented in working memory. Each new stimulus is evaluated against this subjective context. The detection of new attributes requires revision of the context and the P3 is elicited simultaneously [19].

Previously, Lewis and colleagues carried out a three-stimulus oddball task comparing Asian Americans and European Americans. The numbers '8' and '6', and different letter strings were used as standards, targets, and novels, respectively. A greater novelty P3 was observed in Asian Americans as compared with European Americans. Within the framework of the context-updating theory, this finding suggests that Asian Americans are more sensitive to the relationship between contexts and objects. However, a trend for a smaller target P3 in Asian Americans as compared with European Americans was also found. The researchers suggested that novelty P3 and target P3 rely on different cognitive mechanisms. However, population and stimulus factors may also account for the cross-cultural differences observed in these components. Asian Americans perform differently from European Americans in some cognitive domains [20]. In addition, Asian Americans and European Americans probably differ in their first languages. Consequently, the novel letter strings might simply be more unusual for Asian Americans than European Americans and this needs to be taken into account as verbal stimuli were used in that study. It is thus necessary to use nonverbal stimuli in an oddball task to directly compare the performance of East Asians and Westerners.

In the current study, we investigated novelty P3 and target P3 effects in a three-stimulus oddball task in a group of German participants raised in Germany and a group of Chinese participants raised in China. Geometrical forms and images of common objects were used as stimuli. On the basis of findings of previous studies [5], we hypothesized that Asians would attend more to the relationship between contexts and objects. This could be at the base of observed differences in cognitive processing between Easterners and Westerners, and should be reflected in a significantly larger target P3 and/or novelty P3 among Chinese relative to German participants. The novelty P3 elicited by recognizable stimuli is usually smaller than the target P3 [16,18]. The reduction in amplitudes might compromise the potential cultural differences in the novelty P3. Consequently, we expect larger differences in the target P3 than in the novelty P3.

Methods

Participants

Nineteen Chinese (mean age = 26.21 years, SD = 2.2 years, range = 24–33 years, nine women), who completed at least 14 years of formal education in China and studied in Germany when the experiment was conducted, and 20 Germans (mean age = 23.1 years, SD = 1.68 years, range = 21–26 years, twelve women), who were students of Saarland University, participated in the study in return for 8 Euros. All were healthy, right-handed, and provided written informed consent after the procedures had been fully described. Additional data of one Chinese and two German participants were discarded because of excessive α-wave in their ERP data. This study was approved by the ethics committee of Saarland University and was carried out in accordance with the Declaration of Helsinki.

Stimuli and procedure

The standards were composed of eight blank geometrical forms; the targets were the same set of stimuli filled in black; and the novels were 50 images of common objects, such as a bird, basin, and key (see Supplemental materials, Supplemental digital content 1, *http://links.lww.com/WNR/A282*). Participants were instructed to respond only to the targets by pressing the space bar with the right index finger. The number of trials of standards, targets, and novels was 400, 50, and 50, respectively.

The start of a trial was signaled by a fixation cross (+) in the center of the screen for 500 ms. Thereafter, there was a blank screen for 50 ms, then the stimulus appeared at the same location as the fixation cross for 500 ms, and was replaced by the next fixation cross. The vertical and horizontal visual angles for stimuli were less than 6°. The experiment lasted for about 10 min. All stimuli were presented pseudorandomly to ensure that only one target or novel stimulus could appear across any three consecutive trials.

Electrophysiological methods

Scalp electroencephalogram (EEG) was recorded from an array of 59 silver/silver chloride electrodes embedded in an elastic cap and amplified from DC to 100 Hz at a sampling rate of 500 Hz. The EEG was acquired referenced to the left mastoid and re-referenced off-line to linked mastoids. Further off-line data processing included a digital low-pass filter set to 30 Hz. Continuous EEG data were separated into 1200 ms epochs, commencing 200 ms before stimulus onset taken as the baseline.

Data analyses

The behavioral data were analyzed using independent-samples *t*-tests. Peak amplitudes were measured over nine electrodes (F3, F4, FZ, C3, C4, CZ, P3, P4, PZ) and peak latencies were analyzed for PZ where the P3s showed a maximum deflection. A time window of 250–500 ms was used for the detection of P3 peaks. A mixed-design analysis of variance (ANOVA) with the between-participants factor, culture (Chinese, Germans), and the within-participants factors, type (standard, target, novel) and electrode (F3, F4, FZ, C3, C4, CZ, P3, P4, PZ), was used for peak amplitude data and another mixed-design ANOVA with culture (Chinese, Germans) and type (standard, target, novel) was used for peak latencies. Only the main effects of or the interactions with culture or stimulus type are reported for the sake of brevity. Two-tailed results are reported with an α-level of 0.05. The Greenhouse–Geisser correction for nonsphericity was used whenever appropriate. The difference in waves between standard and target/novel stimuli in the 250–500-ms time window were calculated and are depicted in color-coded topographical maps.

Results

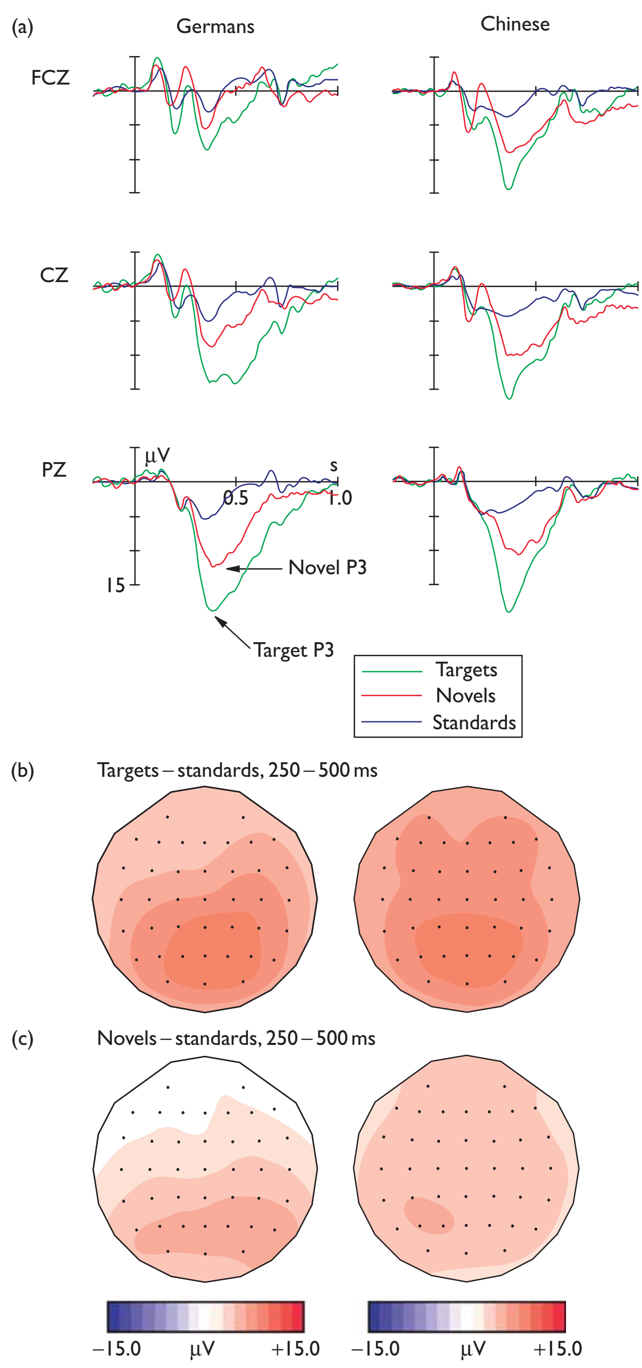
Behavioral data

No between-group difference ($P > 0.1$) was found for the reaction times of correct target detections (Chinese: $M = 400$ ms, SD = 39 ms; Germans: $M = 393$ ms, SD = 52 ms) or the accuracies (Chinese: $M = 0.99$, SD = 0.02; Germans: $M = 0.99$, SD = 0.01).

Event-related potential data

Targets and novels elicited robust P3s in both groups (Fig. 1a). P3 differences between targets and standards had a maximum over posterior areas (Fig. 1b), as did the P3 differences between novels and standards (Fig. 1c). ANOVA for peak amplitudes yielded a significant type effect [$F(2, 74) = 123.75$, $P < 0.0001$, $\epsilon = 0.8992$] and a significant three-way interaction between culture, type, and electrode [$F(16, 592) = 2.67$, $P < 0.05$, $\epsilon = 0.2729$]. Analysis of the interaction showed significant interactions between culture and stimulus type located mainly at the frontal regions at F3 [$F(2, 74) = 4.55$, $P < 0.05$, $\epsilon = 0.8599$] and marginally significant at F4 [$F(2, 74) = 3.13$, $P = 0.05$, $\epsilon = 0.8643$], and with a trend at FZ [$F(2, 74) = 2.17$, $P = 0.12$, $\epsilon = 0.9715$]. Independent-samples *t*-tests were carried out with the combined data at these three electrodes for each condition, showing larger mean amplitudes in the Chinese group than in the German group for targets [$t(37) = 2.38$, $P < 0.05$] and

Fig. 1



Grand-average event-related potentials for standard (blue line), target (green line), and novel (red line) stimuli at three midline electrodes (a), and topographic maps of the voltage amplitudes for difference waves in the 250–500 ms window [(b) targets–standards, (c) novels–standards]. Left, Germans; right, Chinese.

novels [$t(37) = 1.94$, $P = 0.06$] in a trend, but not for standards ($P > 0.1$).

A significant main effect of type [$F(2, 74) = 19.58$, $P < 0.001$, $\epsilon = 0.9200$] and an interaction between culture and type [$F(2, 74) = 4.37$, $P < 0.05$, $\epsilon = 0.9200$] were observed for peak latency data. Analysis of the interaction showed that peak latency for target stimuli in the Chinese group ($M = 370$, SD = 27) was significantly shorter than that in the German group ($M = 403$, SD = 47) [$t(37) = 2.77$, $P < 0.01$].

Discussion

In line with a previous study [21], we observed a robust target P3 and novelty P3 all over the scalp, but most prominently over posterior regions in both Chinese and German participants. Interestingly, Chinese participants showed larger target P3 and novelty P3 amplitudes than the German participants over frontal regions. Moreover, Chinese also showed earlier peak latency for target stimuli in comparison with Germans. Behaviorally, participants in both groups performed the oddball task with comparable accuracy and reaction times. Two reasons might explain why we found cultural differences in the ERPs but not in the behavioral data. First, the task could have been too easy for behavioral differences to emerge (mean accuracies were higher than 0.99 in both groups). Second, ERP measures could be more sensitive than behavioral measures. It is possibly because of these same reasons that two previous studies also observed cultural differences in ERP measures without the corresponding behavioral differences [14,22].

According to the context-updating theory, each stimulus is evaluated in working memory against a subjective context formed from the previously experienced environment [19]. P3s are elicited under the perception of new attributes of the current events. Active processing of the relationship between contexts and objects may play an important role during this mapping process as it has been observed that features of the P3 elicited by a certain stimulus are highly related to the context in which the stimulus is presented [18]. While keeping other variables (such as stimulus probability, target-to-target interval, stimulus sequence, task) constant, a smaller P3 amplitude indicates that the stimulus has larger similarity to the previous contexts and that the participants find it more difficult to process the given object [18]. Therefore, the larger P3 amplitudes observed in the Chinese participants indicate that Chinese may be more sensitive to the relationship between objects and contexts in the current oddball task. Complementary evidence comes from the earlier peak latency for target stimuli in the Chinese group. The peak latency of the P3 has been suggested to be proportional to stimulus evaluation time [23]. Therefore, the higher sensitivity to the context–object relationship could have shortened the evaluation time of the target stimuli for the Chinese participants. This point is also supported by a previous ERP study on the N400 that showed Asian Americans to be more sensitive to the semantic relationship between objects and contexts than European Americans [14].

It needs to be noted that similar findings have been considered as evidence for more attention to objects (as Lewis *et al.* [21] argued in terms of the larger target P3 in the European Americans) or contexts (as Lewis *et al.* [21] argued on the basis of the larger novelty P3 in the Asia Americans). Given the similar scalp distribution of target P3 and novelty P3 in that study as well as the current study, it seems unlikely that target P3 and novelty P3 have such different cognitive mechanisms [24]. Moreover, eye movement data, which reflect the location of attention, seldom showed different fixation patterns to either contexts or objects [9,11,12]. An eye movement study that did find some cross-cultural differences in viewing images reported that this difference appeared 420 ms after image onset [10]. The peak latencies for all stimulus conditions in the current study (mean $\leq$ 403 ms in both groups) were earlier than 420 ms. Therefore, it is conceivable to argue for a higher sensitivity to the context–object relationship rather than more selective attention to either objects or contexts.

We also believe that placing differential sensitivity to the relationship between contexts and objects as the core of cross-cultural differences in cognitive processing shows advantages in explaining the observed data over an account that assumes a differential selective attentional bias to either contexts or objects. Higher sensitivity to the relationship between contexts and objects on the one hand means better incorporation of object and context information. On the other, it can also be framed as difficulty in ignoring the contexts [14]. Taking the framed-line test as an example, Japanese participants were better in copying the relative length of the lines, but had the disadvantage in copying the absolute length of the lines [4]. In addition, differential sensitivity to the relationship between objects and contexts matches the proposal of a more 'holistic' processing style in Easterners and a more 'analytic' processing style in Westerners as suggested by Nisbett *et al.* [2]. 'Holistic' thought includes 'attention to relationship' as its core feature.

Even with similar topographical distributions of target and novel P3s in this study and the one of Lewis and colleagues, findings from the two studies are somehow divergent. Besides a significantly greater novelty P3, Lewis *et al.* [21] found a trend for a significantly smaller target P3 for Asian Americans than European Americans. Differences in the participant populations and experimental stimuli might have contributed toward the divergent findings. Given the observed cognitive differences between Asian Americans and Eastern Asians [20], it is still an open issue as to whether Asian Americans and

Chinese attend to the context–object relationship similarly in an oddball task. Moreover, Asian Americans might be less familiar with the verbal materials used in the study of Lewis *et al.* [21]. A recent cross-cultural ERP study provides evidence consistent with this argument [22]. German participants, who were more familiar with Western buildings, showed N350 differences for buildings with high and low rank, whereas this effect was absent for Chinese participants who were less familiar with Western buildings. The time window of the N350 in that study overlapped partly with the P300. The results were thus consistent with a smaller target P3 in Asian Americans who may be less familiar with the verbal materials in the study of Lewis *et al.* [21]. However, more studies are necessary to clarify this issue.

Conclusion

The findings from the current oddball task suggest that Chinese and Germans attend to the relationship between contexts and objects differently. Chinese seem to be more sensitive to the context–object relationship as compared with Germans. Differential sensitivity to the relationship between contexts and objects could be one of the key mechanisms for cross-cultural differences in cognitive processing.

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Kui Wang and Juliane Hofmann designed the experiment, recorded, and analyzed the data; Kui Wang wrote the first version of the manuscript; Nicola K. Ferdinand contributed in data retrieval and figure illustration; Kui Wang, Katja Umla-Runge, Nicola Ferdinand, and Raymond Chan contributed to manuscript writing and revision.

Conflicts of interest

There are no conflicts of interest.

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