USING GLYPHS TO FACILITATE TRANSITION FROM HIERARCHICAL SELECTION TO GESTURING

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Abstract: The successive strokes made in multi-stroke marking menus form gestures. This paper reports on an experimental study that examines how the use of glyphs affects performance in marking menu selection. Glyph familiarity is manipulated by comparing Chinese style and Mark style glyphs across Chinese and non-Chinese users. Performance benefits are found for familiar and memorable glyphs. The results are discussed in terms of their implications for the design of marking menus and associated gestures and for the role of glyphs in facilitating the transition from novice to expert performance in menu selection.

Keywords: Human-machine interface, Human-centered design, Motor control

1. INTRODUCTION[1]

The PDA and Tablet PC have led to a renaissance in pen and gesture research. Compared to mouse-based point and click interfaces, gestures have many advantages. They can be flexible and powerful, with the ability to combine both commands and operands in a single motion, allowing more fluid interaction (Guimbretiere et al., 2001; Pook et al., 2000). Gestures can also be very efficient to perform (Kurtenbach, 1993; Zhao et al., 2006; Zhao and Balakrishnan, 2004). Since gestures can be executed eyes-free, they are particularly suitable for mobile use (Pirhonen et al., 2002; Zhao et al., 2007).

Gestures also have limitations. They are typically not self-revealing [1] (Kurtenbach and Buxton, 1991), which can make them hard to discover, remember, and learn. However, the discoverability and memorability of gestures can be increased by combining them with other self-revealing interaction techniques such as menus or icons to create techniques such as Marking Menus (Kurtenbach, 1993; Zhao et al., 2006; Zhao and Balakrishnan, 2004) or Gedrics (Geissler, 1995). These approaches use menus or icons as the novice component to facilitate exploration, explanation, and learning of the interface, while using gestures as the expert component to offer terse, unprompted and efficient actions.

Ideally, users of an interface should move quickly from novice to expert performance. How can the transition from novice to expert be facilitated for menu selection gestures? In the case of Interactive Voice Response (IVR) systems, voice menus are used by novice users, while quick access codes are available to expert users. However, because recovering from errors is a costly process, using the quick access code requires a great deal of self-confidence and practice. As a result, most intermediate users listen to the whole list of options repetitively rather than taking the risk of hitting the wrong key. Thus transition to expert performance in IVR systems is difficult, leading to usability problems, which are often referred to as "touchtone hell" (e.g., Yin and Zhai, 2006).

In contrast, marking menus facilitate transition to expert performance (gestures) by making users rehearse the gesture as they carry out the physical movements required to select commands in the menu (as shown in Figure 1 where the rehearsed movement shown in the marking menus on the left results in the expert gesture shown on the right). However, the abstract gestures typically created in marking menus (e.g., Figure 1, right) are not easy to remember, especially when larger numbers of items are involved.

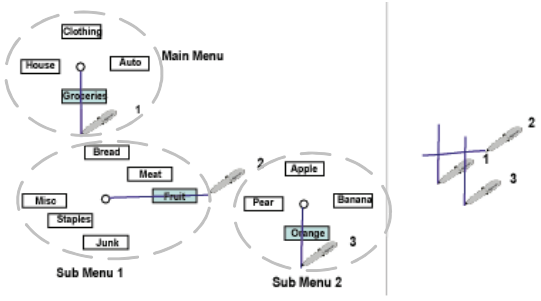

Figure 1: Illustration of how marking menu selection defines an associated gesture (on right).

If the marks (strokes) in a marking menu gesture are not constrained to be continuous (i.e., the next stroke

[1] Self-revealing meaning that available commands are visually presented to the user before the user making a decision on which command to invoke

doesn't have to begin where the previous stroke ended), then the result is a set of strokes that together form a figure reminiscent of Chinese characters and Japanese kanji, This raises the possibility that multi-stroke gestures (referred to here as "glyphs") may facilitate the transition from menu to gestures for multi-stroke marking menus (Figure 2) due to increased memorability of the associated gestures.

In principle, a glyph can serve both as an iconic (visual) representation of the function to be performed, and as a prescription for the gesture to be drawn in order to select that function. Well-chosen glyphs can then capitalize on the impressive picture recognizing ability of the human brain (Park and Gabrieli, 1995). This "picture superiority effect" can make well-chosen shapes more memorable with the additional advantage of having a direct correspondence between the visual glyph and the required gesture. The goal of the research study reported below was to demonstrate that the theoretically beneficial properties of glyphs noted above actually apply in practice, and to provide some initial findings that should eventually lead to a scientific basis for selection and use of glyphs in menu selection tasks. It should be noted that while we focus on multi-stroke marking menus in this paper, our findings will generally apply across all classes of marking menu.

2. GLYPHS AS TRANSITION COMPONENT

Figure 2, shows how a series of marks (select the east node on the first level, south west node on the second level, and south east node on the third level, but with the strokes being arranged differently in space) can be used to construct either a compound mark or a glyph. The lower left part of the figure shows a compound mark which appears as a sequence of arrows forming a path, but not a salient shape. On the right panel of the figure the corresponding glyph is shown, which is recognizable as a Chinese character.

Since these types of glyph are reminiscent of Chinese (and Japanese kanji) characters, it is possible that they are easier to learn for Chinese users. Additionally, it seems likely that well-chosen (visually familiar) glyphs may be easier to learn and remember, as well as use.

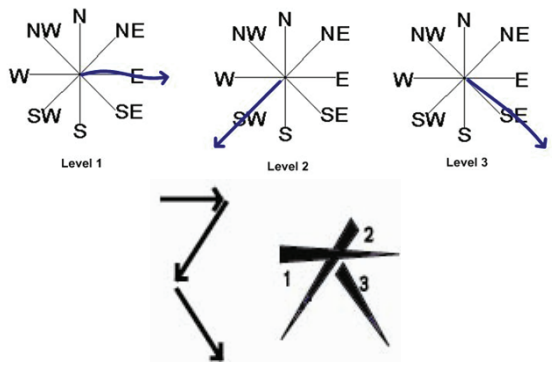

Figure 2: Demonstration of how a series of gestures (top) can be constructed visually as mark style or Chinese style glyphs.

The character on the lower right of Figure 2 represents the word "big" in Chinese. Once it is recognized, Chinese users know how to draw the sequence and direction of the strokes (each Chinese character has a well defined stroke order that is taught in schools). For non-Chinese users, "big" may be unfamiliar, and the required direction and ordering of strokes will be undefined, unless explicitly shown. However, some glyphs may be visually salient for English speaking users. For example, capital letters of the alphabet such as "A" (composed of a sequence of strokes to southwest, southeast, then east) and "T" (composed of two strokes with directions to "east then south"). In addition, some glyphs will be familiar to a wide variety of cultures such as two strokes in the form of a "plus" sign.

One would expect that visually salient shapes should be easier to learn and use than less salient shapes, and that Chinese users should perform better using shapes that closely resemble Chinese characters in the order and direction of strokes (hypothesis 1). In addition, overall performance time for multi-stroke marking menu selection can be broken down into "preparation time" (the time from when users know the command to be drawn to when they actually start drawing it), and "drawing time", which reflects the time spent actually drawing the strokes to complete the command. Given this distinction, it is expected that the response preparation time will be much shorter for Chinese users when the glyphs correspond to Chinese characters because they will be calling up a familiar "stroke writing" routine On the other hand, non-Chinese would not obtain similar benefit from using glyphs that are reminiscent of Chinese characters, due to unfamiliarity with the order and direction of the required strokes.

We were also interested in how much the memorability (or its inverse, difficulty) of glyphs would affect performance where memorability is presumably a property that will vary from glyph to glyph whether or not the glyphs are reminiscent of familiar images/characters or not. It was hypothesized that use of glyphs that are easier to remember would lead to better performance in menu selection (hypothesis 2).

These hypotheses were tested in an experiment that compared menu selection performance using different visual designs for guiding menu selections. The experiment also tested whether the number of levels in the menu hierarchy affects the learning of multi-stroke marking menus. The experiment is reported below, followed by a discussion of the implications of the experimental results for guidelines concerning the use of glyph-like gestures in multi-stroke marking menu.

3. EXPERIMENT

3.1 Participants

14 right-handed volunteers, (5 Chinese females, 2 Chinese males, and 4 non-Chinese males, 3

non-Chinese females) ranging from 20 to 35 years, recruited from the University of Toronto community.

3.2 Apparatus

The experiment was conducted on a standard Pentinum4 1.8 Ghz workstation running Microsoft Windows 2000, with a 17' CRT display. A pen on a 12' x 18' Wacom Intuous2 digitizing tablet was used for input. The pen operated in absolute mode on the tablet. All software was implemented in Java 1.4.

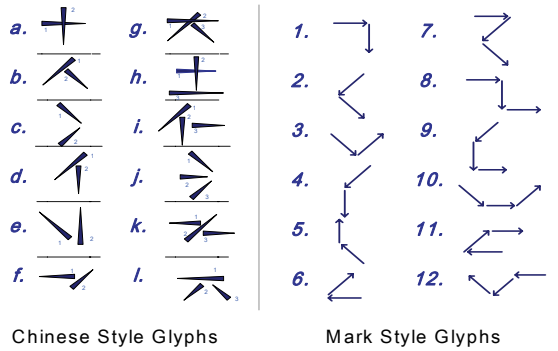

Figure 3: The Chinese Style and Mark Style Glyphs used in the Study.

3.3 Design

A multi-factor, mixed design was used for the experiment. The first of two between-subject factors was the type of gesture being used (i.e., mark style glyphs, as show in the two columns on the right of Figure 3, versus Chinese character style glyphs, as shown in the two columns on the left of that figure). The second between-subject factor was the language familiarity, i.e., whether or not the participant had grown up learning and using Chinese characters (for simplicity, the levels in this factor will be referred to as "Chinese" vs. "Non-Chinese"). The first within subjects factor was the number of strokes in the mark or glyph (two vs. three), and the second factor (only relevant for the portion of the data involving Chinese style glyphs) was whether or not the figure was similar to a Chinese character. In Figure 3, a, b, g, and h are stand-alone Chinese characters, whilst c, d, I, and j are radicals (or sub-groupings of strokes) that can appear in Chinese characters, although they do not form complete characters by themselves.

Each participant saw six two-stroke shapes and six three-stroke shapes selected from either the left or the right side of Figure 3. Each experimental session (one participant per session) consisted of 18 blocks of 48 trials per block. Each block contained all possible combinations, in random order, of the 12 different shapes seen by the participant (six using two strokes and six using three strokes) with each shape being repeated four times within each block. Each shape was assigned a label (a word in English) that was used to refer to that shape in the experiment. The six two-stroke shapes were labeled as different months of the year to represent the stimuli for the two-stroke shape (January through June for the marks, and July though December for the glyphs) and two groups of six country names were used to label the three-stroke shapes (Austria, Belgium, Germany, Greece, Holland, and Spain for the marks; Denmark, England, France, Iceland, Italy, and Sweden for the glyphs).

Cultural differences were manipulated by comparing a sample of Chinese participants with non-Chinese participants, and visual familiarity was manipulated using Chinese characters

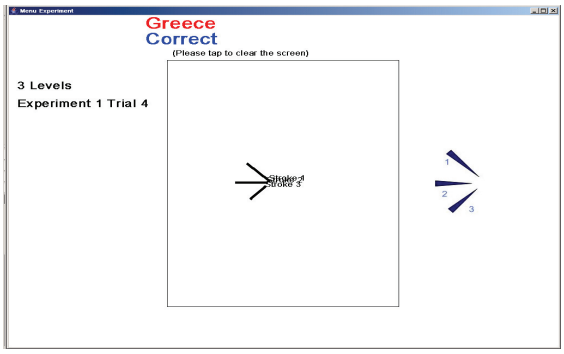

Figure 4: A screenshot of the actual experiment.

3.4 Task and Stimuli

The participants reviewed an instruction sheet of the 12 glyphs that were to be used by them and were then asked to reproduce those glyphs after a period of five minutes had elapsed. An index of difficulty for the glyphs was then estimated as the number of people who failed to recall or reproduce each glyph.

Participants then performed (with a stylus) a series of menu selections by making a set of strokes/marks on a tablet in response to target words (e.g., "Greece") that each represented a menu command. A rectangle was drawn in the screen centre to represent the working area. A small circle was drawn in the middle of the rectangle, and denoted the start position. Instructions to the participant appeared at the top of the screen. Details of the current experimental manipulation were displayed on the left of the screen. (as shown in the example screen in Figure 4).

During each trial, participants were instructed to move the pen (and the corresponding cursor) into the circle. Once the pen cursor dwelled in the circle for at least half a second, the required menu selection instruction was displayed in red. The participant then responded by making the required marks to select that menu item. Once the marks were completed, the resulting menu selection was displayed using color to indicate if the response was correct or not. The ink-trail of the marks the participant made was displayed. The correct strokes (shown on the right of Figure 4) were also shown at the end of the trial to reinforce learning. At the completion of the trial, the participant was instructed to tap on the tablet with the pen to clear the screen and begin the next trial. There was also a "hint" function where participants could at any time during the trial press the 'h' key using the non-dominant hand to see what the visual shape actually was for the label. Measures collected on

each trial included whether or not a hint was used, the time taken from the start of the trial to the start of the first stroke being made (the "preparation" time), the time taken to execute the strokes (the "drawing" time) and the accuracy (whether or not an error was made).

Upon conclusion of the experiment, participants were asked to rank the menu selections (character style shapes or compound style shapes) in terms of how difficult they were to learn.

3.5 Results

Hypothesis 1: Chinese Character Advantage. There was a significant interaction of (glyph style) by race on both preparation time ($F[1,10]=4.99$, $p=.049$ and drawing time ($F[1,10]=7.55$, $p=.02$). The corresponding interaction effects for use of hints and number of errors were not significant. The three-way interactions between glyph style, race, and stroke, and between glyph style, race, and type were also not significant for any of the four measures ($p>.2$ in all cases).

Use of characters (vs. non-characters) shortened the preparation time of Chinese participants (to a level comparable with the non-Chinese participants), but there was no similar benefit for the non-Chinese participants when they used characters, as shown in Figure 5 (Note that the Chinese participants tended to take more preparation time, except when character-like glyphs were used).

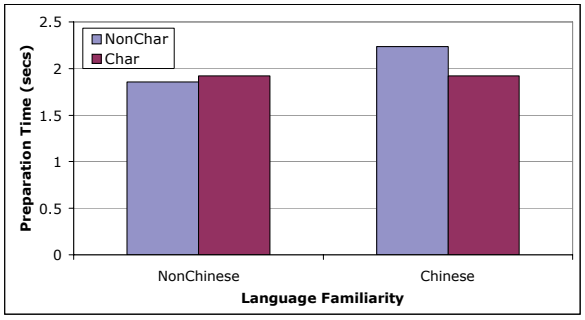

Figure 5: Effect of language familiarity and character type on preparation time.

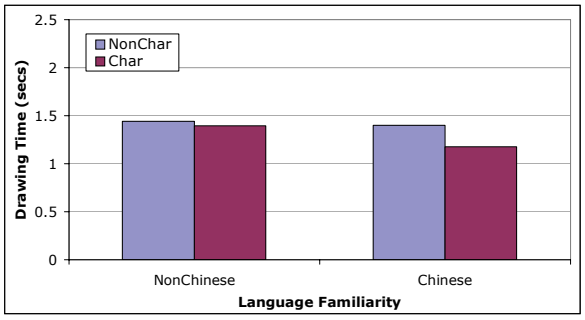

Figure 6: Effect of language familiarity and character type on drawing time.

Similarly, use of characters (vs. non-characters) shortened the drawing time of Chinese participants, but there was no similar benefit for the non-Chinese participants when they used characters, as shown in Figure 6 (it can be seen that Chinese drawing time is similar to Non-Chinese for non-characters, but is faster when characters are used).

Thus Chinese participants benefited from using Character-like glyphs (in terms of both preparation time and drawing time) whereas non-Chinese participants did not.

Hypothesis 2: Glyph Difficulty Effect Figure 7 shows the error rate for six glyphs ranged from left to right in subjective degree of difficulty. The largest error rate was found in the third glyph from the left, with detailed analysis of the results showing that the increased error for this glyph was largely attributable to data from Chinese users. Those participants reported confusion between the glyph and a well known Chinese character particle called "Liang Dian Shui". In Chinese writing, the directions of the two strokes are not strictly defined. Therefore, experienced Chinese users will use their own writing preference to perform the stroke combination which in some cases conflicted with the required stroke direction defined in this study.

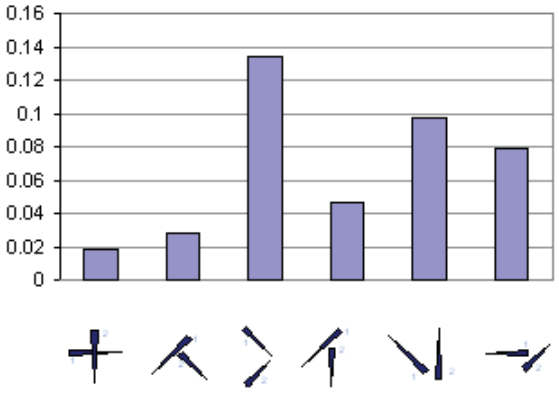

Figure 7: Relationship between glyph "difficulty" and error rate.

Two- versus Three-Level Selections. There was a speed vs. accuracy trade off between the two level and three level menus (two and three stroke glyphs). Some participants reported that in some cases it was easier to remember three level menu items than two level menu items since the three level menu items are easier to build mental associations with.

The Chinese users also did better with the three stroke characters and reported that they were easier to remember and use. There were six participants in the study who used glyphs. Repeated measures ANOVA was carried out with the natural log transformed preparation time. There were significant interactions between strokes and race ($F[1,4]=8.65$, $p=.042$), and strokes and character type, ($F[1,4]=7.94$, $p=.048$). Chinese participants used less preparation time with three vs. two stroke glyphs while non-Chinese participants were not affected by the

number of strokes. The effect of character familiarity was stronger on three stroke glyphs, likely because Chinese participants needed less preparation time with three stroke characters than they did with two stroke characters.

Thus additional complexity in terms of number of strokes may actually be advantageous if it produces good (familiar) shapes. However, while higher numbers of strokes in familiar shapes may improve (learning or remembering the glyphs) (and preparation time in particular) more strokes will tend to lead to less accuracy (as was found in this study). This result is consistent with previous research findings that accuracy decreases with increasing numbers of levels in the menu hierarchy. This raises an interesting problem for designers since more strokes allows deeper hierarchies and possibly more memorable shapes/glyphs, but perhaps at the expense of accuracy and drawing time.

4. DISCUSSION

The research presented in this paper examined the effect of visual salience on performance using glyphs in a menu selection task. In general, the use of familiar glyphs was found to be beneficial, particularly when there was a well-learned stroke order associated with the glyph. However, there were problems when well learned glyphs were written in individualistic styles. For example, the Chinese word "big" can be written in many different ways and there is no strict requirement for the angle of the second and third stroke, but for the glyph recognition used in this study, the second stroke needed to be drawn toward the southwest, and the third stroke needed to be drawn towards the southeast. This resulted in many errors since people had their own style of writing the character which frequently did not conform to these requirements. A similar problem also exists for the “Liang Dian Shui” particle (Figure 7), resulting in a higher error rate. Dealing with this type of idiosyncratic input may require more flexible input recognition (like handwriting recognition).

Our experiment shows that most participants were able to achieve expert performance in less than two hours when use either glyphs or marks. Most of them could remember 80% of the items within 5 minutes. While actual learning may differ in more realistic task settings, this experiment shows that people can eventually reach expert behaviour using a “visual shortcut” technique where glyphs and marks can be previewed with a hint function, and where there is an opportunity to use visual shortcuts to select glyphs (providing opportunities for learning).

We found that cultural differences and the past experience of people both have roles in menu selection. Expert Chinese users learn the Chinese type of multi-stroke marking menu more quickly while the western users learn the Chinese type of glyph composition poorly. On the other hand, for Non-Chinese users, using familiar symbols or graphs should also make it easier for them to learn multi-stroke marking menus.

We found no evidence that the transition from two to three level glyphs/marks affected performance. Further research is needed to see how many levels of glyphs and marks can be remembered by users, and to determine whether or not this relationship changes depending on whether a glyph or a mark is used.

In our study, some of the participants found the three level menus easier to remember than the two level menus due to the meaningfulness of the three-stroke shape. Thus, up to a point, the design of a shape may be a more important determinant of how easy it is to use than the number of strokes that it encompasses.

Error rates were high in the early blocks of the study and errors continued to be made after the glyphs had been learned. The hint function was used less frequently by the Chinese participants and as a result their initial error rates were higher. Further research is needed to determine if differences in using hints are due to cultural differences or were caused in this case by a greater degree of confidence due to the presence of familiar Chinese characters within the stimulus set.

5. DESIGN GUIDANCE

1. Our experiment shows visual appearance of glyphs does have an effect on learning the menu. Visually salient images can accelerate user’s learning while careless design might hinder users learning. It’s suggested to select visually salient glyph images belongs to a user’s culture.

2. Individual users have different experience on remembering an item. Personal customization of the glyph images could future help learning of the menu. Allowing users to customize the glyph representation according to users’ preferences could accelerate learning.

3. Grouping and categorization of menu items according to their visual salience could be advantageous. Imagine a set of menu items all having the “water” particle in their visual shortcuts could be grouped to the “water” category, and “water” can be associated with a specific menu category such as “Tools”. This association will likely help user to remember the menu better.

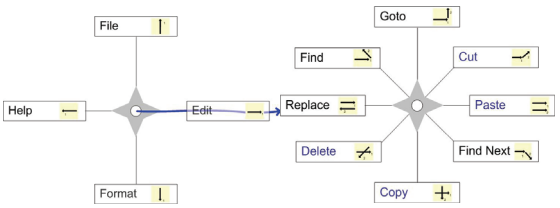

Figure 8: Use of previews and shortcut images in gestural menu selection.

4. Shortcut images shown beside the menu label can be helpful for novices. Figure 8 shows an example of this design. When the user mouse over

"Edit", submenus are shown on the right. User sees the item "Cut" and it's shortcut besides its label (visually, it serves like an image that tells user the direction for the menu selection).

In addition to preview icons, the same icon can be flashed at the end of selection. The gestural icon would provide all the information needed to make a multi-level hierarchical selection. In addition to preview icons, user's learning can be further reinforced by flashing image icons at the end of the menu selection representing the shortcut of menu item. The properties of these icons provide designers with new options for dealing with menu selection on small screens. This leads to two additional guidelines.

5. When incorporating the preview shortcut icons, the images need to be clearly distinguishable from the menu label. Especially in a Chinese system, users might be confused with the visual shortcuts (which could also appear meaningful) with the menu label which is in Chinese). Users need to be informed that they are separate ideas.

6. It is suggested to maximize the association of menu labels with their shortcut images. It's better to put closely related menu items together with an image that people can relate to which will help users to remember the action.

6. CONCLUSION AND FUTURE WORK

In conclusion, different visual glyph composition has a significant effect on gestural menu selection performance, with different kinds of people being affected differently. This result suggests that designers looking to facilitate the transition from novice to expert performance in menu selection should consider carefully who their users are and how to use familiarity and memorability in designing the visual compositions (glyphs or gestures) associated with menu selections. The study reported above also demonstrates the potential value of using glyph-like gestures in menu selection. In addition to being easier to remember, glyphs should also be easier to execute. After characters have been drawn many thousands of times, writing them is likely to become automated. Thus when a user is told that execution of a menu item associated with the Chinese character for "big", not only will she know right away what it looks like, but also she will probably have a motor program for its execution.

For Chinese (or Japanese) users, there are a large number of potentially useful glyphs that can be formulated based on familiar Chinese characters. For non-Chinese (or Japanese) users, it may still be possible to find memorable glyphs (such as capital letters of the alphabet or the plus sign).

The effort to further understand the impact of glyph design on menu selection performance for different user groups seems worthwhile given the potential efficiency of multi-stroke marking menu and the way that the component strokes form gestures that can be utilized directly in expert performance. As applications get more complex, glyphs and gestures represent a way to permit larger menus to be presented to users. While large menus can be problematic in consumer applications there are likely to be many high end professional applications such as CAD design and image editing where glyph based menu selection may be extremely useful in facilitating the transition to expert performance.

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