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Effects of user age and target-expansion methods on target-acquisition tasks using a mouse

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ABSTRACT

Target expansion, i.e., the increase of target size according to cursor movement, can be a practical scheme to improve the usability of target-selection tasks using a mouse. This study examined the effects of different user age groups and target-expansion methods on target-acquisition tasks with grouped icons. Twenty-eight subjects performed acquisition tasks under eight experimental conditions: combinations of four expansion areas (no, one-icon, fish-eye, and group expansion) and two expansion techniques (occlusion and push). Older users took longer to acquire targets than younger users; however, they showed no significant difference in accuracy. Target expansion did not substantially improve performance speed compared to the static condition. However, the error rate was lowest when group area was expanded with the push technique, and both age groups were most satisfied with one-icon area expansion with the occlusion technique. We suggest alternative guidelines in designing target-expansion schemes.

1. Introduction

Graphical user interfaces (GUIs) allow users to interact with personal computers (PCs) by selecting targets such as icons, menus, or hyperlinks using an input device such as a mouse rather than by typing commands with a keyboard. Pointing to targets with a mouse is an essential task in GUIs (Blanch et al., 2004; Cockburn and Brock, 2006; Grossman and Balakrishnan, 2005; Guiard et al., 2004; Keates and Trewin, 2005). Because GUIs are indispensable in various applications (e.g., MS Office and Adobe Photoshop) and in operating systems such as MS Windows and Mac OS X, the usability of GUIs is increasingly important.

Previous studies related to GUI usability have primarily focused on design factors such as target size, color, or shape. Official design guidelines related to these design factors have been also provided (ETSI, 2002a, 2002b; ISO/IEC Guide 71, 2002; W3C WAI, 2008). The usability of GUIs has been steadily improved by these research results and design guidelines and increasingly advanced by the larger size and higher resolution of displays. However, users may still have difficulty when they acquire small targets with a mouse, particularly if those targets are aggregated densely or made smaller (Cockburn and Firth, 2003). Thus, GUI usability in various PC working environments can still be improved. Increasing the size of targets on a screen can simplify the task of positioning a cursor on a target, but this size increase also decreases the amount of information presented and the size of the users' workspace (Cockburn and Firth, 2003; Worden et al., 1997; Zhai et al., 2003). This trade-off may be an important challenge in GUI designs. In particular, it can be a more serious problem in computers with small displays such as laptops and netbooks. Thus, more effective strategies need to be developed and investigated to cope with the trade-off.

Recent studies on target-acquisition tasks have presented methods to ameliorate the limitations of existing GUIs by introducing techniques that simplify the process of placing the cursor on the target (Grossman and Balakrishnan, 2005; Park et al., 2006). Various schemes have been proposed primarily to reduce target-acquisition time without changing the screen space or the target size (Cockburn and Firth, 2003). Specifically, these schemes applied Fitts' law (Fitts, 1954; MacKenzie, 1992) to improve the usability of GUIs by increasing W (target width) or decreasing A (distance from the starting point to the target center), thus decreasing the index of difficulty (ID). Several studies have shown that *target expansion* can improve the usability of GUIs by increasing the size of the target according to the location and movement of a cursor or the distance between cursor and target (Cockburn and Brock, 2006; McGuffin and Balakrishnan, 2002, 2005; Zhai et al., 2003). Users acquired targets more quickly even if target-expansion occurred after the point of 90% of the movement towards the target (McGuffin and Balakrishnan, 2002, 2005), regardless of user expectations for target expansion (Zhai et al., 2003). In addition, Cockburn and Brock (2006) found that visual expansion alone, without enlargement in motor space, had a positive effect on performance in target-acquisition tasks.

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Other studies have evaluated the fish-eye technique, which expands a target when the cursor is nearby and shrinks it when the cursor is far away (Bederson, 2000; Gutwin, 2002; Hornbæk and Hertzum, 2007). The fish-eye technique can also be considered a target-expansion method. However, it can cause usability problems such as *focus-targeting*, i.e., the process in which users must shift their focus to a new location due to the distortion of many targets (Gutwin, 2002). If an unintended target is selected due to the shifting location of targets when the cursor passes over them, the user must relocate the cursor to the intended target. Like the fish-eye technique, other target-expansion schemes may spatially disorder nearby targets during cursor movement, e.g., because they change the layout of toolbars and menus on the screen (Blanch et al., 2004). A possible improvement to this problem is to ensure that the center of the expanded target does not move and that adjacent targets are partially hidden, i.e., *occlusion* (McGuffin and Balakrishnan, 2002, 2005; Zhai et al., 2003). However, this can also be problematic when the expanded target is not the desired target. Thus, the effect of fixing or shifting target centers needs to be investigated in more detail, i.e., a comparison between occlusion and push (see 2.3 Experimental design).

Although there have been several studies of target-expansion methods, some points remain to be considered. Most of the prior studies only analyzed the effects of a specific expansion method compared with the static condition in which target size is fixed. Designs for target expansion can vary in the details of the expansion methods such as expansion area and expansion technique. Thus, various interaction designs based on target expansion should be developed followed by a comparative evaluation of the designs.

The previous tests on target expansion were conducted in conditions with only one starting point and one isolated target (McGuffin and Balakrishnan, 2002; Zhai et al., 2003); few have assessed tasks in GUIs arranged in a two-dimensional (2D) configuration where multiple targets occur in groups or are clustered. Peripheral conditions such as grouped toolbars or menus can affect the usability of target-expansion designs. Because users can be negatively influenced by peripheral nontarget items when selecting a target in 2D GUIs representing real-world working conditions, it is important to consider whether target-expansion schemes are applicable to these conditions.

For the design of expanding targets, previous studies have focused on performance measures such as task-completion time or error rate rather than on user preferences or satisfaction. Two usability measures, i.e., objective performance and subjective ratings, often do not agree (Bailey, 1993; Kissel, 1995). Users' qualitative responses are more significant than quantitative measures (Walker et al., 1998). Objective measures such as time and error are insufficient for predicting system acceptability and user satisfaction (Fu and Salvendy, 2002). Frøkjær et al. (2000) and Hornbæk and Law (2007) also noted the importance of measuring all three aspects of usability (efficiency, effectiveness, and satisfaction) when comparing the usability of different designs. Users' subjective ratings may be an important variable that has a major effect in the design of computer systems and applications. Therefore, users' subjective or affective aspects should be also considered when evaluating target-expansion methods.

In addition, the subjects in the preceding studies were younger users in their twenties; however, older users may have more difficulty selecting targets with a mouse. Substantial evidence shows that older adults are slower or less accurate than younger adults in computer-mouse tasks due to increased motor noise (Chaparro et al., 1999; Keates and Trewin, 2005; Smith et al., 1999; Walker et al., 1996, 1997; Worden et al., 1997) or to the decline of visual abilities (e.g., visual acuity and accommodation) and cognition (e.g., information processing and response) with age (Czaja and Lee, 2002; Fisk et al., 2004). Age differences in performance also increased with task difficulty (Riviere and Thakor, 1996; Sandfeld and Jensen, 2005). Thus, both younger and older adults must be considered simultaneously when designing and evaluating target expansion. It is also necessary to understand the usage characteristics of older adults with respect to target-acquisition tasks with a mouse.

This study examined the effects of different user age groups and target-expansion methods on target-acquisition tasks with grouped icons. We compared various target-expansion schemes in a 2D environment with multiple targets such as icons in toolbars by examining subjective assessments as well as performance measures. In particular, we identified design alternatives to help improve GUI usability for older adults, who may have more difficulty performing target-acquisition tasks. For this purpose, we included older people as test subjects.

2. Methods

2.1. Participants

A total of 28 volunteers (14 females and 14 males) participated in the experiment; they were divided into two age groups: younger (under 60 years of age; range = 24 to 49) and older (over 60 years of age; range = 61 to 76) adults. The criterion of the ages of older adults was chosen referring the relevant literatures on the characteristics of older adults (Fisk and Rogers, 1997; Fisk et al., 2004). Each age group consisted of 14 individuals (7 females and 7 males). All participants had experience using PCs and the internet and had no musculoskeletal disorders (MSDs) of their hands or arms. None had difficulty in recognizing the icons and their layout on the experimental prototype. The amount of experience with computers ($F(1, 26) = 15.54$; $p = .0005$) and the frequency of use ($F(1, 26) = 5.30$; $p = .0296$) both decreased with increasing age (Table 1).

2.2. Apparatus

A 15-inch laptop computer (screen resolution: 1024 × 768 pixels) and an optical mouse were used in the experiment. An experimental prototype was developed with Microsoft Visual Studio 2003® using icon images found in MS Office 2007 (Fig. 1). A total of 114 icons were densely arranged into six groups at the top of the screen to provide a PC working environment with multiple 2D targets (Fig. 2). Each group was composed of 6, 9, 18, 27, or 36 icons presented in three rows. Each icon was 18 × 18 pixels (about 5 mm) in size. The distance between the icons was zero pixels within each group, and the groups were separated by five pixels. A black, 20-mm-diameter 'Ready' button was displayed at the bottom of the screen. The distance from the center of the 'Ready' button to the center of the target was about 170 mm for the closest target and about 210 mm for the farthest. The target to be selected by the user was indicated in red. When the 'Ready' button was clicked correctly, it disappeared, and when the target was selected correctly, the next target turned red and the 'Ready' button reappeared.

The scale and timing of the target expansion was based on the method employed in McGuffin and Balakrishnan (2002), Zhai et al. (2003) and Cockburn and Brock (2006). The length of the side of

Table 1
Participants' information.

mean (SD)			
Age group	Age [years]	PC use experience [years]	PC use time [hours/day]
Younger	39.7 (8.8)	9.2 (4.4)	3.2 (2.4)
Older	66.9 (4.9)	3.9 (2.3)	1.6 (0.7)