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Deviation from core tenets of user-centered design; evaluation of user decision reference points in interaction

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The evolution of the user interface design process has been driven by a focus on optimizing usability and scalability in response to increasing usage. User-Centered Design (UCD) has gained popularity within the design scope as it places the users at the center of all design decisions, modeling design schemes around their needs. While UCD has proven useful in many practical cases, it has also encountered failures. It has become evident that, despite the original intent of this concept, its application in many cases tends to be subjective, unconstructive, and biased. The impact of problems associated with UCD varies among production teams. Product evaluation using UCD concepts often lacks consensus regarding the criteria for heuristics. Consequently, evaluators frequently need to patch up heuristic schemes to comprehensively assess products. These inconsistencies lead to issues in final products, prompting a re-examination of the interaction process and methodologies for adjustment. This investigation, which is an excerpt from a larger study aimed at developing a minimalistic design model for interaction design, aimed to understand the fundamental references users consider when interacting with machine interfaces. The study involved 63 participants in a simple digital interaction task to capture and ascertain factors influencing decision-making in interaction. The analysis outcomes from this study justify and reaffirm the need to reconsider the organization of User-Centered Design (UCD) processes, emphasizing the importance of ensuring the persistence of the missing factors-environment and task variables-in the design process.

Key words: User centered design, usability design, User interface, interaction design, intuitive design, user interaction.

INTRODUCTION

In light of the desire to meet optimal usability and user experience standards, the concept of 'end-user-centeredness' was introduced into design schemes (Henry, 2007). User-Centered Design (UCD), widely utilized in various design spheres, including interaction design/interface design, places users at the core of the design process, aiming to incorporate their needs, priorities, and experiences (Vredenburg et al., 2002). Unlike other design domains, UI design not only values designs for their artistic or constructive splendor but also emphasizes usability and interactivity.

Norman, a cognitive science researcher, coined the

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term "user experience," indicating a shift to encompass emotional and cognitive factors, in addition to pre-existing behavioral concerns within user-centered design (Gube, 2010; Buley, 2013). Rubin's description of UCD, as cited in W3C (2004), highlights its focus on usage context or environment and task details, acknowledging the significance of considering users performing tasks in defined environments/scenarios.

The importance of factoring design schemes around usage contexts is affirmed in the relational scheme for understanding visual ergonomics proposed by Long and Richter (2014). Despite these principles, many design teams find it challenging to implement usability tenets effectively (Svanæs and Gulliksen, 2008; Thoden et al., 2017). Design teams often struggle to strike a balance between the core tenets of UCD, resulting in the development of interaction schemes that do not align with usage contexts. The misapplication or outright neglect of context and task requirements in the interface design process contributes to the failure of many UCD products (Svanæs and Gulliksen, 2008).

In addressing this flaw, Svanaes and Gulliken emphasize the essence of context, as exemplified in ISO 9241-11, listing users, tasks, equipment, and the environment of use. To comprehend the fundamental references users consider when interacting with machine interfaces, a focus group discussion, preceded by an interactive task, was conducted with three groups of participants. The analysis of the study's outcomes justifies and reaffirms the need to reconsider the organization of UCD processes, highlighting the critical importance of ensuring the persistence of often overlooked factors, namely environment and task.

METHODOLOGY

The study employed a qualitative approach by implementing an unlabeled interaction scheme involving a total of 63 participants. The primary focus of the investigation was to identify cognitive reference areas for intuitive interactions, aiming to understand users' thought processes when making decisions during interactions and derive design guidelines to support interaction design. Due to the constraints imposed by the Covid-19 pandemic, the study faced limitations in terms of time frame and the ability to conduct extensive experimentation in traditional lab settings.

To address these challenges, the study opted for a convenient sampling method and utilized digital solutions to gather the necessary data. The 63 participants included 10 students from the chair of Human-Machine systems at the Technische Universitaet, Berlin (MMS-TUB), participating for credit points, and 53 individuals from outside the MMS-TUB. The experimental design featured a virtual interaction scheme developed with JavaScript and deployed as a web/mobile application.

Participants, having provided consent to the data gathering and usage agreement, engaged in the interactive task, which took an average of 3 to 5 min and involved virtual activities through a blind interaction task. The task required participants to make decisions solely based on their intuition or subjective thought processes. User choices, justifications for choices, and response times were recorded at the end of each engagement. Notably, the task did not have right or wrong responses; rather, it aimed to explore the variety of thought patterns leading to choices. The study also aimed to identify correlations in these patterns concerning final choices.

The interaction was deployed via the web, and all data were programmatically captured with the full consent of participants for the study. This approach allowed the study to reach participants during the Covid-19 contact restriction period without compromising their safety. Additionally, this instrumentation provided the study with the advantage of precise interaction data, specifically task completion speed and overall timing. All interaction data were stored on a server for later retrieval and analysis.

Stimulus and deployment

The experiment was made accessible for a period of 14 days. As illustrated in Figure 1, the setup was designed to determine the cognitive reference domains for decision-making during interactions. The stimulus involved an interaction scenario with a digital control panel of an elevator featuring 6 buttons arranged in 2 columns and 3 rows. Each button had a unique color but was labeled with color names for recognition, with no reference to order or progression to influence participants' choices.

The experiment captured participants' button choices along with corresponding response times and their own descriptions justifying their choices. This blind interaction scheme was implemented as a web application accessible on any internet-enabled device. The interaction was available in two languages, English and German, reflecting the locations of the studies. The flow of interactions proceeded as follows:

1) Language choice
2) Participant data
3) Experiment stimuli
4) Appreciation

The stimulus was presented in the layout depicted in Figure 1, which represents a digital screen of an elevator control panel. Assuming the intention is to go to the third (3rd) floor:

1) What would be your choice of button?
2) And what is the reason for your choice?

RESULTS

Demographically, among the 63 participants, 39.68% (25) fell within the age range of 18-23 years, 20.63% (13) were in the age range of 24-29, and the remaining 39.68% (25) were above 30 years. The maximum age observed was 47 years, with a minimum of 18 years, and an average age of 20 years. In terms of gender distribution, 47.62% (30) identified as male, 44.44% (28) identified as female, and the remaining 7.92% (5) identified as non-binary.

This sample description suggests a heterogeneous group primarily consisting of millennials and tech-savvy individuals with significant interactive experience with machines. These distributions indicate a sample that is likely to perform the interaction task without anticipating challenges in task comprehension.

Hypothetical tests for significance among variables

The study's analysis commenced by attempting to identify

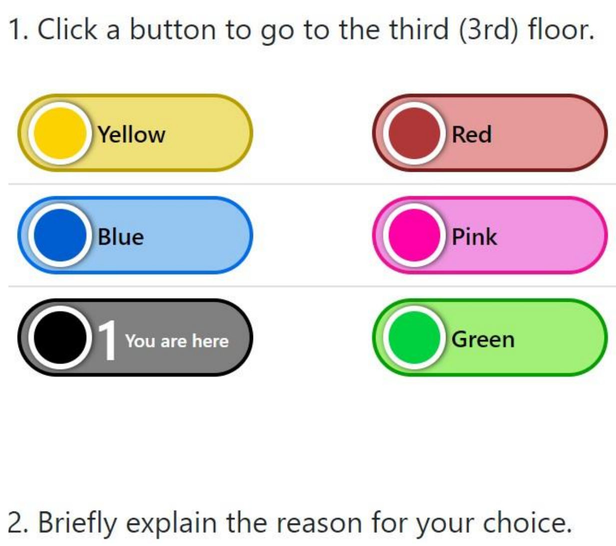

Figure 1. Virtual of Elevator Panel to ascertain influential factor of decision making
Source: Study data.

various forms of significant correlations among and within the categories of accumulated data. All non-numerical data were converted to numerical data before the analysis.

To test for interaction within the data categories, various hypothetical tests were conducted. The correlation between "gender and button choices," "visual disability and button choice," and also "physical disability and button choice" were subjected to the Chi-squared test. Spearman's correlation tests were used to examine the correlation between "age and response time." Additionally, for the correlation between gender and response time, a one-tailed Analysis of Variance was employed.

$$Chi^2 = \sum \frac{(Observed_i - Expected_i)^2}{Expected_i}$$

The analysis of gender and button choice yielded a Chi-squared value of 0.3816 and a p-value of 1, indicating the acceptance of the null hypothesis of no significant association between the variables. Similarly, in the analysis of visual disability and button choice under the Chi-squared test, a chi-squared value of 0.556 and a p-value of 1 were obtained, leading to the acceptance of the null hypothesis, suggesting no significant association between variables. The examination of physical disability and color choice, using the same test, resulted in a chi-squared value of 0.264 and a p-value of 1, again leading to the acceptance of the null hypothesis of no significant association between variables.

Furthermore, Spearman's correlation test was conducted on age and response time to ascertain the existence of a significant relationship.

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$$

di = difference between the 2 ranks of each observation; n = number of observations

The Spearman's correlation test on age and response time produced an output with a coefficient of 0.00131, a T-statistic of 0.01 (using absolute values), a p-value of 0.9919, and a t-critical value of 1.999. The output indicated a low positive correlation. Since the t-critical value is less than the t-statistics, the null hypothesis must be accepted, stating no correlation between age and response time.

For testing the correlation between gender and response time, a single-factor Kruskal-Wallis Hypothesis test (a non-parametric type of ANOVA) was conducted. This choice was made because the number of participants in each gender category is not equally distributed.

$$H = (N-1)\frac{\sum_{i=1}^{g} n_i(r_i - r)^2}{\sum_{i=1}^{g}\sum_{j=1}^{n_i}(r_{ij} - r)^2}$$

N is the total number of observations across all groups; g is the number of groups; n_1*is the number of observations in group i*

r_{ij} *is the rank (among all observations) of observation j from group I;* $r_i = \frac{\sum_{j=1}^{ni} r_{ij}}{n_i}$ *is the average rank of all observations in group I;* $r = \frac{1}{2}(N+1)$ *is the average of all the* r_{ij}

The analysis yielded an H = 1.578798 and p-value of 0.454118. The p-value which is less than 0.005 indicates points to an acceptance of the null hypothesis (no significant difference in the means).

Thematic analysis of user choices

The outcome from the interaction as seen in Figure 2 reveals a high inclination toward button yellow which represents 42.86% (27) of the total number. This was followed by Blue which has 31.75% (20) and green which has 17.46% (11). 7.94% (5) of the respondents chose Red and none (0%) of the respondents chose pink (Figure 2).

From the reasons given in support of button choices, the analysis revealed response themes of "Layout", "User Preference", "Assumption", "Environmental Association", "Knowledge/Cultural Association", "Task", and "No Reason".

The thematic classification of justifications presented in personal preferences for the color used, although the color was not intended to have an impact. Another

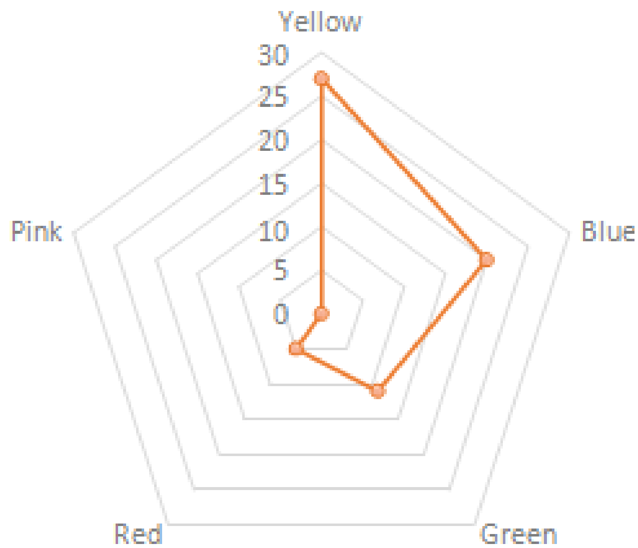

Figure 2. Radar diagram of output from button choices.
Source: Field data.

Table 1. Classification of button choice justifications into theme.

Theme	Yellow	Red	Green	Blue	Pink	Total
Task	12		3			15
Knowledge/culture	1	2	5	6		14
Favourite	4	2	2	5		13
Environment	6			5		11
No reason	1		1	2		4
Assumption	2					2
Layout	1	1		2		4
Total	27	5	11	20	0	63

Source: Field data.

17.46% (11) of participants referenced the operational environment to make their decisions. Following this, 6.35% (4) referenced layout indicators such as legibility and spacing to decide. The same percentage of respondents, 6.35% (4), gave no response, while 3.17% (2) made their decisions based on mere assumption.

Interestingly, all references were not solely centered on user preferences or assumptions but also spanned other domains, mainly "Task," "Environment," and "Knowledge/ Culture." The number of references to subjective user preferences underscores how subtle decisions by designers can have a significant impact on end users. It also highlights how reliance on presumed user preferences can lead to a mismatch between expected and actual user experiences.

The purpose of this engagement was neither to determine "right" or "wrong" responses nor to make users discern accurate responses. The use of distinguishing colors was entirely random and without recourse to any symbolism or association. It was solely intended to facilitate understanding of users' comments without ambiguity during analysis and to explore the wide variety of cognitive reference domains.

DISCUSSION

The comprehensive hypothetical analysis of correlation between variables indicates no significant correlation among the demographic variables and the dependent variables of response time and choice of button. This suggests that none of the demographic variables examined in the study had a significant impact on the outcomes. Although age and gender are recognized as important demographic factors in ergonomics research (Li et al., 2022), and studies have shown significant differences in their effects on driving interaction (Hulse et al., 2018; Useche et al., 2021; Muslim et al., 2021), the outcomes in this study confirm no significant differences. This aligns with the findings in the study conducted by Li et al., 2022. The lack of significant differences in this study could be attributed to the age range of the participants, who are considered digital natives (Reid et al., 2023), and the absence of apparent task risk factors that could induce a different response.

Through thematic analysis of justifications from participants, it was identified that participants' decisions during interaction were influenced by a variety of reference points, notably "Task," "Environment," "Knowledge/Culture," and User preferences. The significant reference to the "Task domain" underscores how users often interpret stimuli in relation to what must be performed with the machines. In this context, users reference known operational principles or mechanics within these machines and relate them to the interaction schemes. This can be valuable, as designers of the interactions typically possess knowledge about the machines their designs mediate. For example, a user with prior interaction experience with elevator operations is likely to reference the operation of elevators to interpret the stimuli.

"*Elevator goes up to 2nd and 3rd floor" "Most elevator have red bottoms"*
"Elevator buttons are arranged from bottom to top"

From the user's prior knowledge of organization or design, the user carries with them an expectation of how the interaction schemes should work. These experiences come from a variety of sources including interaction with similar machines, social ideologies, environmental concepts, etc. The culmination of these forms the users' expectation of an interaction scheme and thus greatly influences their choices. It can be observed that some of the choices from respondents were heavily guided by their prior knowledge of "order", "progress";

"Leserichtung links nach rechts, und in dem Fall unten nach oben"- German Original "Reading direction from left to right, and in this case bottom to top"- English Translation

"I need to go 2 more floors to reach the 3rd floor (yellow) when I am on the 1st floor (black)"

"Yellow is the third from the bottom to the left. The colour didn't play a role for me"

It is from the synthesis of such outcomes that intuitive use can be defined as against the sole customary association of intuitive use as UI/product feature without reference to user groups (Naumann et al., 2007). It can thus be argued that Interface design that draws on exploring connection with not only the user preferences but also task requirements and operating environment's requirements to achieve intuitive use. This will eventually not compel users to learn new interaction modalities each and every time they behold a new interface but draw from their prior knowledge in an unconscious manner.

Implication for design

Interestingly, many models do not incorporate the visual design of interaction schemes and interfaces, despite some recognizing interface design as a crucial factor influencing the degree of intuitive use (Naumann et al., 2007). This exclusion raises concerns about the integration of proper visual design principles in interaction design for intuitive use.

Models of design perception and interpretation typically identify two domains of stimulus interpretation: the General domain and the Expert domain (Neumann et al., 2007). The General domain encompasses both innate and acquired knowledge. Innate knowledge is inborn and activated through genes and prenatal biological adaptations, associated with reflexes. It includes interpretations and associations learned from socio-cultural and environmental contexts, such as knowledge about color symbolism, numeration, sequencing, alphabet and text composition, styling, etc. Although these may vary across communities, globalization has led to significant similarities. On the other hand, the Expert knowledge domain is specific to a particular operating context and device. Interpretation from the Expert domain does not necessarily vary from what is known in the General domain, as many interaction concepts use symbols, color codes, and signals common to both.

During interaction with designs, users explore these domains to make sense of schemes. The choice of the domain to exploit for understanding depends on the user's familiarity with the machine or software. Users typically exploit the Expert domain first when interacting with a familiar system. If the meaning does not align well with feedback, they then turn to the General domain of knowledge. For example, when interacting with a new system for the first time where familiarity is absent, users immediately exploit the General domain to comprehend the interaction. Continuous interaction builds up familiarity, and this accumulated knowledge becomes the new Expert domain. Subsequent interactions with the same or similar systems now leverage this Expert domain for reasons of familiarity.

It can be inferred that when expert knowledge is similar to General knowledge, comprehension, retention, and remembrance are easier than when they are entirely different. The latter scenario requires users to unlearn what is known from the General domain and learn what the Expert scope offers. This process must continue through conscious effort until users become accustomed to operating independently of these two distinct domains.

Although the experiment engaged only 63 participants and is not significant in numerical strength, qualitative analyses of deducing meaning from choices and justifications were sufficient to guide the study. The study focused on information mining and thematic analysis to meet the objectives. Despite the quantitative deficiency of the experiment, the lack of statistical strength does not invalidate the ability of qualitative studies to be used beyond the sample studied.

Conclusion

Due to the experiment's openness in an uncontrolled environment with access to various devices, the experiments were limited to basic interaction information. The absence of monitored participation in a controlled space hindered the researcher's observation of participants' attitudes, concentration, and other physiological variables. Possible negative influences, such as distractions and loss of attention during interaction, could not be monitored and controlled. However, the lack of control over the participants also presents the benefit of a more realistic interaction atmosphere with the advantages of more objective and open output from participants.

Even though users bring subjective conceptions to machines, there are imposed adjustments from the environment and task that dictate their interaction patterns. The integration of principles that comprehensively capture all these considerations is crucial in achieving excellent interaction schemes. The focus on "only user" in design schemes can lead to designs that overly satisfy user expectations but conflict with tasks, making the interaction inefficient. Also, "only-user" interaction often incorporates the subjective views of a few users, potentially limited to the designer's opinion, with the expectation of meeting the needs of a broader user class. Environmental limitations can render the effects of these "so-thought" user considerations impractical.

Although the user-centered design process demands task and context considerations, its workflow can unintentionally lead to only the user being prioritized throughout the design process. A more robust approach is a schema centered on the interaction between users, tasks, and the environment, known as Usage-Centered Design. It is important to note that Usage-Centered Design does not advocate for the removal of the user from its crucial role in the design process; rather, it advocates for the addition of the two other influential factors to enhance overall usage.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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