# Unity in Variety in website aesthetics

## A systematic inquiry

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# Title Page

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**Full Title**: Unity in Variety in website aesthetics: A systematic inquiry

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**Keywords**: Website Aesthetics; Beauty; Unity; Variety; Design Principles; Interfaces

**Abstract**: This research experimentally investigates whether Unity-in-Variety can account for the aesthetic appreciation of websites. In a first study we designed two sets of web pages, differing in layout style and content, to systematically and independently vary on both unity and variety via the design factors contrast and symmetry (for unity) and dissimilarity of elements and colourfulness (for variety). It was demonstrated that only the sets based on symmetry and colourfulness resulted in independent manipulations of unity and variety, respectively. These two sets of web pages were tested in Study 2 showing that, as predicted, both unity and variety independently and positively influence aesthetic appreciation. Following the principle of Unity-in-Variety, simultaneously maximizing unity and variety leads to an optimal balance where aesthetic appreciation is highest. Our research lends further support to the principle of Unity-in-Variety, extends it to the domain of HCI, and provides directions on how to purposefully design for an optimal balance between unity and variety.

# UNITY IN VARIETY IN WEBSITE AESTHETICS: A SYSTEMATIC INQUIRY

ABSTRACT

This research experimentally investigates whether Unity-in-Variety can account for the aesthetic appreciation of websites. In a first study, we designed two sets of web pages, differing in layout style and content, to systematically and independently vary on both unity and variety via the design factors *contrast* and *symmetry* (for unity) and *dissimilarity of elements* and *colourfulness* (for variety). It was demonstrated that only the sets based on symmetry and colourfulness resulted in independent manipulations of unity and variety, respectively. These two sets of web pages were tested in Study 2 showing that, as predicted, both unity and variety independently and positively influence aesthetic appreciation. Following the principle of Unity-in-Variety, simultaneously maximizing unity and variety leads to an optimal balance where aesthetic appreciation is highest. Our research lends further support to the principle of Unity-in-Variety, extends it to the domain of HCI, and provides directions on how to purposefully design for an optimal balance between unity and variety.

Keywords: Website Aesthetics; Attractiveness; Beauty; Unity; Variety; Design Principles



## 1 INTRODUCTION

It has been well established that aesthetic appreciation plays an important role in determining a product's success by contributing to a wide range of positive effects (Bloch, 1995; Creusen and Schoormans, 2005). Within the domain of HCI, aesthetic appreciation, which we define in line with Hekkert (2014) as the pleasure attained from sensory understanding, has been shown to contribute to user satisfaction (Cyr, 2008), usefulness (Van der Heijden, 2003), usability (Tractinsky et al., 2000; Tuch, Roth, et al., 2012), performance (Moshagen et al.,

2009) and a variety of other aspects (For an extensive overview, we recommend readers to read Moshagen and Thielsch, 2010).

Given these beneficial effects, many studies have attempted to identify what design factors determine aesthetic appreciation of (digital) interfaces such as web sites. These studies can roughly be divided in three categories. Firstly, those focusing on basic visual design factors such as symmetry, number of elements and colourfulness (e.g. Bauerly and Liu, 2006; Bauerly and Liu, 2008; Bonnardel et al., 2011; Cyr et al., 2010; Ngo et al., 2002). Secondly, studies that investigate more subjective or psychological dimensions, such as the degree of simplicity or complexity (Moshagen and Thielsch, 2010), order (Schenkman and Jönsson, 2000), (proto)typicality (Tuch, Presslaber, et al., 2012) and novelty (Tuch, Presslaber, et al., 2012). And thirdly, those studies combining both to show how basic visual design factors relate to the subjective perception that gives rise to aesthetic appreciation (e.g. Altaboli and Lin, 2011; Deng and Poole, 2012; Seckler et al., 2015). The added benefit of this latter approach lies in a more complete understanding of the aesthetic experience, while also giving valuable insights on how to purposefully and methodologically influence it.

An aesthetic principle that also has the potential to explain aesthetic appreciation through both objective and subjective design factors, and that has hitherto not been studied within HCI, is that of Unity-in-Variety (UiV). The principle holds that, in order to experience aesthetic pleasure in our interaction with objects, we need to perceive unity in the variety of its parts (Fechner, 1876; Hekkert, 2006; Hutcheson, 1729). The most basic visual properties of almost any object are its colour, shape and texture. Together these form identifiable elements, ranging from structural components to the icons of an interface, which are generally perceived as being parts of a whole impression - the perception of the entire product or scene. It is the way in which these basic design properties and elements are related and organized from which the experience of both unity and variety emerges (Graves, 1951; Lauer and Pentak, 2012).

Humans actively seek variety in the world around them because it stimulates the senses and raises interest (Berlyne, 1971). This appetite for information and resulting appreciation for variety is thought to have evolved over time, as its perception bears the prospect of learning and thereby aided in coping with our environment (Biederman and Vessel, 2006; Hekkert, 2014). Variety, as used in design, can be referred to as the number and intensity of perceived differences between perceptual properties (e.g., colour, line, texture) and elements (the identifiable parts resulting from the way properties are organized)(Berlyne, 1958; Graves, 1951; Post et al., 2016). Structural and functional requirements of a design often dictate the presence of a certain degree of variety (Norman, 2013). However, solely perceiving variety leads to overstimulation, disrupting our ability to make perceptual sense (Cropper and Evans, 1968). Hence, for variety to be enjoyed, we need to perceive the unity within it.

Unity refers to the sensation of perceiving the whole and the order or coherence in sensory information (Berlyne, 1971). It facilitates perceptual processing and is thought to generate a feeling of fluency (Armstrong and Detweiler-Bedell, 2008; Reber et al., 2004). As such, unity aids in efficiently processing sensory information and its resulting pleasure is thought to originate from the evolutionary benefits this brought (Biederman and Vessel, 2006). An absence of unity troubles understanding as we fail to ‘make sense of’ what we see. When unity is perceived however, the *variety* of elements and properties are considered organized, allowing the appreciation of both the variety that stimulates our senses and the unity which enables its effective processing (Parker, 1976). It is this pleasure resulting from sensory understanding that partially determines our aesthetic appreciation of man-made artefacts to this day (Hekkert, 2014).

Since the perception of unity and variety originates from the same sources (i.e. the basic properties and elements of a design), they intercorrelate. One can intuitively recognize that increasing variety, for example through increasing the number of parts in a design, will generally decrease unity as it becomes more difficult to maintain coherence, and vice versa.

In other words, unity and variety counteract each other. As a result of being partial opposites, yet mutually contributing to aesthetic appreciation, it has been theorized that the most beautiful forms of art and design are those that successfully combine high degrees of unity and variety at the same time, hence Unity-in-Variety (Berlyne, 1971; Hekkert, 2006).

Previous studies confirm that unity and variety together explain aesthetic appreciation for simple figures (Berlyne and Boudewijns, 1971) and art (Cupchik and Gebotys, 1988). More recently, it was found that, despite unity and variety suppressing each other's effect, ratings of both unity and variety positively relate to aesthetic appreciation of tangible product designs (Post et al., 2016). A trade-off between unity and variety was demonstrated resulting in an optimal balance where aesthetic appreciation is maximized. However, this last study only statistically demonstrated the independent effects of both dimensions.

The present study aims to experimentally investigate the principle of UiV in the domain of HCI. We seek to find support for the claim that unity and variety are separate dimensions that both positively influence aesthetic appreciation and that, given their suppressing effect, there exists an optimal balance where aesthetic appreciation is highest. To assess the influence of each dimension on aesthetic appreciation, we systematically and independently manipulated unity and variety in the same sets of web pages. Our research consists of two parts. The first study describes the development and validation of different sets of web pages to examine whether it is possible to systematically and independently manipulate unity and variety. The second study assesses the influence of variations in unity and variety on the aesthetic appreciation of these web pages. In doing so, we strengthen support for the relevance of the principle, extend its applicability to the domain of HCI and show how unity and variety can be intentionally influenced.

## 2 STUDY 1: SYSTEMATICALLY MANIPULATING UNITY AND VARIETY IN WEB PAGES

We argue that unity and variety are not opposites on a single dimension, but two distinct dimensions positively influencing aesthetic appreciation. However, unity and variety are intrinsically connected by the basic elements of design that affect both dimensions. This inherent relationship makes it difficult to separate their influence. For example, lowering the number of elements in a design to create more order and increase unity will inadvertently also decrease variety. To show that both can indeed be considered separate dimensions uniquely contributing to aesthetic appreciation, it is essential to manipulate them independently. In order to find suitable means to systematically and independently manipulate unity and variety in web pages as realistically as possible, we identified potential design factors in the HCI and aesthetics literature and discuss them in the next two sections.

## 2.1 FACTORS INFLUENCING VARIETY

Several studies use variety and complexity almost interchangeably as they share common ground and largely overlap (Berlyne, 1960). For example, Nadal et al. (2010) showed visual complexity of artworks to be mainly explained by the number and variety of elements within them. We therefore included studies investigating complexity in this overview if their operationalization was similar to our definition of variety.

Early studies on the perception of line figures showed increases in the number of elements, and consequently the *dissimilarity between elements*, to heighten variety (Berlyne and Boudewijns, 1971; Birkhoff, 1933). In the domain of HCI, Nadkarni and Gupta (2007) showed how subjective impressions of dissimilarity in websites contribute to perceived and objective levels of visual complexity. Further experimental support comes from a study performed by Deng and Poole (2012) who found increasing number of elements in web pages (the links, text and graphics) to positively influence complexity ratings. More evidence for the importance of this design property comes from Reinecke et al. (2013), who showed their computational model to accurately predict visual complexity ratings of participants, based on the number of text groups, image areas and content areas of web pages. Similar

research was performed by Michailidou et al. (2008), also showing the number of links, images and words to positively relate to visual complexity.

*Diversity in colour*, or *colourfulness*, is another design property considered to influence variety and refers to the number and distribution of colours in terms of their hue, saturation and brightness (Graves, 1951). Colourfulness contributes to variety by increasing differences between elements, offering visual richness and stimulation of our senses (Hall and Hanna, 2004; Nasar, 1987; O'Connor, 2013; Oostendorp and Berlyne, 1978). Although colourfulness can therefore be associated with dissimilarity in elements, both have been identified as separate facets of visual aesthetics and are often measured separately (Moshagen and Thielsch, 2010; Nadkarni and Gupta, 2007). Empirical support for the importance of colourfulness in influencing variety comes from a study by Reinecke et al. (2013). Using a computational modelling approach, the authors found subjective scores of colourfulness to increase with complexity ratings of web pages. A similar modelling approach was used by Miniukovich and De Angeli (2014) who found colour variability to explain part of the variance in visual complexity of graphical user interfaces. Lastly, a study on signscape preferences found colour variation to increase perceived variety as well (Nasar, 1987).

## 2.2 FACTORS INFLUENCING UNITY

The Gestalt laws of perceptual grouping are common means to achieve unity and are widely known and used in HCI and design in general (Chang et al., 2002; Graham, 2008; Lidwell et al., 2010; Preece et al., 1994). Experimental support for their importance comes from Bell et al. (1991) who studied how well different styles of furniture fit together as a combination of good Gestalts. Their research showed good Gestalts to positively attribute to the aesthetic appreciation of the furniture, and that this relationship was mediated by perceived levels of unity. However, they did not isolate single Gestalt laws (e.g. similarity, symmetry or proximity), making it unclear which ones are most effective in manipulating unity, which is a requisite for our research in order to test the UiV principle. Ngo et al. (2002) did isolate

Gestalt laws by developing an aesthetic formula for unity in visual screen design based on *similarity in size* and *proximity.* This formula was tested in another study, and further confirmed by Altaboli and Lin (2012), that showed unity to be one of the stronger dimensions explaining aesthetic appreciation of visual screen designs (Ngo and Byrne, 2001). Similarly, Veryzer and Hutchinson (1998) used line drawings of products manipulated in shape similarity to investigate the influence of unity on aesthetic appreciation. Another Gestalt law considered to influence unity is that of s*ymmetry***,** as it facilitates perceptual understanding by reducing redundancy in information, leading to more fluent processing (Garner, 2014; Locher and Nodine, 1989; Reber et al., 2004). In applied terms, it gives structure and creates visual balance to help organize an image (Locher et al., 1998; Wilson and Chatterjee, 2005). Seckler et al. (2015) systematically and objectively manipulated symmetry in web pages, along with other design factors, by centring the layout and creating similarity in background colours. The authors found increasing symmetry to positively influence Gestalt impressions of figural goodness, which is synonymous with unity (Moshagen and Thielsch, 2010).

Although symmetry, similarity and proximity are relevant factors to consider when manipulating unity, candidate design factors need not be restricted to Gestalt laws. *Contrast* is a design property that can influence unity in two directions (Graham, 2008). One way is by increasing unity through decreasing differences between elements and their surrounding, as was shown by Nasar (1987). The author lowered contrast in letter sizing, colour and shape of signscapes, which increased perceived coherence. In other occasions, increasing contrast can work the other direction and enhance unity by facilitating detection of differences, a form of figure-ground contrast that leads to increased clarity and readability (Hall and Hanna, 2004; Hekkert, 2006; Reber et al., 1998; Wagemans et al., 2012). Contrast was used in this way by Deng and Poole (2012) to create web pages high in perceived order. Lowering contrast can thus be used to make elements look more similar, whereas higher contrast emphasizes differences between elements that vary.

## 2.3 STIMULUS DEVELOPMENT

Based on the previously discussed literature, the design factors s*ymmetry* and *contrast* were chosen to manipulate unity while *colourfulness* and *dissimilarity in elements* were chosen to manipulate variety in web pages. While many more design factors have been suggested to influence unity and variety (Graham, 2008; Kim, 2006; Lauer and Pentak, 2012; Lidwell et al., 2010), those described above have been well investigated in the scientific literature and were shown to have a substantial impact on the design dimensions. Although simultaneously manipulating additional factors may result in a more complete operationalization of our design dimensions, the counteracting result is that both dimensions become even more difficult to manipulate independently. Because our goal was to study the principle in a novel and more accurate way by establishing independent manipulations, we focussed on only one design factor for each dimension.

Because the influence of design factors on aesthetic appreciation of web pages also depends on their realism, a trained designer was used for the development of the stimuli. The designer created four sets of nine web pages, 3 levels of unity manipulations (low, medium and high) by 3 levels of variety manipulations (low, medium and high) using Adobe Photoshop and Illustrator. To better generalize our findings and account for possible effects of website type on aesthetic appreciation (such as reported by De Angeli et al., 2006; Schenkman and Jönsson, 2000; van Schaik and Ling, 2009), two of these four sets were created in a commercial style (insurance theme) and the other two in a communicative style (festival theme) (Lee and Koubek, 2010).

For each style, one set was created by using the factors of *symmetry* (for unity) and *colourfulness* (for variety), and another one was created set by using *contrast* (for unity) and *dissimilarity in elements* (for variety). These combinations of factors were chosen as their implementation in the web pages was thought to isolate the unity and variety manipulations as much as possible. For example, changes in layout symmetry can be achieved without affecting the colour of the elements and vice versa (Jusczyk et al., 1999; Seckler et al.,

2015). Similarly, changing the contrast of elements can be done without influencing the shape of such elements.

### 2.3.1 SYMMETRY X COLOURFULNESS

Websites are often designed with hierarchical clusters or sections that identify individual elements such as menus, text fields, links, images or icons. Unity was therefore manipulated in a commercial and communicative set by disrupting vertical and horizontal symmetry through changing the position of clusters and the position of elements within those clusters. This resulted in low, medium and high levels of symmetry (Symmetry-1, Symmetry-2, and Symmetry-3, respectively). Variety was manipulated in both sets of web pages by changing the number of colours. When more colours were added to a web page, brightness and saturation were kept close to constant, as these are known to influence people's preferences as well (Lindgaard et al., 2011; Palmer and Schloss, 2010; Seckler et al., 2015), although see Skulmowski et al. (2016) for an exception to this finding. In our low variety web pages (Colourfulness-1) only one colour was present besides the basic grey-scales. For medium (Colourfulness-2) to high variety (Colourfulness-3), additional colours were added and applied to more elements of the pages (Fig. 1a and 1b).

### 2.3.2 CONTRAST X DISSIMILARITY IN ELEMENTS

For a second communicative and commercial set of web pages, unity and variety were manipulated through contrast and dissimilarity in elements. For increasing levels of unity, more contrast was created between elements by increasing differences in luminance between foreground and background. This creates differences in contrast ratios (Fukuzumi et al., 1998). For example, the contrast ratio between the white background and black clusters in the commercial pages differed from 1.5:1 for low unity (Contrast-1), to 2:1 for medium (Contrast-2) and 9:1 for high unity (Contrast-3), as calculated using the HSV colour space (Hughes et al., 2013). Variety was manipulated through dissimilarity in elements by using different fonts and icon styles (e.g. regular vs. bold). For pages low in variety, dissimilarity in

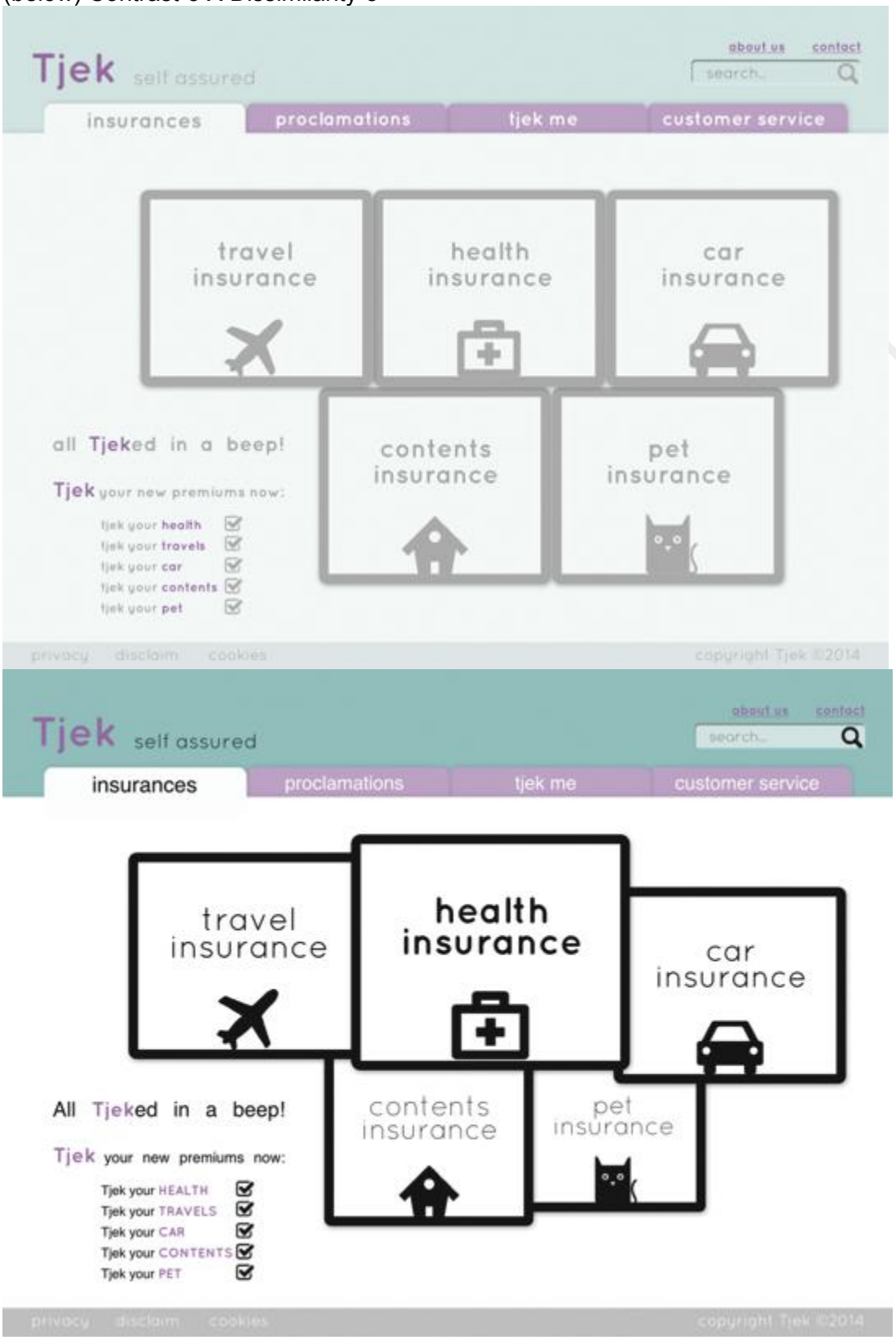
font type and icon styles was small (Dissimilarity-1), whereas the addition of new fonts and icon styles heightened dissimilarity for the medium (Dissimilarity-2) and high variety pages (Dissimilarity-3) (Fig. 2a and 2b).

Fig. 1a. Two of the nine stimuli from the communicative set: (above) Symmetry-1 X Colourfulness-1 (below) Symmetry-3 X Colourfulness-3

Fig. 1b. Two of the nine stimuli from the commercial set: (above) Symmetry-1 X Colourfulness-1 (below) Symmetry-3 X Colourfulness-3

Fig. 2a. Two of the nine stimuli from the communicative set: (above) Contrast-1 X Dissimilarity-1 (below) Contrast-3 X Dissimilarity-3

Fig. 2b. Two of the nine stimuli from the commercial set: (above) Contrast-1 X Dissimilarity-1 (below) Contrast-3 X Dissimilarity-3



## 2.4 TEST 1: ASSESSING UNITY & VARIETY MANIPULATIONS

We performed a first study to investigate whether the chosen manipulations resulted in independent manipulations of unity and variety in the directions we expected. We hypothesized that for both styles, increasing symmetry or contrast heightens unity ratings and not variety ratings. And secondly, for both styles, increasing colourfulness and dissimilarity in elements heightens variety ratings and not unity ratings.

### 2.4.1 PARTICIPANTS

Visitors of two Dutch university libraries, all having completed secondary education, were approached to voluntarily participate in an online questionnaire. Of the participants who completed the questionnaire, 10 were removed due to consecutive scoring (i.e. rating '5' on all items), leaving a total of 85 participants (mean age = 24.9; SD = 4.9; 43 women).

### 2.4.2 PROCEDURE

The four sets of web pages were administered in a within-subjects design. Groups of 20 to 25 participants were randomly assigned to one of four sets of nine web pages (presented in 948x710 resolution at 96DPI). They were informed that they would rate nine different versions of a web page on their visual appearance. At the start, all versions of the web page were shown in random order for a timed five seconds each to let participants briefly familiarize themselves with the web pages. Participants then filled in an online questionnaire and rated all nine pages, one at a time and in randomized order, on three items measuring unity, three items measuring variety, and two filler items[1] (7-point scale, 1: strongly disagree; 7: strongly agree). The unity and variety items were validated earlier by Blijlevens et al. (2016) and also used to determine the workings of the UiV principle for different product categories (Post et al., 2016). For unity, these items were: 'This is a unified design', 'This is an orderly design', 'This is a coherent design'. For variety, these items were: 'This design is

[1] Filler items were: 'This is a typical homepage design' and 'This is a novel homepage design'.

made of different parts', 'This design is rich in elements' and 'This design conveys variety'. All items and stimuli presentation orders were fully randomized and unity (Cronbach's α, all sets > .86) and variety (Cronbach's α, all sets > .73) items were averaged for further analyses.

## 2.5 RESULTS

We now describe the four sets separately. After visual inspections of graphs of the ratings, we determined whether further statistical testing of our hypotheses was meaningful. The four sets are now discussed two by two, depending on the type of manipulation.

### 2.5.1 CONTRAST X DISSIMILARITY IN ELEMENTS

#### 2.5.1.1 COMMUNICATIVE SET

Plotted mean unity and variety ratings revealed that unity and variety were both influenced by the degree of *contrast*, resulting in a strong linear relationship for the communicative set (Fig. 3 and Table 1). The mutual positive effects of contrast on unity and variety can be explained by its ability to help discriminate elements in perception. Increasing contrast facilitates perceptual understanding and legibility because the structure and organization of the web pages becomes easier to perceive (O'Connor, 2013). On the other hand, the differences between elements in the website are also emphasized, lowering similarity and increasing variety. While the effect of contrast on unity was strong and in the intended direction, it did not independently influence unity as it also had a strong effect on variety. Furthermore, it dominated the effect of *dissimilarity in elements* that showed to have no influence on either unity or variety.

#### 2.5.1.2 COMMERCIAL SET

Similar effects of *contrast* were found for the commercial set, as both unity and variety ratings increased with higher contrast. *Dissimilarity in elements* did increase variety ratings in this set, possibly because the effect of contrast was less salient. However, unity ratings simultaneously decreased with stronger dissimilarity in elements. While the altered fonts and

icon styles created dissimilarity them and heightens variety, they at the same reduced coherence of the overall web page to such a degree that unity diminished. The finding that dissimilarity in elements had relatively little influence on variety in the communicative set can be explained by the observation that this set contained more text and clusters than the commercial set, making the dissimilarity manipulations less apparent.

Although the manipulations did not result in independent effects on unity and variety, this was not entirely unexpected as impressions of unity and variety arise from shared properties of design. However, due to these strong simultaneous effects of contrast and dissimilarity on unity and variety, their appropriateness for independent manipulations becomes questionable.

Fig. 3. Plotted mean Unity and Variety ratings of the communicative web pages manipulated in three levels through respectively *Contrast* and *Dissimilarity in elements*.

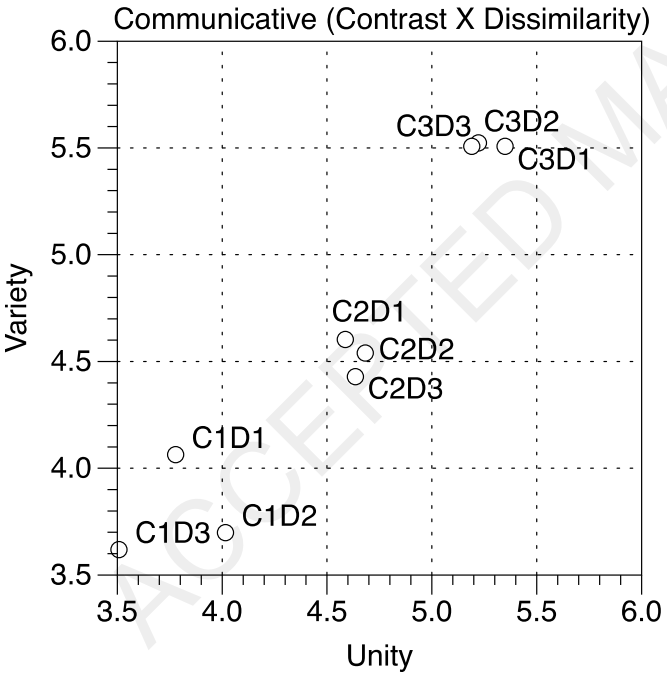



Fig. 4. Plotted mean Unity and Variety ratings of the commercial web pages manipulated in three levels through respectively *Contrast* and *Dissimilarity in elements*.

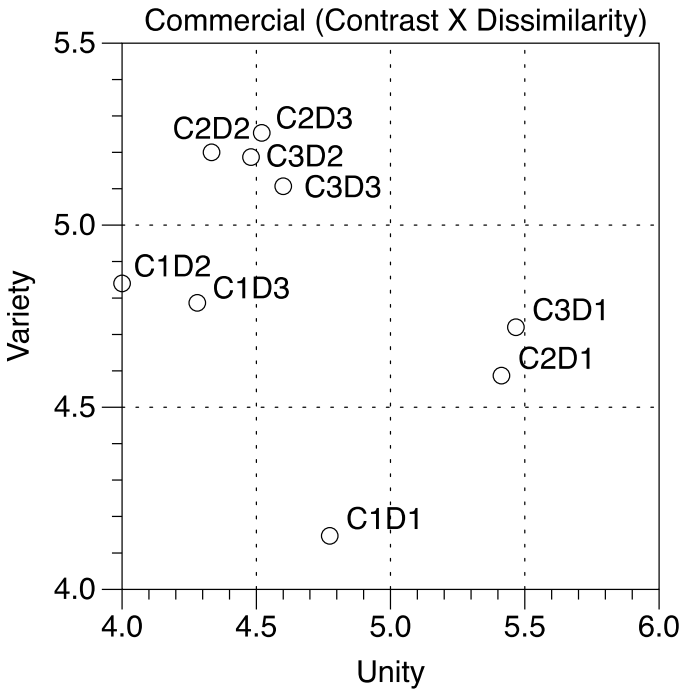



Table 1. Mean and standard error of Unity and Variety ratings averaged per manipulated level of *Contrast* and *Dissimilarity in elements for both sets of web pages.*

| | Communicative | | Commercial | |
|---|---|---|---|---|
| | Unity M (SE) | Variety M (SE) | Unity M (SE) | Variety M (SE) |
| Contrast-1 | 3.8 (.15) | 3.8 (.15) | 4.4 (.17) | 4.6 (.15) |
| Contrast-2 | 4.6 (.12) | 4.5 (.12) | 4.7 (.14) | 5.0 (.14) |
| Contrast-3 | 5.3 (.12) | 5.5 (.08) | 4.9 (.15) | 5.1 (.13) |
| Dissimilarity-1 | 4.6 (.16) | 4.7 (.15) | 5.2 (.13) | 4.5 (.15) |
| Dissimilarity-2 | 4.6 (.13) | 4.6 (.15) | 4.3 (.17) | 5.1 (.14) |
| Dissimilarity-3 | 4.5 (.16) | 4.5 (.17) | 4.5 (.15) | 5.1 (.14) |

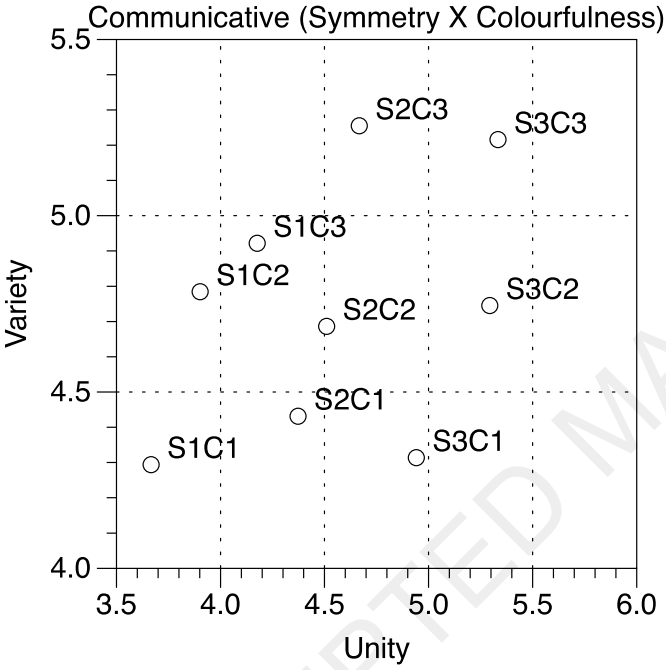
### 2.5.2 SYMMETRY X COLOURFULNESS

#### 2.5.2.1 COMMUNICATIVE SET

Visual inspection of the plotted mean unity and variety ratings in the communicative set showed clear differences in the intended directions (Fig. 5 and Table 2). Higher symmetry increased unity ratings, while variety ratings stayed the same. At the same time, adding colour steadily increased variety ratings, while keeping unity constant. Closer inspection showed that unity and variety ratings per web page stayed within their respective manipulation level. This meant that for unity ratings, all web pages designed to be low in

unity (Symmetry-1) received lower mean unity ratings than web pages with medium symmetry (Symmetry-2), while mean unity ratings for medium symmetry pages were lower than for high symmetry (Symmetry-3). The same applied to the variety ratings when looking at the colour manipulations (for mean variety ratings, all Colourfulness-1 < Colourfulness-2, and all Colourfulness-2 < Colourfulness-3). Given this positive first inspection, we performed additional statistical analyses to accurately assess independence of the manipulations.

Fig. 5. Plotted mean Unity and Variety ratings of the communicative web pages manipulated in three levels through respectively *Symmetry* and *Colourfulness*.




To statistically test whether unity and variety were independently manipulated through symmetry and colourfulness, we performed a series of linear mixed-effects analyses with REML estimation. Linear mixed model analyses are a relatively new and flexible approach to analysing repeated-measures designs. Distinct advantages are that it is robust against violations of homoscedasticity and sphericity, it can take sampling hierarchy into account, it can handle incomplete data and it has higher power in hypothesis testing than repeated-measures ANOVA (Quené and Van den Bergh, 2004). The analyses were performed by adding the three manipulated levels of symmetry and colourfulness as two factors predicting either unity or variety ratings. The model included fixed-effects for symmetry and

colourfulness. Random intercepts were included for subjects to account for baseline differences in unity and variety ratings, which increases the sensitivity of the test (Barr et al., 2013).

The first model ($R^2$ = .44) revealed that symmetry significantly predicted unity ratings ($F_{(2, 132)}$ = 20.14, $p$ < .001), while colourfulness did not ($F_{(2, 132)}$ = 2.00, $p$ = .14). Bonferroni corrected pairwise comparisons of the different levels of symmetry revealed that level 3 symmetry was rated significantly higher in unity than level 2 ($\Delta Mean_{unity}$ = .67, $t$ = 3.35, $p$ = .003) and level 1 ($\Delta Mean_{unity}$ = 1.27, $t$ = 6.34, $p$ < .001), and symmetry level 2 was also rated higher in unity than level 1 ($\Delta Mean_{unity}$ = .60, $t$ = 2.99, $p$ = .010).

The second model ($R^2$ = .71) showed that colourfulness significantly predicted variety ratings ($F_{(2, 132)}$ = 22.40, $p$ < .001), whereas symmetry did not ($F_{(2, 132)}$ = .604, $p$ = .55). Bonferroni corrected pairwise comparisons of the different levels of colourfulness revealed that level 3 colourfulness was rated significantly higher in variety than level 2 ($\Delta Mean_{variety}$ = .39, $t$ = 3.35, $p$ = .003) and level 1 ($\Delta Mean_{variety}$ = .78, $t$ = 6.70, $p$ < .001), and colourfulness level 2 was also rated higher in variety than level 1 ($\Delta Mean_{variety}$ = .39, $t$ = 3.35, $p$ = .003). Based on the analyses, we can conclude that for the communicative set, symmetry independently and positively influenced unity, while colourfulness independently and positively influenced variety.

#### 2.5.2.2 COMMERCIAL SET

In line with our expectations, the commercial set showed symmetry to generally increase mean unity ratings (Fig. 6 and Table 2). However, the mean unity rating for symmetry level 2 was slightly higher than for level 3. At the same time, symmetry did not affect variety ratings, indicating that symmetry generally had the intended isolated effect. Similar results were found for colourfulness. High colourfulness increased variety ratings, while unity ratings stayed stable. Overall, this set thus showed unity and variety manipulations to have an effect in the directions we intended, except for a lack in unity differences between level 2 and level

3 symmetry (respectively, 5.2 – 5.1). We therefore decided to adjust the commercial set and validate it in a second test.

Fig. 6. Plotted mean Unity and Variety ratings of the commercial web pages manipulated in three levels through respectively *Symmetry* and *Colourfulness*.

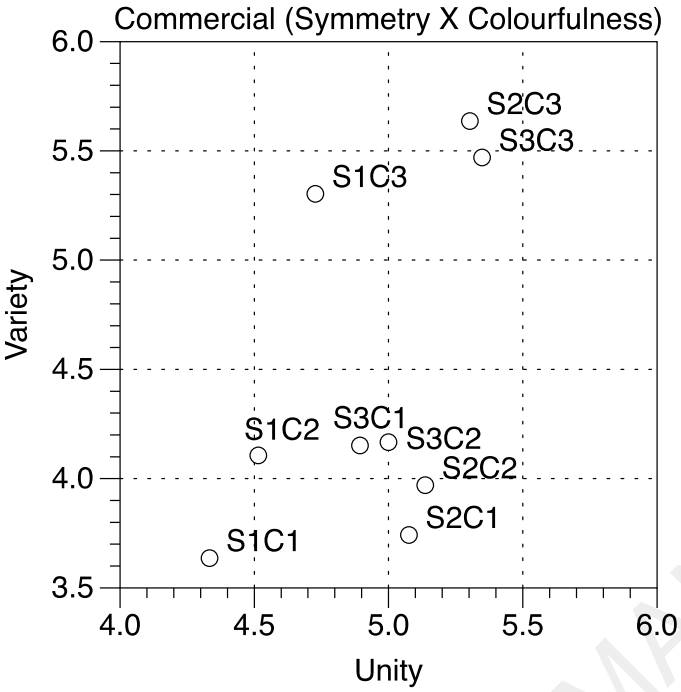



Table 2. Mean and Standard Error of Unity and Variety ratings averaged per manipulated level of *Symmetry* and *Colourfulness* for both web pages.

| | Communicative | | Commercial | |
|---|---|---|---|---|
| | Unity M (SE) | Variety M (SE) | Unity M (SE) | Variety M (SE) |
| Symmetry-1 | 3.9 (.20) | 4.7 (.14) | 4.5 (.15) | 4.4 (.18) |
| Symmetry-2 | 4.5 (.16) | 4.8 (.15) | 5.2 (.12) | 4.5 (.17) |
| Symmetry-3 | 5.2 (.16) | 4.8 (.16) | 5.1 (.14) | 4.6 (.16) |
| Colourfulness-1 | 4.4 (.21) | 4.3 (.16) | 4.8 (.15) | 3.8 (.16) |
| Colourfulness-2 | 4.6 (.19) | 4.7 (.14) | 4.9 (.14) | 4.1 (.15) |
| Colourfulness-3 | 4.7 (.17) | 5.1 (.13) | 5.1 (.13) | 5.5 (.12) |

## 2.6 TEST 2

We performed a second study using a redesigned set of the commercial web pages to assess the improved manipulations. Identical to the previously validated communicative set of web pages, we hypothesized that increases in symmetry heighten unity ratings and not

variety ratings. And secondly, increasing colourfulness heightens variety ratings and not unity ratings.

### 2.6.1 PARTICIPANTS

Visitors of a Dutch university library, all having completed secondary education, were approached to participate in an online questionnaire. Twenty-three participants completed the questionnaire and two were removed for clear consecutive scoring on all items (e.g., all 5's). The remaining participants were used for further analyses (mean age = 30.8, SD = 4.0, 10 women).

### 2.6.2 STIMULI

The unity ratings of the level 2 and level 3 symmetry pages of the commercial set largely overlapped (Table 2). We therefore removed the level 2 symmetry pages, effectively making the level 1 symmetry pages replace level 2. To complete the set and create a larger spread in ratings than before, we designed three new pages lower in symmetry by distorting horizontal and vertical symmetry of elements more strongly (Fig. 7).

### 2.6.3 PROCEDURE

The procedure of this study was identical to the previous test. The unity and variety items were averaged for further analyses (Cronbach's $\alpha_{unity} = .95$; Cronbach's $\alpha_{variety} = .77$).

Fig. 7. Comparison of the original (above) and redesigned (below) Symmetry-1 X Colourfulness-1 web page.

## 2.7 RESULTS

Visual inspection of the redesigned commercial set showed a clear distinction in unity and variety ratings as a result of changes to the symmetry and number of colours (Fig. 8). Higher symmetry primarily resulted in increasing unity ratings, whereas more colours mainly increased variety ratings. Furthermore, mean unity and variety ratings for each web page stayed within the intended manipulation level (Table 3; e.g. for unity ratings, all Symmetry-1 < Symmetry-2, and all Symmetry-2 < Symmetry-3. For variety ratings, all Colourfulness-1 < Colourfulness-2, and all Colourfulness-2 < Colourfulness-3). We performed two linear mixed model analyses, identical to those in the previous pre-test, to statistically assess the effects of our manipulations.

The first model ($R^2$ = .51) revealed that symmetry significantly predicted unity ratings ($F_{(2, 164)}$ = 46.27, $p$ < .001), while colour did not ($F_{(2, 164)}$ = .40, $p$ = .67). Bonferroni corrected pairwise comparisons of the different levels of symmetry revealed that symmetry level 3 was rated significantly higher in unity than level 2 ($\Delta Mean_{unity}$ = .63, $t$ = 3.21, p = .005) and level 1 ($\Delta Mean_{unity}$ = 1.86, $t$ = 9.47, $p$ < .001), and symmetry level 2 was also rated higher in unity than level 1 ($\Delta Mean_{unity}$ = 1.23, $t$ = 6.27, $p$ < .001).

The second model ($R^2$ = .66) showed that colourfulness significantly predicted variety ratings ($F_{(2, 164)}$ = 59.64, $p$ < .001), while symmetry did not ($F_{(2, 164)}$ = 2.20, $p$ = .125). Bonferroni corrected pairwise comparisons of the different levels of colourfulness revealed that colourfulness level 3 was rated significantly higher in variety than level 2 ($\Delta Mean_{variety}$ = 1.00, $t$ = 7.32, $p$ < .001) and level 1 ($\Delta Mean_{variety}$ = 1.46, $t$ = 10.70, $p$ < .001), and colourfulness level 2 was also rated higher in variety than level 1 ($\Delta Mean_{variety}$ = .46, $t$ = 3.38, $p$ = .003).

Similar to the communicative set of web pages, symmetry now independently and positively influenced unity, while colourfulness independently and positively influenced variety.

Fig. 8. Plotted Unity and Variety ratings for the redesigned commercial set manipulated in three levels through respectively *Symmetry* and *Colourfulness.*

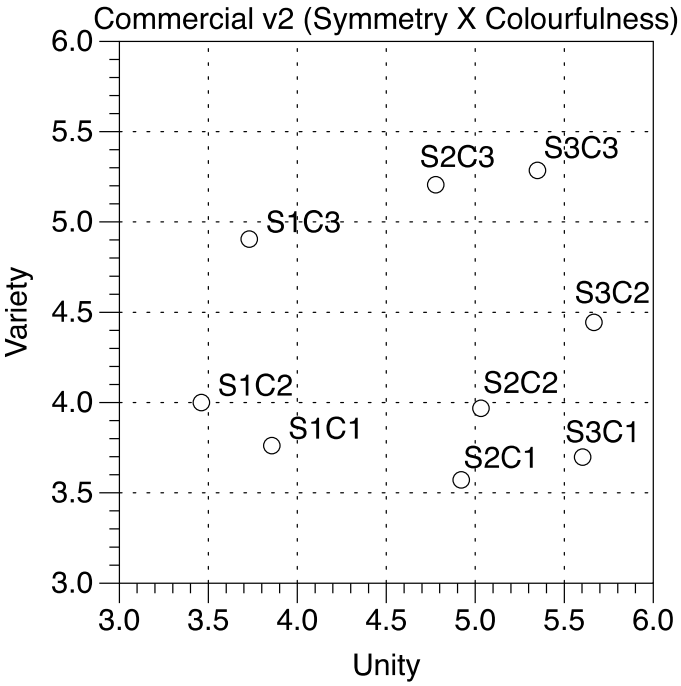



Table 3. Mean and Standard Error of Unity and Variety ratings averaged per manipulated level of *Symmetry* and *Colourfulness* for the redesigned commercial set.

| | Unity<br>M (SE) | Variety<br>M (SE) |
|---|---|---|
| Symmetry-1 | 3.7 (.22) | 4.2 (.16) |
| Symmetry-2 | 4.9 (.16) | 4.3 (.18) |
| Symmetry-3 | 5.5 (.11) | 4.5 (.16) |
| | | |
| Colourfulness-1 | 4.8 (.19) | 3.7 (.15) |
| Colourfulness-2 | 4.7 (.21) | 4.2 (.14) |
| Colourfulness-3 | 4.6 (.20) | 5.1 (.14) |

## 2.8 DISCUSSION

The first study resulted in the development and validation of two sets of web pages, with different content styles, that systematically and independently differ on unity and variety. Unity was manipulated through symmetry, whereas variety was manipulated through colourfulness. The two sets of stimuli allow us to isolate the effects of unity and variety on aesthetic appreciation in the next study.

# 3 STUDY 2: AESTHETIC APPRECIATION OF UNITY & VARIETY

The principle of UiV entails that unity and variety independently and positively contribute to aesthetic appreciation, and increasing the two ultimately leads to an optimal balance where aesthetic appreciation is highest. We tested these two hypotheses in the upcoming study using the two validated sets of websites from the previous study.

## 3.1 METHOD

### 3.1.1 PARTICIPANTS

Members of a Dutch consumer panel, all having completed secondary education, were approached to fill in an online questionnaire on the visual appearance of web page designs. A total of 49 participants rated the communicative set and 60 rated the commercial set. Due to consecutive scoring on all items (e.g. all 5's) six participants were removed for the communicative set and three participants were removed for the commercial set. The remaining 43 participants for the communicative set (mean age = 29.5, SD = 4.4, 23 women) and 57 participants for the commercial set (mean age = 31.6, SD = 5.2, 34 women) were used for further analyses.

### 3.1.2 PROCEDURE

The same between-subjects procedure was used as in the previous study with one group rating the web pages in a communicative style, and another group rating the web pages in a commercial style. Participants were asked to rate aesthetic appreciation using three items (7-point scale, 1: strongly disagree; 7: strongly agree): 'This is a beautiful homepage design', 'This is an attractive homepage design' and 'I like the design of this homepage'. The aesthetic appreciation items were averaged for analyses (Cronbach's $\alpha_{communicative}$ = .92; $\alpha_{commercial}$ = .96). Two additional filler items were included.[2] All items were validated in a cross-cultural study on product design aesthetics by Blijlevens et al. (2016). We included a question concerning the realism of the web pages at the end of the questionnaire (10-point

[2] Filler items were: 'This is a typical homepage design' and 'This is a novel homepage design'.

scale, 1: not realistic at all; 10: very realistic): 'Based on their visual appearance, how realistic did these web pages look to you?' (Communicative: Mean = 7.7, SD = 1.9; Commercial: Mean = 6.8, SD = 2.0).

## 3.2 RESULTS

### 3.2.1 SEPARATE EFFECTS OF UNITY AND VARIETY

To test our hypotheses, we performed two linear mixed model analyses per website style. The first analysis aimed to assess whether unity and variety independently and positively influence aesthetic appreciation for web pages of both styles. Linear mixed-effects models using REML estimation were calculated on non-aggregated data. The model included level of unity manipulation and level of variety manipulation as fixed-effect factors predicting aesthetic appreciation, and by-participant random intercepts to allow for baseline differences in unity and variety scores.

#### 3.2.1.1 COMMUNICATIVE SET

The analysis confirmed our first hypothesis as the model ($R^2$ = .69) revealed that both unity ($F_{(2, 340)}$ = 3.780, $p$ = .024) and variety ($F_{(2, 340)}$ = 21.179, $p$ < .001), significantly and positively predict aesthetic appreciation ratings in the communicative set. The parameter estimates revealed that variety affected mean aesthetic appreciation ratings to a larger degree than unity, as the estimated mean difference in aesthetic appreciation ratings between low and high manipulations was approximately two times larger for variety than unity (Table 4).

Table 4. Fixed-effects parameter estimates of mean Aesthetic Appreciation ratings for manipulated levels of Unity and Variety in the communicative set.

| | b | SE | t | *p* |
|---|---|---|---|---|
| Unity Low | -.25 | .09 | -2.68 | .008 |
| Unity Medium | -.17 | .09 | -1.86 | .063 |
| Unity High | . | . | . | . |
| Variety Low | -.58 | .09 | -6.33 | < .001 |
| Variety Medium | -.41 | .09 | -4.49 | < .001 |
| Variety High | . | . | . | . |

Note: Negative values of the estimates indicate that mean Aesthetic Appreciation of the respective level is lower than the 'High' reference category.

#### 3.2.1.2 COMMERCIAL SET

In line with the previous set, the statistical model ($R^2$ = .54) of the commercial set also confirmed our first hypothesis that unity ($F_{(2, 452)}$ = 6.393, $p$ = .002) and variety ($F_{(2, 452)}$ = 73.080 $p$ < .001) significantly and positively predict aesthetic appreciation ratings. Also, similar to the communicative set, differences in mean aesthetic appreciation ratings between low and high manipulations were stronger for variety than for unity (Table 5).

Table 5. Fixed-effects parameter estimates of mean Aesthetic Appreciation ratings for manipulated levels of Unity and Variety in the commercial set.

| | b | SE | t | *p* |
|---|---|---|---|---|
| Unity Low | -.40 | .11 | -3.55 | < .001 |
| Unity Medium | -.16 | .11 | -1.39 | .165 |
| Unity High | . | . | . | . |
| Variety Low | -1.32 | .11 | -11.76 | < .001 |
| Variety Medium | -.93 | .11 | -8.31 | < .001 |
| Variety High | . | . | . | . |

Note: Negative values of the estimates indicate that mean Aesthetic Appreciation of the respective level is lower than the 'High' reference category.

These findings thus confirmed that unity and variety independently and positively influence aesthetic appreciation for both sets of web pages. Finding support for this does however not automatically imply that web pages combining both are aesthetically preferred.

For example, it is possible that some web pages were mainly appreciated for their unity and not for their variety, whereas other pages were appreciated for their variety and not for their unity. To confirm our second hypothesis that it is the combination of unity and variety that leads to the highest aesthetic appreciation, it is necessary to combine both effects.

### 3.2.2 COMBINED EFFECTS OF UNITY AND VARIETY

We grouped together web page ratings with comparable combined unity and variety levels based on Study 1 (e.g., Symmetry-1/Colourfulness-2 and Symmetry-2/Colourfulness-1) to create a variable with five levels representing web pages with increasing Unity-in-Variety (Table 6).

Table 6. Coding of the five levels of Unity-in-Variety following the three levels of respective manipulations from the pre-tested web pages in Study 1.

| | | | |
|---|---|---|---|
| High Variety | 3 | 4 | 5 |
| Medium Variety | 2 | 3 | 4 |
| Low Variety | 1 | 2 | 3 |
| | Low Unity | Medium Unity | High Unity |

A second linear mixed-effects analysis was performed for each style of web pages to determine whether web pages combining increasing levels of unity and variety are aesthetically appreciated the most. A model was built with combined levels of unity and variety as a fixed-effects factor predicting aesthetic appreciation and random intercepts for the subjects.

#### 3.2.2.1 COMMUNICATIVE SET

In line with our prediction, the statistical model ($R^2$ = .69) of the communicative set showed that the combined effects of unity and variety significantly predicted aesthetic appreciation ($F_{(4, 340)}$ = 10.663, $p$ < .001). Estimates of the parameter coefficients revealed that mean aesthetic appreciation increased for higher combinations of unity and variety, and that the highest level of combined unity and variety was significantly higher than any of the lower combinations (Table 7).

Table 7. Fixed-effects parameter estimates of the mean Aesthetic Appreciation ratings for the combined Unity and Variety levels in the communicative set.

| | b | SE | *t* | *p* |
|---|---|---|---|---|
| UiV Level-1 | -.83 | .16 | -5.09 | < .001 |
| UiV Level-2 | -.77 | .14 | -5.54 | < .001 |
| UiV Level-3 | -.45 | .13 | -3.44 | .001 |
| UiV Level-4 | -.35 | .14 | -2.49 | .013 |
| UiV Level-5 | . | . | . | . |

#### 3.2.2.2 COMMERCIAL SET:

Identical to the previous results, the statistical model ($R^2$ = .50) also revealed combining levels of unity and variety to significantly predict aesthetic appreciation for the commercial set ($F_{(4, 452)}$ = 28.361, $p$ < .001). Inspection of the parameter estimates showed similar results to the previous set of web pages. Mean aesthetic appreciation increased for higher combinations of unity and variety and the highest combination of unity and variety was significantly higher than any other combination (Table 8). For both sets of web pages, the analyses confirmed our second hypothesis that web pages combining unity and variety are aesthetically appreciated the most.

Table 8. Fixed-effects parameter estimates of the mean Aesthetic Appreciation ratings for the combined Unity and Variety levels in the commercial set.

| | b | SE | *t* | *p* |
|---|---|---|---|---|
| UiV Level-1 | -1.68 | .20 | -8.35 | < .001 |
| UiV Level-2 | -1.56 | .18 | -8.94 | < .001 |
| UiV Level-3 | -1.02 | .17 | -6.18 | < .001 |
| UiV Level-4 | -.67 | .18 | -3.85 | < .001 |
| UiV Level-5 | . | . | . | . |

## 3.3 DISCUSSION

This study investigated the influence of unity and variety on aesthetic appreciation of web pages with two different content styles. In line with our hypotheses, the results show that for both styles, unity and variety positively influence aesthetic appreciation of web pages and their combination leads to the highest aesthetic appreciation. Given their inherent negative

correlation and suppressing effect on each other, the result indicates that increasing unity and variety ultimately leads to an optimal balance between both where aesthetic appreciation is highest.

Inspection of the relative unity and variety contributions revealed that variety influenced aesthetic appreciation to a larger extent (two to three times) than unity. Variety was manipulated through colour, a highly salient design property (Lindgaard, 2007), whereas unity was manipulated through symmetry. A comprehensive study on web page aesthetics by Moshagen and Thielsch (2010) showed that colourfulness was judged as more important by participants than symmetry. However, a recent study by Douneva et al. (2015) did not find an effect of colourfulness on web interface aesthetics. In line with these authors, we argue that the strength of the manipulations themselves is likely the most important reason underlying their relative contributions. Colour possibly offers a greater range of manipulation than symmetry without resulting in unrealistic stimuli, especially considering that a lack of variety is not necessarily catastrophic for a product's appreciation. However, a lack of unity results in complete disorder and risks preventing appreciation altogether. In line with this, our designer was instructed to prevent breaking symmetry to such a degree that the layout of web pages would become completely unbalanced (Chang et al., 2002). The overall layout of the designs might therefore still have been considered fairly balanced, suppressing the overall effect of unity.

# 4 GENERAL DISCUSSION AND CONCLUSION

This research aimed to assess whether aesthetic appreciation of web pages can be explained by the principle of Unity-in-Variety (UiV). Both unity and variety, independently manipulated through respectively *symmetry* and *colourfulness*, positively contributed to aesthetic appreciation of two sets of web pages that differed in content style (communicative versus commercial). As a result, web pages are aesthetically appreciated the most when both unity and variety are increased to reach an optimal balance. Our research demonstrates

the importance of UiV in explaining aesthetic appreciation for web pages and shows how our impressions of interface aesthetics arises from the perception of basic factors of visual design. We thereby further strengthen evidence for the UiV principle as a reliable and robust means to study and design beautiful product designs and we extend its applicability to the field of interface design.

Many design factors that have been studied, both in and outside the field of HCI, can be considered as influencing the UiV principle in one way or another (Kim, 2006). Our first studies showed that symmetry, contrast, dissimilarity in elements and colourfulness indeed do so. Symmetry and colourfulness were found to be important means to purposefully and selectively achieve a desired balance between unity and variety and, despite relatively minor changes, were shown to influence aesthetic appreciation to quite a degree (aesthetic appreciation ratings ranged from 3.2 to 5.0 in the commercial set). We thereby show how aesthetic appreciation is dependent on an optimal balance between unity and variety, and demonstrate that the basic building blocks of visual design underlie these two opposing dimensions.

Besides these contributions, our study also adds to the understanding of why we appreciate websites in the first place. The principle of UiV argues that there is an optimal balance in sensory processing that we aesthetically prefer. When potentially new information (variety) can be perceptually processed in a coherent and meaningful way (unity), such an optimal balance is struck. This balance leads to highly efficient processing of information and simultaneously stimulates our senses. From this information processing perspective, the principle can additionally inform us why beautiful interfaces are also more usable (Tractinsky et al., 2000). Web pages conforming to UiV are likely more efficiently processed, making it easier for users to perform tasks through them. Future research could also look into the ability of UiV to explain the usability of HCI systems.

Lastly, our aim was to use stimuli that are realistic and generalize to modern web sites. Therefore, a trained designer was instructed to make the manipulations of unity and variety

in newly build web pages similar to those found in modern websites. This approach follows that of a designer's natural methodology, closing the gap between scientific research and design practice. The knowledge generated through this research can therefore be translated more easily into the field of interface design and many other creative domains, giving designers tools through which they can create more beautiful. As a general guideline, beauty resides in balancing opposites in such a way that they can coexist.

## 4.1 LIMITATIONS AND FUTURE DIRECTIONS

In this research, we have shown that *symmetry* and *colour* can be used to independently influence the degree of unity and variety in web pages. While we also manipulated unity through *contrast* and variety through *dissimilarity in elements* in pre-tests, both design factors mostly influenced unity and variety simultaneously. Particularly in the commercially styled set, increasing contrast resulted in more unified and at the same time varied web pages. While contrast was therefore not considered a suitable property for independent manipulations of unity, the test does suggest that it is an important means to maximize unity and variety. Since the principle of UiV states that optimizing both unity and variety leads to the highest aesthetic appreciation, this design factor warrants further research.

The influence of *dissimilarity in elements* varied between both sets of web pages. In the commercial set its effect was relatively small, as it was mostly the changes in contrast that dominated impressions of unity and variety. In the communicative set, more dissimilarity in elements led to a decrease in unity and an increase of variety at the same time. This does not mean that dissimilarity in elements plays no useful role in influencing unity and variety, only that their effect is more difficult to systematically control.

These previous points also illustrate the difficulty of attempting to both systematically and independently manipulate unity and variety. The consequence of our approach to systematically manipulate was that a selection of suitable design factors had to be made because not all design factors can be manipulated at once. Furthermore, our goal for

independence of these manipulations implied that not every design factor was suitable, as the pre-tests revealed that certain design factors impact both unity and variety. As a result, unity and variety were in the end operationalized by one design factor each (symmetry and colourfulness, respectively). Although the scientific and design literature considers these important means to influence unity and variety, the concepts of unity and variety are much broader (or richer) than captured by these two design factors. Because we have not systematically manipulated and assessed the effect of other design factors on unity, variety and aesthetic appreciation, our results make no definitive claims on whether the effect of unity and variety on aesthetic appreciation may have changed if more design factors had been included. Future studies could attempt to find alternative ways to implement contrast and diversity of elements in web pages, apply finer changes to the texts and icons, or use different design factors altogether to (independently) manipulate unity and variety in other ways.

Participants in our study rated nine newly designed web pages, from one of two differently themed sets, that resemble web pages that can be found while browsing the internet. We used common web page features, such as multiple colours, photographs, menus, different fonts and various buttons, to increase the generalizability of our findings. Nonetheless, our stimuli are only a relatively small sample of the type of web pages that the internet offers. Variations in website designs are virtually limitless and more website themes exist than those tested in our studies (Lee and Koubek, 2010). It is also conceivable that there exist uglier or even more beautiful web pages than the nine variations within our manipulated sets captured. Studies in HCI should therefore strive to include as many possible stimuli from a representative sample (Hassenzahl and Monk, 2010). Future work could include more stimuli with different themes and that vary more extremely in both unity and variety.

Although meticulous care was taken to manipulate symmetry and colourfulness, the interdependent nature of how basic elements of design are perceived prevents completely

isolating effects on other design factors. As a result, it may be that other design factors may have differed slightly between the different versions of the web page. For example, increasing symmetry affects the proximity of certain elements on the web page, thereby also affecting its overall unity. Additionally, our colourfulness manipulations implied adding more and new colours to our designs. Literature suggests that some people prefer certain colours to others (Bonnardel et al., 2011; Chen et al., 2016). In particular, people tend to prefer blue hues in websites (Seckler et al., 2015). Hence, it may be that aesthetic appreciation ratings were not only affected by changes in variety, but also due to changes in the overall hue of the web pages. For the aforementioned reason, it is extremely difficult for realistic web pages to keep all design factors constant except for those of interest. Hence, future studies could instead include subjective ratings for these factors so that they can be statistically controlled for.

Besides the UiV principle, there are other design principles that can be studied in parallel. Impressions of unity and variety are directly attributable to the organization of the most basic elements and properties that can be identified in web pages. As such, judging the degree of unity and variety is likely a relatively low-level perceptual process (Veryzer and Hutchinson, 1998). There are however also design principles that may explain aesthetic appreciation through different properties of web pages. Such is, for example, the MAYA principle. It states that product designs maximizing both typicality and novelty are aesthetically preferred (Hekkert et al., 2003). The typicality of a product refers to the degree to which a product is considered comparable with the prototype of its category and has been shown to also positively attribute to the aesthetic appreciation of web pages (Tuch, Presslaber, et al., 2012). Novelty on the other hand, refers to the originality of a design and is another design dimension contributing to the aesthetic appreciation of web pages (Zeng et al., 2009). Their joined influence on web pages has not yet been researched. Additionally, it may be possible to control for more than two design dimensions if they can be separated

enough in their effect. UiV and MAYA may offer such a combination as their impressions arise from different design properties.

Participants in our study viewed web pages for several seconds. Various studies have looked at the viewing time needed to form an aesthetic judgment of websites and have found as little as 50ms to generate consistent results (Lindgaard et al., 2006; Tractinsky et al., 2006). The previous assertion, that judgments of unity and variety are largely based on low-level perceptual processes, could be further investigated in this regard. We would expect unity and variety ratings to be reliably assessed with short viewing times. However, because a website is likely to lose some of its interest after a while, the relative contribution of variety would be expected to increase over time.

Lastly, our findings lead to several suggestions for design practice. Designers can apply the design factors such as symmetry, contrast, diversity in elements and colourfulness to iteratively design variations of web pages to reach an optimum balance between unity and variety. While most design factors will contribute to unity and thereby decrease variety, or the other way around, the use of contrast (in colour) seems particularly promising to optimize both simultaneously. This is not a free permit to maximize contrast, as too much (e.g. colour) contrast will eventually break unity as dissimilarities become too large. Applying a more gradual shift between contrasting elements can alleviate such dissimilarities. The use of gradients in colour, line, shape or texture of a website is an excellent way to create unity while maintaining variety. Gradients guide perception by offering the senses information about the next line, shape, or material (Graves, 1951). In websites, this implies creating contrast between the different text and menu areas that contain different functions, while simultaneously creating a gradient of visual information between these elements and the web page's background. Such is the example in Figure 2a (Contrast-3 X Dissimilarity-3), where transparency is used to keep the background slightly visible behind the white menu elements. This need for balancing a design factor is also apparent for symmetry. Symmetry is often regarded as a necessity to create unity and a determinant for a beautiful design.

However, perfect symmetry is not always appreciated, as a product's appreciation depends on the design's overall balance and the emotional response it generates (Hekkert, 2006; Lauer and Pentak, 2012; Locher and Nagy, 1996). A highly incoherent design is in need for symmetry to create structure and increase comprehensibility. However, a perfectly balanced design might be boring because it offers little variety. As a solution, introducing certain asymmetry to a perfectly balanced design can excite the overall impression of the product. Furthermore, the principle suggests that heightening unity (e.g., through symmetry) should be compensated for by also heightening variety through variegating design factors. This gives a great degree of design freedom in choosing how to achieve such a balance and illustrates the relative ease with which design factors can be understood and verbalized in terms of balancing unity and variety. Doing so can greatly facilitate the design and discussion of design choices that affect the visual appeal of websites and we direct readers interested in applying these design factors to O'Connor (2013).

An important last note is that creating unity does not mean using one design factor over and over. Creating similarity in a design creates order, but solely using similarity between properties will soon lead to a highly repetitive pattern and the appreciation of this unifying factor will go down. While we have studied several design factors in isolation, we did so for methodological reasons. Beautiful designs consist of various unifying design factors simultaneously to generate a harmonious and balanced whole. It is the designer's duty to pick and choose those design factors that best work together to create Unity-in-Variety.

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# LITERATURE


Altaboli, A., & Lin, Y. (2011). Objective and subjective measures of visual aesthetics of website interface design: the two sides of the coin. In J. A. Jacko (Ed.), *Human-Computer Interaction. Design and Development Approaches* (pp. 35-44). Berlin: Springer-Verlag.

Altaboli, A., & Lin, Y. (2012). *Effects of unity of form and symmetry on visual aesthetics of website interface design.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society 56th Annual Meeting, HFES 2012, Boston, MA. doi: 10.1177/1071181312561152

Armstrong, T., & Detweiler-Bedell, B. (2008). Beauty as an emotion: The exhilarating prospect of mastering a challenging world. *Review of General Psychology, 12*(4), 305-329. doi: 10.1037/a0012558

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of memory and language, 68*(3), 255-278.

Bauerly, M., & Liu, Y. (2006). Computational modeling and experimental investigation of effects of compositional elements on interface and design aesthetics. *International journal of human-computer studies, 64*(8), 670-682.

Bauerly, M., & Liu, Y. (2008). Effects of symmetry and number of compositional elements on interface and design aesthetics. *Intl. Journal of Human–Computer Interaction, 24*(3), 275-287. doi: 10.1080/10447310801920508

Bell, S. S., Holbrook, M. B., & Solomon, M. R. (1991). Combining esthetic and social value to explain preferences for product styles with the incorporation of personality and ensemble effects. *Journal of Social Behavior & Personality*.

Berlyne, D. E. (1958). The influence of complexity and novelty in visual figures on orienting responses. *Journal of Experimental Psychology, 55*(3), 289.

Berlyne, D. E. (1960). *Conflict, arousal, and curiosity* (Vol. 331): McGraw-Hill New York.

Berlyne, D. E. (1971). *Aesthetics and psychobiology*. New York: Appleton-Century-Crofts.

Berlyne, D. E., & Boudewijns, W. J. (1971). Hedonic effects of uniformity in variety. *Canadian Journal of Psychology/Revue canadienne de psychologie, 25*(3), 195-206. doi: 10.1037/h0082381

Biederman, I., & Vessel, E. (2006). Perceptual Pleasure and the Brain: A novel theory explains why the brain craves information and seeks it through the senses. *American Scientist, 94*(3), 247-253. doi: 10.1511/2006.59.995

Birkhoff, G. D. (1933). *Aesthetic measure*: Harvard University Press Cambridge, MA.

Blijlevens, J., Thurgood, C., Hekkert, P., Chen, L.-L., Leder, H., & Whitfield, T. W. A. (2016). The Aesthetic Pleasure in Design (APiD) Scale: The development of a scale to measure aesthetic pleasure for designed artifacts. *Psychology of Aesthetics, Creativity, and the Arts*(In press).

Bloch, P. H. (1995). Seeking the ideal form: Product design and consumer response. *The Journal of Marketing, 59*(3), 16-29. doi: 10.2307/1252116

Bonnardel, N., Piolat, A., & Le Bigot, L. (2011). The impact of colour on Website appeal and users' cognitive processes. *Displays, 32*(2), 69-80.

Chang, D., Dooley, L., & Tuovinen, J. E. (2002). *Gestalt theory in visual screen design: a new look at an old subject.* Paper presented at the Proceedings of the Seventh world conference on computers in education conference on Computers in education: Australian topics.

Chen, N., Tanaka, K., Matsuyoshi, D., & Watanabe, K. (2016). Cross preferences for colors and shapes. *Color Research and Application, 41*(2), 188-195. doi: 10.1002/col.21958

Creusen, M. E. H., & Schoormans, J. P. L. (2005). The different roles of product appearance in consumer choice. *Journal of Product Innovation Management, 22*(1), 63-81.

Cropper, A. G., & Evans, S. (1968). Ergonomics and computer display design. *Computer Bulletin, 12*(3), 94-&.
Cupchik, G. C., & Gebotys, R. J. (1988). The search for meaning in art: Interpretive styles and judgments of quality. *Visual Arts Research*, 38-50.
Cyr, D. (2008). Modeling web site design across cultures: relationships to trust, satisfaction, and e-loyalty. *Journal of Management Information Systems, 24*(4), 47-72.
Cyr, D., Head, M., & Larios, H. (2010). Colour appeal in website design within and across cultures: A multi-method evaluation. *International journal of human-computer studies, 68*(1), 1-21.
De Angeli, A., Sutcliffe, A., & Hartmann, J. (2006). *Interaction, usability and aesthetics: what influences users' preferences?* Paper presented at the Proceedings of the 6th conference on Designing Interactive systems.
Deng, L., & Poole, M. S. (2012). Aesthetic design of e-commerce web pages–Webpage Complexity, Order and preference. *Electronic Commerce Research and Applications, 11*(4), 420-440.
Douneva, M., Haines, R., & Thielsch, M. T. (2015). Effects Of Interface Aesthetics On Team Performance In A Virtual Task.
Fechner, G. T. (1876). *Vorschule der aesthetik* (Vol. 1). Leipzig: Breitkopf & Härtel. doi: 10.1017/cbo9781139854580
Fukuzumi, S. I., Yamazaki, T., Kamijo, K. I., & Hayashi, Y. (1998). Physiological and psychological evaluation for visual display colour readability: a visual evoked potential study and a subjective evaluation study. *Ergonomics, 41*(1), 89-108.
Garner, W. R. (2014). *The processing of information and structure*: Psychology Press.
Graham, L. (2008). Gestalt theory in interactive media design. *Journal of Humanities & Social Sciences, 2*(1).
Graves, M. (1951). *The art of color and design* (2nd ed.). New York: McGraw-Hill Book Company.
Hall, R. H., & Hanna, P. (2004). The impact of web page text-background colour combinations on readability, retention, aesthetics and behavioural intention. *Behaviour & Information Technology, 23*(3), 183-195.
Hassenzahl, M., & Monk, A. (2010). The inference of perceived usability from beauty. *Human–Computer Interaction, 25*(3), 235-260.
Hekkert, P. (2006). Design aesthetics: Principles of pleasure in design. *Psychology Science, 48*(2), 157-172.
Hekkert, P. (2014). Aesthetic responses to design: A battle of impulses. In T. Smith & P. Tinio (Eds.), *The Cambridge Handbook of the Psychology of Aesthetics and the Arts* (pp. 277-299). Cambridge: Cambridge University Press. doi: 10.1017/cbo9781139207058.015
Hekkert, P., Snelders, D., & van Wieringen, P. C. W. (2003). 'Most advanced, yet acceptable': Typicality and novelty as joint predictors of aesthetic preference in industrial design. *British Journal of Psychology, 94*(1), 111-124. doi: 10.1348/000712603762842147
Hughes, J. F., Van Dam, A., Foley, J. D., & Feiner, S. K. (2013). *Computer graphics: principles and practice*: Pearson Education.
Hutcheson, F. (1729). *An inquiry into the original of our ideas of beauty and virtue: in two treatises*. Indianapolis: Liberty Fund. doi: 10.1037/11692-000
Jusczyk, P. W., Johnson, S. P., Spelke, E. S., & Kennedy, L. J. (1999). Synchronous change and perception of object unity: Evidence from adults and infants. *Cognition, 71*(3), 257-288.
Kim, N. (2006). A history of design theory in art education. *The Journal of Aesthetic Education, 40*(2), 12-28. doi: 10.1353/jae.2006.0015
Lauer, D. A., & Pentak, S. (2012). *Design basics* (8th ed.). Belmont: Wadsworth.

Lee, S., & Koubek, R. J. (2010). Understanding user preferences based on usability and aesthetics before and after actual use. *Interacting with Computers, 22*(6), 530-543. doi: 10.1016/j.intcom.2010.05.002

Lidwell, W., Holden, K., & Butler, J. (2010). *Universal principles of design, revised and updated: 125 Ways to enhance usability, influence perception, increase appeal, make better design decisions, and teach through design*. Beverly: Rockport publishers.

Lindgaard, G. (2007). Aesthetics, visual appeal, usability and user satisfaction: What do the user's eyes tell the user's brain. *Australian Journal of Emerging Technologies and Society, 5*(1), 1-14.

Lindgaard, G., Dudek, C., Sen, D., Sumegi, L., & Noonan, P. (2011). An exploration of relations between visual appeal, trustworthiness and perceived usability of homepages. *ACM Transactions on Computer-Human Interaction (TOCHI), 18*(1), 1.

Lindgaard, G., Fernandes, G., Dudek, C., & Brown, J. (2006). Attention web designers: You have 50 milliseconds to make a good first impression! *Behaviour & Information Technology, 25*(2), 115-126.

Locher, P., & Nodine, C. (1989). The perceptual value of symmetry. *Computers & mathematics with applications, 17*(4), 475-484.

Locher, P. J., Stappers, P. J., & Overbeeke, K. (1998). The role of balance as an organizing design principle underlying adults' compositional strategies for creating visual displays. *Acta Psychologica, 99*(2), 141-161. doi: 10.1016/S0001-6918(98)00008-0

Michailidou, E., Harper, S., & Bechhofer, S. (2008). *Visual complexity and aesthetic perception of web pages.* Paper presented at the Proceedings of the 26th annual ACM international conference on Design of communication.

Miniukovich, A., & De Angeli, A. (2014). *Quantification of interface visual complexity.* Paper presented at the 2014 12th International Working Conference on Advanced Visual Interfaces, AVI 2014, Como. doi: 10.1145/2598153.2598173

Moshagen, M., Musch, J., & Göritz, A. S. (2009). A blessing, not a curse: Experimental evidence for beneficial effects of visual aesthetics on performance. *Ergonomics, 52*(10), 1311-1320.

Moshagen, M., & Thielsch, M. T. (2010). Facets of visual aesthetics. *International journal of human-computer studies, 68*(10), 689-709. doi: 10.1016/j.ijhcs.2010.05.006

Nadal, M., Munar, E., Marty, G., & Cela-conde, C. J. (2010). Visual complexity and beauty appreciation: Explaining the divergence of results. *Empirical Studies of the Arts, 28*(2), 173-191. doi: 10.2190/EM.28.2.d

Nadkarni, S., & Gupta, R. (2007). A task-based model of perceived website complexity. *Mis Quarterly*, 501-524.

Nasar, J. L. (1987). The effect of sign complexity and coherence on the perceived quality of retail scenes. *Journal of the American Planning Association, 53*(4), 499-509. doi: 10.1080/01944368708977139

Ngo, D., & Byrne, J. (2001). Application of an aesthetic evaluation model to data entry screens. *Computers in Human Behavior, 17*(2), 149-185.

Ngo, D. C. L., Teo, L. S., & Byrne, J. G. (2002). Evaluating interface esthetics. *Knowledge and Information Systems, 4*(1), 46-79.

Norman, D. A. (2013). *The design of everyday things: Revised and expanded edition*. New York: Basic books.

O'Connor, Z. (2013). Colour, contrast and gestalt theories of perception: The impact in contemporary visual communications design. *Color Research & Application*.

Oostendorp, A., & Berlyne, D. (1978). Dimensions in the perception of architecture: I. Identification and interpretation of dimensions of similarity. *Scandinavian Journal of Psychology, 19*(1), 73-82.

Palmer, S. E., & Schloss, K. B. (2010). *Human preference for individual colors.* Paper presented at the IS&T/SPIE Electronic Imaging.

Parker, D. H. (1976). *The principles of aesthetics*: Greenwood Press.

Post, R. A. G., Blijlevens, J., & Hekkert, P. (2016). 'To preserve unity while almost allowing for chaos': Testing the aesthetic principle of unity-in-variety in product design. *Acta Psychologica, 163*, 142-152. doi: 10.1016/j.actpsy.2015.11.013

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human-computer interaction*: Addison-Wesley Longman Ltd.

Quené, H., & Van den Bergh, H. (2004). On multi-level modeling of data from repeated measures designs: A tutorial. *Speech Communication, 43*(1), 103-121.

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review, 8*(4), 364-382. doi: 10.1207/s15327957pspr0804_3

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological Science, 9*(1), 45-48.

Reinecke, K., Yeh, T., Miratrix, L., Mardiko, R., Zhao, Y., Liu, J., & Gajos, K. Z. (2013). *Predicting users' first impressions of website aesthetics with a quantification of perceived visual complexity and colorfulness*, Paris.

Schenkman, B. N., & Jönsson, F. U. (2000). Aesthetics and preferences of web pages. *Behaviour & Information Technology, 19*(5), 367-377.

Seckler, M., Opwis, K., & Tuch, A. N. (2015). Linking objective design factors with subjective aesthetics: An experimental study on how structure and color of websites affect the facets of users' visual aesthetic perception. *Computers in Human Behavior, 49*(0), 375-389. doi: 10.1016/j.chb.2015.02.056

Skulmowski, A., Augustin, Y., Pradel, S., Nebel, S., Schneider, S., & Rey, G. D. (2016). The negative impact of saturation on website trustworthiness and appeal: A temporal model of aesthetic website perception. *Computers in Human Behavior, 61*, 386-393. doi: 10.1016/j.chb.2016.03.054

Tractinsky, N., Cokhavi, A., Kirschenbaum, M., & Sharfi, T. (2006). Evaluating the consistency of immediate aesthetic perceptions of web pages. *International Journal of Human Computer Studies, 64*(11), 1071-1083. doi: 10.1016/j.ijhcs.2006.06.009

Tractinsky, N., Katz, A., & Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers, 13*(2), 127-145.

Tuch, A. N., Presslaber, E. E., Stöcklin, M., Opwis, K., & Bargas-Avila, J. A. (2012). The role of visual complexity and prototypicality regarding first impression of websites: Working towards understanding aesthetic judgments. *International journal of human-computer studies, 70*(11), 794-811. doi: 10.1016/j.ijhcs.2012.06.003

Tuch, A. N., Roth, S. P., HornbæK, K., Opwis, K., & Bargas-Avila, J. A. (2012). Is beautiful really usable? Toward understanding the relation between usability, aesthetics, and affect in HCI. *Computers in Human Behavior, 28*(5), 1596-1607.

Van der Heijden, H. (2003). Factors influencing the usage of websites: the case of a generic portal in The Netherlands. *Information & Management, 40*(6), 541-549.

van Schaik, P., & Ling, J. (2009). The role of context in perceptions of the aesthetics of web pages over time. *International Journal of Human Computer Studies, 67*(1), 79-89. doi: 10.1016/j.ijhcs.2008.09.012

Veryzer, R. W., & Hutchinson, J. W. (1998). The influence of unity and prototypicality on aesthetic responses to new product designs. *Journal of Consumer Research, 24*(4), 374-385.

Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Singh, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure-ground organization. *Psychological bulletin, 138*(6), 1172-1217. doi: 10.1037/a0029333

Wilson, A., & Chatterjee, A. (2005). The assessment of preference for balance: Introducing a new test. *Empirical Studies of the Arts, 23*(2), 165-180.

Zeng, L., Salvendy, G., & Zhang, M. (2009). Factor structure of web site creativity. *Computers in Human Behavior, 25*(2), 568-577. doi: 10.1016/j.chb.2008.12.023