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Towards Essential Visual Variables in User Interface Design

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Abstract—**This paper focuses on visual variables in user interface design from the user perspective. Visual design of user interfaces is essential to users interacting with different software. The study is conducted with 3E-templates for users to express their impressions by writing and drawing regarding visual website design. The data is analyzed with qualitative content analysis through interpretation framework. The results of this study provide new insights into user-centered visual user interface design. The results indicate which are the most essential visual variables in user interface design and therefore should be emphasized in user-centered design that promotes positive UX and, thus, benefit user-centered visual UI design. The results of this study are beneficial for researchers in the field of visual aesthetics in human-computer interaction and to user interface designers.**

Keywords-visual user interface design; visual variables; user-centered design; human-computer interaction

I. INTRODUCTION

Visual design of user interfaces (UIs) is significant to users interacting with different software. In addition to the traditional efforts in human-computer interaction (HCI), current and future UIs need to be developed in a novel way to match the potentials offered by the newest computing technologies and the users´ requirements based on their visual experiences. However, the snowballing research of UI design has, until now, largely left the study of visual variables in UI design aside as means to enhance user experience (UX). Current research concentrating on visual UI design in the research area of visual aesthetics in HCI has mainly focused on high-level attributes [1]. The high-level attributes, which have been in focus are, for example, unity and prototypicality [2], novelty [3], typicality and novelty [4]. Visual aesthetics in HCI lacks knowledge of low-level attributes, i.e., visual elements, such as color, size, and balance [5]. In this paper, a qualitative approach is adopted in order to increase knowledge of visual elements in UI design.

In addition, from a user-centered viewpoint, the rapid development of UI technologies demands clarification of how visual variables should be utilized in UI design to promote positive UX. In this study, visual representations that draw on the theories of two-dimensional pictorial elements are utilized as theoretical vehicles to create novel insight into visual UI design. The dispensation of visual theory is in that it provides knowledge of exact visual variables, such as size, value, hue, orientation, contrast, texture [6], shape, proportion, and position [7] and, for instance, form, and expression [8], that are seen as visual elements inherent in contemporary UIs. Mullet and Sano [7] refer to visual language in designing visual UIs. Through visual language, based on visual elements, UIs communicate to the users. Visual language of UIs is divided into visual UI design factors, which are visual characteristics (shape, color, position, texture, size, orientation, etc.) in a specific set of design elements (point, line, volume, plane, etc.) and the factors by which they relate to each other; such as balance, structure, proportion, and rhythm.

These elements facilitate in finding the essential visual elements that should be applied intentionally to modern UI design in a manner that enhances interaction between UIs and users. Further, visual theory serves as a starting point in the study because aesthetic impressions conveyed by visual representations are the best way of evoking UX [9] that may promote positive feelings on UIs [10] due to the emotional nature of an aesthetic experience [11], [12].

In addition, the improvement of visual aesthetics of UI design will also enhance the usability of the product, by promoting visual organization, clarity, and conciseness of UIs [7]. More profound understanding of visual variables in UI design from user-centered perspective contributes to enhanced visual usability of UIs [13]. Moreover, in the current era of visual UIs, usable designs need to highlight aesthetic expression as meaningful presence for users instead of just providing designs from the functional tool perspective [14]. Clearly, research on users' experiences on specific visual variables in UIs is needed.

Aesthetic qualities are currently emphasized in designing software for HCI. According to Tractinsky [1] usability experts and designers came to the conclusion that these two aspects of design, visual aesthetics and usability, could and should coexist in the same context of use. Before this shift in the first decade of 21th century, visual aesthetics and usability were often seen to have a contradictory relation, in that, when one was emphasized the other one was automatically omitted. The shift has emerged mostly because recent research corroborates a positive correlation between aesthetic and usability principles [9], [15], [16], [17].

Yet, often in the software development process, only the implementation of software (e.g., programming) and the traditional, general usability design [18] are considered as the most important parts of the process [19]. In reality, users'

needs are not taken into account in the software development process [20]. The essential deficit in UI design lies in the absence of visual UI design specialists in the development process.

This paper focuses on studying the visual elements as variables in UIs in order to provide usable insight into the evaluation and design of visual variables in UIs that promote UX and thus, to benefit user-centered visual UI design. This study focuses on shedding light into the following research questions: *which visual variables contribute to positioning of the viewer as UIs´ ability to communicate the whole content in a visual manner as quick and easy to grasp? What are the essential visual variables in modern UIs´ from a users' point of view?*

The rest of the paper is organized as follows. First, the method for the study is described. Second, the analysis of the data is presented. Third, the results of the study are discussed and finally, conclusions with future research and limitations of the study are presented. The results of this study will provide novel insights into what are considered as the most essential visual variables in UI design. Also, the results provide knowledge of what is considered important in visual UI design for future programmers, engineers, and practitioners in the field of information technology.

II. METHOD

When people encounter visual representations, such as visual UIs, numerous visual elements are encountered [21]. People may experience visual elements as both explicit and simple, but also as elements involving interpretation. Therefore, the research method should facilitate the combination of the analysis of qualitative and quantified issues. As Collier [22] points out, a studied phenomenon must first be examined without a precocious descent into analyses, maintaining a focus on pre-existent structures and points of interest. In this study, the data is collected and analyzed with a mixed methods approach [23].

First, a data driven qualitative analysis is conducted to find and describe the UI elements depicted by the informants after having looked at the selected UIs. Second, the elements found and defined were quantified in order to find the visual variables that are considered important in visual user interface design, particularly in layout design. The analysis was conducted with these two procedures, which supported the analysis from two different viewpoints.

The quantification of the explicitly written words representing specific objects is important, but it also relates to the qualitative procedures. Krippendorf [24] emphasizes the meaning of context in content analysis. Texts and images are always produced in some specific cultural context and they also refer to wider cultural context. Regarding content analysis, this aspect is considered by first deploying the interpretative viewpoint as an independent phase before quantifying the found elements.

The methodological decisions for the study are influenced by the nature of the visual viewpoint: instead of directly analyzing visual UIs, the data is comprised of participants' descriptions of those visual UIs. Therefore many methods, for example visual anthropology [22], semiotics and iconography [25] as well as social semiotic visual analysis [26], are not applicable because they assume that the data along with the object of analysis are visual images. Furthermore, even though the data collected by other methods (such as eye tracking) could enable the extraction of specific points of attention, it would be impossible to analyze which particular element draws attention; color, form or, for instance, a tension between elements.

The data collection was conducted in the University of Jyväskylä in the "The User-centered software development: Designing, realizing and testing the visual appearance and usability of user interface" course, held in the Department of Mathematical Information Technology. The course included 10 lectures and 5 demo exercises. Three lectures dealt with visual UI design. The first lecture of visual design concentrated on user-centered visual UI design, the second dealt with layout design and composition and the third with color design. The data was collected with the 3E (expressing emotions and experiences) -template [27], [28] from the lecture dealing with layout design. The 3E-template was selected as a data collection method to allow respondents to express their thoughts both verbally and non-verbally: by writing and drawing (Fig. 1).

Figure 1. The 3E-tempalate.

From the beginning of the lecture, participants were familiarized with the design process in general, the evaluation methods of visual UIs, pictorial elements, such as lines with different characters, visual rhythm, dynamics, balance, tension, contrast and Gestalt laws. After this part of the lecture, the participants were introduced to the 3E-template and they were asked to write and draw their thoughts and impressions of two still pictures of web pages, with a unique focus on the compositional elements.

The participants took approximately 20 minutes in answering the two templates. The research data is comprised of the written and drawn reflections and interpretations on the compositional aspects of example web pages. A total of 100 templates were answered; 50 templates times two visual web pages.

The common factors between the participants were that they all were in the same auditorium, heard and saw the same content of the lecture, and were all introduced to the web pages as well as to the template at the same time with the same advice, and were allotted the same amount of time for answering the template. In addition, all the participants were university students, mainly from the faculty of information technology. The group of participants included

both novice and expert users of information technology. Of the participants, 18.5 % were female and 81.5 % male. The age of the participants ranged from 19 years to 50 years. The average age of the participants was 25 years, standard deviation of the age was 5.8. The circumstances of the data collection were designed similarly for all the respondents.

The objects for the compositional reflection were two web pages (Fig. 2) from the CSS Zen Garden web page gallery, a web page created with CSS-based design [29]. All the web pages have the exact same content but altering visual appearances. The CSS Zen Garden web pages were scoured in order to find two example layouts that would differ from each other. Especially with regards to the amount of elements that divide the surface; diagonal and horizontal lines, and the overall use of space.

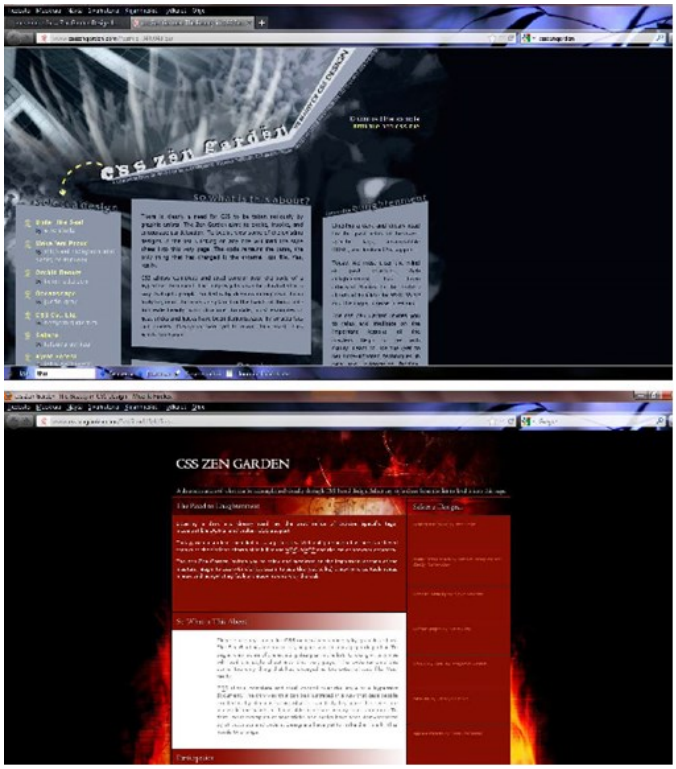


Figure 2. The two UIs used in data collection.

All the CSS Zen Garden web pages were looked through and opened in new tabs. The web pages were first divided into two categories and then compared step by step, finally resulting in two example web pages.

Emphasis on a choice of web pages according to their differentiating elements was made in order to provoke participants towards a comparative analysis between web page layouts. Bell [30] also emphasizes that evaluations with content analysis are often comparative. The web pages were therefore selected with a comparative setting, regarding the pages' differences in constructing visual elements. This was achieved in the study by using two different web pages with similar content but differing visual appearances.

III. ANALYSIS

The data analysis proceeded as follows. First, the data was observed as a whole by reading the templates. The purpose was to first focus on the visual variables in a neutral context in order to gain an understanding of the visual elements that are seen as important in visual UI design despite of the emotions they might evoke. Therefore, emotional aspects of the visual variables are not studied in this paper. The human figure in the templates was only used in a few papers to illustrate emotions by drawing facial expressions. Almost none of the drawings emphasized the written content or the facial emotions of the figure, but brought to attention something without a clear connection to the written content. Due to these characteristics of data, the focus of the analysis was on the written texts describing the visual elements.

The aim was on finding the visual variables that have drawn the most attention and can be seen to have importance due their frequent emergence and contentual significance. After becoming acquainted with the data, a data-driven interpretation rule was developed, which was used to assist in the analysis. The interpretation rule included the items, which directed the focus on a conceptual level during the data analysis, in interpreting and comparing interesting insights within the data. The interpretation rule consisted of compositional interpretation [31] and visual variables in UI design [7].

Compositional interpretation refers to describing the appearance of images with a detailed terminology. This form of visual analysis requires contextual knowledge of art work and a particular way of looking at images ("the good eye"), which is not methodologically explicit, but functions as visual connoisseurship and is a specific way of describing images. Compositional interpretation focuses on the image itself by trying to comprehend its significance mostly by focusing on its compositionality. Interpretation does not focus on "external factors" such as, what kind of messages the image sends and does it have some functional meaning.

The terminology of compositional interpretation includes several components. First, the content: what the image actually shows. The second component is color, which is more specifically defined with concepts of hue, saturation value and the harmony of color combinations. Thirdly, spatial organization, which includes volume, lines, static and dynamic rhythm, geometrical perspective, logic of figuration (how the elements of a picture offer particular viewing position outside the photo) and focalisers (the visual organization of looks and gazes inside the picture and in relation to the viewer's gaze). The fourth is light, what type of light is represented and from what sources of light. The last component is expressive content, which describes the "feel" of the image combining the effect of the subject matter and visual form.

Compositional interpretation approach is established in Art History and is usually used in studying paintings [31]. Visual UIs can be comprehended as paintings or, in a more general viewpoint, as any two-dimensional representation that is constructed with pictorial elements, such as lines and

volumes. Compositional interpretation can, therefore, also be extended to analyzing visual UIs.

Mullet & Sano [7] present visual UI design factors, which are shape, color, position, texture, size, orientation, point, line, volume, balance, symmetry, scale, contrast, structure, proportion, rhythm and position. The emphasis on visual factors in UI design is to provide insight into designing good visual usability and effective visual communication. They also point out that negative space and grouping are important components in visual UI design.

The interpretation rule combined the discussed visual elements. The elements were derived from the two approaches described above and created the content of the interpretation rule. The interpretation rule included, but was not restricted to, the following components: color (hue, saturation, value, harmony of color combinations), spatial organization, geometrical perspective, volume, lines, points, size, texture, shape, static and dynamic rhythm, orientation, balance, symmetry, scale, structure, proportion, negative space, grouping, position, figuration logic, focalisers, contrast and light.

From a compositional interpretation, the expressive content component was excluded from the interpretation rule because of its emphasis on subject matter evoking emotionality which is not in the focus in this study. The templates that comprise the data were mainly used by the participants to express their impressions of the UIs in written form. Examples of written expressions in the speech and think bubble are presented in Fig. 3 below.

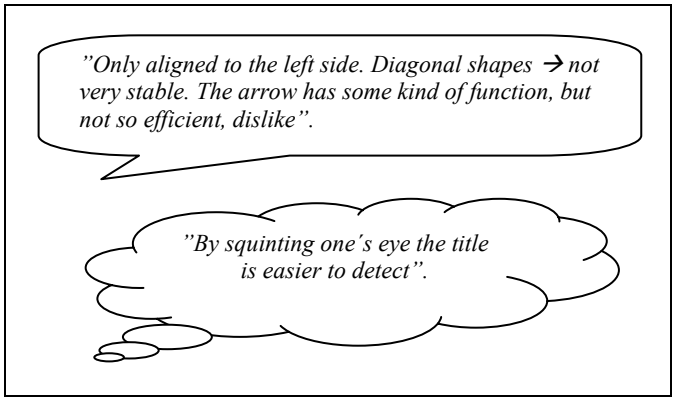


Figure 3. Examples of written expressions.

The interpretation rule functioned as a ‘theoretical lens’ in the analysis. The lens was constructed based on the elements that were included in the rule. The analysis required accuracy and concentration in detecting tiny nuances in finding the relations between the different visual elements, which required close attention in detecting how many altering ways there are, for instance, to describe the use of space in UIs. All the 100 templates were analyzed by writing down all the described elements in the templates and by counting the frequency of their occurrence.

The second phase was to create categories of relations and then to critically combine several different categories of relations between elements, into main categories. For instance, from the example described above the first observation about left side alignment is related to the spatial organization as is the second notion of diagonal lines. The stability refers to symmetry and the role of the arrow is related to functionality. The interpretation rule guided the detection of written reflections of the described elements. For instance, the interpretation rule did not include usability, which emerged from the data as a connective factor between relations of different elements, especially in terms of visual usability [13] of the UI. In many templates think bubbles were used to express additional reflections, mostly about the supposed functionality of the UI.

In the data, spatial organization was reflected in detail and visual elements referring to this category were most often mentioned. Observations of balance and imbalance were seen in relation to symmetry. Justification and alignment to the left or right were often in the same context as the sensation of space. The use of negative space was taken into account, but overall was not in focus. Another important relation was often found between the continuity, groupings and togetherness of the whole.

Even though the participants were instructed to only use the template for reflecting the impressions of the compositional elements of the layout, a lot of attention was paid towards contrasting colors and their role in visual usability. In relation to contrast most of the remarks were about contrasting colors, especially between the texts and background, which was, moreover, attached to readability. Size was only discussed in the context of the font size.

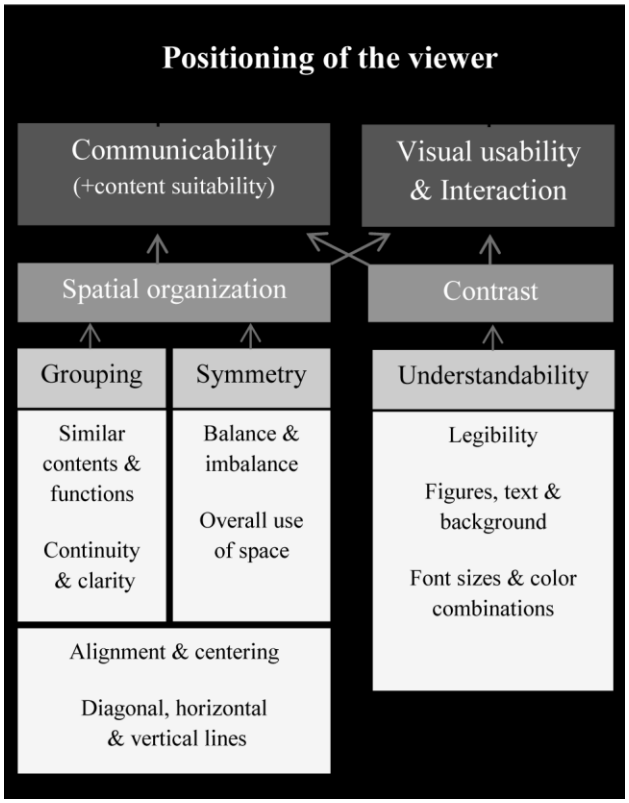
The position of the viewer (including figuration logic and focalisers) was seen as a visual strategy that guides the viewer’s gaze in the UI. The shape of an arrow along with horizontal, diagonal and vertical lines, were especially emphasized and seen as visual elements that guide the gaze forward. There was a strong emphasis on describing how the visual elements function and how they support visual usability and interaction, especially the ways by which visual elements direct attention in the UI towards the important areas. Without knowledge of the context and aid of the interpretation rule, the data driven qualitative interpretation would have been problematic.

IV. RESULTS

The analysis is reflexively highlighted and evaluated in the following sections. Implications for future research and limitations of the study are also discussed. Based on the results, insights into the essential visual variables in UIs are represented in Table 1: Essential visual variables contributing to positioning of the viewer.

Positioning of the viewer refers UIs ability to communicate the whole content in a visual manner as quick and easy to grasp. Positioning of the viewer gathers all the results under one definition, and functions as the main viewpoint in interacting with visual UIs from user-centered perspective. Positioning of the viewer was emphasized regarding the communicative ability of the visual variables [7], and in relation to the UIs content suitability. The overall visual impression of the UI´s appearance should be suitable for the context for which it is designed.

TABLE I ESSENTIAL VISUAL VARIABLES CONTRIBUTING TO POSITIONING OF THE VIEWER



Besides communicability, positioning of the viewer was approached from the viewpoints of visual usability and interaction. Visual usability and interaction include the ways how different visual elements guide the interaction and usability. Users appreciate UIs that fluently communicate the content in an understandable visual form. Thus, in designing visual UIs the power of the visual elements to guide users´ attention need to be taken into account.

Positioning the viewer was discussed in relation to visual variables contributing to spatial organization and contrast. Spatial organization and contrast were seen to apply both to communicability and to visual usability and interaction. Spatial organization was emphasized by focusing on grouping and symmetry. Grouping and symmetry were seen as the two primary visual variables essential to spatial organization of visual UI elements, and in creating an impression of the UI as a consistent totality, in which visual variables contribute to the impression of the UI as a whole.

Grouping of similar contents and functions were seen as substantive factors creating continuity and clarity. Spatial organization through balance and symmetry was seen important regarding the overall use of space. Grouping and symmetry were further discussed in terms of aligning or centering the content, and were seen constitutive factors influencing both grouping and symmetry. Diagonal, horizontal and vertical lines were highly emphasized as visual variables that strongly affect the positioning of the viewer and lead the interaction as the main low-level variables.

In addition to spatial organization, contrast was seen as influential variable. Functional and communicative impressions of the visual elements were in focus regarding understandability and legibility of the content. Contrast between figures, text and background was conveyed through different font sizes and color combinations. These ways in creating contrast between visual elements in UIs were often mentioned, especially concentrating on the contrast between background color and the size and color of fonts. Moreover, designing contrast between these elements was highlighted due to its ability to promote effortless visual usability, which leads to better UX in interacting with visual UIs. Essential visual variables contributing to fluent and pleasurable interaction have a strong impact on users´ perceptions and interpretations of the UIs´ communicative abilities and visual usability. Therefore, in designing visual UIs, the essential visual variables should be noticed as factors contributing to position the viewer.

V. CONCLUSION AND FUTURE WORK

The results of this study provide novel insights into what are considered the most essential visual variables in UI design that contribute to communicability, visual usability and interaction aiming to position the viewer. Spatial organization and contrast, with the lower-level variables which they are based, such as diagonal lines and font colors, are essential to users in visual UI design that promote fluent interaction and visual usability. Characteristics of lines have an important role in emphasizing visual usability and communicability of UIs. Spatial organization through balance and symmetry contribute to the overall impression of the UI, and grouping similar objects contributes to understandable and effective design. Contrast between figures, texts and backgrounds enhance visual usability and interaction with the UI. In addition, through contrast UIs can be designed to communicate the content in an effortless manner, by grasping the content with one glance. Communicability of the UI also refers to the content´s suitability in relation to the context.

Without contrast between visual elements, UIs could not communicate the content to the users interacting with them. This notion emphasizes the essence of visual variables contributing to fluent HCI. UI´s ability to position the viewer through visual variables is essential for pleasurable interaction and efficient visual usability leading to good UX. Moreover, the results of this study provide knowledge of what is considered important in visual UI design among future programmers, engineers, and practitioners in the field of information technology.

Future research focuses on proceeding from specific contexts towards the discussion of a more general understanding of the studied phenomena. Data collection could also be conducted with participants, with differing backgrounds in order to get more insight in dealing with the importance of different visual variables. In addition, participants could vary more according to their cultural backgrounds in order to provide understanding of the essential visual variables in different cultures. Moreover, the UIs of this study could also be analyzed through different

data collection methods, such as questionnaires, in order to test the validity of 3E-template and to compare different approaches in relation to the subject of study.

Visual design of UIs is not universally understood and appreciated similarly in different cultures. Different meanings attached to, for instance, dimensions of visual space are highly influenced by the writing and reading direction [32]. Therefore, due to the context of this study, the results can be applied to Western culture. In addition, this study was conducted in relation to visual web site design and therefore, might not be applicable to other visual UI design contexts, such as mobile UI design.

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