Design Mode, Color, and Button Shape: A Pilot Study on the Neural Effects of Website Perception

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Abstract. The investigation of website aesthetics has a long history and has already been addressed in NeuroIS research. The extant literature predominantly studied website complexity, symmetry, and colors. However, other design factors have not yet been examined so far. We studied two new factors (design mode: light vs. dark, button shape: rounded vs. sharp angled) along with color (blue vs. red). Specifically, we examined the impact of these three factors on several outcomes. Results from a repeated-measures MANOVA indicate: (i) design mode (light vs. dark) significantly affects users' pleasure, arousal, trust, attitude, and use intention, (ii) color (blue vs. red) significantly influences pleasure, arousal, and use intentions, while (iii) button shape (rounded vs. sharp) does not significantly influence any of the dependent measures. Based on these results, follow up functional near-infrared spectroscopy studies are developed which aim to further complement our self-report findings.

Keywords: Website aesthetics · Button shape · Color · Dark website design · Attitude · fNIRS · Brain

1 Introduction

Website aesthetics is a major determinant of user perception and use intention [1–4]. Aesthetics impact perceived trustworthiness, usability, and user experience (UX) [5, 6], and is therefore a critical factor in web design (e.g., ecommerce websites). Within the field of website aesthetics, several determinants of aesthetic and beautiful websites have been identified, such as symmetry, complexity, balance, colors, and shapes [1, 4, 5, 7]. Several aesthetic factors have also already been investigated based on neurophysiological measurement, such as symmetry [8] and color [9, 10]. However, other design factors have received much less attention or have not been studied at all, including shapes of different user interface (UI) elements, in particular the shape of buttons [11]. Research indicates that different shape forms (curved, sharp) influence perceptions of aesthetics, emotion, and purchase intentions [12, 13]. The stimuli used in these studies comprise lines, abstract

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figures, products, and interior designs [14–17]. More importantly, it has been consistently found that sharp objects and designs often lead to increased activation in arousal and fear-related brain areas, particularly in the amygdala, while curved designs elicit activations in reward-related brain areas, particularly in the anterior cingulate cortex (ACC) [12, 13, 15]. At this point, it needs to be noted that all neurophysiological studies on shapes were conducted with functional magnetic resonance imaging (fMRI) [12, 15]. Although fMRI offers high spatial resolution, it is limited in its external validity due to participants' being required to stay in position. Especially for measurements which involve looking at or using a website, more natural measurements must complement fMRI research since restraining the movements of users may have an impact on the intensity of emotional experience [18]. Thus, an investigation of button shapes on websites not only offers room for upcoming studies with self-reported and behavioral measures, but also with mobile neuroimaging methods such as functional near-infrared spectroscopy.

In addition, a recent trend in UI design in general, and in website design in particular, is the use of dark mode. Although this design trend has been around for several years already, scientific research on the effects of different design modes (dark vs. light) is scarce [19, 20]. First results indicate that while no significant impact on user performance seems to exist [19], trust ratings are higher for the light mode [20]. However, practice more often adapts this trend in major operating systems and apps (i.e. Windows 10, macOS X), as well as on websites. While the use of dark mode is often justified with saving resources of OLED displays, an investigation on how this impacts users' experiences is still lacking [20].

Consequently, both button shape and design mode may have a significant impact on users' perceptions and attitude towards a website. Given that, to the best of our knowledge, only little scientific research on the effects of round versus sharp button design exists, along with the fact that only few studies on the effects of dark design mode are available, this study aims to instigate such research. Because color in website design may strongly affect website perception, and hence may even override the effects elicited by button shapes [21], we also consider color in our study. Against this background, based on the context of ecommerce websites, this pilot study investigates three design factors with an online survey: sharp versus curved buttons, dark versus light design mode, and red versus blue color scheme of the website. The results of this survey will then be used to select stimuli and experimental designs for a follow-up neuroimaging study.

The remainder of this paper is structured as follows: First, we discuss related work on human evaluations of curved versus sharp designs, as well as the use of color and design mode in website design. Next, we develop our working hypotheses. Afterwards, the experimental design and method is presented, followed by the results. We close this paper with a brief discussion and an outlook on the follow-up study.

2 Related Work and Hypotheses

2.1 Human Preference for Curved Shapes

Humans tend to prefer round or curved shapes and objects over sharp, rectangular, or angular shapes and objects [12, 14, 16, 17]. This has been consistently found across several research contexts such as car design, consumer product designs, abstract shapes, or interior architectural design [12, 13, 15, 17, 21]. Since this preference can also be observed in new born babies and great apes, evolution has likely shaped this preference [22]. Also, curved designs tend to be regarded as more natural and harmonious compared to sharp angled design [23]. Following the processing fluency theory of aesthetic pleasure, curved design might be more fluently processable by humans and is therefore regarded as more beautiful [24, 25]. This finding is substantiated by an fMRI study in which participants judged curved designs as more beautiful, which was associated with activations in a neural network related to aesthetic and reward processing [15]. Next to aesthetic evaluations, curved designs also tend to be associated with quiet or calm sounds, green color, and relieved emotion while sharp designs are more attributed to loud and dynamic sound, red color, and excited emotion [26]. For consumer products, sharp or angular design seems to elicit negative emotions associated with threat [12, 16, 27–30], while curved designs lead not only to more positive aesthetic evaluations, but also to increased purchase intentions [13]. Consequently, we propose that websites with round buttons will elicit a more positive emotional experience (measured with pleasure), which further results in approach behavior (measured with use intention):

H 1. Websites with round buttons will be rated higher in pleasure and use intention, if compared to websites with sharp buttons.

2.2 Color and Design Mode

Research on the impact of color on human perception and emotion has a long history [31–33], and has also been frequently researched in the context of website design [10, 34, 35]. In essence, blue colors on websites have a calming, positive emotional effect, while red colors tend have a more negative emotional effect and are related to arousal [2, 35–44]. Furthermore, blue websites are perceived as more trustworthy than red or yellow websites [40]. The described effects were consistently found across a variety of studies, all of which were including different shades of blue and red, and identified the effects in behavioral and neural measurements [10]. Consequently, we propose that color has a significant effect on pleasure and arousal as measures for the emotional experience, and perceived trustworthiness and attitude as indicators for behavioral intention:

H2. Blue websites will be rated higher in pleasure, perceived trustworthiness, and positive attitude towards the website, but lower in arousal, if compared to red websites.

Related to colors in website design is design mode, which can either be dark or light. Design mode is an uprising UX design element, and a dark design is currently a trend in UI design as signified by its integration into major operating systems such as Windows, macOS, iOS, and Android [45]. Interestingly, there is a paucity of academic literature on the effects of dark mode on UX. Generally, dark mode could delay visual fatigue and increase visual comfort, especially in environments with poor lighting conditions [46, 47]. However, although users perceive their performance to be increased on dark over light designs [47], studies have found that there are no significant differences in reading performance between the designs [19, 48]. With respect to perceived trustworthiness, first results suggest that websites designed in dark mode can lead to lower perceived trustworthiness than light mode [20]. Consequently, we propose:

H3. Websites designed in dark mode will lead to lower ratings in perceived trustworthiness, if compared to websites in light mode.

3 Method

To test our three hypotheses and to identify potential stimulus material for the neuroimaging follow-up study, different versions of an ecommerce website (e-learning courses) were created and tested in this pilot study through an online survey. In this survey, participants viewed the different website designs and evaluated their perceived pleasure, arousal, trust, attitude towards the website, and use intention for each website version.

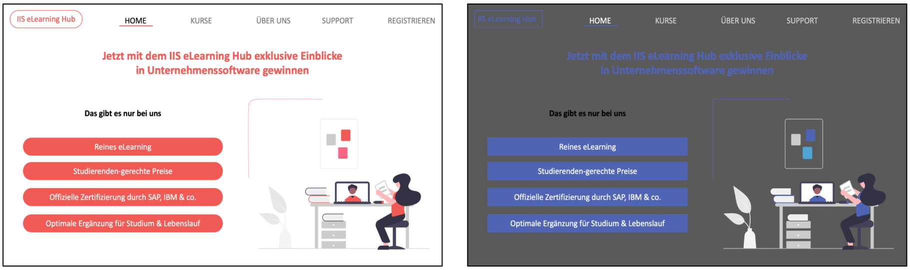
3.1 Sample

The online survey was distributed through the platform clickworker to 137 participants from Germany, Austria, and Switzerland. The data of 20 participants were excluded due to missing data or because the rating of the attention check question was wrong (this question was randomly hidden between the other scales and asked participants to select '4' on the Likert scale). Consequently, a dataset of $N = 117$ participants remained for further analysis. The average age of the sample was $M_{\text{age}} = 40.7$ years ($SD_{\text{age}} = 13.1$ years) with 54.7% being male and 45.3% being female. Regarding work status, 76.1% are currently employed, 12% are students, 6.8% searching for employment, 3.4% retired, .9% are in internship, and .9% are still pupils. Moreover, we asked the participants to indicate disposition to trust towards websites and their familiarity with booking e-learning courses on the web with validated scales taken from [49, 50]. Both ratings are based on a 5-point Likert scale resulting in $M_{\text{dispotrust}} = 3.01$ ($SD_{\text{dispotrust}} = .771$) for disposition to trust, and in $M_{\text{familiarity}} = 3.62$ ($SD_{\text{familiarity}} = .773$) for familiarity.

3.2 Stimuli and Study Design

We used a 2 × 2 × 2 factorial within-subjects study design with color (red, blue), button shape (round, sharp), and design mode (light, dark) as independent variables, and pleasure, arousal, trust, attitude, and use intention as dependent variables. The scales for pleasure were adapted from [51], arousal scales were adapted from [52], trust scales were taken and adapted from [49, 53], attitude towards the website scales were taken and adapted from [54], and finally, use intention scales were adapted from [55]. Since the study was conducted in Germany, examples of the used stimuli can be seen in Fig. 1 (in German). The time participants took was not manipulated by the survey so that each participant could proceed at his/her own speed.

All of the website versions and the scales were shown in randomized order. Each website version was shown with the scales of the dependent variables on one page of the questionnaire. When all scales were evaluated for the shown website version, participants



a) Light design, red color and round buttons b) Dark design, blue color and sharp buttons

Fig. 1. Examples for stimuli in the pilot study

had to click on a button to proceed with the next website. After having evaluated three different website versions, a questionnaire page with scales of the control variables disposition to trust and familiarity were shown without the websites. After that, further three website variations were presented with the scales of the dependent variables each, which was followed by a questionnaire page with demographic questions. Finally, the remaining two website versions were shown. This procedure was chosen to avoid fatigue in participants due to them having to rate the same items eight times without breaks.

3.3 Results

The data was analyzed with a repeated measures multivariate analysis of variance (RM-MANOVA) with the independent variables color, button shape, and design mode as repeated measures. Because we only included two levels per measure, sphericity is assumed. Although multivariate normality was not provided for half of the website design variations (measured with Mardia's skewness and kurtosis, threshold $p < .05$) [56], RM-MANOVA still seems to provide more robust results than non-parametric alternatives [57]. Yet, the following results may be treated with care.

Across all included dependent variables, significant differences could be identified for color ($F(5, 112) = 6.159$, $p < .001$, $\eta^2{}_p = .216$) and design mode ($F(5, 112) = 4.161$, $p = .002$, $\eta^2{}_p = .157$), but not for button shape ($F(5, 112) = 1.707$, $p > .05$, $\eta^2{}_p = .031$). Furthermore, only a slightly significant interaction effect between color and design mode could be detected ($F(5, 112) = 2.405$, $p = .033$, $\eta^2{}_p = .097$). No interaction effects between all three independent variables (color x button shape x design mode), nor between color and button shape, or between design mode and button shape were found (all with $p > .05$).

Regarding button shape, no significant differences were identified in any of the dependent variables (all with $p > .05$). Thus, based on the data of this pilot study, H1 has to be rejected. However, a medium strong effect could be identified for color for which the most significant difference was found for arousal ratings ($F(1, 116) = 12.873$, $p < .001$, $\eta^2{}_p = .100$), followed by slightly significant different ratings of pleasure ($F(1, 116) = 4.139$, $p = .044$, $\eta^2{}_p = .034$), and use intention ($F(1, 116) = 4.264$, $p = .041$, $\eta^2{}_p = .035$); all of which were rated more positive for the blue website versions. However, no significant differences could be identified for trust ($F(1, 116) = 2.389$, $p > .05$, $\eta^2{}_p$

= .02) and attitude ($F(1, 116) = 1.465$, $p > .05$, $\eta^2{}_p = .012$) between the blue and red website versions. Hence, H2 is only partly supported. Finally, the strongest effect was found for design mode, thus, all included dependent variables revealed significant differences between light and dark design, with all ratings being in favor of the light design mode ($F(1, 116) = 26.03$, $p < .001$, $\eta^2{}_p = .183$ for pleasure, $F(1, 116) = 13.269$, $p < .001$, $\eta^2{}_p = .103$ for arousal, $F(1, 116) = 20.913$, $p < .001$, $\eta^2{}_p = .153$ for trust, $F(1, 116) = 21.304$, $p < .001$, $\eta^2{}_p = .155$ for attitude, and $F(1, 116) = 22.794$, $p < .001$, $\eta^2{}_p = .164$ for use intention). Consequently, H3 is supported by these results.

4 Discussion and Follow-Up Neuroimaging Study

4.1 Discussion of Self-reported Results

Given the consistency of findings in the related literature on sharp versus round object designs over several research contexts, the rejection of H1 was unexpected. Paired with the significant differences in arousal for color, and the significant differences between light and dark designed websites for all included outcome variables, we conclude that color and design mode tend to have stronger effects than button shape. In particular, this pilot study shows that an in-depth investigation of the effects of design mode on website users' perceptions is crucial.

Our investigated outcomes can have a significant effect on actual website use and thus, business success. What follows is that further investigation of design mode has high relevance for both academia and practice. Specifically, based on the findings of this pilot study, we will study potential differences in the neural processing of light and dark designed websites to gain further insights into how both design modes are perceived and processed in the brain. Also, because the extant brain imaging literature on sharp versus round designs has revealed significant differences in neural activity related to emotion and threat processing [12, 58], we surmise that even though no significant differences in self-reports could be observed in this pilot study, an identification of significant neurophysiological differences is likely. Furthermore, the increase in self-reported arousal for the red website is supported by neural investigations of color on websites which revealed increased activations for websites designed in reddish color [9, 10]. In an attempt to further validate these results, color manipulation is also planned to be included in the follow-up brain imaging study. At this point, it needs to be mentioned that the impact of color on user perceptions and processing might depend on the intensity and shade of the used colors. In our pre-study, only one level of intensity and shade was considered which was held constant across the red and the blue website version. Follow-up research on color could therefore focus on different shades and intensity levels to detect possible effects of these features on user perceptions and behavioral intentions.

Finally, as already pointed out, design mode had a significant effect on users' perceptions in this pilot study. In fact, the impact of design mode might have been so overwhelming that effects due to button shape for the outcome variables were not consciously recognized by the participants.

4.2 Follow-Up Neuroimaging Study

The upcoming neuroimaging study will thus primarily focus on the effects of button shape and colors by means of the mobile neuroimaging method functional near-infrared spectroscopy (fNIRS) in an attempt to overcome the limited external validity of fMRI measurements. fNIRS offers a lightweight method which is portable and thus, it can be applied to realistic use contexts [59, 60]. Although fNIRS has shown to be a promising method to investigate NeuroIS constructs [10, 60–63], its application in NeuroIS research is still scarce [64].

Further, the neural effects of color and shapes have been primarily measured with fMRI [12, 15, 65, 66] which also assesses the hemodynamic response function (hrf) as measure to identify neural activations. While fNIRS also relies on the hrf, it is applicable in more realistic scenarios than fMRI and does not require participants to lay down. Still, since it does measure hrf, too, results from fNIRS heavily correlate with fMRI results which offers potential to compare fMRI and fNIRS results between studies [67–70]. Next to fNIRS, electroencephalography (EEG) also offers a mobile method that allows for field experiments and is frequently applied in NeuroIS research [64, 71]. Although EEG has higher temporal resolution [72], fNIRS is more robust against task un-related activations on cortical surfaces due to respiration or movements [73], and also offers higher spatial resolution than EEG [74]. While both EEG and fNIRS are limited to measuring neural activations on cortical structures, we will further focus on areas of the prefrontal cortex (PFC) as regions of interest.

Although fMRI studies on color and shapes have found activations primarily in the amygdala, they have also found significant activations in the PFC [15, 66]. Explanations for this can be found in several studies which investigate the links between the PFC and other brain regions. That is, across several contexts, the dorsolateral and ventrolateral PFC were found to exhibit top-down control on activations in the visual cortex due to their role in attention control [75–77]. Furthermore, the dorsomedial and ventromedial PFC were found to exhibit control on amygdala activations for means of emotion regulation [78–82]. These findings make the PFC an interesting region to study in relation to the processing of color and button shapes, which is also well assessable by means of fNIRS. This approach is further supported by related research focusing on neural activation changes in the PFC depending on color use in the context of ecommerce websites which were assessed with fNIRS [9, 10].

Beyond the planned upcoming study, future research could investigate design elements such as color, button shapes, and design mode with combined EEG-fNIRS measurements to cover both the electrical potential, as well as hrf related to website design variations. Since applications of fNIRS in this research domain are still scarce, combined measurements are even rarer [83]. Therefore, this offers a fruitful approach for other follow-up studies.

As a first step, however, fNIRS offers a still novel, yet appropriate approach to validate whether prior results apply to website design, too, that go beyond the conscious recognition of design elements.

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