

# High and low spatial frequencies in website evaluations

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## **Abstract**

Which features of websites are important for users' perceptions regarding aesthetics or usability? This study investigates how evaluations of aesthetic appeal and usability depend on high vs. low spatial frequencies. High spatial frequencies convey information on fine details, whereas low spatial frequencies convey information about the global layout. Participants rated aesthetic appeal and usability of 50 website screenshots from different domains. Screenshots were either presented unfiltered, low-pass filtered with blurred targets, or high-pass filtered with high-pass filtered targets. The main result is that low spatial frequencies can be seen to have a unique contribution in perceived website aesthetics, thus confirming a central prediction from processing fluency theory. There was no connection between low spatial frequencies and usability evaluations, whereas strong correlations were found between ratings of high-pass filtered websites and those of unfiltered websites in aesthetics and usability. This study thus offers a new perspective on the biological basis of users' website perceptions.

Keywords: aesthetics; usability; website evaluation; website perception; spatial frequency

## **Statement of significance**

This research links ergonomics to neurocognitive models of visual processing. We investigate how high and low spatial frequencies, which are neurologically processed in different visual pathways, independently contribute to users' perceptions of websites. This is very relevant for theories of website perceptions and for practitioners of web design.

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## 1. Introduction

As the impact of the World Wide Web on our daily business and private life is still growing, the quality of websites has become more and more important in satisfying users' needs. In an effort to enhance the quality of websites, designers are increasingly relying on user evaluations of websites, collecting ratings of overall user reactions and of opinions on specific features, such as usability, aesthetic appeal, or intelligibility of content. Especially in business contexts, this has led to many well-designed websites that look extremely similar to each other. This is our first indication that perceptions of websites may be brought about by very basic cognitive processes that are similar across different users.

But what are the processes that give rise to web users' perceptions of websites? How are these altered by the properties of websites? These and related questions have been the subject of much interest since Kurosu and Kashimura's (1995) seminal publication on the influence of aesthetics on usability measurements. Over the last several years, aesthetics and related qualities, such as pleasantness and enjoyability, have become more and more important for researchers as well as for practitioners. This interest has been triggered by two trends in ergonomics in general. First, there has been a general trend to look beyond pure instrumental factors (e.g., Lindgaard and Whitfield 2004, Liu 2003, Mack and Sharples 2009); this trend has also arisen within the domain of website design (e.g., Moshagen and Thielsch 2010, Schenkmann and Jönsson 2000, Schmidt *et al.* 2009, Tarasewich *et al.* 2001). Second, some authors are interested in the link between aesthetics and usability (e.g., Thüring and Mahlke 2007, Tractinsky *et al.* 2000) – this is best reflected in Norman's (2004) claim that “attractive things work better”. Given the enormous amount of time people spend online (Nielsen//NetRatings 2009), every factor that might enhance the effectiveness of human-computer interaction is of great importance. There is some recent evidence, for instance, that aesthetics has a beneficial effect on users' search-task completion times (Moshagen *et al.* 2009, Sonderegger and Sauer 2010).

Whether one wants to look at aesthetics in isolation or at its' relation to usability, a major aim research in ergonomics has to develop an adequate understanding of the processes that give rise to aesthetic perception. A great number of psychological theories on aesthetic perception have been cognitive in nature (for a review see Martindale 2007). They mostly agree on the relevance of fast, unconscious processes that determine if a stimulus is perceived as more or less aesthetic pleasant (Zajonc 1980). The processing fluency theory (Reber *et al.* 2004) integrates the various factors that affect aesthetic perceptions into a common framework. The main concept is that the more fluently perceivers are able to process an object, the more positive will be their aesthetic response. Winkielman *et al.* (2006) uncovered empirical evidence for this theory related to the prototypicality of design elements. Based on the results of their experiments, they suggest that the preference for prototypical stimuli arises partly from a general mechanism linking fluency and positive affect. By linking aesthetic perception to perceptual processes, this theory provides a unifying framework to explain why some design variables, such as figural precision, figure-ground contrast, and symmetry, enhance perceived aesthetics. Furthermore, the processing fluency theory can be used to link aesthetic judgements to neurocognitive models of visual processing.

From neurocognitive studies, we know that the human visual system operates on two parallel pathways: a very fast magnocellular and a slower parvocellular pathway. This differentiation can already be seen in retinal ganglion cells that project either magnocellular or parvocellular cells. Importantly, these two pathways can best be thought of as different modules, each tuned to specific spatial frequencies (Marr 1982). During visual processing, visual input is decomposed into various frequency components (see Figure 1 for the decomposition of a website screenshot), in a process akin to Fourier analysis. While the magnocellular pathway conveys very coarse information based on low spatial frequencies, the parvocellular pathway provides highly detailed information based on high spatial frequencies. Several studies have investigated the importance of different frequencies for various tasks (Collin and McMullen 2005; Kveraga *et al.* 2007; Shyns and Olivia 1994). Generally there is evidence that high spatial frequencies play an important role in making distinctions based on fine details (Collin and McMullen 2005), whereas low spatial frequencies are important for rapidly extracting the overall gist of a scene (Kveraga *et al.* 2007; Shyns and Olivia 1994). Based on these findings, it has been suggested that icons in software applications should be easily discernable on the basis of low spatial frequency information (Queen 2006). Very fast low spatial frequency information is thought to trigger top-down predictions concerning those objects that enhance the ease of processing (Bar *et al.* 2006; Kverga *et al.* 2007), which is critical for answering the question of which of these two types of information drives the perception of websites.

Furthermore, several experimental studies support the hypothesis that very rapid processes form the basis of aesthetic judgements (Lindgaard *et al.* 2006; Tractinsky *et al.* 2006; van Schaik and Ling 2009). These studies investigated the stability of judgments on website attractiveness using stimuli of different presentation times. But since high spatial frequency information is processed much more slowly than is low spatial frequency information, these studies imply important constraints as to which information is important for making said judgments. Tractinsky and colleagues (2006) asked participants to evaluate 50 website screenshots and found high correlations ( $.86 \leq r \leq .95$ ) between ratings given after brief exposures (500 ms) and ratings given after free viewing (for 10 s). Lindgaard *et al.* (2006) further compared ratings given after 50 ms exposures to those given after 500 ms exposures and also found remarkably high correlations between both conditions ( $r = .95$ ). The study by Lindgaard and colleagues in particular suggests that very fast processes, most likely based on low spatial frequencies, are central to aesthetic perceptions. Van Schaik and Ling (2009) provided further evidence for the stability of the evaluation of visual website aesthetics over time, replicating the former studies while using different task contexts.

The aim of the current study is to test the predictions of processing fluency theory within the context of website perception. If aesthetic judgments are altered by those factors enhancing the speed with which a website can be cognitively processed (Reber *et al.* 2004), and if low spatial frequency information enhances the ease of processing (Kveraga *et al.* 2007), then low spatial frequency information should make a strongly unique contribution to aesthetic judgments.



Figure 1. Effects of spatial filtering on website screenshots. Top: unfiltered; middle: low-pass filtered; bottom: high-pass filtered (contrast was adjusted to optimise for print).

Three different groups of participants evaluated the perceived aesthetics and the perceived usability of a set of 50 websites. Screenshots of these websites were either presented unfiltered, corresponding to a natural viewing experience; high-pass filtered, so that all low spatial frequency information is removed; or low-pass filtered, without high spatial frequency information. Each participant only saw the screenshots under one of the three conditions. Similarly to studies on the timing of aesthetic judgements (Lindgaard *et al.*, 2006; Tractinsky *et al.*, 2006, van Schaik and Ling 2009), the correlations between the ratings of the original, unfiltered website image and the two spatially filtered images are of main importance. The underlying rationale

is as follows: if low spatial frequency information is important for aesthetic judgments, we should find a high correlation between ratings of unfiltered screenshots and ratings of screenshots that contain only low spatial frequency information. We also use multiple regressions to test whether the ratings of the two filtered website images explain unique variance in the ratings of the original image.

## **2. Method**

### **2.1 Participants**

Ninety-one participants took part in the experiment: 34 saw the unfiltered screenshots, 30 saw the high-pass filtered screenshots and 27 viewed the low-pass filtered screenshots. Participants were between 19 and 86 years old ( $M = 36.69$ ;  $SD = 16.07$ ). Sixty-one of the participants were female, and 30 were male. Additional 33 persons started the experiment but dropped-out before the end of the study or gave the same response to all screenshots. Such drop-out is very common in online studies (e.g., Birnbaum 2004) and leads to differences in our group sizes. We performed several analyses with a randomly chosen subset of 27 participants from each group. These analyses led to very similar results: The maximal deviation between correlations was 0.02, the maximal deviation in beta-weights was 0.03.

### **2.2 Stimulus material**

A review and integration of previous categorization schemes for websites (e.g., De Marsico and Levialdi 2004, Hoffmann *et al.* 1995, Hong and Kim 2004) identified ten different content domains. These domains were labelled ‘e-commerce’, ‘entertainment’, ‘e-learning’, ‘e-recruitment’, ‘information sites’, ‘communication and community sites’, ‘web portals’, ‘corporate websites’, ‘social software’, and ‘search engines’ (Thielsch 2008, p. 87). To ensure diversity of the stimuli, for each content domain five typical sites, as indexed by high Google ratings, were selected. This set of fifty websites was developed to represent a maximum possible range of institutional and corporate websites in Germany and is in use in several ongoing research projects (e.g., Moshagen and Thielsch 2010).

Screenshots of these websites always showed the index page for the site. Screenshots were scaled to 640X480 pixels (so that they subtended a maximum of 9 deg visual angle if seen from a distance of 100 cm on a 21' CRT) and filtered using Adobe Photoshop. Unfiltered website screenshots were transformed to greyscale to exclude the selective effects of colour (high- and low-pass filtering distorts colour). Low-pass filtering was performed using a Gaussian blur filter with a 6.1 pixel kernel, resulting in images low-pass filtered at  $\approx 6$  cycles per image. For the high-pass filter, we used the Adobe Photoshop high-pass filter set to a radius of 0.1 to 0.3 pixels, resulting in images high-pass filtered at  $\approx 30$  cycles per image, followed by an adjustment of luminance and contrast (see Figure 1).

### **2.3 Procedure**

A three-group between-subjects design was used. The three conditions were: unfiltered website screenshots in greyscale, high-pass, and low-pass filtered website screenshots. Websites were presented online within custom-made software (Hirschfeld *et al.* in press) that allowed for a randomised presentation of the 50 screenshots. Randomisation was used to avoid systematic errors while presenting stimuli in a fixed order (Liu and Salvendy 2009). After some initial information about

the study, each of the participants were presented with the screenshots along with two items measuring perceived aesthetics and perceived usability, respectively. Participants indicated their aesthetic evaluations on a scale ranging from “1” (very pleasant) to “7” (very unpleasant), while usability was judged on a scale ranging from “1” (very usable) to “7” (very unusable). Participants had unlimited time to rate the websites but ratings that took more than 60 seconds (1.51% of all responses) were excluded. It took participants on average 17.56 seconds to rate a website, with no significant differences between the unfiltered, high-pass, and low-pass filtered screenshots (18.34s, 16.7s, and 17.64s respectively).

### 3. Results

As in previous studies, correlations were scrutinised. As individual differences are not a matter of concern, the results of the data are reported averaged over participants, which is the most important way to summarise this data to professionals designing websites (Monk, 2004). Differences in the magnitude of correlations were assessed using the procedure developed by Meng *et al.* (1992). Additionally, multiple regressions using the ratings of the two filtered conditions as predictors were used to predict the unfiltered ratings.

As expected, all correlations between ratings of unfiltered and filtered stimuli were significant (all  $ps < 0.01$ ; see Table 1).

Table 1. Correlations between ratings of different screenshot versions (upper half = aesthetic ratings; lower half = usability ratings)

	<i>Unfiltered</i>	<i>High-pass filtered</i>	<i>Low-pass filtered</i>
<i>Unfiltered</i>	-	0.73**	0.56**
<i>High-pass filtered</i>	0.83**	-	0.33**
<i>Low-pass filtered</i>	0.52**	0.50*	-

Note: \* =  $p < 0.05$ ; \*\* =  $p < 0.01$

Considering the aesthetic ratings in greater detail shows that the correlations to the ratings of the unfiltered screenshots were numerically larger for high-pass filtered ( $r = 0.73$ ,  $p < 0.01$ ) than for low-pass filtered stimuli ( $r = 0.56$ ,  $p < 0.01$ ). However, this difference was not statistically significant.

The regression analysis showed that together ratings of high-pass and low-pass filtered screenshots explained 65% of the variance in the ratings of unfiltered screenshots. Importantly, both ratings had significant beta weights (see Table 2), indicating independent contributions of both high and low-frequency factors, corroborating findings from the bivariate correlation analysis (see Table 1). Aesthetic ratings of both low-pass and high-pass filtered screenshots predicted a unique amount of variance in the ratings of unfiltered screenshots above and beyond the other predictor.

Comparing the two filter conditions with regard to usability ratings showed that ratings of high-pass filtered screenshots correlated more strongly with the ratings of unfiltered screenshots than did the ratings of low-pass filtered screenshots ( $p < 0.01$ ). The regression analysis confirmed this as only the high-pass ratings had a significant beta weight (see Table 2).

Table 2. Results of the linear regression analysis for predicting unfiltered ratings for aesthetics (upper part) and usability (lower part)

Evaluation	Condition	B	SE B	$\beta$
Aesthetic ratings	High-pass filtered	1.031	0.153	0.616**
	Low-pass filtered	0.741	0.189	0.357**
Usability ratings	High-pass filtered	0.909	0.109	0.762**
	Low-pass filtered	0.240	0.156	0.140

Note: \*\* =  $p < 0.01$

#### 4. Discussion

To the best of our knowledge, this is the first study to investigate the effects of different spatial frequencies on the evaluation of aesthetic appeal and usability of websites. We found high correlations between ratings of filtered website images and the original unfiltered versions. Both the ratings of high-pass filtered and low-pass filtered images equally predicted the ratings of perceived website aesthetics. We will discuss the findings regarding aesthetics and usability separately before turning to limitations of the study and providing an outlook for future studies.

As expected, we found that low spatial frequencies do contribute uniquely to aesthetic ratings. This is consistent with predictions based on the processing fluency theory as put forward by Reber *et al.* (2004). Aesthetic appraisal is mediated by processing fluency, which in turn depends on low spatial frequencies. These results offer a new perspective on the properties that affect user perceptions of websites. However, in this study aesthetic ratings were predicted just as well by ratings made only with high spatial frequency information. This large overlap might be due to non-visual factors. An important difference between the two different filter-versions was that the text was readable in the high-pass filtered screenshots but not in the low-pass filtered ones. As there are some effects of content on aesthetic-ratings (De Wulf *et al.* 2006) this might explain the large overlap between those ratings. Importantly the difference between high and low spatial frequencies suggests that other website features that are based low-spatial frequencies should have a similarly early effect on website impressions. For example, movement-perception is also based on low-spatial frequencies, thus making it an important factor in website impressions. In any case designers should keep in mind that the low-spatial frequency layout of the website has an important impact on the overall impression of the site. To test the impression conveyed by this frequency-component they might use procedures to filter screenshots, sketches or prototypes of their designs or use a “squint test” as described by Queen (2006).

In contrast to aesthetics ratings, we did not note a remarkable contribution from low spatial frequency information for usability ratings. While this seems at odds with previous research, which emphasised the influence of low spatial frequencies on usability, it is important to keep in mind that the study by Queen (2006) investigated the effect of low spatial frequencies on search tasks on icons in software applications. In the current study, the subjective perception of the overall site was in question, rather than search time for single elements. Thus, low spatial frequencies might affect behavioural performance on specific items, as Queen (2006) shows, but they have no

impact on global evaluations of usability. The high correlation between the high-pass image ratings and those of the unfiltered screenshots suggests that the participants in our study might have used very specific design cues from the websites upon which to base their usability-judgement. For example, they may have taken the time to locate a search field as a sign of usability. Using actual tasks in subsequent studies might control for such differences in implicit tasks. It is also imaginable that perceptions of usability are more closely connected to content features than to aesthetic perceptions; for example, Hartmann *et al.* (2008) found a connection between usability and content evaluation. Since text was readable only in the high-pass filtered and in the unfiltered condition this might be an alternative explanation for the strong correlation between the ratings for each. While these influences of content and specific design cues are possible confounded variables that future research should control, this opens possibilities for practitioners: They can alter the overall perception of usability by a careful design of specific functional elements (e.g., icons, navigation elements or forms) and by adapting them to website content. The success of such actions can be tested by filtering the website.

Some limitations should be considered when interpreting the results of our study: Since we were interested in investigating ratings made in a natural environment and were so trying to induce ecological validity (a problem in ergonomics discussed by Hoc, 2008), we had no precise control over the participants' visual distance from the monitor. Changes in distance would have essentially changed the visual angle from which the screenshot was seen, and thus the spatial frequencies conveyed in the picture would also change. Moreover, viewing time was not limited, since we were interested only in general website evaluations. The influence of low frequency information should be larger in more controlled environments and when screenshots are presented very briefly. Tractinsky *et al.* (2006) stressed the importance of first impressions, and maybe low spatial frequencies are one key to further understanding the basic principles behind these impressions.

To sum up, our main finding is that low spatial frequencies contribute uniquely to perceived website aesthetics, thus confirming a central prediction from processing fluency theory. There was no such connection between low spatial frequencies and usability evaluations, whereas strong correlations were found between ratings of high-pass filtered websites images and unfiltered images for both aesthetics and usability.

At a more general level, our study suggests new directions by using a neurocognitive approach to test predictions at the cognitive level. Given that aesthetic evaluations seem to be based on very rapid and unconscious processes (Zajonc, 1980), approaches that experimentally manipulate properties of websites and assess the effect of these manipulations on users' perceptions are needed. The ultimate goal of such approaches would be to explain findings like those of Tractinsky *et al.* (2006) in terms of underlying differences in neural processing. For example, a recent study has also shown that emotional content can enhance low-spatial frequency-processing while it decreases processing of high-spatial frequencies (Bocanegra and Zeelenberg 2009). We accordingly might expect larger effects of low-spatial frequencies on website impressions when it comes to emotional contents. Thus evaluating of spatial frequencies is only a first step in integrating the processes that give rise to perceptions of website usability and aesthetics into a larger neurocognitive framework. This is not

only important for theorising in aesthetics but should also inform current practices in designing websites. For example, designers should place a great emphasis on the global layout of the website and the ease with which users can perceive the overall concept behind the site. Whereas aesthetic evaluations could be improved in this way, improvements in perceived usability might be easier to produce by structuring the fine details of a website: in the end only websites with a well-arranged layout and clearly structured information will result in an enjoyable experience for the user.

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