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A COMPARISON ON THE CIRCLE-DRAWING TASKS BETWEEN THE NON-SIGHTED PEOPLE

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ABSTRACT:

This study examined the task of plotting circles with two different compasses, CR1: the ruler used at school for visually impaired people and CR2: the new created ruler, to see the proper one. Four circle-drawing tasks were conducted between non-sighted people, 12 blindfolded subjects and 12 blind subjects. The tasks were: (1) center-point specified circle; (2) radius specified circle; (3) center-point and radius specified circle; and (4) two specified homocentric circles. And the actions of each task were separated into 3 stages, Adjusting, Positioning, and Plotting; the response time and deviation of the circle drawn were recorded. It was found in the two-sample t-test that the blindfolded subjects performed better than the blind subjects on the response time at the task (1), and (4). The CR2 performed better at Adjusting stage on the response time while the CR1 performed better on the deviations at Adjusting and Plotting stage. For the blindfolded subjects, in paired t-test, the CR2 did a better job on the response time at Adjusting and Positioning stage while the CR1 did better at Plotting stage. For the blind subjects, the CR2 was good at Adjusting stage on the response time while CR1 was better at Plotting stage on the deviation. In summary that this design, CR2, reduced the response time of circle-drawing tasks, while the deviations of the tasks were not improved significantly. However, the further work would focus on the complex tasks of circle-drawing, such as circle-closing and tangential circles.

Keywords: evaluation, industrial design, circle-drawing, non-sighted people, compasses

1. INTRODUCTION

The exploration of haptic drawing with hands involves primarily our fingertips to percept the condition of the surface we touched. As researchers reported, that the hand and finger have remarkable tactile acuity at sensing the properties of objects, such as size, orientation and curvature (Goldreich et al., 2003; Song et al., 2004; Louw et al., 2002). Some studies claimed that the tactile acuity is enhanced by the Braille training (Kauffman et al., 2002). In the recent study by Goldreich et al. (2003) the raised effect of acuity may be not only the reading finger of Braille but all over the hands, though the authors said the longitudinal studies should be done to track the differences between the reading and non-reading fingers of the blind individuals. This inferred that the sensitivity of fingers of blinds could be exerts in order to help blind people to integrate information more efficiency. This work here was a research project, supported by the National Science Council, which was to design a tool to help blind people to plot geometric drawing as sighted people do. On our approach to design a tool for the blinds, the raised-line board was the first choice in the longitude development. There were many possible ways of making haptic drawings as Edman (1992) wrote in his book, tactile graphics, the most convenience way of them was the raised-line drawing board. Many works mentioned that the raised-line pictures are useful for haptic picture recognition (Haller et al., 2002, 2005; Kennedy, 2003). While researchers reported that tactile acuity of blind subjects is enhanced independently of the degree of childhood vision, light perception level, and Braille reading (Johnson and Phillips, 1981; Craig, 1999; Goldreich et al., 2003), blind person has the stronger acuity at sensing the tactile information than sighted people (Fagg et al., 1992). The strategy of our design was to make most use of the index finger to be the major sensor in the design. The design team developed a ruler with a concept that employed the acuity of the index finger, and this paper was a result about an evaluation experiment for the new design.

This project focused on the topic of designing a tool for the non-sighted people to plot a circle on a raised-line drawing board. The design team concentrated on conducting the tactile acuity of index finger to be the major tactile sensor and developed a prototype of new compasses with which proposed a different way of plotting a circle. The major differences between this new ruler, as we named CR2 (**Fig.1 left**), and the ruler used at the school for visually impaired people, called CR1 (**Fig. 1 right**), were shown in three parts.

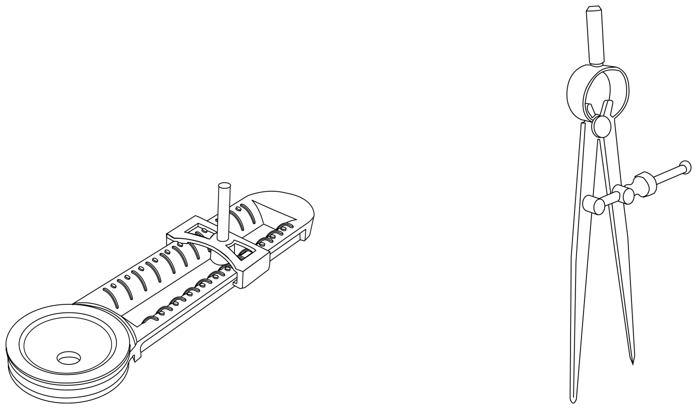

Figure 1: the two different tools in this experiment of circle-drawing tasks.

The left one, **CR2**, was the prototype created which employed index finger as the major sensor of defining the center point. Also there was a mover across the radius groove to settle the required radius. The right one, **CR1**, was a compasses at the school for visually impaired people which employed a tip edge for positioning the center point and an obtuse edge for the plotting, and a screw on the topside for adjusting the radius.

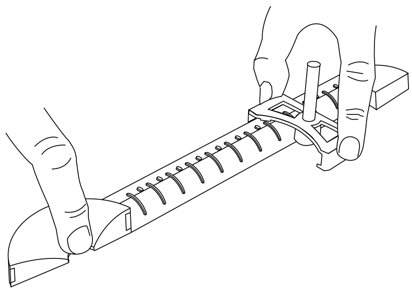

Figure 2: the details of the CR2, in a section view.

The major features of the new ruler were: (1) to conduct the index fingertip as a center tip to percept the center point on the raise-line paper and to define the position of the center point; and (2) a mover across the groove as a indicator and the plotting pen of the ruler.

Firstly, the way of defining the center point, the CR2 (**Fig. 2**) employed the index fingertip as the indicator of the compasses in a way of pressing the finger right on the requested tactile center point. Secondly, the way of adjusting the radius, there was a mover along a groove with markers on the proper location for the index finger to touch. The user could easily move the mover to the position, the radius, which he decided. Thirdly, the way of plotting the circle, as the user felt that his index fingertip was right on the top of the center point, then he could press the hollow cover down to fix the center position and then turn the mover, as a plotting pen, around the center point to achieve the circle.

2. METHODS

Participants

Twelve blind subjects whom recruited from the Taipei Association of Visual Impairment were invited to participate this study, that were 4 males from 32 to 42 years old (M=38.2) and 8 females from 28 to 40 years old (M=36.0). And twelve sighted persons, who were blindfolded in this experiment, were 7 males from 23 to 27 years old (M=24.8) and 5 females from 23 to 24 years old (M=23.2) recruited from Tatung university. None of them reported that had any kind of injury at hands or fingers. There were 6 left-handed, 2 in the blind group and 4 in the blindfolded group. On the visual state, there were 4 CB (congenitally blind), 2 EB (early blind), and 6 LB (late blind) invited, and those sighted subjects were blindfolded through the whole experiment. The details of those participants were shown in the **Table 1**.

Table 1 The 24 subjects recruited in this experiment.

group	sex	n	Age (mean)	Vision state	Reading hand
Blind	Male	4	32-42 (38.2)	2 CB / 2 EB	Left 1 / Right 3
	Female	8	28-40 (36.0)	2 CB / 2 EB / 4 LB	Left 1 / Right 7
Blindfolded	Male	7	23-27 (24.8)	Sighted	Left 3 / Right 4
	Female	5	23-24 (23.2)	Sighted	Left 1 / Right 4

Materials

As the general procedure that the blind person learned how to draw a circle, plastic films were prepared as the drawing paper for each task of the experiment. There were 4 tasks designed from those general activities of circle plotting in order to compare the performance of the 2 rulers, that were, **(1) center-point specified circle:** to plot a circle at the point specified pre-located on the film (a cross line on the center of the film represented the center point of the circle requested); **(2) radius specified circle:** to plot a circle with the specified radius (showed on the lower corner of a film represented with a straight line); **(3) center-point and radius specified circle:** a film prepared with a pre-located center point in the center of the film and a radius specified on the lower corner of this film; and **(4) homocentric circles:** to draw two circles on the same required center point with two specified radiuses on the lower corner. The film was fixed on a rubber plate at the same position for each task and the rubber was stick on the desk in case of unintended movement by the subject which might interrupt the normal action and severely affected the results.

Procedures

In the beginning of the experiment the subject was freely to practice the two rulers at the activities of plotting after a fully instruction from the experimenter. After about 5 minutes the experimenter asked the subject to draw a circle with a specified radius at a specified center point to see whether the subject fully understood the procedure of circle-drawing tasks with each compasses. The 4 circle-drawing tasks were randomly assigned to the participants; and the experimenter gave the oral instructions to the subject at the beginning of each task, then the subject was asked to perform the plot with no explanations or supports from the experimenter.

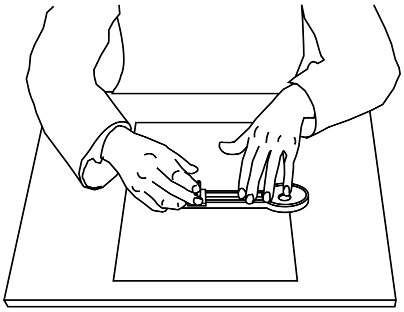

Figure 3: one example of the circle-drawing task for this experiment.
Subject was told to use the tool to plot a circle at the specified condition of center point or radius or both, the response time was recorded in video, and the deviation of the plot was compared to the standard circle.

Two video cameras were prepared in front of the desk, one was to record the overall response of the subject (**Fig. 3**) and the other one focused on the actions at close view for the experimenter to identify the stages of this plot task and to determine the response time for each stage. In this experiment, the 3 stages of a circle-drawing task were identified as followed: **(1) Adjusting stage:** the response time was counted from the subject pick up the tool till he adjusted the radius to the final position which he felt right. **(2) Positioning stage:** from the time the subject moved the tip of the compasses to the position he felt right on the film till the tip touched the point he positioned, and **(3) Plotting stage:** from one hand left the center point to plot the circle till the other hand lifted the tool away from the film. The response time for these 3 stages was recorded; and the deviations of those plots were measured at radius, center position, and the uncompleted distance of the circle represented the deviation of Adjusting, Positioning, and Plotting stage, respectively.

3. RESULTS AND DISCUSSIONS

The evaluation of the new design for circle-drawing tasks was done by comparing the performance between these two compasses on the response time and the position deviation. There were two independent variables which were: (1) the subjects: which was two levels, blind group and blindfolded group; (2) the compasses: which was two levels, CR1 and CR2. The interested performance variables were response time and position deviation. All of the comparisons were made at the views of: (1) the tasks: which was set as task 1, task 2, task 3, and task 4; (2) the stages: to see the differences among 3 stages which were Adjusting stage, Positioning stage, and Plotting stage.

The response time

The two-sample *t*-test showed in comparisons of these 4 tasks, the blindfolded group had the less mean response time than the blind group at the **task 1**, $t(46)=2.510$ $p=.016$, and at the **task 4**, $t(46)=2.181$ $p=.034$. This implied that the blindfolded persons were faster in doing the complex circle-drawing task such as the homocentric circle task (task 4). But that was a hypothesis only, because the other two tasks (task 2 and task 3) showed no significant differences.

Among the 3 stages, the blindfolded persons had the less mean response time at the **plotting stage**, $t(46)=2.073$ $p=.044$. And at the **adjusting stage** the CR2 had the less mean response time than CR1, $t(46)=2.511$ $p=.016$, It seemed that the reason why the sighted group performed faster was due to the less time spent on the plotting stage. And the CR2 took less time at the adjusting stage was one of the prediction from design team, because there was an indicator in our design, CR2, which could smoothly move (which meant a faster adjustment) across the groove, and the indicator also clasped on the mark for the user to treat it as a pen to draw the circle. The summary of the results showed in the **Table 2**.

The position deviation

The two-sample *t*-test revealed that the blind group had a less deviation at **adjusting stage**, $t(46)=-2.253$ $p=.029$, which could be a hint that the blind group was more cautiously concentrated on the tasks than the blindfolded group. To tell the differences between the two rulers at deviations, it showed that at the adjusting stage and the plotting stage, the CR1 was better, $t(46)=-2.842$ $p=.007$, $t(46)=-3.664$ $p=.001$, respectively. It appeared that although the CR2 achieved the goal of speed (less response time); it had to be improved at the deviation performance. When we checked the video for this part, we found that the reason might be the mechanism of 'lock' the pen on the right position which was not steady now at the prototype. Also from the interviews with the subjects after the experiment, some comments suggested that the indicator should be smaller and kept a smaller tolerance at the gap of indicator and the up surface of the ruler in order to keep it much more stable. The total mean deviation measured of the CR2 at the plotting stage was larger than the CR1. This was partially caused by the individual differences at the plotting, it was found from the video that some of the subjects lost the balance of plotting, some of the plotted circles seemed to be enlarged ellipses and some of them were also segmented and discontinuous. That should also be studied in the next design.

Table 2 The results of this experiment.

t-test		Item	Response time		Position deviation	
			subjects	rulers	subjects	rulers
Two samples	Tasks	Task 1	¦ B.>B.F.	---	---	---
		Task 2	---	---	---	---
		Task 3	---	---	---	---
		Task 4	¦ B.>B.F.	---	---	---
	Stages	Adjusting	---	¦ CR1>CR2	¦ B.F.>B.	¦ CR2>CR1
		Positioning	---	---	---	---
		Plotting	¦ B.>B.F.	---	---	¦ CR2>CR1
paired	Blind	Adjusting	---	¦ CR1>CR2	---	---
		Positioning	---	---	---	---
		Plotting	---	---	---	¦ CR2>CR1
	Blindfolded	Adjusting	---	¦ CR1>CR2	---	¦ CR2>CR1
		Positioning	---	¦ CR1>CR2	---	---
		Plotting	---	¦ CR2>CR1	---	¦ CR2>CR1

Paired comparisons

The paired *t*-test was employed to see the performance of the two compasses by each subject group. As showed in the **Table 2**, for the blind group, the CR2 performed better at the **adjusting stage**, $t(11)=2.435$ $p=.033$, while the CR1 performed better at the plotting stage on the deviation of arc, $t(11)=-3.338$ $p=.007$, these same result also showed in the blindfolded group, $t(11)=5.462$ $p<.001$, $t(11)=-2.311$ $p=.041$, correspondingly. This implied that the CR2 had a better mechanism at the adjusting function than the CR1 which meant the design of the mover really affected the response time of the subjects. The disadvantage of the CR2 at the plotting stage on the deviation (incompletion of arc) was also significant at the two sample *t*-test; it was clear that the stability of the indicator should be held in the next design. For the blindfolded group, there was a significant difference at the **positioning stage** between the compasses, $t(11)=2.204$ $p=.005$, which indicated that the new way of positioning the center point, see **Fig. 2**, could be a good way.

4. CONCLUSIONS

To develop new and helpful tools for the visually impaired people is a long way for design teams to create possible solutions. The blind people can't tell you the story before you show them a temporal model with definitely physical shape for them to figure out the functions you offer for them. In this work, the new circle-drawing compasses seemed to reduce the response time of those tasks but loose some at the deviation. That would be notified at our next design in other propose for the original design goal. To discuss the disadvantages of the CR2 at the performance of deviation, as we reviewed the video, it seemed that the deviations of the radius and center point were occurred at two different parts: (1) static error: happened at the very beginning of their attempt to locate the position, and (2) dynamic error: happened at the plotting stage which the subject lost their control of the tool without his perception. The static errors can be measured from the result of the film the subject done, while the dynamic errors need the researcher to review the video to realize the reason for the vary kinds of mismatch.

It was observed by the design team while looking closely at the hollowly cover of the CR2 compasses that the shape of the touch hole, see Fig. 2, don't have to be a round shape, it should be more suitable to the fingertip, And the shape of the groove, for the index finger to sense the tactile lines under it, could be designed into other possible shapes to see the proper one. The future study will focused on those issues mentioned in order to make most use of the sensibility of human fingers.

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