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Effects of drawing direction and angle on stability of point-to-point drawing task varying length of drawing for the elderly

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Abstract

The aim of the present study was to show the effects of drawing direction (top-down vs. bottom-up) and angle of trace participant drew (0° vs. 60° vs. 300°) on stability varying length of drawing (5.7 cm vs. 11.4 cm vs. 17.1 cm) for the elderly. These three independent variables were within-subject factors. Thirty-eight older adults (18 females, 20 males; mean age = 71.7, SD = 5.5) participated in the study. The drawing task was performed on a computer with touch screen, using an electronic pen. Drawing performance was analyzed using a 3-way repeated measures ANOVA model. Results indicated that the error for top-down was significantly larger than that for bottom-up condition; the error for the length of drawing at 5.7 cm was larger than those at 11.4 cm and 17.1 cm. Data analysis also revealed that the effect of drawing direction on drawing velocity, indicating that drawing velocity for bottom-up was significantly greater than that for top-down condition. Additionally, the drawing velocity of length of drawing was significantly greater for 17.1 and 11.4 cm than it was for 5.7 cm. The angle of trace participant drew also significantly affected drawing velocity: 60° yielded significantly greater velocity than did 0° and 300° conditions. These results have implications for product and interface design for the elderly.

1. Introduction

Cognitive aging is a normal phenomenon, implying that people's cognitive ability will decrease over their lifetimes. The elderly may experience a decline in some of cognitive functions, such as memory, attention, executive functions, and processing speed. Cognitive degeneration for the elderly has shown to lead to difficulty for them to perform basic daily activities (Nouchi et al., 2012). Therefore, effective product redesign interventions may have the potential to help the elderly to easily use product and could result in improved quality of life and longer independence for the elderly.

Widespread use of computers has reduced the amount of handwriting tasks in several settings, such as in offices and schools (Medwell & Wray, 2008; Sülzenbrück, Hegele, Rinkenauer, & Heuer, 2011), however, handwriting- and drawing-like movements have increased in daily life, for example, swiping movements, pointing, and writing movements on touch screen tablets, smartphones, and other similar devices (Van Gemmert, 2015). These drawing and handwriting tasks require the coordinated action of numerous limb components, minimally the wrist and the fingers (Teuling, 1996). The stability of the drawing and handwriting pattern was significantly affected by the associated attentional cost (Kostrubiec et al., 2013). The link between attention and coordination dynamics has been examined within a dual-task paradigm involving the concurrent performance of continuous bimanual movements and a discrete secondary probe RT task (Temprado et al., 1999, Temprado et al., 2001). In particular, Hiraga et al. (2004, 2005) used a dual-task method to examine the attentional demands of continuous interlimb circle drawing movements. The results showed that coordination pattern stability and central cost covary. These studies suggested that the easier and more stable the coordination pattern to be performed the less the central cost associated with maintaining that pattern. Similarity, Miyahara et al. (2006) suggested that inaccurate drawing is not caused by an attention deficit, but that it is a manifestation of a motor deficit as a separate entity for attention deficit.

A number of researchers (Athenes et al., 2004; Danna et al., 2011; Kostrubiec et al. (2013) have quantified the effect of drawing direction on drawing performance. For instance, Athenes et al. (2004) manipulated the relative phase of the x and y orthogonal oscillators to generate various ellipsoid shapes: relative phase amounts to 0° for a right-slanted line, 180° for a left-slanted line, 90° for a circle, to 45° for right-slated ellipse, and to 135° for left-slanted ellipse. Subjects in the right handedness were required to reproduce the perceptual models by superposing the produced trace over the shown shapes. The drawing performance was assessed through the produced relative phase and a classification of graphic patterns was established from the most to the least accurate (0° and 180° > 30°-45° and 105°-135° > others) and from the most to the least stable (0° > 180° > 30°-45° > others). Danna et al. (2011) asked right-handed subjects to reproduce eight series of 84 ellipses, whose relative phase (RP) varied from 0° (a line) to 90° (a circle), and twelve orientations, the long axis of the ellipses aligned in a direction ranging from three to nine o'clock with respect to the body transverse plane. The results showed that subjects preferred a line (0°) and an ellipse of intermediate eccentricity (45°); in the 10:30 o'clock direction, line drawing (0°) increased in variability and the intermediate ellipse (45°) was attracted towards a circle (90°). Recently, Kostrubiec et al. (2013) asked eight right-handed adults to trace graphic patterns, characterized by a 0°, 45°, 90°, 135° or 180° relative phase and corresponding to shapes ranging from lines to ellipses to circles. The results showed that there was a strong and significant correlation between the stability of the produced pattern and the associated attentional cost. The amplitude of the minor and major axes of the produced ellipsoids decreased with the increase of movement frequency. In addition, Vinter et al. (2011) summarized previous results and suggested that effect of orientation and eccentricity in the drawing of elliptic shapes was biased by preferred coordination patterns. The orientations between 12.00 and 2.30 were preferential; those between 9.00 and 11.30 appeared as non-preferred orientations.

Age-related changes in a coordination pattern were observed between the arms during bimanual movements (Serrien et al., 2000; Stelmach et al., 1988) as well as among the individual fingers during a multiple-finger force production (Shim et al., 2004; Shinohara et al., 2004), resulting in slowness of aiming movements for the elderly, especially when the complexities of tasks are increased (Ketcham et al., 2002). Moreover, the elderly has an increased reliance on vision as source of sensory information, which may result in their diminished position sense (Haaland, Harrington, & Grice, 1993; Seidler-Dobrin & Stelmach, 1998), both in the ability to detect movement and active repositioning of limbs (Meeuwsen, Sawicki, & Stelmach, 1993; Petrella, Lattanzio, & Nelson, 1997). Although the fact that drawing or tracing task forms a critical part of daily activities (Gowen & Miall, 2006), few studies of factors affecting the stability of drawing or tracing task for the elderly were investigated. Consequently the present research was designed to investigate possible differences in error of point-to-point drawing task as related to the length of drawing,

drawing direction, and angle of drawing.

2. Method

2.1 Subjects

Twenty men and 18 women, 65 to 80 years old (M=71.7, SD=5.5), were recruited by an advertisement posted at Taoyuan Elderly Recreation Center. All participants reported a 12/20 corrected visual acuity or better and had no physical impairment impeding producing the required drawing. Participants received 200 New Taiwan dollars for their participation.

2.2 Stimuli and Experimental Design

The point-to-point drawing task was performed on a computer with touch screen, using an electronic pen. In the center of the white screen (19.5 cm × 15.0 cm) of the computer, a drawing model, typically, two black points were displayed. One is start point, another is end point. The task of participant is to drawing a straight line from the start point to the end point. Experimental set-up illustrated in Figure 1.

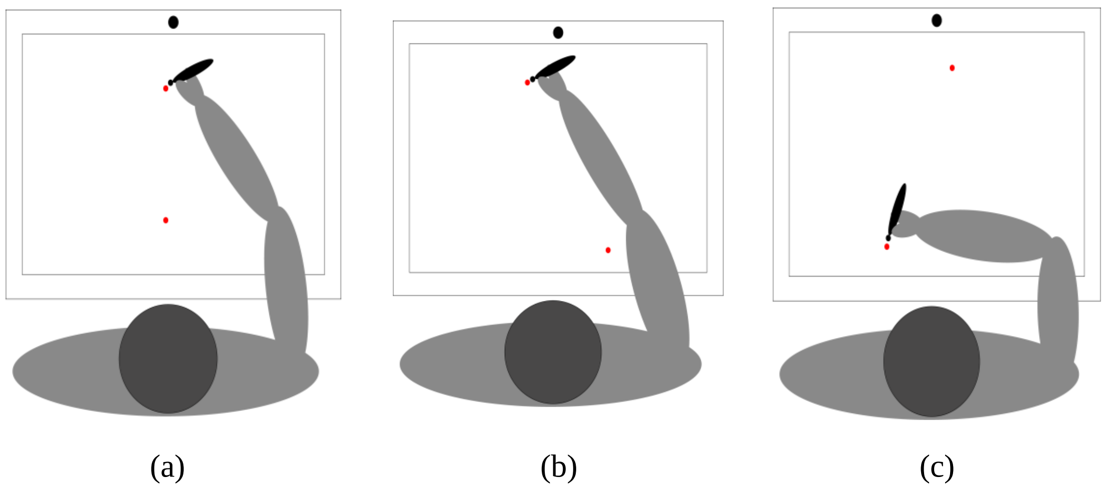

Figure 1: Experimental set-up. The subject held the electronic pen in a normal pen grip. The subject moved the pen from start point to the end point after click the “START” on the screen. Example of the stimuli in the different conditions (length of drawing (i.e., space between points), drawing direction, angle of trace participant drew): (a) 11.4 cm, top-bottom, 0°, (b) 17.1 cm, top-down, 300°, (c) 17.1 cm, bottom-up, 60°.

The present experiment investigated three independent variables were investigated: spacing between points, drawing direction, and angle of drawing. Three spaces between start and end point were used: 5.7, 11.4, and 17.1 cm, respectively. Two levels of drawing direction were used: top-down and bottom-up. Three angles of trace participant drew were used: 0°, 60°, and 300°. The 0° was defined as the two points were displayed in vertically. The 60° was defined as the two points were displayed in right-up and left-down. The 300° was defined as the two points were displayed in left-up and right-down. These three independent variables were tested in a within-subject design. Thus, each participant was presented with 18 trials (3 spaces × 3 angles × 2 drawing directions) in a random order.

2.3 Procedure

At the beginning of the experiment, participants spent 1 minute reading on-screen instructions to familiarize themselves with the experimental procedure. Before the experiment started, participants received three practice trials. All participants were tested individually in a quiet experimental room in which the light level was approximately 300 lux.

To begin each trial, participant had to click on a virtual START button, which was presented on the screen, by using a computer pen. Once the participant clicked START two points appeared on the screen. One is the start point, another is the end point. Participants were required to put the computer pen on the start point. When the experimenter report "to draw," participants were asked to draw a straight line from the start point to the end point using a computer pen as quickly and as accurately as possible. When the participant moved computer pen to the end point, "Finish" was displayed on the screen. After 20 sec "Finish" disappeared and the "Start" was presented again, next trial was displayed. This procedure was repeated until all 18 trials had been presented. The drawing time and trace participant drew were recorded by computer. The experiment was conducted in a single session, approximately 15 min in duration.

2.4 Data Analysis

Drawing performance was analyzed in terms of velocity [drawing length (calculated in millimeter) / drawing time (sec)] and accuracy [error in line drawing = (length of trace participant drew - length of straight line)/ length of straight line – was calculated in percentage). A repeated-measures analysis of variance was conducted using SPSS software

(Chicago, IL, USA).

3. Results

3.1 Error in line drawing

In Table 1 are means and standard errors for all parameters. The main effect of drawing direction on error in line drawing was significant ($F_{1, 37} = 63.75$, $p<.001$, partial $\eta^2 = 0.63$), indicating that the error in line drawing for top-down was significantly larger than that for bottom-up condition. Analyses identified a main effect for space between points on error in line drawing ($F_{1.52, 56.35} = 21.61$, $p<.001$, partial $\eta^2 = 0.37$). A Bonferroni *post hoc* analysis showed that the error in line drawing was significantly larger when the space between points was 57 mm than when it was 114 or 171 mm; however, no difference between the latter two conditions was found. No significant effects of angle of trace participant drew was found ($F_{1.97, 72.75} = 3.05$, $p=.053$, partial $\eta^2 = 0.08$).

TABLE 1

Means and Standard Errors of Drawing Velocity (mm/sec) and Errors (%) (n=38)

Independent Variable	Velocity		Error in line drawing	
	M	*SE*	*M*	*SE*
Space between points (cm)				
5.7	29.05	1.23	6.64	0.54
11.4	41.43	1.84	4.69	0.32
17.1	49.10	2.57	4.02	0.21
Drawing direction				
Top-down	41.35	2.02	6.16	0.37
Bottom-up	38.37	1.78	4.08	0.27
Angle of trace participant drew (degree)				
0	37.07	1.80	4.65	0.41
60	44.68	1.97	5.33	0.34
300	37.83	1.82	5.37	0.29

These results showed one two-way interactive effect. A significant interaction between the space between points and angle of trace participant drew ($F_{3.48, 128.87} = 3.41$, $p=.011$, partial $\eta^2 = 0.09$) on error in line drawing, as shown in **Fig. 2.** These data implied that the drawing velocity decreased when the space between points increased regardless the angle of trace participant drew. Moreover, the effects of the angle of trace participant drew on drawing velocity for space between points at 57 mm and 171 mm were greater than that for 11 mm condition, the difference of error in line drawing among three angles of trace participant drew under space between points at 114 mm was not obvious.

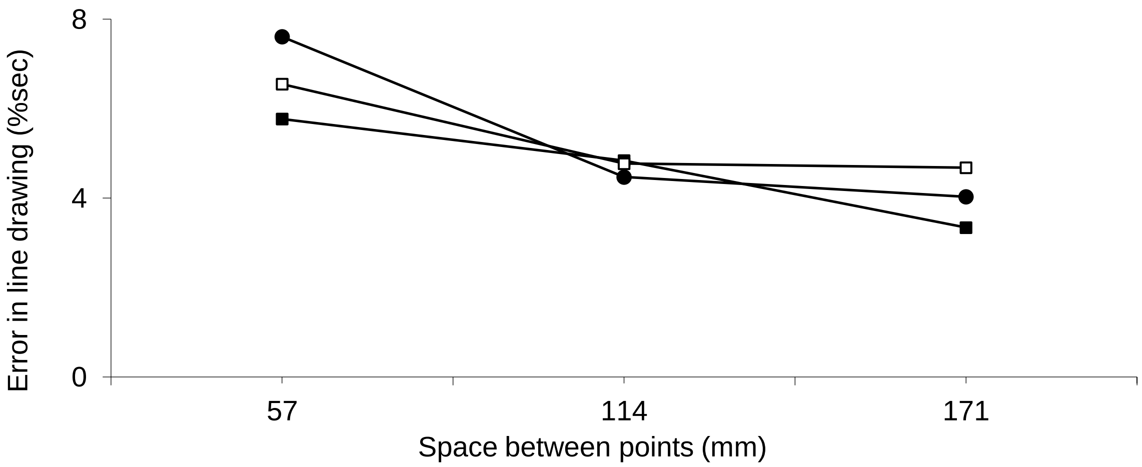

Fig. 2. Error in line drawing as a function of space between points and angle of trace participant drew (■ 0° , □ 60° , ● 300°)

3.2 Drawing velocity

Analysis of variance showed a main effect of drawing direction on drawing velocity ($F_{1, 37}$ = 4.98, p=.032, partial η^2= 0.12), indicating that drawing velocity for top-down was significantly greater than that for bottom-up condition. Analyses identified a main effect for the angle of trace participant drew on drawing velocity ($F_{1.79, 66.26}$ = 37.34, p<.001, partial η^2= 0.50). The Bonferroni *post hoc* analysis indicated that the drawing velocity for angle of trace participant drew of 60° was significantly greater than those for 0° and 300° conditions; however, no significant difference in drawing velocity was found between 0° and 300°. Also, the main effect for the space between points on drawing velocity was significant ($F_{1.25, 46.09}$ = 102.37, p<.001, partial η^2= 0.74). The Bonferroni *post hoc* analysis demonstrated that the drawing velocity for space between points of 171 mm and 114 mm were significantly greater than that for 57 mm; moreover, the drawing velocity of 171 mm was significantly greater than that for 114 mm condition.

These findings indicate two two-way interactive effects. The first is a significant interaction between drawing direction and angle of trace participant drew on drawing velocity ($F_{1.78, 65.76}$ = 5.33, p=.007, partial η^2= 0.13). The interaction was illustrated in **Fig. 3**, revealing the effect of drawing direction on drawing velocity was greater when the angle of trace participant drew at 0° and 300° than when at 60°. Here the drawing velocity for drawing direction of bottom-up was lower than that for top-down under the angle of trace participant drew at 0° and 300° conditions; however, under the angle of trace participant drew at 60°, the difference between top-down and bottom-up on drawing velocity was not obvious.

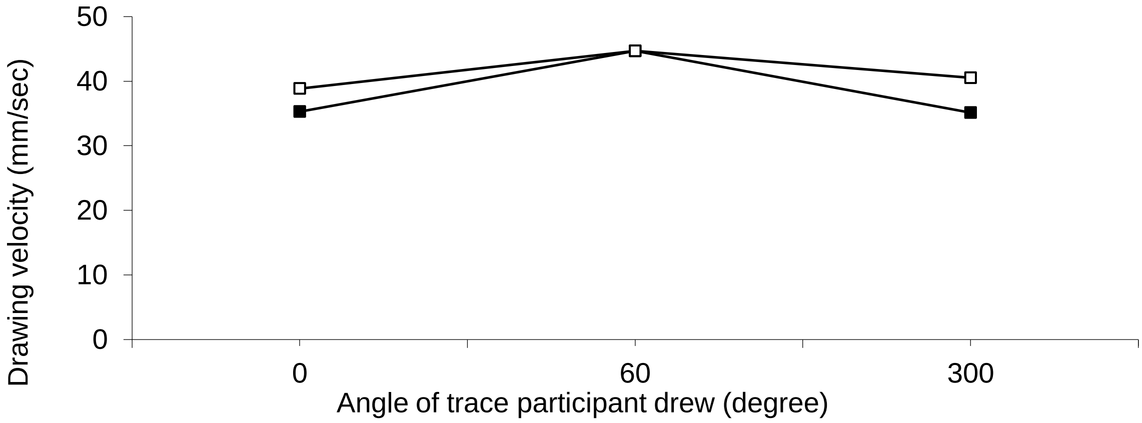

Fig. 3. Drawing velocity as a function of angle of trace participant drew and drawing direction (■bottom-up, □top-down)

The second significant interaction was between angle of trace participant drew and space between points on the drawing velocity ($F_{3.02,\ 111.90} = 5.20$, p=.001, partial $\eta^2 = 0.12$). **Fig. 4** shows the drawing velocity versus angle of trace participant drew for the range of space between points. The drawing velocity increased when the space between points increased regardless the angle of trace participant drew. Moreover, the drawing velocity for angle of trace participant drew of 60° was greater than those for 0° and 300° regardless the space between points.

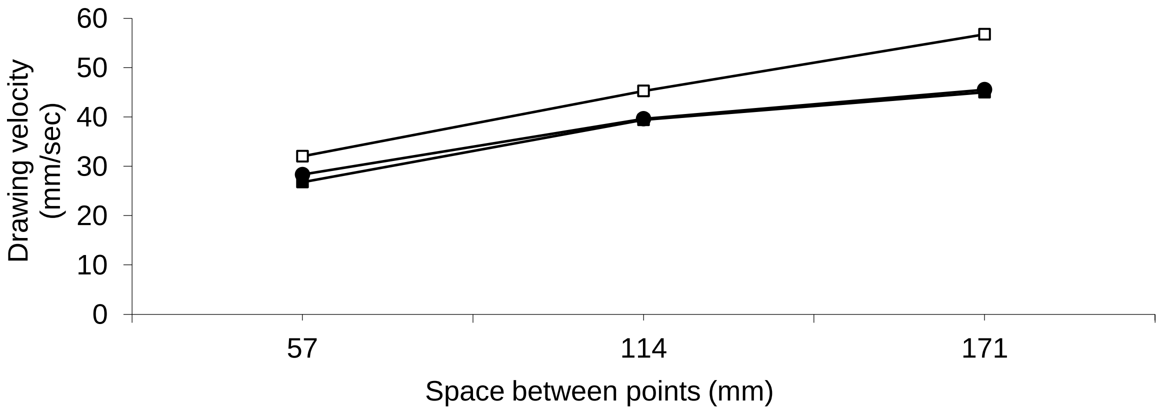

Fig. 4. Drawing velocity as a function of space between points and angle of trace participant drew (■ 0°, □ 60°, ● 300°)

4. Discussion

The results indicated that drawing direction significantly affected error in line drawing, indicating that the error in line drawing for top-down drawing direction was significantly larger than that for bottom-up condition. One explanation for this is the participants used to drawing or tracing from top to down rather than from bottom to up. Therefore, the drawing speed of top-down was faster than that for bottom-up condition. This was also supported by the present results which showed that drawing velocity for top-down was significantly greater than that for bottom-up condition. This result is consistent with the classic aiming movement speed-accuracy trade-off.

The data indicated that space between points significantly affected the error in line drawing, demonstrating that the error in line drawing was significantly larger when the space between points was 5.7 cm than when it was 11.4 cm and 17.1 cm. One explanation may account for the present finding. Subjects have more opportunity to modify the drawing direction in accordance with the linear movement from start point to end point when they drew 11.4 cm and 17.1 cm line than when they drew 5.7 cm line. Moreover, the result revealed that drawing velocity for space between points of 17.1 cm and 11.4 cm were significantly greater than that for 5.7 cm. One possibility is the subject decreased the amplitude of their movements at 5.7 cm; subject increased the amplitude of their movement with increases, resulting in smaller velocity at 5.7 cm than at 11.4 cm and 17.1 cm conditions.

The data analysis showed a significant effect of angle of trace participant drew on drawing velocity, indicating that the drawing velocity for angle of trace participant drew of 60° was significantly greater than those for 0° and 300° conditions. One explanation may account for the present finding. Most of the subjects were right-handed person, they easily drew the line of angle at 60° than at 0° and 300° regardless the drawing direction.

5. Conclusions

Overall, our results demonstrate that space between points, drawing direction, and angle of trace participant drew affected drawing performance in a point-to-pint drawing task. The findings of this study may contribute to improvements in drawing performance in real work situations by prompting consideration for the impact of visual impairment (for example, the elderly) and by evaluating the relative effectiveness of drawing direction and angle of trace.

Moreover, the results also have implications for the design of human–machine interfaces, and are relevant both for product design and information design pertaining to websites.

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