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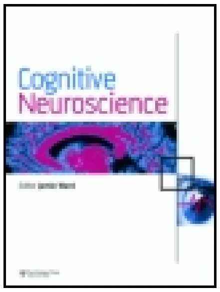

Cognitive Neuroscience
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pcns20

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Published online: 19 Dec 2013.

To cite this article: Axel Mecklinger, Olga Kriukova, Heiner Mühlmann & Thomas Grunwald , Cognitive Neuroscience (2013): Cross-cultural differences in processing of architectural ranking: Evidence from an event-related potential study, Cognitive Neuroscience, DOI: 10.1080/17588928.2013.869740

To link to this article: http://dx.doi.org/10.1080/17588928.2013.869740

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COGNITIVE NEUROSCIENCE, 2013, http://dx.doi.org/10.1080/17588928.2013.869740

Cross-cultural differences in processing of architectural ranking: Evidence from an event-related potential study

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Visual object identification is modulated by perceptual experience. In a cross-cultural ERP study we investigated whether cultural expertise determines how buildings that vary in their ranking between high and low according to the Western architectural decorum are perceived. Two groups of German and Chinese participants performed an object classification task in which high- and low-ranking Western buildings had to be discriminated from everyday life objects. ERP results indicate that an early stage of visual object identification (i.e., object model selection) is facilitated for high-ranking buildings for the German participants, only. At a later stage of object identification, in which object knowledge is complemented by information from semantic and episodic long-term memory, no ERP evidence for cultural differences was obtained. These results suggest that the identification of architectural ranking is modulated by culturally specific expertise with Western-style architecture already at an early processing stage.

Keywords: Visual object identification; Event-related-potentials; Object model selection.

People can quickly categorize objects and it is generally assumed that this categorization ability involves matching of a percept to object representations in long-term memory. Object knowledge is widely distributed in the brain and initial activating of this knowledge during categorization, a process referred to as object model selection, can lead to implicit memory for structural and conceptual aspects of an object, as revealed by priming or repetition effects (Schacter & Buckner, 1998). Depending on task and stimulus characteristics, object model selection can also lead to explicit memory, like feelings of familiarity (Curran, Tanaka, & Weiskopf, 2002) or activation of associated knowledge that enables secondary identification-related processes, naming, or the recollection of prior encounters with this object (Schendan & Kutas, 2003).

Event-related potential (ERP) studies allow important insights into the temporal and representational characteristics of visual object knowledge activation. The N350 is an ensemble of spatiotemporally overlapping subcomponents peaking at different latencies between 200 and 400 ms (Schendan & Maher, 2009), that has been identified with activation in an object knowledge network (Schendan & Kutas,

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We wish to thank Anna-Lena Scheuplein, Marie Schwartz and Guifang Xu for assistance in data collection, Timm Rosburg for his assistance in data analyses and Xuchu Weng for providing the experimental facilities for the study in China.

O.K. and A.M. contributed equally to this manuscript. This research was carried out in the context of the International Research Training Group “Adaptive Minds” funded by the German Research Foundation [DFG-IRTG 1457].

2003). It is assumed that in the N350 time window the appropriate object model is selected from long-term memory to match the percept. During object model selection matching, memory representations are facilitated (reflected in attenuated N350 components) and inconsistent ones are inhibited. In support of this view, the N350 is sensitive to categorization success irrespective of nameability (Schendan & Maher, 2009) and decreases as a function of the match between a perceptual cue and object knowledge (Schendan & Kutas, 2003). Recent findings also suggest that the N350 is sensitive to prior visual expertise with objects. For example, the N350 is smaller for views of objects which people experience more often than for unusual views of objects (Schendan & Kutas, 2003). On the basis of these findings it has been suggested that the N350 is an ERP index of visual object categorization success: The smaller the N350, the more matching memory representations and the better the categorization process.

While object model selection and matching with a percept is assumed to be reflected in the N350, secondary identification processes including name retrieval or recollection from explicit memory are supported by other brain systems and can be monitored by late positive components (LPC), an ensemble of components, indexing multiple processes related to object identification, memory, and decision making. For example, the LPC varies with categorization success (Mecklinger & Ullsperger, 1993), and is larger for famous than for unfamiliar faces (Trautner et al., 2004) and for namable than for non-namable objects (Schendan & Maher, 2009). In direct tests of memory the LPC is larger for studied than for new items and co-varies with decision confidence (Friedman & Johnson, 2000), suggesting that the LPC in tasks related to object knowledge may also reflect the contribution of explicit memory processes.

In a recent study (Oppenheim et al., 2010) we explored ERP indices of visual object knowledge using pictures of newly designed buildings varying in their ranking according to the rules of the architectural decorum in Western cultures. The technical term “decorum” refers to a well-established rule-system, which specifies the appropriateness of ornament to respective content or function of the building relationship (Mühlmann, 1996, 2013). It consists in marking the social/artistic status of the piece of art by certain elements. In architecture, all buildings can be positioned on a scale between the two poles of low-ranking and high-ranking. Various ornamental elements as gates, arches, and columns, mark higher ranking buildings, such as important governmental, sacred, or military constructions. In contrast, unornamented buildings, like agricultural and industrial architecture, represent the low pole. In this recent study the buildings were classified in two groups of high- and low-ranking according to the Western architectural decorum (see Figure 1 for examples).

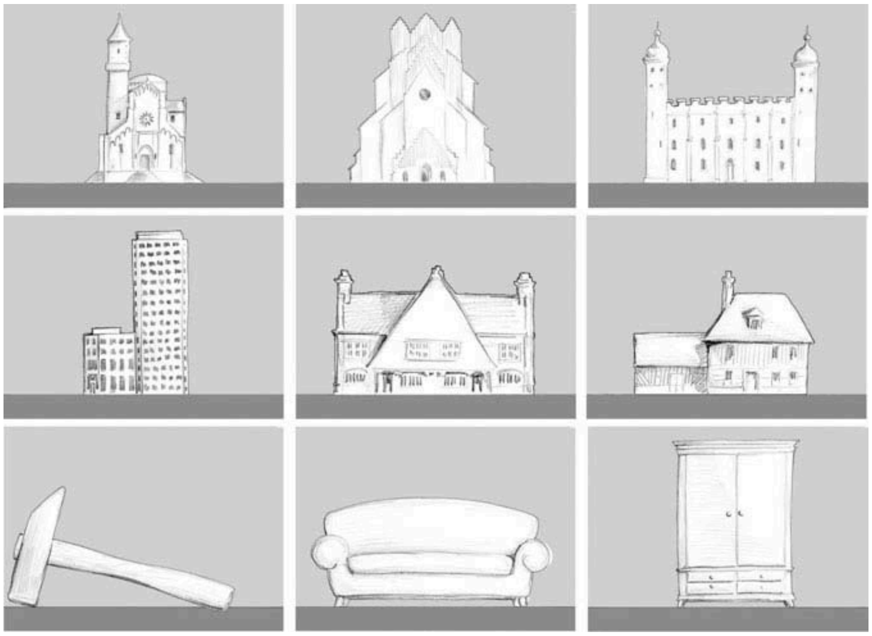

Figure 1. Examples of the high-ranking (upper row), low-ranking (middle row) buildings and the objects (lower row) used in the experiment.

Participants performed an object versus building discrimination task and were unaware of differences in the architectural ranking of the buildings. An early negative potential (N350) between 200 and 400 ms was smaller in amplitude to high- than to low-ranking buildings, suggesting that object model selection was facilitated and object knowledge was more readily available for stimuli indicating higher architectural ranking. Also, a late positive component (labeled as LPP by Oppenheim et al., 2010) following the N350 was enhanced for high-ranking buildings, suggesting that contingent upon successful object selection, secondary visual identification processes including the activation of semantic knowledge or episodic retrieval took place. Interestingly, in our study a group of patients with temporal lobe epilepsy (TLE) with hippocampal sclerosis showed an ENP effect highly similar to that of healthy controls, whereas for the LPC no difference between high- and low-ranking stimuli was observed for these patients. The observation that hippocampal sclerosis selectively eliminates the sensitivity of the hippocampus to architectural ranking suggests that the hippocampus is critically involved in the second stage of visual identification and mediates the activation of semantic and possibly of episodic knowledge for these events (Oppenheim et al., 2010).

An important implication of the aforementioned results is that initial object model selection and secondary visual identification processes are modulated by the perceptual experience with visual stimuli (Tanaka & Curran, 2001). In fact, as the architectural ranking followed the rules of the architectural decorum of Western cultures it is reasonable to assume that the sensitivity of the N350 and the LPC is modulated by experience with these stimuli, such as the number of prior encounters with Western-style building types in media and real life. In other words, it can be assumed that people being born and growing up in a country with prevailing Western-style architecture are experienced in identifying these buildings. This view is also supported by a body of research showing that cultural context can modulate perceptual processes (Miyamoto, Nisbett, & Masuda, 2006; see Nisbett & Miyamoto, 2005 for an overview) and that ERP components like the N350 are sensitive to perceptual expertise (Schendan & Kutas, 2003). Therefore, it may be hypothesized that these effects are restricted to participants with extensive expertise in the Western architectural decorum.

In the present study we investigated the modulation of visual object identification by cultural expertise in a cross-cultural ERP study. Two groups of native German and Chinese participants performed a classification task with high- and low-ranking buildings according to the rules of the Western architectural decorum. All participants were university students and were born and raised either in Germany or in China. They considered the official language of the country as their mother tongue and attended school and university in this country. To make sure that the pictures do not activate personal episodic memories care was taken that the buildings were not identical to buildings existing in reality. The N350 and the LPC were used as electrophysiological estimates of object model selection and secondary visual identification processes, respectively. If facilitated object model selection for high-ranking buildings (as reflected in an attenuated N350) is modulated by cultural expertise with these buildings, the N350 effects should be absent for Chinese participants. In a similar vein, if the processes reflected in the enhanced LPC for high-ranking buildings are determined by the prevailing exposure to Western-style architecture, LPC effects should be revealed for German participants, as in the Oppenheim et al. (2010) study, but attenuated for Chinese participants.

METHODS

Participants

Eighteen native German subjects took part in the experiment conducted at Saarland University, Germany. One participant was excluded because he was not born in Central Europe. All remaining 17 participants (10 female) were students at Saarland University and were born and raised in Central Europe (mean age 22.4 years ranging from 18 to 30 years). Eighteen native Chinese subjects (10 female) participated in the experiment (mean age 22.9 years old, age range 20–25 years). They were all students at Peking University. All Chinese participants were born and raised in China and, with one exception, have not been to a foreign country. All participants indicated to be physically and psychologically healthy, to have normal hearing, and normal or corrected to normal vision. They received payment or course credit for their participation. The study has been approved by the local Ethic committee of Saarland University (Ärztekammer des Saarlands).

Materials

All pictures were grayscale drawings produced by a professional artist and previously used in Oppenheim et al. (2010). Pictures of buildings were designed to represent two categories of high and low-ranking. Care was taken that the pictures in the two categories were matched for size and visual complexity. The stimuli were classified according to the composition and nature of decorated ornamental modules (e.g., columns, archways, facades, vertical/horizontal orientation, etc.) and these modules were arranged according to their supposed ranking postulated by the decorum system (Mühlmann, 1996). With this procedure a total of 120 pictures of buildings were produced (60 high- and 60 low-ranking). In addition, 120 pictures of everyday life objects were designed. For more details on the picture classification procedure, see Oppenheim et al. (2010).

Design and procedure

Informed consent was obtained from each participant before the EEG cap was fitted. The design of the experiment was identical to that employed by Oppenheim et al. (2010). Each trial started with a 200 ms presentation of a stimulus display followed by an inter-stimulus interval ranging from 1700 ms to 1950 ms. Participants' task was to decide whether a given stimulus was an object or a building and to indicate their decision by pressing a respective response key on a keyboard with a left/right index finger. Finger assignment was counterbalanced across participants. The experiment consisted of 240 trials that included 120 objects and 120 buildings (60 high- and 60 low-ranking). Pseudo-randomization ensured that no more than two items from the same category and no more than four buildings were presented subsequently. There was a self-paced break after every 60 trials. Participants were not informed about the inclusion of the two types of buildings. Prior to the start of the experiment, participants went through 10 practice trials to familiarize themselves with the procedure.

Data acquisition

In Germany, electrophysiological data were acquired by means of EEG recording devices and software provided by Brain Products. Continuous EEG data were recorded from 58 silver/silver-chloride electrodes embedded in an elastic cap (Easy-cap). In China, the data was recorded using Neuroscan recording devices and applications. Scalp voltages were recorded with a 66-channel Quick Cap (Neuroscan). In both studies electrode positions of the extended International 10–20 system were used.

In both studies the EEG-recordings were referenced to the left-mastoid and offline re-referenced to the average of the left and right mastoid. Electrooculogram (EOG) was obtained from four electrodes located above and below the right eye and on the outer canthi of each eye. Data were filtered with an amplifier bandpass from DC to 70 Hz (German study) and from 0.05 to 100 Hz (Chinese study) and digitalized at a sampling rate of 500 Hz with a resolution of 16-bit. Electrode impedances were kept below 10 kΩ in both studies. The respective filter settings were the standard settings used in both labs and correspond to the common standards for ERP recordings (Luck, 2005). A digital high pass filter (0.05Hz) was used in the Chinese study to avoid voltage drifts in the EEG data which were less common in the German lab.

Special care was taken to keep offline analyses of the two EEG data sets as comparable as possible. In order to do that, all data were processed using the eeprobe software package (Version 1). A low-pass filter set to 30 Hz was applied and the data were split into individual epochs from 100 ms pre-stimulus to 1200 ms post-stimulus. Epochs containing eye artifacts were corrected using the regression procedure suggested by Gratton, Coles, and Donchin (1983). After eliminating artifact containing trials, mean averages were computed for the conditions of interest for each participant at all recording sites. In the German data, the mean number of artifact-free trials and the respective range contributing to individual subject grand averages was 43 (range: 26–57) and 43 (range: 25–55) for high- and low-ranking buildings and 89 (range: 48–106) for objects, respectively. The respective numbers in the Chinese data were 33 (range 16–56), 35 (range 18–54) and 62 (range 19–109). By this, the signal-to-noise ratio in the conditions of interest (high-, low-ranking buildings) was comparable between both groups. For presentation purposes, the data were further filtered with a low-pass filter set to 12 Hz.

Data analysis

Visual inspection of the electrophysiological data suggested the emergence of an early negativity and a late positivity in the 200–380 ms and 380–560 ms time windows, respectively. Consistent with earlier studies on visual object identification these two components will be referred to as N350 and LPC. An array of nine electrodes taken from frontal (F3, Fz, F4), central (C3, Cz, C4), and parietal locations (P3, Pz, P4) was chosen for the analysis of both components.

Consistent with the main goal of the present study, i.e., to explore the N350 and the LPC to high- and low-ranking buildings and their modulation by cultural expertise, the analyses of the ERP data focused on the two groups of buildings. The ERPs to objects did not enter the statistical analyses but are illustrated for reasons of completeness together with the ERPs to buildings in Figures 2a and 2b. The data from each time window was submitted to a four-way ANOVA with factors Group (German, Chinese), Item Type (high-ranking building, low-ranking building), Location (frontal, central, parietal) and Laterality (left, midline, right). Only effects including factor Item Type or Group are reported. Holm-Bonferroni correction was used for the post-hoc *t*-tests in the aforementioned analyses as appropriate. Huynh-Feld correction was employed in cases when sphericity was violated. Uncorrected degrees of freedom and corrected p-values (two-tailed) and MSE values are reported, unless reported otherwise.

RESULTS

Behavioral results

Accuracy and reaction time data for correct responses to high- and low-ranking buildings are summarized in Table 1. Both German and Chinese participants performed comparably accurately on the categorization task regardless of the item type (> .96% correct for either stimulus condition). This was confirmed by an ANOVA with a within-subject factor Item Type (high-ranking building, low-ranking building) and a between-subject factor Group (German, Chinese) which failed to reveal any significant effects, all *p*-values > .251. Analysis of response times revealed that across groups participants were faster in responding to high-ranking buildings than to

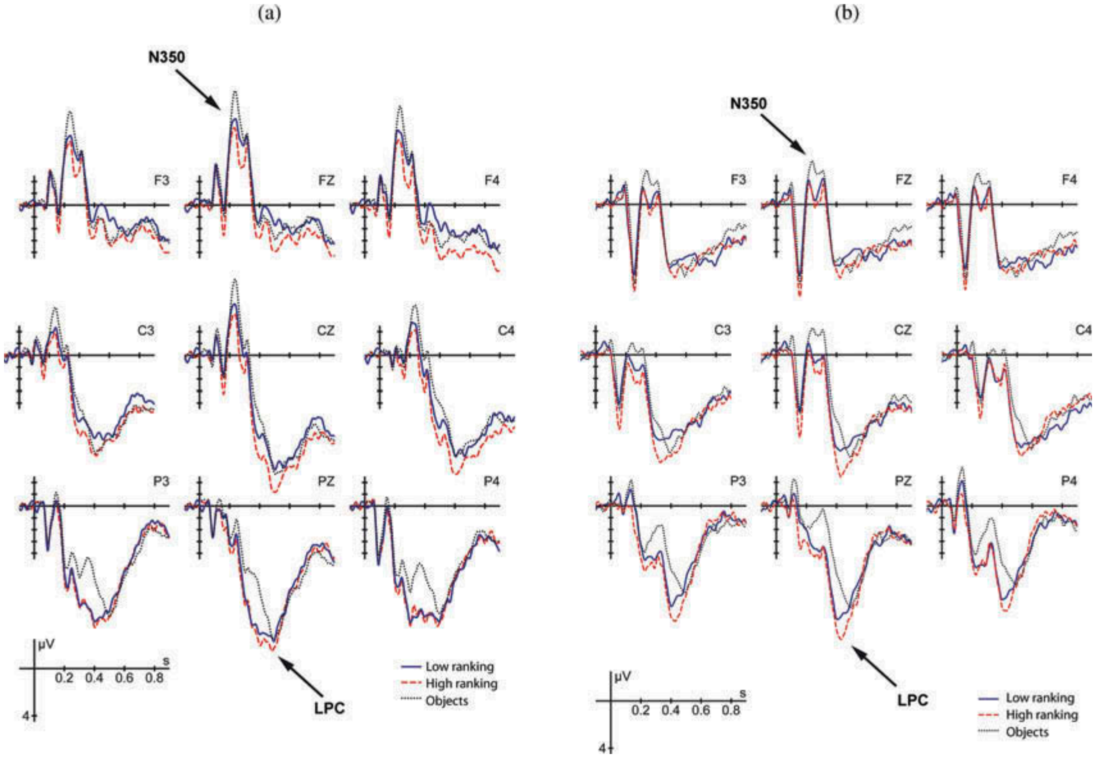

Figure 2. **(a)** Grand average ERPs for the German (Figure 2a) and Chinese (Figure 2b) participants to high- (red dotted lines) and low-ranking (blue lines) stimuli and to objects (dotted lines) at the three frontal (F3, Fz, F4), central (C3, Cz, C4), and parietal (P3, Pz, P4) recording sites. The ERPs to objects did not enter the statistical analyses and are plotted for illustration purpose only in this Figure. ERPs are plotted between –100 and 900 ms and the arrows denote the N350 and the LPC. The N350 to high-ranking buildings was attenuated relative to low-ranking buildings at frontal and central sites. (**b**) Grand average ERPs for the Chinese participants to high- (red dotted lines) and low-ranking (blue lines) stimuli and to objects (dotted lines) at the three frontal (F3, Fz, F4), central (C3, Cz, C4), and parietal (P3, Pz, P4) recording sites. ERPs are plotted between –100 and 900 ms and the arrows denote the N350 and the LPC. For the N350 no differences between high- and low-ranking buildings were found at either recording site.

TABLE 1
Mean accuracy (percent correct) and reactions times for both classes of buildings for the German and Chinese participants (standard error of the mean in parentheses). The corresponding data for objects, which were not included in the statistical analyses, were .96 (German) and .97 (Chinese) and 536 ms (German) and 564 ms (Chinese)

	Accuracy		*Reaction times*	
	High-ranking	*Low-ranking*	*High-ranking*	*Low-ranking*
GERMAN	.97 (.03)	.96 (.03)	501.44 (13.78)	509.86 (14.17)
CHINESE	.97 (.01)	.97 (.01)	537.57 (21.43)	556.66 (22.43)

low-ranking ones (see Table 1), as suggested by a main effect of Item Type, *F*(1, 33) = 11.216, MSE = 3307.74, $p < .01$, whilst yielding no reliable differences between the participant groups, both *p*-values > .121.

ERP results

The grand average ERP waveforms for both groups of participants are illustrated in Figures 2a and 2b. The topographic distribution of the N350 and the LPC for high- and low-ranking buildings are shown in Figure 3. As apparent from the figures, the overall ERP profile was similar in both groups. For both groups the N350 was smaller and the LPC larger for both building types than for objects. Notably, for German participants, ERP differences between high- and low-ranking buildings emerged in the N350 time interval at frontal and central recording sites. The N350 was attenuated for high-ranking buildings at these recording sites, whereas for Chinese participants no such differences were obtained at either recording site. Contrary to that, the LPC was larger for high-ranking than low-ranking buildings in both groups.

These observations were confirmed by the statistical analyses. For the N350 time interval there was a significant Group by Item Type by Laterality interaction, *F*(2, 66) = 3.899, *MSE* = 2.467, *p* = .038, and a marginally significant Group by Item Type by Location interaction, *F*(2, 66) = 3.598, *MSE* = 6.25, *p* = .052. Subsequent *t*-tests revealed a significant N350 difference between low- and high-ranking buildings at frontal and central electrode sites (both *p*-values < .05) for Germans but not for Chinese. For the latter group the N350 did not differ between high- and low-ranking buildings at either of the three levels of the location factor (all *p*-values > .195).

The same ANOVA conducted for the LPC time window, revealed a Group by Item Type by Location interaction, *F*(2, 66) = 6.122, *MSE* = 14.175, *p* = .010. As shown by subsequent *t*-tests, the three-way interaction reflected that for Germans the LPC effect (high-ranking < low-ranking) was significant at frontal and central locations (both *p*-values < .05) but not at parietal sites (*p* = .399), whereas for Chinese participants this LPC effect was more posteriorly distributed. It reached significance at central locations (*p* < .026) and was marginally significant at parietal locations (*p* = .054).

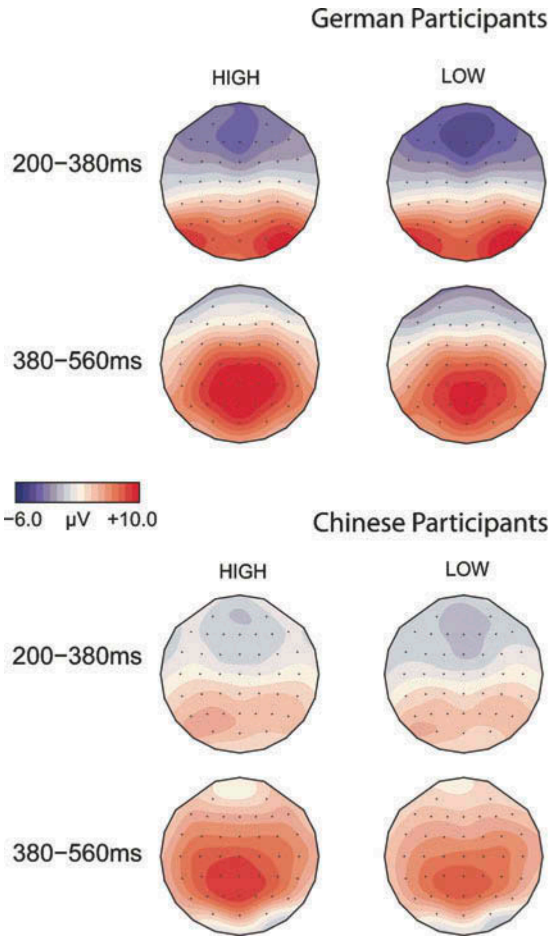

Figure 3. Topographic maps showing the scalp distribution of the ERPs to high-ranking and low-ranking buildings in the time interval of the N350 and LPC for the German (upper part) and the Chinese (lower part) participants.

In sum, for German participants the N350 to high-ranking buildings was smaller than to low-ranking buildings, whereas for the Chinese participants both classes of buildings elicited highly similar N350. Conversely, the LPC was enhanced for high- relative to low-ranking buildings in both groups with this effect showing a more posterior extension for Chinese participants.

DISCUSSION

We investigated the modulation of visual object identification by visual expertise in a cross-cultural ERP study. As object knowledge and object identification are sensitive to prior perceptual experience (Tanaka & Curran, 2001; Schendan & Kutas, 2003), we assumed that object knowledge about Western-style buildings ranked according to the architectural decorum should be specific to Westerners. Being born and raised in a culture with prevailing Western-style architecture, they should have a larger number of encounters with Western-style high-/low-ranking buildings in their daily lives than East Asians and we explored whether this cultural variance is reflected in differential ERP correlates of visual object identification. Classification performance was high and not affected by cultural expertise and response times in both groups were faster for high-ranking buildings. Confirming our predictions, cultural expertise modulates the identification of buildings at the early stage of visual object identification, i.e., object model selection, at which an object model is selected from long-term memory and matched to an incoming percept. The N350, an ERP component that has been implicated in object model selection, was smaller for high-ranking than for low-ranking buildings for German participants. This suggests that the appropriate building model is more easily accessible during the matching process and as a consequence categorization is facilitated for high-ranking buildings. Notably, this effect was obtained even though the task did not require an overt classification of both classes of buildings and by this confirm the implicit nature of object knowledge activation as reflected in the N350 (Schendan & Maher, 2009). Consistent with the smaller N350 to canonical than unusual views of objects (Schendan & Kutas, 2003) the effect may reflect the higher familiarity of the buildings in the high-ranking category. This effect was virtually absent for Chinese participants for whom fewer encounters with high/low-ranking Western architecture in media and daily life can be assumed. This may suggest that object models in long-term memory that match with the percepts of Western-style buildings were not as readily available in Chinese as in German participants. An objection against the view that object model selection is facilitated in German but less so in Chinese participants could be that no supporting behavioral evidence was obtained as reactions times were speeded up for high-ranking buildings in both groups. However, it is well conceivable that object models were in fact more accessible for the German participants and that ERP measures were simply more sensitive to pick up these effects as compared to behavioral measures, which are more indirect in nature, and the present study did not even require to discriminate between high- and low-ranging buildings.

In a later time window, in which secondary (post model selection) identification processes take place, a mixed pattern of results was obtained. Firstly, the LPC an ERP component, that is associated with this second stage of visual object processing was larger for high-ranking than for low-ranking buildings for German and Chinese participants, albeit this effect also propagated to more posterior recording sites for Chinese participants. Finding highly similar LPC high > low effects across groups together with the highly comparable ERP waveforms across groups in other portions of the waveforms (except for the N350 time window) confirms the view that ERP data were indeed comparable across groups.

After object model selection, secondary identification processes are initiated that comprise the activation of object-associated knowledge, name retrieval, and also episodic memory processes like the incidental recollection of prior encounters with a similar building, all of which are associated with late positive ERP components (Mecklinger, 2000; Schendan & Kutas, 2007). The present finding of larger LPC for high-ranking than for low-ranking buildings in both groups of participants suggests that high-ranking buildings activate a larger amount of knowledge associated with the buildings or gave rise to more recollective processing. For example, it has been shown that salient pictorial cues can initiate incidental recollection of prior encounters with an object and that this is associated with an enhanced LPC (Richardson-Klavehn & Gardiner, 1995). The minor expertise of the Chinese participants with Western-style buildings may have been sufficient to trigger this recollective processing. Also, mere attempts to retrieve episodic memories are associated with late positivities with similar temporal characteristics (Mecklinger, Parra, & Waldhauser, 2009). Thus, it is conceivable that high-ranking buildings to a larger extent than low-ranking buildings activate personal memories or give rise to mere retrieval attempts and this may have also facilitated the classification of these buildings, as reflected in their faster response times relative to low-ranking ones. Even though the high > low-ranking LPC effect was similar in magnitude in both groups it showed a more posterior distribution for the Chinese participants. This may suggest that the same episodic and semantic memory operations were engaged in both groups, but that the representations of the stimuli employed may not have overlapped entirely in both groups.

Another potential objection, that could raise the question of validity, concerns the fact that East Asian buildings rank ordered on a similar rule-system were not explored and by this only a single dissociation was found. It is certainly true that care has to be taken before strong conclusions can be drawn on the functional roles of ERP components on the basis of a single dissociation as the one found here. Admittedly, the present findings are exploratory in nature and require confirmation by data showing complementary effects with rank-ordered East Asian buildings. Nonetheless, in support of our conclusions the present between-group differences were highly specific. It was only at the initial stage of object identification at which object model selection most likely takes place where group differences were obtained. At a later processing stage, similar LPC effects (albeit differing in scalp topography) were obtained for both groups. As N350 effects of a similar kind have been related to better accessible memory traces (object models) as, for example, the smaller N350 for canonical than unusual views of objects (Schendan & Kutas, 2003) as discussed before, we conclude that this early stage of object identification may be facilitated in participants with perceptual expertise with Western-style architecture.

The present data support the view that cultural environment affects visual cognition (Miyamoto et al., 2006) and provides novel evidence that object model selection is facilitated for buildings with high architectural ranking according to the Western architectural decorum for participants born and raised in Central Europe, but not for East Asian participants with much lower visual encounters with Western-style architecture. At a later stage of object identification, in which object-associated semantic and episodic knowledge is activated, no electrophysiological evidence for cultural differences was obtained and these late effects reflect a mixture of secondary identification processes and strategic effects of task performance. Further studies, exploring cultural differences in perceptual expertise that use stimuli from both cultures (see Miyamoto et al., 2006 as an example), are required to better understand how cultural expertise affects a process as basic as object identification.

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