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Pie Menus or Linear Menus, Which Is Better?

¹Pietro Murano, ²Iram N. Khan

¹Department of Computer Science, the Universal Design of ICT Research Group, Oslo and Akershus University College of Applied Sciences, Oslo, Norway

²University of Salford, School of Computing, Science and Engineering, Salford, M5 4WT, UK

¹pietro.murano@hioa.no, ²I.N.Khan@edu.salford.ac.uk

ABSTRACT

This paper is about a continuing investigation aiming to find out which menu type is more useable on a web site or application. This paper specifically compares pie menus with linear menus. Although other researchers have investigated similar themes it is felt that there is still not enough knowledge regarding the various effects of different menu types, including their positioning on a screen. An empirical approach using an experiment to test the effectiveness and user satisfaction of a pie menu and a linear menu is described in detail. Four tasks were administered to experimental participants under each menu design in a within users experimental design. Overall task time, number of errors and participants' subjective opinions were measured. The data were statistically analysed. There were no statistically significant results for task times and errors. However, subjective opinions were overall statistically significant, suggesting a preference for the pie menu by participants. These results are interesting for all web designers, user interface designers and developers. The issues being investigated are rather complex, because there is no clear pattern of results to suggest a categorical 'best design'. These results add to the current knowledge in existence regarding menu types and to the wish of understanding better the issues involved with menu types.

Keywords: *Pie menus, radial menus, linear menus, usability, evaluation*

1. INTRODUCTION

In 2010 Kevin Kelly [1] suggested that the web contained approximately one trillion web pages. Whether this figure is correct or not, the amount is likely to be more in 2015 than in 2010. Furthermore, most web pages are not entities in isolation, but in most cases web pages make up the content of web sites, i.e. a web site is likely to contain two or more web pages.

Also, most web sites containing several web pages will tend to have a navigation mechanism or structure to allow users to navigate from one page to another within a particular site.

Depending on how the navigation structure is designed, this can either create a good or bad user experience (UX). The researchers in this paper are investigating the usability of different types of menus on web pages. While there have been other researchers investigating these issues, it could appear that there is no more work left to do in this area. However, when one looks collectively at the results of these other studies, there is no overall consistent pattern of results to suggest that one menu type is much better than some other. This therefore suggests that there is still some lack of knowledge in this important aspect of web site construction.

A pie menu (radial menu) is a type of menu which can be used for navigation purposes, e.g. on a web site or application. Such a menu can have the same functionality as a linear menu. Further, a pie menu, with degrees of variance, can be similar in appearance to a pie chart used in a typical spreadsheet application.

In this paper therefore, a brief consideration of some of the main literature in the area is presented. Then

an experiment the authors conducted is described along with the results obtained. This is followed by some conclusions.

2. KEY LITERATURE

Most efforts in the research and development community have concentrated on linear menus. Therefore the amount of work that has been done in relation to pie menus is limited when compared with the work done with linear menus.

In a study by Kalbach and Bosenick [2] an evaluation was carried out for the development of the Audi Cars web site. They tested linear menus on the left and right sides of the web pages of the Audi web site.

They found that there was no significant difference in terms of task times between the two menu types. However they did not test out any other metrics, which could have led to some interesting information.

In contrast a study [3] carried out by one of the authors of this paper indicates that measuring other metrics can give other interesting and useful information.

In the study by Murano and Lomas [3], four linear menu positions (top, bottom, left and right of a page) were evaluated in the context of an online store. The results showed in agreement with Kalbach and Bosenick [2] that tasks times did not seem to be affected.

However in the Murano and Lomas [3] study errors and mouse clicks were recorded along with final participant subjective opinions. The results showed that the top horizontal and left vertical positioned menus incurred fewer errors and fewer mouse clicks. Further,

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participants' levels of satisfaction were in line with the efficiency aspects observed in the study.

The issues of task time seem to be in agreement with Faulkner and Hayton [4] too. They tested left and right positioned menus on a fictitious web site selling various goods to do with Christmas celebrations. They found no significant differences in task times (in this case buying something). However the study would have perhaps been much more rounded if other performance metrics had been evaluated along with participant satisfaction.

However in some work done by McCarthy, Sasse and Riegelsberger [5] the position of menus was studied. Their context was a commercial web site where they had simple or complex versions. They evaluated left, top and right hand side menu positions. In recording tasks times, these were significantly longer with the complex site version. The three menu positions did not differ significantly when averaged across the tasks done and the simple and complex sites. However there was better performance with the left menu when users interacted with the first page of the site. However, when users interacted with the second page there were no differences for performance.

The authors reasoned that users are able to adapt swiftly to other web page layouts, with performance not being affected negatively. However the impact of having reduced performance with the interaction of the first page is not clear and would need investigating further.

Although more work has been carried out in the context of linear menus as described briefly above, the work concerning pie menus is more limited, e.g. in Rubio and Janecek[6] some improvements to basic pie menus are described. They developed pie menus as contextual menus to have transparency, the possibility for the user to move the menu and a feature allowing the user to lock the pie menu open and deploy several commands on one object. This was in the context of a 'graphical schema editor for modelling spatio-temporal databases' [6]. The ideas described in the paper are very interesting; however it would have been also interesting and useful if some evaluation of this design had been done.

In Samp and Decker [7] a comparison by means of an experiment was carried out with various versions of pie menus and linear menus. Overall they found that 'visual search' was faster with linear menus. However radial menus were found to be faster for pointing. The authors tested some interesting aspects. The task they designed for users was for them to 'select a three word phrase of the form adjective-adjective-noun' [7]. However it would have been good if the tasks used in the experiment had a more realistic setting or better ecological validity.

In Bailly, Lecolinet and Nigay [8] flower menus are described and evaluated. Flower menus can be viewed

as being related to pie menus because the options appear in a vaguely radial fashion on the screen. However their functionality somewhat differs from a typical pie menu.

These allow the use of mouse-based gestures in option selection. They also have an expert and novice mode available. The authors compared flower menus with linear menus and polygon menus. Polygon menus are also linked to radial menus where the selectable options are displayed in a more symmetrical fashion around a radial type shape. Focusing on expert mode and learning, the authors obtained results from an experiment to suggest that flower and polygon menus were better for learning how to use the expert mode. However flower menus were better for 'activation' and expert mode learning. The authors conclude that flower menus are good for 'large breadth menus' [8].

The menu concept and work carried out is interesting. However it is felt that not enough is known about how such a menu would fare in a real world context. This aspect would need evaluating further. Also flower menus do function in a different manner when compared with a typical pie menu.

This brief review of the key literature indicates that in some areas there is still knowledge lacking concerning the usability of pie menus and indeed of linear menus too. The sections that follow will now describe an experiment and the results from the experiment conducted by the authors of this paper.

3. MENU COMPARISON EXPERIMENT

3.1 Hypothesis

Our main key question regarding the use of pie menus or linear menus is: Which of the two would be better in terms of user performance and user satisfaction?

To that end the following hypotheses were devised to help focus the evaluation efforts:

- H₁: The pie menu will be faster than the horizontal linear menu for task time.
- H₀: There will be no difference for task time between the pie menu and the horizontal linear menu.
- H₁: The pie menu will incur fewer errors than the horizontal linear menu.
- H₀: There will be no difference for errors between the pie menu and the horizontal linear menu.
- H₁: Participants will have more positive perceptions for the pie menu compared to the horizontal linear menu.
- H₀: There will be no difference for participant perceptions between the pie menu and the horizontal linear menu.

3.2 Participants

For this study we wanted participants to be experienced with computers and the internet. The main reasons for this requirement were to remove potential

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problems of lack of basic knowledge with computers and the internet in novices and to see the effects of the experimental conditions on experienced users.

In order to try and discover prospective participants' experience levels we used a recruitment questionnaire. We asked recruits to report the amount of time they spent on the web and their experience with e-commerce explicitly. It was decided that spending a large amount of time on the web and remaining engaged in e-commerce was taken to indicate expertise and engagement with the Web as a medium. On average, participants were expected to use the internet on a daily basis or 20 hours per week or more.

Potential participants' comfort levels with computer usage were also ascertained by means of the recruitment questionnaire. We expected reported comfort levels to be fairly high (3 points or more on a Likert-type[9] scale of 5 points on the questionnaire). Further there was the expectation that participants should be using computers for a wide range of purposes, preferably using the internet for academic research, e-shopping, gaming and information gathering, e.g. job hunting and browsing the news etc.

Lastly all participants had never used a pie menu in their computing usage experiences.

3.3 Pilot Test

Prior to conducting the experiment with the recruited participants, a pilot test was conducted with two participants. They were selected after they met the desired recruitment criteria. Observations from the pilot test were used to revise the method for carrying out the experiment with the eventual real participants of the study.

At the end of the pilot test, the participants were given a post-experiment questionnaire to elicit their opinions about their performance, but they had difficulty in answering four questions which were specifically related to the tasks (see the Apparatus and Materials section below for a full description of the tasks) as they could not remember what had 'happened' in the four different tasks. In these questions users had to mark a Likert-type scale according to the level of ease they experienced to accomplish the tasks.

In order to resolve this issue, in the actual experiment it was decided to ask participants to complete each question relevant to each task immediately after completing a respective task.

3.4 Design

A within users design was used to execute the experiment. This was chosen because a within users study can help in reducing issues associated with individual differences. Hence, all the participants were exposed to both menu designs.

Furthermore, the within users design was applied by having half of the participants using the pie menu first and then the linear menu. The other half of the group of participants used the linear menu first and then the pie menu. Random allocation was used to allocate participants to a particular ordering of menu use.

3.5 Variables

The independent variables were the two menu types (pie and linear) and the type of tasks which involved finding items/information on a specially developed prototype web site.

The dependent variables were the performance and the participants' subjective opinions.

The dependent measures were the overall task time, the number of errors (i.e. errors occurred when the user selected an incorrect menu item), and participants' subjective opinions regarding various features of the web site and the navigation used.

The perceptive opinions were elicited by means of a post-experiment questionnaire which covered detailed aspects of the design of the basic web site, the navigation bar used and aspects of the participants' feelings during the experiment. A Likert-type scale ranging from 1 to 5 was used for all the questions, where for all questions a 5 score was the highest possible positive score that could be allocated. The questionnaire covered the topics of ease of learning, simplicity of the navigation and ease of use.

3.6 Apparatus and Materials

For the experiment various items of apparatus and equipment were used. These were:

- An HP laptop with the following main specification:
 - HP Pavilion dv6 Notebook PC,
 - Windows Vista Home Premium 64-bit English,
 - Intel® Core™2 Duo CPU @ 2.00GHz,
 - 4 GB RAM,
 - 14.5" Screen.
- A stopwatch.
- A pre experiment questionnaire.
- A post experiment questionnaire.
- A consent form.
- The tasks sheets containing four tasks for each menu type.

The tasks were formulated to be performed at both website versions separately. In each task participants were required to find particular products having specific characteristics. For each menu type four different tasks were devised. The tasks were equivalent to each other in terms of efficiency, difficulty, time taken to search menu items and in terms of where the required items appeared on the screen. This approach was used to minimize

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possible learning effects from one menu type to another in the within users design setup. Two out of four tasks were easier as they belonged to the second level of the pie menu while the remaining two tasks were comparatively difficult belonging to the third level of the menu design.

Furthermore, four different tasks were devised as familiarization tasks for the pie menu.

Therefore the actual task list used is listed below:

Pie Menu Task list:

- Task1 - Find out the screen size of the “HTC Rhyme” Mobile Phone.
- Task2 - Find out the processor speed of the “Apple IMAC MC309” Desktop Computer.
- Task3 - Find out the resolution of the “LG L1510M 15” LCD Flat Panel Monitor.
- Task4 - Find out how many print modes are supported by the “Canon SELPHY CP710 Compact Photo Printer”.

Linear Menu Task list:

- Task1 - Find out the screen size of the “Apple iMac MC510LL/A” Desktop Computer.
- Task2 - Find out the platform for the “HTC One V” Mobile phone.
- Task3 - Find out the aspect ratio of the “W2040T 20-Inch 720p LCD” LG Monitor.
- Task4 - Find out the item width of “Canon PIXMA MP 210” Photo Printer.

The Pie Menu familiarization tasks are listed below (see next section for how these were used during the experiment):

- Task 1- Please clicks on the ‘Bird’ menu item.
- Task 2 - Please find and click the ‘Ford’ menu item under ‘Cars’ menu item.
- Task 3 - Please click the ‘Banana’ menu item.
- Task 4 - Please find and click the ‘Nandos’ menu item under the ‘Fast-food’ menu item.

4. PROCEDURE

A sample of 16 participants was recruited encompassing students at a university. The experiment was conducted in a project study room at the university. The experimenter was in the same room as the participants. The room was quiet and private. The door was kept closed to avoid distractions. Overall each session with each participant lasted approximately 15 minutes.

Once a participant had arrived they were greeted and asked to be seated. Afterwards, a consent form was read and signed by the participant. The consent form specified some details of the research and assured participants that there was no risk to them, that confidentiality would be maintained, that their participation was voluntary and that they could terminate

their participation at any time. Signing the consent form was followed by filling out a pre-experiment questionnaire. This questionnaire inquired about the demographic information of participants as well as their experience and comfort levels regarding computer and internet usage.

Participants were then randomly assigned to one of the menu types (see Design section above for specific details)

At the start of each task, each participant was requested to read aloud the task description from a printed copy of the task list and then to begin the task. As each participant had no experience with pie menus, just before the tasks were undertaken with the pie menu, the participants were given some familiarization tasks with a pie menu. Then the real tasks were undertaken by each participant. The pie menu used in the familiarization stage was different to the pie menu used in the actual experiment. The functionality was similar, but the imagery and content were different.

After completing the tasks with both websites, a post-experiment questionnaire was handed to participants to record their experiences. The questionnaire asked participants' opinions about ease of learning, simplicity of the navigation and ease of use.

During the experiment if a participant asked questions regarding issues that arose which they felt were not resolvable, with the hope of receiving hints from the experimenter, a prepared response was given. To avoid any bias, the response to all the questions regarding help or hints to complete a task was: ‘Go ahead and give it a try and I will note where it will take you’.

At the end of the experiment with the participants, each received a chocolate bar as a small remuneration for their participation.

5. RESULTS

All the collected data was firstly explored with summary statistics and examining the distributions and overall patterns. Complete results are not included here for the purpose of brevity. However means and standard deviations (SD) are included in Appendix 1. The initial examination suggested that there was enough normality in the data to use a parametric test. Therefore repeated measures one-way ANOVA was used.

For task times and errors, no significant differences were indicated by the ANOVA test and will therefore not be discussed further in this section. These were the only two performance aspects recorded in the experiment.

The other data that was collected was of a subjective nature and was elicited by means of a 10 question post-experiment questionnaire using Likert-type scales. Each question was asked in relation to each menu

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type. Therefore each question had two answers which could then be compared.

Question 1 asked users to rate how simply they felt the navigation to be. Question 3 asked users to rate the ease of learning for each menu. Question 9 asked users to rate how logical they felt the organisation of the menu and sub-menus to be. Question 10 asked users to rate how confused they became during their interaction with the menus. For all these questions, there were no statistically significant results. Therefore the actual ANOVA results are not presented here for brevity.

However, for Question 2, there was a statistically significant result $F(1,15) = 19.12$, $p < 0.001$. This asked users to rate how pleasant they felt each menu to be in appearance. The pie menu was scored significantly higher than the equivalent linear menu.

For Question 4, there was a statistically significant result $F(1,15) = 5.45$, $p < 0.034$. This asked users to rate their comfort levels whilst using each menu type. The pie menu was scored significantly higher than the equivalent linear menu.

For Question 5, there was a statistically significant result $F(1,15) = 5.95$, $p < 0.028$. This question concerned Task 1 and asked users to rate the ease of their 'searching' for this task. The pie menu was scored significantly higher than the equivalent linear menu.

For Question 6, there was a statistically significant result $F(1,15) = 5.95$, $p < 0.028$. This question concerned Task 2 and asked users to rate the ease of their 'searching' for this task. The pie menu was scored significantly higher than the equivalent linear menu.

For Question 7, there was a statistically significant result $F(1,15) = 4.75$, $p < 0.046$. This question concerned Task 3 and asked users to rate the ease of their 'searching' for this task. The pie menu was scored significantly higher than the equivalent linear menu.

For Question 8, there was a statistically significant result $F(1,15) = 6.36$, $p < 0.023$. This question concerned Task 4 and asked users to rate the ease of their 'searching' for this task. The pie menu was scored significantly higher than the equivalent linear menu.

6. DISCUSSION AND CONCLUSION

Having statistically analysed the data collected during the experiment, some interesting results were obtained. For performance no statistically significant results were observed. For times and errors during the tasks, the data suggests that using a pie menu or linear menu does not affect performance in terms of times and errors. Positive hypotheses 1 and 2, which suggested that the pie menu would perform better, are therefore rejected on the basis of the above.

However, the last positive hypothesis which suggested that the pie menu would be 'preferred' is accepted, because the data for subjective opinions has a substantial amount of significant statistical results indicating the pie menu to have been perceived more positively than the linear menu.

However, one of the potential issues that is unclear is whether the subjective opinions were as a result of seeing and interacting with something that was perhaps perceived at that moment in time as being new, different and maybe a fun activity. This question is not easily resolved and it would probably take a longer term study to investigate this matter. This would need to be done with some software or a web site that is more fully developed and in the context of something more real that users could engage with on a regular basis. Preferences over time could thus be elicited from a group of users. This can be difficult to achieve because users would need some positive incentive to use such a system over a period of time and thus form more mature opinions.

Some of the main previous studies involving pie menus (or similar) have suggested a difference in performance depending on menu type. Some studies also had the common characteristic of having tasks that were not of the kind used in real world situations whilst using a computer. The work described in this paper is advancing this area, because firstly, the tasks designed for the experiment were much more 'real' and therefore had more ecological validity. Secondly, the fact that our study suggests no difference in performance with either menu type, while other studies have shown some differences, can indicate that there are still some issues to discover.

Furthermore, this study and some of the other studies may have the fault of using menus that are too simple in nature. Perhaps future studies should ensure that deeper levels of menus are tested. This may show some differences at deeper levels but not at higher levels and having this knowledge could be useful and interesting.

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APPENDIX 1

Descriptive statistics

	Mean	SD	N
Time T1 Linear	37.37	20.232	16
Time T1 Pie	34.12	21.587	16
Time T2 Linear	29.31	10.229	16
Time T2 Pie	28.50	8.748	16
Time T3 Linear	44.75	10.517	16
Time T3 Pie	39.44	14.408	16
Time T4 Linear	35.38	15.819	16
Time T4 Pie	33.25	13.883	16
Errors T1 Linear	1.06	.929	16
Errors T1 Pie	.75	.775	16
Errors T2 Linear	.06	.250	16
Errors T2 Pie	.13	.342	16
Errors T3 Linear	2.13	1.025	16
Errors T3 Pie	1.69	.946	16
Errors T4 Linear	.75	.683	16
Errors T4 Pie	.75	.683	16
Linear Q1	3.87	.719	16
Pie Q1	4.06	.680	16
Linear Q2	2.94	.772	16
Pie Q2	4.37	.806	16
Linear Q3	3.56	.629	16
Pie Q3	4.06	.772	16
Linear Q4	3.75	.683	16
Pie Q4	4.31	.704	16
Linear Q5	3.31	.946	16
Pie Q5	3.94	.680	16
Linear Q6	3.44	.629	16
Pie Q6	4.06	.680	16
Linear Q7	2.88	.719	16
Pie Q7	3.50	.816	16
Linear Q8	3.69	.793	16
Pie Q8	4.25	.577	16
Linear Q9	4.00	.730	16
Pie Q9	4.06	.854	16
Linear Q10	2.38	1.147	16
Pie Q10	2.13	1.204	16