Investigating the Impact of Website Menu Presentation Style on User Performance

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***Abstract*—This paper investigates website navigation menu presentation styles. An experiment comparing three menu styles vertical, horizontal, and radial was conducted to determine their effect on user performance and preference. Although menu presentation style did not affect task completion time and error rate significantly, its effect on task completion time variance was significant and Radial menus were most inconsistent in terms of task completion time. Users preference was highest for horizontal menus.**

Keywords-Human-computer interaction; Human-Web Interaction; Interface Design; User Experience; Navigation User interface design.

I. Introduction

One aspect of website design is the implementation of navigation menus as they constitute the primary conduit through which users navigate and interact with a website's content.

Menu design has been a subject of significant discourse in Human Computer Interaction [1], however, few studies have focused on the web. This is important as menu design influences the user experience and performance. Novices unfamiliar with the menu content and command locations have to search for items visually and visual search dominates the overall selection time [2]. However, users quickly develop and rely on spatial knowledge for menu item locations (i.e., they become expert users) if the layout of the menu is stable [3], [4]. Consequently, visual search time decreases and the overall selection time then depends mainly on decision and pointing times [5], [6].

Even though physical appearance and colour play an important role on user experience, the same holds for menu layout and design features [7]. There have been different proposals for menu presentation styles in the literature which include horizontal, vertical, or radial menus. While several comparisons on menu organization have been made, fewer studies compare menu presentation styles to each other especially in the context of web navigation. We present here such an investigation. In the background section, we analyse existing research on the impact of menu presentation style and their application on user navigation patterns on websites. Subsequently, in the methods section we describe how we facilitated a controlled experiment three menu presentation styles vertical, horizontal and radial are compared. The objective is to determine if a given presentation style, among the tested variations, results in the most effective and efficient performance and enhances the hedonic user experience. In the results section we present our findings from the experiment, while in the discussion section we discuss what the results mean for our research question before we conclude the paper in the conclusion section.

II. Background

Menus are a well-studied topic in Human Computer Interaction (HCI) and several studies have investigated the influence of menu design on user experience and performance. The main parameters that are varied in the experiments are menu width and depth, whereas menu design and placement have received less attention.

Kim, Jacko, and Salvendy present [1] a comprehensive summary of investigations with respect to menu structure (width and depth), ordering, but also menu type on computers and mobile phones discussing both two- and three-dimensional menus. Three-dimensional menus leverage the depth dimension to provide additional information and enhance usability, however, the challenges associated with 3D interaction have influenced their potential. For our study we focus on 2D menus.

A significant aspect in menu design is breadth versus depth, i.e., the number of options available in each menu level versus the number of levels a user encounters as they move through the menu to a target item. Early findings supported the conclusion that a broader menu was more effective than a deeper one [8]. Miller [8] investigated the impact of menu configurations on speed and accuracy in an interactive computer terminal environment. He observed in his study a U-shaped function in goal acquisition time, with an optimal configuration of two menu levels and eight choices per level. This is because increased depth involves additional visual search and associated uncertainty about the location of a target menu item. However, excessive breadth can also lead to a crowded display. Therefore breadth should also be used with moderation and a balance between breadth and depth needs to be achieved. Contrary to the Miller's two-level approach [8], Kingsburg and Andre's [9] study on three-level menus suggests positive effects when distributing menu levels on different planes. Their findings also revealed that placing the first menu level on the left side of the screen had a positive impact. Furthermore, when the second and third menu levels were grouped in the same plane opposite from the primary menu, it resulted in improved user performance. Their research also revealed that users preferred menus situated in the left or

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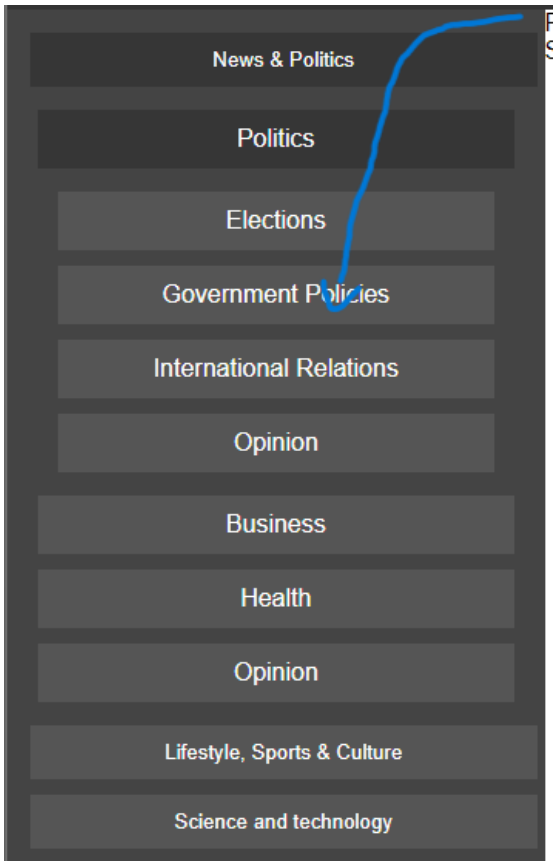


Figure 1: The vertical menu used in experiment.

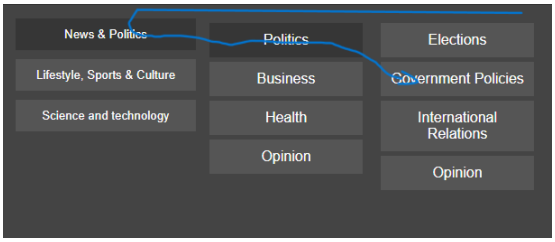


Figure 2: The horizontal menu used in experiment.

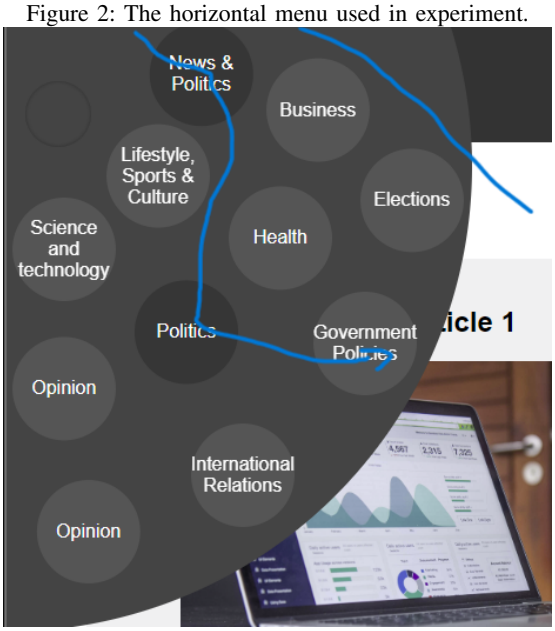


Figure 3: The radial menu used in experiment.

right planes. These findings are significant for the design of multi-level website menus and this experiment.

Moreno-Bote, Ramírez-Ruiz, Ramírez-Ruiz and Hayden [2] also investigated the breadth-depth dilemma in multi-alternative risky choices. Their study found that optimal strategy depends on capacity available. With limited capacity, favouring breadth is advantageous. However, when you have greater capacity a transition happens, emphasizing the importance of choosing the right balance between breadth and depth. When screen is small as in mobile devices, breadth must be limited due to practical considerations and narrow hierarchies perform better [10]. Filling the screen as much as possible without requiring scrolling while keeping a reasonable font size is the optimal solution when small screens are considered [11].

Another aspect of menu design is adaptation, i.e., whether a menu is static or the content is adjusted dynamically. Even though adaptation, can increase performance as frequent options appear first, it may increase learning time and slow down users until they become accustomed to this style [12]. A benefit for user design adaptable menus has been reported [13].

A third aspect discussed in the literature is menu ordering. Categorical menus are useful when categories can give a clue to target items, while alphabetical menus provide an advantage compared to random menus as users can guess the location of items in next levels [3], [14] [15]. This has been investigated for various tasks in experiments: (a) Search for a known item; (b) Search for the first suitable item with a known target characterization; (c) Search the most suitable item with a known target characterization; and (d) Browsing among the items. Categorical performs better in most cases an exact word is not required to be found.

A further parameter in relation to menu design is menu type. Several researchers compared hierarchical to fisheye menus. Hierarchical menus are also classified as categorical index menus (simply placing all items in a categorical index) as well as horizontal and vertical cascading menus (hierarchically cascade the menu items upon mouse-over). Fisheye menus magnify a menu region while elements in other regions are shown in gradually reduced sizes and can thus accommodate more items. Index menus have been found to lead to a more efficient interaction compared to hierarchical menus [10], perhaps due to a more tight layout on screen and visibility. Furthermore, users are faster and more accurate in finding known items with hierarchical compared to fisheye menus.

Another menu type arranges items on the circumference of a circle and is called radial [16], pie [6], or marking menu. Radial layouts were initially used to support small, single level menus. Support for hierarchies was first realized

by a series of single level radial menus. Pie menus were compared to a linear menu in expert mode, using 8 item menus, yielding 15% faster selections [6]. Marking menus generalize to multiple hierarchies by presenting each level in the displayed menu as a separate pie menu [4], [17], [18] and also provide an expert selection mode, in which the user can issue a straight 'mark' in the direction of a desired item without the actual menu being displayed. Radial menus are generalized to multiple hierarchies by presenting the elements in the next level in overlapping or non-overlapping menus. The Wave Menu presents new levels at the centre of the menu circle, while *inverted* Wave Menus outside the initial circle. Wave menus typically perform better than overlapping pie menus in which only one hierarchy level is visible at each time. The efficiency of such menus is higher than this of vertical menus as long as the number of items is small and no additional hierarchy levels are used. In another approach, radial menus expand outwards, however, the elements are not distributed over the whole circle but rather placed next to each other along the circumference of the corresponding level [16].

Parush and Yuviler-Gavish [19] explored navigation structures, endorsing broader horizontally oriented menus for potentially faster task completion. Their emphasis on considering device-specific factors further underscores the need to assess user interactions across various devices.

Significant work has been directed in modelling menu performance. This involves visual search times and mouse movement in relation to the target width and distance to target [20]. Another relevant model is Drury's model (1971) [21] which has been reformulated as Steering Law in the context of HCI [22]. This model posits that movement time is linearly related to the ratio of path length (A) to path width (W), offering invaluable insights for designing interfaces in precision-critical applications.

Kořistová and Spiratos [23] observed a correlation between mega menus and heightened user experience, while conversely noting the detrimental effects of hamburger menus and neutral impact of horizontal menus.

Cuddihy and Spyridakis [24] shifted the focus towards user comprehension and navigation, emphasizing the importance of visually distinct navigation schemes. Their exploration introduced the intriguing concept of perceived knowledge gain. They suggest that user experience goes beyond mere comprehension; it involves how users subjectively interpret and assess their own learning experiences within the context of the provided navigation schemes. These insights led them to incorporate user feedback on perceived knowledge gain within experimental designs.

Yu, Roh and Han compared a simple selection menu as well as global (next level in the screen centre) and local (pull-down) navigation menus [25]. They found that participants performed better in searching with the pull-down menu but were faster in browsing with the global and local navigation aid menu. However, users' perception of the three menu designs was not significantly different.

Bodrunova and Yakunin's research [5] introduced the concept of menu complexity and its influence on navigational behavior. The distinctions between productive and non-productive search strategies offer a promising framework for evaluating various menu presentation styles efficiency.

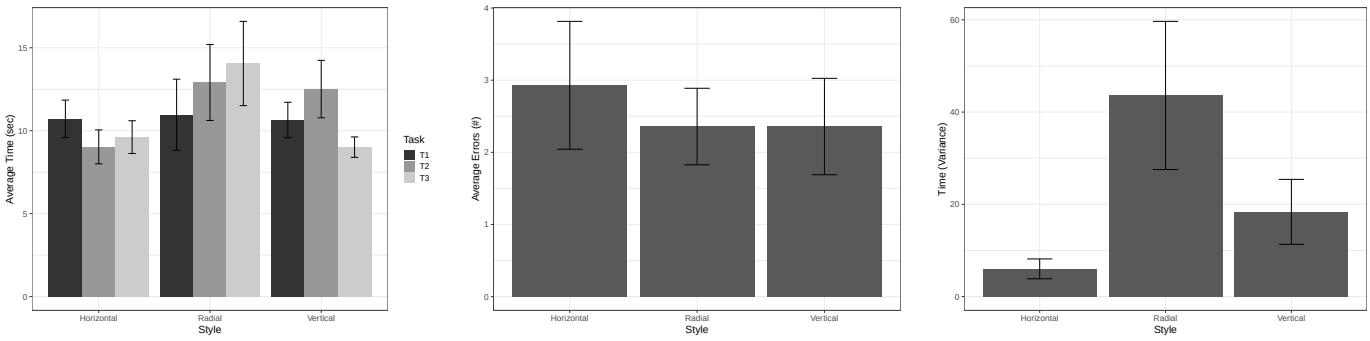
A. Summary

Several studies have identified menu structure, type, adaptation, and ordering as factors influencing user performance. Looking more closely at our application domain, the web, menus tend to be placed either on the top or the side of the screen and expand along the horizontal or vertical dimension respectively. Horizontal menus are space-efficient and often have a familiar placement on top of websites. Vertical menus, often also called side menus, are a popular choice in web interfaces. Their visibility on the website makes them accessible without the need for additional interactions. The style is a valuable tool for designers seeking intuitive and accessible content organization. Radial menus are not as common. The literature indicates that radial menus can offer advantages in terms of seek time, error rates, and minimizing drift distance. However, the radial menu's appropriateness depends on other factors like the number of items on the menu, space on the website and user preferences. Based on the literature, it is not easy to make predictions with respect to user performance and preference in horizontal, vertical, and radial menus in the context of a web page. This is especially true if menus are balanced in terms of breadth and width. and no significant interaction problems appear. However, the visual style of the menus is considerably different, therefore it is quite interesting to investigate if this can lead any performance differences but also how user preference is affected. Web menus differ from mobile applications the option to hover thereby requiring its own study. To investigate this research question regarding user performance with the three menu types we designed an experiment in which users selected items with a horizontal, vertical, and radial menu.

III. Method

A. Experiment design

The independent variables were the menu type (vertical, horizontal, and radial) and trial (1-3). Both were repeated measures. The dependent variables were task completion time as measured by the time taken to complete the tasks and task completion accuracy as measured by the menu selection error rate. As Kingsburg and Andre's [9] study suggests, users prefer menus placed on the left or right planes of a website and we have used this preference to create menus that align with user expectations. The horizontal menu used in the experiment, along with an example mouse-path, is displayed in Figure 2. The vertical menu was also located on the left side of the website [26]. Figure 1 displays menu and an example mouse-path for a vertical style [26]. The radial menu with mouse-path used in the experiment is displayed in Figure 3 [27]. The various study's on breadth/depth led to the menus in this experiment being 3 levels with 4 options per level. Elements were ordered alphabetically in each level.



(a) (b) (c)

Figure 4: Graph showing (a) the average task completion time, (b) task completion errors, and (c) standard deviation of task completion time in the different conditions in the experiment. Error bars how standard error of the mean.

B. Apparatus & Materials

The experiment was created as an HyperText Markup Language (HTML) web site with a page using JavaScript code and Cascading Style Sheets (CSS) for design (Figure 1). The experiment website was created in a news-website manner due to its commonness.

C. Tasks

To mimic the typical web menu use cases from previous experiments, [3], [14], [15] each participant were required to navigate to a specific section of the website using only the navigation menu. Paths were randomly generated for each participant. An example of this is: *"Find the section for Music under the Lifestyle, Sports & Culture part of the page"*, meaning that they have to find the button labeled "music" in the navigation menu. Participants performed three trials with each menu type.

D. Procedure

Before engaging in the evaluation tasks, each participant were provided with a 90 seconds familiarization period for each of the three navigation styles. To maintain validity, a standardized A-Z categorization structure was established for each style, neutralizing its impact on performance evaluation. The same laptop was used by all participants to ensure the same form, size and interaction style.

Participants were presented with a starting screen containing a start-button and the text for where to navigate. When the start button was clicked, the test sequence which is explained in the section "Tasks" began. After the completion of the tasks, the following questions were asked: **Q1:** How would you rate your overall experience with the website navigation on a scale from 1-10, where 10 is the best? **Q2:** What made you not rate it higher/ lower? **Q3:** Were there any aspects of the navigation that you found particularly frustrating or confusing? **Q4:** What did you like about the menu navigation on the website? **Q5:** Were there any specific design elements or features that you felt made navigation more straightforward?

After the questionnaire for each presentation style, participants were introduced to the next style, and the entire process repeated. Once the participant had repeated the process for the 3 menu types, the following questions were asked: **OQ1:** Which menu presentation style did you find the easiest to use, and why? **OQ2:** Opposed to the others, were there any specific design elements or features that you felt made navigation more straightforward? The researchers took notes on the participants responses. This approach gathered insights into the hedonic user experience and performance in the various menu presentation styles.

E. Participants

A sample of 14 participants, all university college students, were recruited using a Google form. Some students studied computer science-related subjects at a bachelor level, while others studied unrelated subjects. All participants reported familiarity with computers and web-based navigation. Each participant was presented and signed a consent form, where they could read about the experiment and how their personal data would be processed, used, and eventually deleted.

F. Data analysis

The hypotheses were examined by testing for significant differences in the dependent variables among the three menu styles. Quantitative analysis involved two-way repeated measures analysis of variance (ANOVA) to examine the effects of style on completion time and error rate, while one-way ANOVA assessed variance in completion time among styles. Post-hoc t-tests with Holm correction were conducted to identify specific differences between styles. Qualitative text data, representing users experience, was analyzed systematically by categorizing responses and identifying common themes across different menu styles. The ratings (0-10) provided by the users in first round of questions were added together to get an average rating for each menu style.

IV. Results

The data on task-completion time and error rate are displayed in Figure 4. Figure 4a shows average tasks completion time in the three trials and the menu presentation styles in the experiment. The variation between styles and trials is small.

The same was the case for error rate, shown in Figure 4b. Task completion time and error rate were analyzed using two-way (Trial $\times$ Type) repeated-measures ANOVAs. Neither the effect of trial nor the effect of style was significant. The interaction between trial and style was also not significant. The same results appeared for error rate.

Figure 4c shows the variance in task completion time for the three menu styles in the experiment. This was also analyzed using a one-way ANOVA with variance in task completion time per participant as the dependent variable and menu presentation style as the independent variable. The effect of menu presentation style was significant F(2.26) = 4.26, p = 0.025. The calculated effect size of the tests was $\eta^2 = 0.15$ with a Greenhouse-Geisser correction value of $\varepsilon = 0.67$. Post-hoc t-tests with Holm correction for pairwise comparisons shows that the horizontal style led to smaller variance in completion time among trials compared to the radial style (p = 0.03). However, all other pairwise comparisons were not significant. The difference in variance in completion time among trials was not significant when comparing vertical to radial or vertical to horizontal.

For vertical, Horizontal and Radial menu style the average rating was respectively 6.78, 8.92 and 7.92 (**Q1**). People preferred the width for overview, against length like offered in vertical presentation style (**Q2**). Nothing was frustrating other than area of focus in center for vertical presentation style (**Q3**). Every menu type gave good overview, but level-separation was clearest in horizontal and radial presentation style (**Q4**). The vertical presentation style had a natural mouse-path, while horizontal and radial presentation style had clear level separation (**Q5**).

Overall people preferred the horizontal menu presentation style, as it gave the best overview and was the most "common" (**OQ1**). The clear level separation of the horizontal menu made it easy to see where to click next, while the width gave good overview (**OQ2**).

V. Discussion

Our study set out to examine the influence of the menu presentation styles radial, vertical and horizontal on user navigation behaviors and task completion rates on a website. We examined the hypothesis that there would be a statistically significant difference in user performance as measured with task completion time and error rate among these three menu styles.

The result showed that the average task completion time and the average task completion errors were not affected by menu presentation style. Interestingly, trial number also did not consistently impact completion times across menu styles, as evidenced by the non-significant main effect for the trial. All menu styles were therefore used equally well. Contrary to our initial hypothesis, the style of menus did not have a statistically significant effect on task completion time and error rates which challenges the notion that differences in the examined menu styles play a significant role in minimizing user errors during navigation tasks.

However, the variance in task completion time varied significantly across menu styles and the main effect of presentation style on the variance of the average completion time for each participant was significant. On average, task completion time varied more when menu type was radial and less so when it was horizontal or vertical. However, only the difference between horizontal and radial menus was significant indicating that radial menus led to less consistent performance in the experiment.

Qualitative insights from participants align with the quantitative results, indicating a preference for the horizontal presentation style due to its clear level separation and overall familiarity. However, it is noteworthy that the horizontal style, while efficient in terms of completion times, exhibited on average the highest average error rate. These qualitative findings provide nuanced context, suggesting a correspondence between user preferences and observed quantitative outcomes.

The observed variance in completion times across menu styles indicates that designers should carefully consider the trade-offs between different menu types, particularly concerning efficiency in completing tasks. We cannot explicitly refer to the exact reason for this result. One possibility is that the variance in task completion times for the radial menu is due to the lack of familiarity with such menus. However, it is not possible to conclude without further experimentation.

It is essential to acknowledge certain limitations in our study. The selected tasks might not fully represent the complexity and diversity of real-world user interactions. Additionally, participant characteristics, such as affinity for technology and prior experience with certain menu styles, were not explicitly controlled and could have influenced the results. Future research should therefore explore these factors more comprehensively.

Considering the usability facets within the wider menu design context, while the examined styles may not significantly impact completion times or error rates, other usability dimensions such as learnability, efficiency, and satisfaction still play crucial roles in shaping the overall user experience. By acknowledging the nuances of user preferences, task efficiency, and accessibility considerations, designers can make informed decisions about menu design to create interfaces that are not only functional but also intuitive and user-friendly.

VI. Conclusion

In this study, we investigated the impact of menu type on navigation performance as measured by task completion time and task completion rates. Participants navigated a website using radial, vertical, and horizontal menus. The results showed that menu presentation style did not affect task completion time and error rate significantly. However, the variance in completion times was affected significantly by menu presentation style and radial menus showed the highest variance and less uniform performance. Users expressed a preference for the width in the overview.

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