The spatial frequencies influence the aesthetic judgment of buildings transculturally

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Recent evidence has shown that buildings designed to be high-ranking, according to the Western architectural decorum, have more impact on the minds of their beholders than low-ranking buildings. Here we investigated whether and how the aesthetic judgment for high- and low-ranking buildings was affected by differences in cultural expertise and by power spectrum differences. A group of Italian and Japanese participants performed aesthetic judgment tasks, with line drawings of high- and low-ranking buildings and with their random-phase versions (an image with the exact power spectrum of the original one but non-recognizable anymore).

Irrespective of cultural expertise, high-ranking buildings and their relative random-phase versions received higher aesthetic judgments than low-ranking buildings and their random-phase versions. These findings indicate that high- and low-ranking buildings are differentiated for their aesthetic value and they show that low-level visual processes influence the aesthetic judgment based on differences in the stimuli power spectrum, irrespective of the influence of cultural expertise.

**Keywords:** Visual processing; Aesthetic judgment; Visual aesthetic perception; Architecture; Decorum.

In both Western and Eastern cultures the exposure to buildings presenting different architectural styles is a common daily experience. Although people intuitively know that the characteristics of their own public and private built environment can affect their quality of life and have an impact on their mental functioning, surprisingly only a few studies addressed the question of the cognitive and affective processes than can be triggered by the architectural stimuli (e.g., Vartanian et al., 2013; see for commentaries, Goldstein, 2006; Sternberg & Wilson, 2006). Functional imaging studies have identified brain regions within the ventral visual pathway involved in the visual processing of buildings (e.g., Aguirre, Zarahn, & D’Esposito, 1998; Epstein & Kanwisher, 1998), although whether or not these findings suggest the existence of a specific module for building perception is still under debate (e.g., Ishai, Ungerleider, Martin, Schouten, & Haxby, 1999).

Interestingly, some recent electrophysiological studies (Mecklinger, Kriukova, Mühlmann, & Grunwald, 2014; Oppenheim et al., 2009, 2010) have shown that visual perception of buildings and its neural correlates are sensitive to the architectural ranking of buildings, which follows, at least in the Western cultures, the rules of the classical architectural decorum. 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). According to this system, which traces back to Vitruvius’s Ten books on architecture, and has evolved into modernity, all the buildings can be scaled between the poles of “high ranking” or sublime and “low ranking” (Mühlmann, 1996).

In this system, the architectural modules and ornaments that served to signify the “high ranking” included arches, columns, gates, and temple fronts. They were designed (both by the architectural evolution and by individual architects) to be outstanding—thus attracting attention and becoming “unforgettable”—and to elicit the feeling of imperium/maiestas. In general, the architectural modules indicating higher ranking were reserved for public sacral buildings and constructions associated with matters of political and military sovereignty. These modules were not used in the unornamented “low-ranking” buildings associated with economy (agricultural and industrial architecture) or biological reproduction (the private and profane life).

If the decorum system actually succeeded in making high-ranking buildings more prominent, one might expect that visual encounters with these modules and ornaments leave traces of their cultural prominence in the beholder’s memory and that visual-semantic processing of high-ranking buildings is facilitated compared to low-ranking buildings.

This assumption has been verified for the first time in an ERP study (Oppenheim et al., 2010), in which participants performed an object versus building (including high- and low-ranking buildings) discrimination task. Although participants were unaware of the two categories of buildings, ERPs differentiated between pictures of high- and low-ranking buildings: An early negative potential (N350) was smaller in amplitude to high- than to low-ranking buildings, indicating that visual object categorization was facilitated for high-ranking stimuli, and a late positive potential (LPP) was enhanced for high-ranking buildings suggesting that also the categorization-related processes (e.g., retrieval of semantic knowledge and name, and possibly of episodic knowledge) were facilitated. This late effect was compromised in patients with hippocampal sclerosis, in line with previous evidence on the contribution of the hippocampus proper to semantic processing of visual objects (e.g., Vannucci et al., 2003, 2006).

In a more recent ERP study, Mecklinger et al. (2014) found that cultural differences only partially modulated the ERP responses evoked by high- and low-ranking buildings during the categorization task: The N350 was smaller for high-ranking than for low-ranking buildings in German participants but not in Chinese. However, the late positive component (LPC) was enhanced for high- relative to low-ranking buildings in both groups. As suggested by the authors, the highly specific effect of culture on the early process of categorization (N350), may reflect the higher incidence of visual encounters (high level of familiarity) with Western-style high-ranking buildings reported by German participants, which might have facilitated their categorization.

Here, we aimed to investigate, in a cross-cultural perspective, the effects of the architectural ranking on the visual aesthetic judgment of buildings. According to the model proposed by Chatterjee (2003; see also Leder, Belke, Oeberst, & Augustin, 2004), adapted from the cognitive neuroscience of vision, visual aesthetic perception involves a complex hierarchy of processes, including perceptual and recognition processes common to the processing of any other visual object, plus the additional activation of emotional processes (state of pleasure or satisfaction in case of beauty). The final resulting experience of beauty arises from the interaction between the properties of the stimulus (e.g., complexity, novelty, symmetry, contour, proportion, and balance; Di Dio, Macaluso, & Rizzolatti, 2007; Vartanian et al., 2013) and the perceiver’s cognitive and affective processes (e.g., personality, expertise in art; in Furnham & Walker, 2001; Kirk, Skov, Christensen, & Nygaard, 2009), with the latter being influenced by the personal experiences of the individual and by the cultural context (e.g., Jacobsen, 2006). To date, no systematic investigation of the visual aesthetic judgment for high- and low-ranking buildings has been reported.

Following an interactionist approach, in the present study we questioned whether and how the aesthetic perception of high- and low-ranking buildings was affected by cultural differences and by low-level physical characteristics. On one hand, one might argue that since the distinction between high- and low-ranking buildings was based on the rules of architectural decorum developed in Western cultures, high-ranking buildings would be perceived as more appealing than low-ranking buildings only by Western observers. However, there is also evidence that higher-order statistical properties of visual images contribute to aesthetic appearance. For example, some studies (Redies, 2007; Redies, Hasenstein, & Denzler, 2007; Spehar, Clifford, Newell, & Taylor, 2003) have shown that works of art (of different cultures, techniques, and subject matters) and natural scenes share similar degree of scale invariance and fractal-
like properties and that humans have a consistent aesthetic preference across fractal images, regardless of the type of image (natural, man-made, or computer-generated).

Globally, these findings indicate that visual aesthetic judgment is also tightly linked to visual perception and neural function (Gregory, Harris, Heard, & Rose, 1995; Ramachandran & Hirstein, 1999; Zeki, 1999) and suggest that aesthetic appreciation probably relates to general aspects of visual information processing that are implemented by our visual brain (Redies, 2007). The idea that some specific combination of spatial frequencies can be considered more pleasant than others, was somewhat inspired by the above-mentioned research and by the results showing that just a few lines can change the perceptual meaning of an artwork (e.g., Burr, 2000; Gori, Pedersini, & Giora, 2008; Troncoso, Macknik, & Martinez-Conde, 2009). These results may suggest that very low-level characteristics of the stimulus could influence a complex cognitive process like the aesthetic judgment.

Since high- and low-ranking buildings are composed of different architectural modules (e.g., arches, columns, gates), the repetition of these modules in their facades affects systematically their spatial frequency. Our visual system is evolved to be very sensitive to differences in the power spectrum. Consequently, different power spectra could lead to different aesthetic judgments. If it is true, we should find differences in the aesthetic judgment between high- and low-ranking buildings also when the phase of sinusoidal waves composing their power spectrum is randomized (random-phase version from now on). This process, based on the Fourier transformation, produces unrecognizable images without changing their respective power spectra. In this case, a similar pattern of response might be expected in both Western and East Asian samples of participants, because the difference in the aesthetic judgment should be related to a basic processing of the visual system that it is not supposed to be influenced by differences in cultural experience, namely, differences in the amount of visual encounters with Western-style architecture (which is much higher in Western compared to East Asian observers).

To investigate the modulation of aesthetic judgment by differences in cultural expertise and by differences in the power spectra between high- and low-ranking buildings, we asked two groups of native Italian and Japanese participants to perform two aesthetic judgment tasks, one with a standardized set of line drawings of high- and low-ranking buildings (Task 1) and the other one with the “random-phase version” of the same buildings (Task 2).

**METHOD**

**Participants**

Twenty-three native Italian participants, psychology students of the University of Florence (11 females; mean age = 25.2 years, SD = 2.6) and 23 native Japanese participants, psychology students of Kanazawa University (14 females; mean age = 21.00 years, SD = 1.8), participated in the experiment. All the participants had normal or corrected-to-normal vision, normal hearing, and were born and raised respectively in Italy and Japan, and had not been to a foreign country for long periods. None of them had formal education/training in visual arts or architecture or interest in artootnote{Interest in architecture was assessed by administering participants a modified version of the nine-item “questionnaire on art interest” developed and employed in their study by Leder, Carbon, and Ripsas (2006) for visual art and here adapted for architecture.} in the field. The study was approved by the local research committee. All participants gave their genuine informed consent.

**Stimuli**

Two sets of stimuli were used: A set of line drawings of buildings and a set of random-phase versions of the same buildings.

*Buildings:* 120 black-and-white drawings of fictitious buildings (including 60 high and 60 low ranking) taken from a standardized set of stimuli, already employed in previous experiments (Mecklinger et al., 2014; Oppenheim et al., 2009, 2010), were used. 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). More details on the stimuli can be found in Oppenheim et al. (2010). To make sure that the pictures do not activate personal episodic memories, in the development of the set care was taken that the buildings were not identical to buildings existing in reality. A sample of the stimuli is reported in Figure 1 (upper row).

To control for the possible effects of familiarity, visual complexity, and typicality of the buildings on the aesthetic judgment, we asked a different group of Italian (n = 20) and Japanese (n = 20)
students to perform three rating tasks, one for each property.\(^2\)

**Random-phase version:** Random-phase versions of the buildings were created using the procedure already employed by Giora and Gori (2010): Line drawings of buildings were fast Fourier transformed, their power spectra was computed, the phases of the sinusoidal components waves were randomized, and finally, the inverted fast Fourier transformation was applied. The result was a series of stimuli with a different structure and appearance from the original buildings but with the same power spectrum and mean luminance. A sample of the stimuli is reported in Figure 1 (lower row).

**Procedure**

Informed consent was obtained from each participant. Participants were placed in a comfortable chair in a sound attenuated room, facing a portable computer screen at a distance of 57 cm, and they were asked to perform two aesthetic judgment tasks in the following order: The first one with pictures of buildings and the other one with the random-phase versions. The procedure was the same in both tasks:

\(^2\)In each task, the 120 line drawings of buildings were displayed centrally on a high-resolution computer monitor for two seconds, one at a time, and participants were requested to express a judgment by pressing one of five buttons on the keyboard, ranging from 1 to 5: Button 1 indicated the lowest degree of familiarity (unfamiliar), visual complexity (visually simple), and typicality (bad example of the category in question), and button 5 indicated the highest degree (very familiar, very complex, good example of the category in question). All participants performed first the familiarity task and then half performed the visual complexity and typicality, while for the other half the task order was inverted. For each building, the mean rating for familiarity, visual complexity, and typicality was calculated over the participants.

On each trial, the word “beauty” was presented centrally for 1000 ms on a gray background, followed by a stimulus (building or random-phase image) presented for 2000 ms. Participants were instructed to press one of seven buttons to indicate their aesthetic judgment (1 = *very unappealing*, 7 = *very appealing*). Each task consisted of a training phase and an experimental phase divided into three blocks with a two-minute rest period between each block. The order of the stimuli in each block was pseudo-randomized across subjects. The session lasted approximately 25 minutes.

**RESULTS**

Two separate analyses were carried out, one on responses to buildings and the other one on responses to the altered-versions of buildings (random-phase versions).

**Buildings**

A 2 (Ranking: High and low) × 2 (Group: Italian and Japanese) mixed model ANOVA conducted on the mean ratings of aesthetic judgment revealed that high-ranking buildings were judged as more appealing \((M = 4.30, SD = 0.71)\) than low-ranking buildings \((M = 2.96, SD = 0.77)\) \([F(1, 44) = 161.52, p < .01, \eta^2 = .47]\). The interaction Ranking by Group was also significant, \([F(1, 44) = 13.36, p < .01, \eta^2 = .07]\). Post hoc tests (Bonferroni) showed that the difference between the two groups was significant for high-ranking buildings \((p < .01)\), for which Italian participants reported higher aesthetic judgment \((M = 4.55, SD = 0.62)\) than Japanese \((M = 4.04, SD = 0.71)\).
Since Japanese participants judged high-ranking buildings as less familiar than Italian participants, we performed a second analysis on a subset of high-ranking buildings ($n = 18$) matched for familiarity. At $t$-test, the difference between the two groups in the aesthetic judgment was not statistically significant ($t < 1$).

**Random-phase versions**

A $2 \times 2$ mixed model ANOVA conducted on the mean ratings of aesthetic judgment revealed that random-phase versions of high-ranking buildings were judged as more appealing ($M = 3.43$, $SD = 0.82$) than random-phase versions of low-ranking buildings ($M = 3.11$, $SD = 0.95$) [$F(1, 44) = 22.33; p < .01$, $\eta^2 = .33$]. Neither the effect of Group nor the interaction was significant, confirming that Japanese and Italian participants did not significantly differ in their aesthetic judgment.

The significant advantage of random-phase versions of high-ranking compared to low-ranking buildings was confirmed by a complementary analysis. For each participant, we calculated the distribution of aesthetic judgments for all the random-phase images and we selected the images that received top judgments (top 16% of the aesthetic judgment values). We therefore calculated the proportion of high- and low-ranking images included in this subset of the “most appealing” images. We found that in both groups of participants the random-phase versions of high-ranking buildings were overrepresented in the top 16% of aesthetic judgment values of each subject (Italian: 70%; Japanese: 61%) (chi square $(1) = 30.394$, $p < .001$), suggesting that in both groups, the random-phase versions of high-ranking buildings were evaluated as more aesthetically pleasing than the low-ranking counterparts.

**DISCUSSION**

At least in Western cultures, from the Roman times, specific architectural ornaments and modules (e.g., arches, columns, gates, temple fronts) have been used to make religious and state (seats of government) buildings prominent and outstanding (e.g., attracting attention and being memorable). Recent ERP studies with Western participants (Oppenheim et al., 2009, 2010) have shown that high-ranking buildings have, indeed, more impact on the minds of their beholders than low-ranking buildings, being facilitated in both categorization processes and retrieval of semantic and possibly episodic knowledge, compared to the low-ranking counterparts.

Here, we asked whether also the visual aesthetic judgment of buildings was sensitive to the rules of the classical decorum system, with high-ranking buildings judged as more appealing than low-ranking ones. Thus, we examined the effects of cultural expertise and low-level properties of the visual stimuli (specific spatial frequency domains characterizing the stimulus) on this process.

To this aim, we asked a group of native Italian (Western) and Japanese (East Asian) students to perform two aesthetic judgment tasks: One with the standardized line drawings of high- and low-ranking buildings and one with their random-phase versions.

In the first task, we found that high-ranking buildings were judged by both groups as more aesthetically appealing than low-ranking buildings. Interestingly, in the second task, the same pattern of differences was found also with the random-phase versions of the stimuli: Both groups judged the random-phase images of high-ranking buildings as more aesthetically appealing compared to the low-ranking counterparts. This result was also confirmed by the higher proportion of random-phase images of high-ranking buildings included in the subset of the “most appealing” random-phase images in both groups.

These findings clearly show, for the first time, that the differences in the power spectrum of the visual stimuli affect and contribute to the visual aesthetic judgment, and that the differences in the power spectrum between high- and low-ranking buildings could lead to differences in the aesthetic judgment for buildings in both Western or East Asian observers.

Our “spatial frequency effect” is consistent with the results of previous studies showing that higher-order statistical properties of visual images contribute to the aesthetic appearance (e.g., Mallon, Redies, & Hayn-Leichsenring, 2014; Redies, 2007; Redies et al., 2007). Our findings also provide relevant empirical support to the biological/neuroscientific approach in the field of experimental aesthetics, which suggests that visual aesthetic judgment is tightly linked to low-level visual perception and that aesthetic appreciation probably relates to general aspect of visual information processing that are implemented by our visual brain (Redies, 2007).

Although our findings demonstrate the effect of low-level visual processes on the aesthetic judgment, they do not deny the contribution of other factors,
related to the characteristics and experiences of the perceiving subject, as the level of familiarity with the stimuli. In our study, Italian participants reported higher aesthetic judgments for high-ranking buildings compared to Japanese, and this effect was due to the higher level of familiarity with high-ranking buildings reported by Italian participants. These findings are consistent with the positive effect of familiarity on the aesthetic judgment reported in some previous studies (e.g., Cutting, 2003; Zajonc, 1968), and with the effect of familiarity on the process of categorization of buildings reported in the recent cross-cultural study by Mecklinger et al. (2014).

Future developments

Our pioneering findings pave the way for potentially exciting future interdisciplinary cross-cultural studies that can systematically investigate how biological/perceptual processes and preferences might have implicitly affected architectural rule systems. In particular, an important contribution in understanding the neural mechanisms underlying the “spatial frequency effect” on the aesthetic judgment may come from the application of neuroscience measures (for a review on neuroaesthetics, see Chatterjee & Vartanian, 2014).

Previous studies on the aesthetic judgment for novel graphic patterns have found that ERP responses dissociated beautiful from not-beautiful geometrical shapes as early as 300–400 ms after the stimulus onset, showing a two-stage ERP pattern of response (e.g., Jacobsen & Höfel, 2003). Neuroimaging studies have shown that visual aesthetic appreciation engages brain structures implicated in evaluating reward-based stimuli, suggesting that preferred/beautiful stimuli act as rewards and their appreciation generates a rewarding experience (for a meta-analysis, see Brown, Gao, Tisdelle, Eickhoff, & Liotti, 2011).

Future studies are expected to investigate whether our brain might feel more rewarded by the aesthetic appreciation of high- compared to low-ranking buildings, whether this experience might also arise during the aesthetic judgment of meaningless but somewhat pleasant visual patterns, and how spatial frequency component processing contributes to the aesthetic feeling. Another intriguing future aim could be to consider how eye movements and fixation patterns may be modulated by the spatial frequency content of high- and low-ranking buildings, which may, in turn, modulate aesthetic appreciation. In support of this hypothesis, a recent research (McCamy, Otero-Millan, Di Stasi, Macknik, & Martinez-Conde, 2014) has found that highly informative regions of natural scenes produce longer fixation durations and higher microsaccade rates during free-viewing than regions where information content is low.

Cross-cultural studies are required to better understand the quality of the aesthetic experience reported by Western and East Asian participants: The fact that Italian and Japanese participants reported a similar behavioral pattern of aesthetic judgment challenges future study in investigating whether similar or different covert patterns of neural activity underlie the similar overt aesthetic judgment.

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