Effects of Menu Types and Item Lengths on Operation Efficiency

Yu-Hsuan Chang and T.K. Philip Hwang

Graduate Institute of Innovation and Design, National Taipei University of Technology
1, Sec. 3, Chung-hsiao E. Rd., Taipei, 10608, Taiwan, R.O.C.
sharonchang0919@gmail.com, phwang@ntut.edu.tw

Abstract. Pop-up menus enable more efficient interface operation. Inspired from empirical inference, observation, and literature reviews, this study investigated the operation efficiency of pop-up menus through examining human's superior physical characteristics of visual search and mouse movement. A new style of menu type, Elliptic-Pie Menu, was proposed and examined on operation efficiency against traditional linear menus and (circular) pie menus while different item lengths were also analyzed. The study revealed: (1) Menu type is a significant factor of the operation efficiency; (2) Short items turn out to be more efficient than long items do; (3) Linear Menu presents the highest operation efficiency, whereas Circular-Pie Menu delivers the lowest error rate; (4) Elliptic-Pie Menu occurs significant improvement of operation efficiency with the use of short items.

Keywords: pop-up menu, pie menu, operation efficiency, menu type.

1 Introduction

As software development, more items derived from functions lead to complicated operations in searching the target item, which require great cognitive effort. Facing this challenge, pie menus [1] were proposed to save target seek time (response time) and to reduce cursor moving distance needed in contrast to traditional linear menus. Various efforts have been done to improve quality of human interface such as different menu layouts, item order, and text features. However, no previous research studied the influence of the human's physical characteristics of visual search and mouse movement as well as item lengths on pop-up menus. The goal of this study was to evaluate operation efficiency of the pop-up pie menus by taking human's physical characteristics of visual search and mouse movement into consideration. A new menu type, Elliptic-Pie Menus, was proposed and examined along with Linear Menu and Circular-Pie Menu. Eventually, operation efficiency of different menu types and effects of item lengths were delved in this study.

2 Menu Layout

Menu layout is a significant factor of menu design. Their influences on efficiency of menu operation have been proved by many studies. [1] showed that target seeking time

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was significant of menu operation efficiency while pie menus were inspired by Fitts' Law. Additional experimental results [2] [3] [4] also indicated that menu types had significant effects on either response time or error rate. Further, a variety of pop-up menus, for instant, slant linear menus [2], pie menus [1], and rotary menus [3], were brought out against liner menus.

3 Visual Search of the Target Item

The issue of visual search arises from the increase of mental demand imposed on users due to complicated functions.

Referring to user experiences, it is intuitive that left-to-right visual search was favored than the reverse direction. Moyle's experimental evidence [5] showed that people tended to drag mouse left- to-right more frequently regardless of selecting a target letter, word, or sentence while reading a passage.

Though researchers increasingly devoted themselves to the investigation of visual search, few research concentrated on vision movement of different item-like object arrangement. Through measurement of the eye tracking system, the results of Feng & Shen's research [6] demonstrated that people were obviously more efficient on horizontal tasks than vertical tasks. Thus, it seems reasonable that users might perform more efficiently on clicking an item target in horizontal dragging directions than that in vertical.

4 Mouse Movement and Clicking

Mouse movement is associated with human's wrist characteristics of operating the mouse. As noted by Moyle [5], vertical directional mouse movement required people to extend (up) or contract (down) their thumb and fourth or little fingers often with arm movement. Conversely, horizontal movement only involved a lateral flexing of the wrist with almost no arm movement. Furthermore, Donker & Reitsma [7] mentioned that the wrist was used to moving horizontally, so people favored move the mouse left-to-right like reading and writing. Both perspectives were supported by experimental resutls, in which Moyle's results revealed that people caused dramatically longer time and more angular errors for downward mouse movement; Donker & Reitsma pointed out people performed faster with fewer errors on horizontal dragging tasks than vertical tasks. In addition, Whisenand and Emurian [8] noted people outperformed in horizontal directions over vertical and diagonal directions.

5 Experiments

Based on previous research results, Elliptic-Pie Menu was introduced and expected to benefit by better efficiency of horizontal cursor movement and visual search. Then, experiments were conducted to examine the operation efficiency of different menu types with various item lengths.

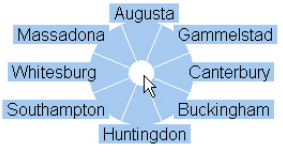
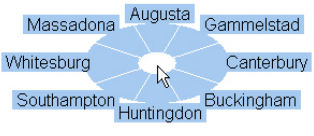
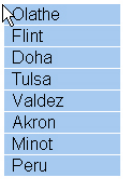
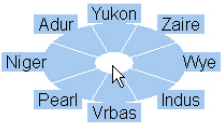
5.1 Experimental Methods

To analyze how efficient users could use the pop-up menus, performance was measured including average response time and error rate. Actually, there is a trade-off between speed and accuracy [9] [10]. Hence, the "quality of search" (*Q*) Score [11], originally used in the measurement of visuospatial performance, was introduced into efficiency evaluation of human interface. Hence, the influence of errors on the response time was considered to summarize the performance for different menu types.

5.2 Stimuli Design

There were six examples of menu designs contributed by three menu types and two sets of item lengths (Table 1). In each set of item length, two groups of uncommon 8 items which were referred to city names and river names were adopted to minimize the effect of familiarity. As a result, there were twelve menu layouts in experiments eventually.

Table 1. Menus Used in Experiment

	Linear Menu	Circular-Pie Menu	Elliptic-Pie Menu
Long Item			
Short Item			

5.3 Subjects and Apparatus

A total of 60 (30 females and 30 males) objects of right-hand experienced mouse users were invited. The age and educational background were not restricted.

The experiments were conducted on one Acer laptop running MS Windows XP. The screen was 14 inches with resolution of 1280x800. Three optical mice were prepared, allowing subjects to pick one based on their preferences.

5.4 Procedures

Subjects divided into 6 gender-equal groups were instructed to complete 60 tasks in a pre-determined "sequence" of menu type (for example, Linear-Circular-Elliptic) to reduce the impact of sequence effect. Thus, every menu type was executed for 20 times, including 10 long-item tasks and 10 short-item tasks. This procedure of each task was

the same as regular operation without learning in advance. Subjects popped up a menu by pressing the right mouse button and then selected the given target item according to the instruction on the top of the experimental interface. During the course of operation, response time was measured in milliseconds automatically by program as well as error rate.

6 Results

36 subjects' data were selected equally from six equal-gender groups and analyzed after eliminating outliers and anomalies. Significant results among menu types were found.

6.1 Response Time Analysis

Menu type. As illustrated in Table 2, irrespective of item lengths, Linear Menu appeared to be the highest performance while Circular-Pie and Elliptic-Pie Menus presented similar operation speed on average. Results also suggested that males had advantages over females especially in operating Elliptic-Pie Menu while males and females had similar performance on the other two types of menu. A repeated measures one way ANOVA found a significant difference between menu types ($F = 7.972$, $p < 0.01$).

Table 2. Results of Mean Response Time per Task (ms) of Different Menu Types (N=36)

Menu Type		Linear	Circular-Pie	Elliptic-Pie
Mean Response Time (ms)	Female	1708.619	1895.328	1930.733
	Male	1688.392	1900.372	1869.542
	Mean	1698.506	1897.850	1900.138

Item length. As regards the factor of item lengths, on average, a short-item task required less response time than a long-item task did shown in Table 3. Males performed faster than females in both cases. The following ANOVA displayed that mean response time was found to be slightly significant between long and short items (F=3.458, p =0.065).

Table 3. Results of Mean Response Time per Task (ms) of Different Item Lengths (N=36)

Item Length		Long Item	Short Item
Mean Response Time (ms)	Female	1886.892	1802.893
	Male	1852.549	1786.323
	Mean	1869.720	1794.608

Menu type x Item length. Table 4 shows the mean response time of three menu types across two item lengths. Surprisingly, Linear Menu with short items demanded more response time than with long items, whereas Circular-Pie and Elliptic-Pie Menus favored short items. Particularly for Elliptic-Pie Menu, time was reduced dramatically by 218.172ms while an ANOVA indicated its significant difference (F=4.775, p =0.034, η^2 =0.087).

Table 4. Results of Mean Response Time per Task (ms) of Menu Types by Item Lengths (N=36)

Item Length / Menu Type	Long Item	Short Item	Mean
Linear	1672.008	1725.004	1698.506
Circular-Pie	1927.930	1867.770	1897.850
Elliptic-Pie	2009.223	1791.051	1900.138
Mean	1869.720	1794.608	

6.2 Error Rate Analysis

Menu type. The error rate analyses were proceeded for all types of menu. The results showed that Circular-Pie Menus obtained the lowest error rate of 0.97%, followed by Linear and Elliptic-Pie Menu sequentially (see Table 5). As well, males' error rate in Elliptic-Pie Menu was superior to females' while females had extremely lower error rate in Circular-Pie Menu. Referring to previous results of mean response time analyses, it would appear that males favored Elliptic-Pie Menu and achieved efficient performance.

Table 5. Results of Mean Error Rate of Different Menu Types (N=36)

Menu Type		Linear	Circular-Pie	Elliptic-Pie
Mean Error Rate	Female	0.0111	0.0056	0.0250
	Male	0.0139	0.0138	0.0167
	Mean	0.0125	0.0097	0.0208

Item length. Menus that adopted short items resulted in slightly higher error rate without difference between males and females. However, no significant result was found (see Table 6).

Table 6. Results of Mean Error Rate f Different Item Lengths (N=36)

Item Length		Long Item	Short Item
Mean Error Rate	Female	0.0101	0.0176
	Male	0.0111	0.0148
	Mean	0.0106	0.0162

In the error rate analyses, the error rate was extremely low so that its distribution did not pass the normality test, one basic assumption. Accordingly, a repeated measures one way ANOVA was not performed to examine whether menu types and item lengths had significant effects on error rate.

6.3 Efficiency Quality

However, it was manifest that Linear Menu, which had the least mean response time, did not turn out to have the lowest mean error rate. For evaluating menu operation efficiency of menu types and item lengths, *Q scores* were administrated to examine the effects of error rate on mean response time.

$$\text{Q Score} = \frac{\text{Correct responses}}{\text{Total task number}} \times \frac{\text{Correct responses}}{\text{Total response time (sec)}}$$

Where *correct responses* are the total number of successful tasks; *total task number* is tasks executed, and *total response time* is the accumulated response time of each task, calculated in seconds (not milliseconds). Based on this formula, it is clear that higher *Q* scores reflect more efficient performance.

Menu type. Firstly, in terms of different menu types, Table 7 shows the efficiency evaluation across three menu types. Linear Menu obtained the highest *Q* score, which was consistent with the result of response time analyses. Meanwhile, Circular-Pie Menu had a slight higher *Q* score than Elliptic-Pie Menu did. Further, the significant difference between menu types was found by ANOVA ($p < 0.01$). It seems reasonable that menu type is a critical factor of influencing menu operation efficiency.

Table 7. Efficieny Evaluation of Different Menu Types

	Linear	Circular-Pie	Elliptic-Pie	*p*
Performance Score (*Q* Score)	.58	.53	.52	.001*
Correct Response (0-20)	19.75	19.81	19.58	
Total Response Time (sec)	33970.11	37957.00	38002.75	

*p <.05, **p < .001.

Item length. Secondly, the overall performances of different item lengths are displayed in Table 8. Based on *Q* scores analyses, the efficiency of short-item tasks was higher

Table 8. Efficieny Evaluation of Different Item Lengths

	Long Item	Short Item	*p*
Performance Score (*Q* Score)	.53	.55	.271
Correct Response	29.61(0-30)	29.53(0-30)	
Total Response Time (sec)	56091.61	53838.25	

*p <.05, **p < .001.

than that of long-item tasks. An ANOVA showed that there was no significant difference in Q scores between long-item and short-item tasks ($p > 0.05$). Consequently, the effects of item lengths were not as significant as the effects of menu types on menu operation.

7 Conclusion and Discussion

The experimental results showed that Linear Menu had better efficient performance according to the best Q score than Pie Menus (Circular-Pie and Elliptic-Pie Menus) did.

This result was supported by Samp and Decker's measurement result [12]. It presented that while the item number was fixed to six, one-level linear menus performed superior to most of various pie menus with shorter total time (response time). Moreover, Whisenand and Emurian's research [8] brought out positive response to this study indirectly. It indicated that square icon-like targets had faster movement time (response time) and lower error rate compared with circle icon-like targets.

However, the results manifestly disagreed with the research results of Jack Callahan et al. [1], the initial developers of the pie menu, which asserted that pie menus had vantage of faster operation and lower error occurrence. Under the circumstance where users have adapted to linear menus on existing consumer products, it is not odd to attribute best efficiency to users' experiences of menu operation. That is, the more familiar with a specific type of menu, the more efficient it could be.

Regarding Pie Menus, Circular-Pie Menu turned out to be less efficient but better performed in error rate, and short items were probably beneficial to improve efficiency. Comparatively, Elliptic-Pie Menu had superior efficiency improvement to other menu types by being adopted short items.

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