A Study on the Straight-Line Drawing Tasks for the Non-sighted People

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Abstract. A new ruler employs the finger touch to be the main pointing sensor with two locators at the two ends, and a unique pen in a smooth track to draw a line. The tasks of making straight line with two difference rulers (Ruler S: ruler used at school; Ruler C: new touch ruler) between non-sighted people (blindfolds and blinds) were observed: (1) free-line; (2) constrained-line; (3) extension-line; (4) closing-line; and (5) conjoining-line. Stages of those tasks were measured: searching, positioning, plotting, and checking, with reacting time and the deviation. The Paired *t*-test shown Ruler S had a larger reacting time for blinds at task (4), (5). MANOVA shown the blinds had larger reacting time at task (3), while (5) on deviation; Ruler C had a larger error at start- point of task (3) and a larger length error of task (3); while Ruler S had a larger error at end-point of task (4). Conclude that some revised design of the ruler really affected the performance of the straight-line tasks, while some did not.

Keywords: Industrial design, Straight-line drawing, non-sighted people, ruler.

1 Introduction

The blinds have to spend more years of learning on the geometric drawing, owing to the lack of visual contacts on the pictures of the textbooks and on the teaching aids [6] [10] [13]. Researchers, [11] [14], had studied on the issues of learning the geometric drawings for blinds for few years. It showed that the blinds usually have to touch all of the pictures to understand the overall shape of pictures, then gathering the oral words to realize the knowledge behind the pictures. Many works, [5] [12], had contributed on the differences of perception of tactual pictures of 2D and 3D, and some others dedicated on the recognition of different views of pictures, such as side-view and perspective view, and some works approached the sizes, scales, and complexity of the drawings showed to the blinds [1] [3]. Those studies focused on the overall recognition ability of participants about the pictures they supported or the pictures the participants drew, in some way, their objectives were to find out the ability of picture discrimination between the subjects. The study here was focused on

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the precision issue to draw a picture at a right size, differed from works before, and proposed a method of comparison about the outcome of non-sighted participants.

Pictures drawn by the blinds usually mixed with some different parts of an object come up with their memory, sometimes with different views of the object they percept, so studies involved pictures drawn by blinds usually had to have the subject to explain about the picture they drawn, not to mention of gaining a exact size of picture the blinds attempt to draw. On the observations of making pictures by blinds, the line thrashed and the endpoints opened usually [7] [4]. It might be caused by lacking of good tools to aid them to predict the direction of their line, and this raised the idea of this work. The purpose of this article was to compare two straight line rulers, with different ways of approaching, on aiding the non-sighted to draw different types of lines, and reported the phenomena found the experiment.

Table 1. The types of straight line and the stages of making them were studied, and the reacting time, shown as solid circles, was recorded in this work

Task	Stage							
	searching		positioning		plotting		checking	
	Start	End	Start	End	Start	End	Start	End
Free-line	○	○	○	○	●	●	○	○
Constrained-line	○	○	●	●	●	●	●	●
Extension-line	●	○	●	●	●	●	●	●
Closing-line	○	●	●	●	●	●	●	●
Conjoining-line	●	●	●	●	●	●	●	●

2 Methods

It seemed to be a simple task to draw a straight line on the swell paper for a sighted people, but the similar task for a blind to draw a precise line will be a rather difficult job. A five-task of experiment was conducted, and each of the tasks was decomposed into four stages, Table 1. Considering the task to draw a line on a paper, there will be some possible types of doing this. Firstly, a *free-line* with no constrain will be the first place to do, which means no limits about its length and direction. Secondly, a *constrained-line* with a specific length is another type that usually happened for the sighted people, and which is still hard to the blind people for they have to search for the start position and aim the pen on the position to draw the line, and to stop at the exactly point of the end position, with no visual contact onto the start and end point. Thirdly, to draw an *extension-line* that is from a pointed start point to a free position. Fourthly, to draw a *closing-line* that is from a free start point to a specific end position. And finally, to draw a *con-joining line* that is to join two lines with a new line. Those 5 types of line were the major tasks of this experiment, and the participants had to draw all of the lines within this approach with random assigned order. Also when carefully analyzed the process of making a line on the paper, subjects usually doing it through four consecutive stages, *searching, positioning, plotting*, and *checking*. In this study, the time spent in the 4 stages was measured to see the differences between the participants and between the rulers.

Thus, all of the participants were to go through all of the 5 straight-line drawing tasks and to be measured their action time about the 4 possible stages happened in the tasks as the time variables. To know the precision of the lines drawn by the subjects, the result swell papers were to be measured the deviation as the accuracy variable.

2.1 Participants

Within the 24 participants, *Table 2*, in the experiment, 12 were blindfolded recruited from Tatung University, and 12 were blind. Seven of the 12 blinds were males volunteered from the Taipei Association of visual Impairment, whose age were 25 to 55 years old (mean is 37.2), and 5 females whose age were 30 to 42 years old (mean is 37.6). The blindfold group was half males, whose age were 21 to 26 years old (mean is 23.6), and half females, whose age were 20 to 23 years old (mean is 21.8).

Table 2. The 24 subjects recruited in this straight-line experiment

Description	Subject			
	Blinds		Blindfolds	
	female	male	female	male
Amount	5	7	6	6
Age (range)	30~42	25~55	20~23	21~26
Age (mean)	37.6	37.2	21.8	23.6
Blind since	CB 2 LB 3	CB 3 LB 4	(sighted)	(sighted)

2.2 Materials

The two rulers (Fig. 1), *Ruler S* and *Ruler C*, were totally different in shape and manipulation. Ruler S had been used at school for visual impairment now, which had the shape similar with the normal ruler for the sighted, only with Braille and dots unit (1 inch/unit) printed upon the surface and an undercut at each unit on the edge of the ruler for the feedback of plotting. Ruler C was a new design concept created by the authors, with the help of CAID Lab, Tatung University, that proposed a new way to draw a line with 2 locators, as point locators and interrupters of the pen (a unique pen placed between the locators), which were to be found at the two end of the ruler, and with thin tactual rod pointed the unit (1 inch/unit).

The key idea of this ruler C is, to draw a line, firstly to search and position the start point and end point by using the finger touch and move the locator to the proper point, then push the pen freely to plot the line. Hopefully in this manner of operation, the blinds could get an exact straight line they wish to draw.

The ruler was situated on a table (29cm x 29cm) covered with a rubber sheet; a swell paper was affixed upon the rubber cover and changed by the experimenter as those different tasks proceeded. The swell paper was suitable for the study for it allowed smooth lines to be produced with no dots and the lines produced could be percept well by hands [2] [8] [9]. In this study, swell paper prepared for those 5 straight-line tasks were: (1) free-line task: a blank paper, the subject was asked to

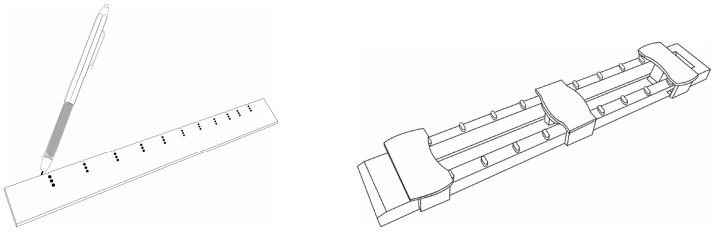

Fig. 1. The straight-line rulers studied in this article, Ruler S, the left one, used at the school of visual impairment, which was made of aluminum with undercuts on the unit position and Braille marks raised on the surface; Ruler C, the right one, a new concept created for the straight-line task, which had 2 indicators at the two ends and a special pen could smoothly move back and forth in between

Fig. 2. The experiment was conducted in the study room in CAID Lab., Tatung University with 2 video cameras and 3 experimenters. The right front camera focused on the movement of the major operating hand for the analyzer to determine the reacting time carefully later on.

draw a free length of straight line; (2) constrained-line: another blank paper, the subject was asked to draw a 3 units long of straight line; (3) extension-line: a paper with a dot in the left side, and the subject was about to draw a line from the dot (start-point) to a 3 units away to the right; (4) closing-line: a paper with a dot in the right side, subject was to draw a line from the left side 3 units away the dot to the specific dot (end-point); (5) conjoining-line: 2 dots at the opposite side of the paper with a 5 units distance, the subject was to link the 2 dots with a straight line.

Two video cameras were positioned in the study room (Fig. 2); one was located on the left front side to see the overall action of the participant; the other located on the front top of the subject to observe the hand moving. Three experimenters stood aside in the study room, the first one operated the facade camera to catch the hand movement of the subject in detail; the second one had to change the swell paper before each task proceeded; and the third one read the instruction to the subject and gave the help when subjects needed. The subjects could ask any question when they felt needed in any tasks and the third experimenter would not give any hints unless the subject asked.

2.3 Procedures

The free-line task was to verify whether the subject could actually understand the operations of the rulers, so the data excluded. The other four tasks were randomly assigned to the subjects in order to prevent the possible bias among tasks. The subject was blindfold first, and touched the ruler followed the introduction of its function and operation way by the experimenter. Then the researcher setup the training table for the subject to test the function, and this training phase ended when the subject responded well understood about this ruler.

From this on, the subject was to follow the instruction to use the 1st ruler to draw 5 types of line, and then use the 2nd ruler to draw other 5 types of line in a randomly assigned order. After all the 10 tasks being finished, an interview followed to gather her (his) opinions about the two rulers.

The reacting time of each stages (searching, positioning, plotting, checking) of those tasks (constrained-line, extension-line, closing-line, conjoining-line) were recorded by the video cameras. Because those stages were happened at different tasks, the incision method needed to be standardized, e.g. the time period from the command of beginning till the subject find out the point on the swell paper was recorded to be the searching stage, the time period from the subject moved the ruler to match the point found till the pen picked up was recorded to be the positioning stage, etc., and the questioning time or inessential action time were omitted. Also the deviations of the line drawn were measured included the position error at the start-point and the error at the end-point, also the length of the line drawn.

3 Results

The aims of this study were to evaluate the performance of the 2 straight-line rulers, this involved 2 subject groups, blinds and blindfolds, with 4 straight-line tasks.

The overall means and S.D. were shown in Table 3, and Table 4. The task (2), constrained-line task, had the lowest mean reacting time (38.1 sec.), while the task (5), conjoining-line, had the highest mean (53.8 sec.); the line drawn in the task (2) had the lowest deviation (but the S.D. was very high, 12.4 mm), the task (4) had the largest deviation (interestingly the value shown, -1.7 mm, shorter than it should be); and finally the deviation about the endpoints revealed task (3) and task (5) kept almost the same deviation, but at opposite direction, at the start-point, -0.88 mm and 0.83 mm, respectively, while the task (4) performed better than task (5) at the end-point of the line (1.2 mm compared with -0.6 mm).

Table 3. The overall means and S.D. of reacting time

	T2_ALL	T3_ALL	T4_ALL	T5_ALL
n (people)	48	48	48	48
Mean (sec.)	38.12	51.47	49.41	53.77
SD (sec.)	26.24	38.53	39.43	42.17

Table 4. The overall means and S.D. of deviation

	T2_ERR _L	T3_ERR _L	T4_ERR _L	T5_ERR _L	T3_ERR _S	T5_ERR _S	T4_ERR _E	T5_ERR _E
n (people)	48	48	48	48	48	48	48	48
Mean (mm)	0.00	1.09	-1.68	1.57	-088	0.83	-056	1.29
SD (mm)	12.36	12.29	10.82	7.73	1.77	5.14	8.00	6.12

The analysis was separated into two parts. Firstly, the paired *t*-test was to find out which ruler had better to the subject groups by looking at the reacting time. Secondly, between the tasks, the MANOVA was applied to compare the effect of subjects and rulers at the 4 tasks by looking at the total reacting time and deviation of each task.

3.1 Between Rulers

Of the Blind group, it showed that significant differences shown between the rulers at the task (4), t (11) = 2.30, p=.04, and task (5), t (11) = 2.24, p=.04. Which meant Ruler S > Ruler C at the reacting time of task (4), $M_{Ruler\ S} = 66.6$; $M_{Ruler\ C} = 45.9$; also task (5), $M_{Ruler\ S} = 71.4$; $M_{Ruler\ C} = 45.0$. Although other tasks, (2), (3), did not show clear evidence of improvement, the reacting time of the Ruler C were also shown lower than the Ruler S about 10 sec. at least. This gave a confidence to the design team members of the new ruler (Ruler C) that some part of the new design did improve the straight-line task.

Of the Blindfolds group, however, one part of the data in this group had some hint of defeat about the new design ruler, which was at the task (2) the Ruler C, 44.4 sec., had a larger reacting time than the Ruler S, 29.1 sec. The task (2) was to draw a 3 unit long of line, and the reacting time was optimistically at the blinds group, Ruler S > Ruler C, $M_{Ruler\ S}$ (45.5) > $M_{Ruler\ C}$ (33.5), this indicated that there were still some parts of the new design needed to be adjusted.

3.2 Between Tasks

The MANOVA was employed to analyze the multiple dependent variables measured in this work, included were reacting time of task (2), (3), (4), (5), and deviation of length of task (2), (3), (4), (5), and the deviation of point about start-point of task (3), (5), and about the end-point of task (4), (5), independently within the effects of 2 factors, Subject / Ruler, with 2 treatments in each of them.

The Wilks' Lambda was not significant at Subject, F (12, 33) = 1.07, p= .42, or Ruler, F (12, 33) = 1.70, p= .11, nor the (Subject x Ruler), F (12, 33) = 0.77, p= .67, indicated the interaction between the two factors was not strong enough. The Levene test shown significant differences only at the T3_ERR_L, p=.013, the deviation of length at task (3), and the T3_ERR_S, p=.008, the deviation of start-point at task (3).

At the paired-comparisons between subjects with all the rulers, the T3_ALL, reacting time of task (3), had significant effects of M_{blinds} (63.59) > $M_{blindfolds}$ (39.35), at F (1, 44) = 5.03, p=.03, and also the T5_ERR_E, the deviation of end-point at task (5), had significant effects of M_{blinds} (3.25) > $M_{blindfolds}$ (-0.68), F (1, 44) = 5.27, p=.03. This suggested that the job of task (3) was harder for blinds or somehow there

were some difficulties for them to do it. And the T5_ERR_E measured the deviation of the end-point of the conjoining-line task it seemed that the blindfolds were much more cautious when the pen near to the end-point, so the deviation was less than the blinds.

With all of the subjects to see the effects of the two rulers on those tasks, it was found that Ruler S performed well than Ruler C at T3_ERR_L of $M_{Ruler\ C}$ (4.83) > $M_{Ruler\ S}$ (-2.64), $F(1, 44) = 4.75$, p=.04, also at the T3_ERR_S of $M_{Ruler\ C}$ (-1.69) > $M_{Ruler\ S}$ (-0.07), $F(1, 44) = 11.88$, p=.00, this indicated that Ruler C was not at a good position to help the blinds at the task (3), which was to draw a line from a specific start-point. The other significant differences at this part was the T4_ERR_E of $M_{Ruler\ S}$ (-2.89) > $M_{Ruler\ C}$ (1.77), $F(1, 44) = 4.25$, p=.05, this seemed to be a phenomena that the subjects were afraid to over draw the line asked in length, so at Ruler S, they lifted the pen much earlier than it should be and caused the short in length of this line, and much more to say was the indicator of Ruler C seemed to be a little too loose in holding up the pen that led the pen over drew a little on the swell paper.

4 Conclusions

The 2 rulers were all designed for the tasks of straight-line, especially for visually impaired people, but in different ways. Ruler S showed excellent, simple, of characteristics at plotting, changing the position, and response of units (with the undercuts). While the Ruler C focused on the precision of line and exact endpoints at its original idea. This article was an attempt of reasoning the advantages and defeats of the new concept, Rule C, and by this study this design was encouraged and looking forwards for the next more detailed and useful one yet to come.

4.1 To Draw a Line in a New Way

In general, the new tool opened a different idea to draw a line, i.e. to decide the two end-points first, then bringing two indicators over there to stop the pen, and finally moved the pen freely back and forth and done. The experiment verified the part mentioned that the lines drawn could be straight for the blinds, and with the help of the two indicators the precision should be good enough than the other one.

To draw a line in this case, the 5 tasks were to test overall performance of those rulers, and to find out the directions for the design to be revised. To summarize this work, the next few points have to point out:

(1) As the means shown, the reacting time were Ruler S > Ruler C, in all of the tasks and in all of the subjects, except for the task (2) of blindfolds group, this was a message for our team to follow up with this development for better results.

(2) As the detailed data revealed, at the task (3), to draw a line from the point asked, the new ruler C achieved the lower reacting time but raised at the length error, also the start-point error, whether this was caused by the actions differences or other reasons should be further observed.

(3) As those deviation variables hit, it could not be told between the subjects about the deviation, length drawn and positions, happened at different tasks, except the end-point of task (5) for blindfolds performed well better.

4.2 Implication for Future Work

Following the experiment a face to face interview was performed with the participant, in general, they were interested in the study with the new ruler. But, still they gave the design team many opinions could be launched into the next design, e. g., the indicators were a little bit larger than needed; the groove for the index finger to touch should be wider in case of different tactual surfaces and situations.

More subjects to test the new design will be necessary for gathering more detailed information. It will be a consideration of taking more factors into the study in the future, include wide range of age, profession, and educational level, especially bringing the new ruler to the school of visual impairment for practical evaluation.

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References

1. Dulin, D., Hatwell, Y.: The Effects of Visual Experience and Training in Raised-Line Materials on the Mental Spatial Imagery of Blind Persons. Journal of Visual Impairment & Blindness, pp. 414–424 (2006)
2. Heller, M.A., Brackett, D.D., Scroggs, E.: Tangible picture matching by people who are visually impaired. Journal of Visual Impairment & Blindness, pp. 349–353 (2002)
3. Heller, M.A.: Picture and pattern perception in the sighted and the blind. The advantage of the late blind. Perception 18, 379–389 (1989)
4. Kamel, H.M., Landay, J.A.: The use of labeling to communicate detailed graphics in a non-visual environment. In: Extended Abstracts of the ACM Conference on Human Factors in Computing, pp. 243–244 (2001)
5. Kawai, Y., Tomit, F.: A support system for the visually disabled to recognize 3D objects. In: Proceedings of Second International ACM Conference on Assistive Technologies, pp. 45–50 (1996)
6. Kennedy, J.M.: Drawing and the blind. Yale University Press, New Havent, C. T (1993)
7. Kurze, M.T.: A computer-based tactile drawing tool for blind people. In: Proceedings of Second International ACM Conference on Assistive Technologies, pp. 261–266 (1996)
8. Lotzsch, J.: Computer-Aided access to tactile graphics for the blind. In: Zagler, W., Busby, G., Wagner, R.R. (eds.) ICCHP 1994. LNCS, vol. 860, pp. 575–581. Springer, Heidelberg (1994)
9. Nomad, P. D.: In audio-tactile tool for the acquisition, use and management of spatially distributed information by visually impaired people. In: Second International Symposium on Maps and Graphics for visually Handicapped People (1988)

10. Schiff, W., Foulke, E.: Tactual perception: a sourcebook. Cambridge University Press, Cambridge (1982)
11. Tu, Y.H., Wu, C.F., Yeh, I.T.: The effects of object name perception and object represented drawing on the recognition of tactile pictures. In: 2005 International Design Conference. p. 37 (2005)
12. Tu, Y.H., Wu, C.F., Yeh, I.T.: Evaluation of Recognizing Tactile Pictures in Different Size Display in Sighted and Blind People. In: The 6th Asian Design International Conference (2002)
13. Warren, D.H.: An individual differences approach. Blindness and children (1994)
14. Wu, C.F., Tu, Y.H., Yeh, I.T.: A Study of Elements Influencing the Visually Impaired on Recognition of Haptic Pictures. In: The 11th International Conference Human-Computer Interaction p. 1273 (2005)