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The Effect of Tactile-Based Signage Design Intervention on the Wayfinding Permormance of Visually Impaired Students Through Navigation Task

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ABSTRACT

Loss of visual function reduces the accessibility of the environment. A person's ability to move around is closely related to their skills in wayfinding, i.e. finding clues and mental mapping. Individuals with visual impairment use non-visual sensory aspects, such as tactile clues, to form a cognitive map of the structure of the environment. Navigating new and complex environments can cause confusion, anxiety and take longer. Environmental interventions through tactile-based media conditioned into signage design are still scarce, therefore this study aims to try to identify the different roles of three design conditions namely; Rised lines (RL), Texture (TX) and Elevated Graphics (EG) on the wayfinding performance of blind individuals through a navigation task. Data collection involved an experiment with the participation of totally blind and low vision individuals in a simulated environment with three design conditions: raised lines, textures and raised graphics. The experimental process used spatial tasks including; navigation tasks. Measurements on the navigation task used questionnaires and duration scores. This experiment used repeated measure procedures on the three tactile design conditions, as well as a randomized sequence of conditions. The data obtained was analyzed through statistics using repeated measure ANOVA test to test the effect and difference of intervention of three tactile sensor-based signage designs. The findings showed that there was no significant difference in the navigation experience, but there was a significant difference in the navigation task duration score. The Rised Lines (RL) condition showed good performance especially in the aspect of duration score. This research has concluded that, tactile-based signage design has a significant role to help blind individuals understand the environment. This signage design is expected to be a medium for blind individuals, especially special education students in practicing Orientation & Mobility skills properly.

KEYWORDS

Signage Design
Wayfinding
Visually Impaired
Tactile Sensory

INTRODUCTION

Independent travel is both an essential and challenging aspect for visually impaired individuals (Goldschmidt, 2018). Independent travel is an important part of daily life for all individuals. (Vilar et al., 2012) Difficulties in independent travel can affect work, learning and fulfillment. For visually impaired individuals adapting and moving freely in new environments is problematic (Espinosa et al., 1998; Goldschmidt, 2018). The process of independent travel for blind individuals is dangerous, requires extra focus, and can cause confusion and anxiety (Gaunet & Briffault, 2005; Lawton, 1994), resulting in decreased motivation for blind individuals to travel independently (Ottink et al., 2022). Therefore, orientation and mobility skills need to be improved through time, intensive practice, and a deep understanding of the environment (Gaunet & Briffault, 2005; Ishikawa & Zhou, 2020).

One important aspect of independent travel is wayfinding, which is the ability to determine and follow a route between a starting point and a destination (Golledge, 1999). Wayfinding involves cognitive processes such as encoding, processing, and retrieving information from the environment (Downs & Stea, 1973; Griffin et al., 2020; Kitchin & Blades, 2002). (Allen, 1999) explains the theory of wayfinding means which includes oriented search, following continuous marked trails, piloting between landmarks, and referring to cognitive maps (Vilar et al., 2012). Referring to the theory and understanding of wayfinding provides an understanding that, the ability to travel independently for individuals is inseparable from the cognitive process and integration of users with the environment. Interrelated objects and environmental features have an important role to play in a person's wayfinding process. The visual limitations of visually impaired individuals make them highly dependent on non-visual information such as tactile, sound, and smell (Gori et al., 2017; Israr et al., 2012).

The focus of this research is to identify tactile sensors as stimuli to assist the navigation process of visually impaired individuals in new environments. The sense of touch is the ability to respond and capture non-visual information such as; shape, size, texture on objects and environmental features used in daily activities (Fielder & Proulx, 2019). This touch-based information has a role as a point of reference to determine position, map information about the relationship between objects and environmental features and markers to avoid danger when traveling independently (Fielder & Proulx, 2019; Koutsoklenis & Papadopoulos, 2014; Millar, 1997). The sense of touch can identify environmental features and objects accurately and quickly (Heller & Ballesteros, 2006).

Tactile-based information has the potential to characterize an environment that can be utilized by blind individuals in accessing the environment. Therefore, the utilization of tactile information needs to be developed to improve environmental accessibility for visually impaired individuals. Several studies have shown the effect of tactile-based media on the wayfinding performance of visually impaired individuals. Caddeo et al. (2006) found that embossed maps are more effective than verbal instructions in assisting the wayfinding of visually impaired individuals. Ottink et al. (2022) showed that both blind and sighted individuals performed well in spatial tasks and cognitive mapping using embossed maps. This research suggests that tactile-based media has the potential to be developed as a navigation aid in new environments for visually impaired individuals.

Based on a review of previous research, tactile-based media show potential to be developed as navigation aids in new environments for visually impaired individuals. This research explores the development of tactile-based media into signage with a conventional, low-tech approach (Fadhlillah, 2022; Hersh & Johnson, 2008). The signage approach is a novelty that can enhance learning and make the experience interesting (Farosa & Irfansyah, 2023). The use of sign system format as a tactile-based media aims to improve access between users and the environment (Sari & Purnomo, 2021). Tactile-based signage design consists of Rised Lines, Texture and Elevated Graphics (Edman, 1992; Mukhiddinov & Kim, 2021), which are applied to vertical media such as walls to assist trailing, basic orientation and mobility techniques for visually impaired individuals. The utilization of symbols (Rised Lines, Texture, and Elevated Graphics) on this signage media functions as information (Saputra et al., 2022), namely directional information and location identity.

This study aims to explore the effect of three tactile-based signage design conditions on the wayfinding performance of visually impaired individuals in a new environment. The main research questions are how significant is the difference in wayfinding performance between design conditions, and which design condition is most effective for a given navigation task?

METHOD

1. Subject

The selection of test subjects included in this study was purposive sampling, which is an approach in selecting research subjects determined based on the criteria of the POMSK program. The

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subjects were junior & senior high school students (SMP & SMA) of SLB Negeri A Pajajaran Kota Bandung, with an age range of 14 - 21 years. There were 11 participants who became experimental test subjects, with criteria aligned with the POMSK (Pengembangan Orientasi, Mobilitas, Sosial & Komunikasi) special program curriculum, namely having completed basic orientation and independent mobility training, experienced in traveling independently, able to read braille and have familiarity with tactile-based media.

2. Instrument

a. Navigation Experience Questionnaire

The first measurement tool is to use a questionnaire to measure how far the participants experience when navigating in an environment that has been intervened by design conditions. This questionnaire is a self-report of each participant after the navigation process. The questions on this questionnaire were made based on the results of preliminary research, namely the interview stage with visually impaired individuals and have gone through an O&M instructor feasibility assessment. This questionnaire consists of 8 questions with Likert scale measurement: with a range of 1 (Strongly Disagree) and 5 (Strongly Agree). This questionnaire has gone through the Pearson's Product Moment validity test and reliability test (Cronbach's Alpha $r = 0.854 > 0.602$; $n=11$) when used with test participants during the experimentation process.

b. Duration

Each participant who performs the navigation process in each design condition is measured using a time counting system in seconds format in each session. This duration measurement aims to see the effectiveness and navigation ability of each participant when facing environments with different interventions.

c. Environment Simulation

The environment simulation designed is a track or path formed with panels. This condition will resemble a maze with one path. Semi-constructed is a configuration that has several combinations of straight paths and paths to the left and right, this aims to provide challenges to participants, because the participants already have basic Orientation & Mobility training. In addition to the navigation path, this simulation will have several points that are conditioned as space markers. This simulation design is made in the library room of SLB Negeri A Bandung City which is 3.5 meters wide and 9 meters long. Environmental simulation uses a panel 2 meters long and 1 meter wide. The placement of signage adapts the height of the handrail that is applied to the wall around 80 cm.

Figure 1. The Environment Simulation Track

d. Signage Design

1) Rised Lines (RL)

The first tactile-based signage design is Rised Lines. It has basic dimensions of 1 meter long, 18.5 cm wide, for the design part it has a height of 5 cm, a length of 50 cm on the straight part and for the fractured lines each fracture has a length of 5 cm totaling 10 fractures. The material used is sterofoam, white and yellow in color. The design of the straight section has a directional function and for the fault section has an identification function.

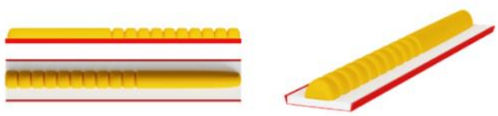

Figure 2. Rised Lines (RL) Design Condition

2) Texture (TX)

The second design condition is texture. It has two different materials, in the first part is white with foam material with embossed texture, in the second form has polyurethane foam material with embossed circles and hollows with a thickness of 2.5 cm in yellow. Each part has dimensions of 18.5 cm wide and 50 cm long. The smooth texture part functions as directional and the foam texture as an identification function.

Figure 3. Texture (EG) Design Condition

3) Elevated Graphics (EG)

The last condition is elevated graphics, consisting of two different shapes, namely pyramid and box shapes. The signage design has a material made from polyurethane foam with a height dimension of 5 cm. The first part, the pyramid shape, has 24 pieces, with a total length of 50 cm, for the box shape there are 10 pieces with a total length of 50 cm. Both shapes are black in color.

Figure 4. Elevated Graphics (EG) Design Condition

4) Experiment Procedure

The main experiment was conducted based on the results of the predecessor experiment as a testing stage for each instrument and procedure carried out in the main experiment. The subjects who became participants amounted to 11 blind students of SLB Negeri A Bandung City. The stages of navigation experiments in the three design conditions, wayfinding strategies use verbal descriptions to provide overall clues and briefs.

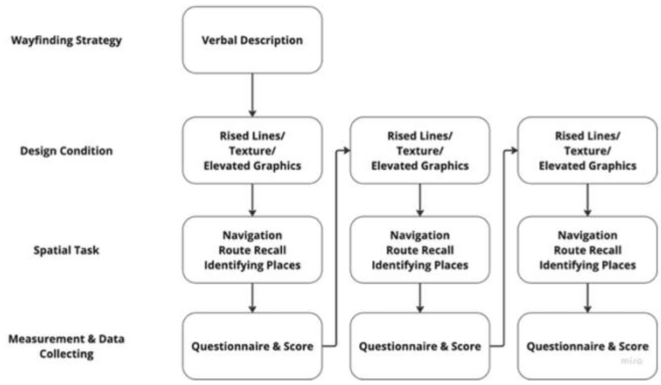

Figure 5. Experiment Process

The verbal description was adapted from the O&M instructor's method of performing the exercise. Furthermore, each participant went through the three design conditions of Rised Lines (RL), Texture (TX) and Elevated Graphics (EG). The spatial task was used to measure the wayfinding performance indicators of visually impaired individuals. The navigation task was measured using a navigation experience questionnaire and duration calculations. The navigation process in the three design conditions applied a randomized ordering system to each participant to reduce the learning effect bias in the repeated measure condition used.

5) Data Analysis Process

In the analysis process there are several results that are tested, namely the results of the navigation experience questionnaire and the duration score. First, on the navigation task using the navigation experience questionnaire instrument and time calculation, for the navigation experience questionnaire, the validity test and reliability test were carried out because this questionnaire was made by the researcher based on the results of interviews and specifications assessed in a navigation process. For the duration score, through descriptive analysis to see the tendency of the average value of each condition.

The next process for each measuring instrument result data must meet the requirements of parametric statistical tests by conducting the Shapiro-Wilk normality test. The test hypothesis applied to the Shapiro-Wilk normality test is if p-v> 0.05 indicates that the data is normally distributed. The navigation experience and duration questionnaire data have been tested for normality against the three design conditions. For the navigation experience questionnaire, the p-v of condition 1 RL = 0.300; p-v of condition 2 TX = 0.661; p-v of condition 3 EG = 0.819). Duration data shows normal distribution in all three conditions with a significance value of (p-v condition 1 RL = 0.126; p-v condition 2 TX = 0.779; p-v condition 3 EG = 0.472). From the normality test process, it can be seen that the requirements for parametric tests have been met. The next process in data analysis is a difference test through repeated measure ANOVA on navigation experience questionnaire data and duration data.

RESULT AND DISCUSSION

The results of the analysis of the ANOVA repeated measure test difference of three design conditions (RL, TX and EG) in the navigation experience and duration score are shown through three tables, including the following. The first is Table 1. *The test of within subject* presents the results of the comparison between the three design conditions as a whole, Table 2. *Estimates Marginal Means* presents the results of the average value, the last is Table 3. *Pairwise Comparison* or can be called *a post hoc test*, describes the cross-comparison between conditions and the resulting average difference.

1. *ANOVA Repeated Measure Difference Test Results of Navigation Experience Questionnaire*

The results of the repeated measure ANOVA difference test on the participants' navigation experience questionnaire with the three design conditions of RL, TX, and EG can be seen from the three tables generated from the statistical test. To determine the basis for decision making, the difference test hypotheses set include:

H_0 = There is no difference in the results of the navigation experience test between the three variable conditions (RL, TX and EG).

H_a = There is a difference in the results of the navigation experience test between the three variable conditions (RL, TX and EG).

Table 1. Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Conditions	Greenhouse-Geisser	11,455	1,554	7,371	0,597	0,522

Table 2. Estimates Marginal Means

Conditions	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
RL	33,091	1,140	30.551	30.551
TX	32,000	1,198	29.330	29.330
EG	33,364	0,664	31.883	31.883

From the hypothesis that has been determined, the basis for making hypothesis decisions is; If the p-v value <0.05 alpha value, it rejects H0 and Ha is accepted, otherwise if p-v> alpha value 0.05, H_0 is accepted. As presented through the data Table 1 Test of Within-Subjects Effects, Table 2 Estimates Marginal Means, and Table 3 Pairwise Comparison shows the results of comparing the navigation experience questionnaire in the navigation task process with three tactile-based signage design conditions (RL, TX, and EG). Overall, the level of difference between conditions shown in Table 1 through the Greenhouse-Geisser data source illustrates that between the three conditions there is no significant difference (F (1,554) = 0.597; p-v > 0.522). This is presented in more detail through the test results in Table 2 and Table 3 the averages between variables are shown, and compared with each other. From the values obtained in the table, it can be concluded that the variables have a very slight difference between the averages, but if the small difference is still considered, the highest average result is the EG condition followed by the RL condition and the TX condition. However, this small difference is still indicated through the alpha value of the cross comparison, each of which shows a p-v> 0.05. In accordance with the established test hypothesis, it is concluded that H_0 is accepted, i.e., the results of the navigation experience questionnaire on the navigation task have no difference.

Table 3. Pairwise Comparisons

(I) Conditions	(J) Conditions	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
RL	TX	1,091	1,626	1,000	-3,576	5,758
	EG	-0,273	1,229	1,000	-3,800	3,255
TX	RL	-1,091	1,626	1,000	-5,758	3,576
	EG	-1,364	1,038	0,655	-4,343	1,616
EG	RL	0,273	1,229	1,000	-3,255	3,800
	TX	1,364	1,038	0,655	-1,616	4,343

In the research that has been conducted, the results show the navigation task that has been measured through two instruments, namely the navigation experience questionnaire, and duration indicates several conclusions from each instrument. In the navigation experience, referring to the results of the ANOVA difference test analysis, there is no significant difference in the experience of each participant when navigating in an environment that has been intervened by three different design conditions. This shows that each participant showed a good ability to navigate the environment. Because this questionnaire has several aspects that are measured including aspects of ease of route, comfort of travel, ability to determine directions and turns, ability to remember objects and environmental features and confidence when carrying out the navigation process.

This answers the problems associated with visually impaired individuals when faced with a new environment, which will feel anxious, confused and require a lot of time and attention. (Lawton, 1994; Thinus-Blanc & Gaunet, 1997). The results of the navigation experience proved that the three design conditions served as non-visual information that assisted participants in the navigation process. Espinosa et al., (1998) suggest that when individuals can safely perform independent orientation and mobility, it indicates that the individual has a sense of security and independence.

The absence of differences in navigation experience can be influenced by several factors, first is the condition of the simulated environment that has been designed by creating interrelationships of objects and features that integrate the environment, such as signage design, obstacles and route configuration. Allen (1999) suggests that individuals who follow consistent signs or instructions will reduce the cognitive performance required. Ultimately, this will improve the quality of one's

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navigation of the environment (Vilar et al., 2012). From some of these indicators, it can indicate that there is a relationship between the differences in signage design conditions that are not significant with the participants' abilities and environmental conditions.

2. *ANOVA Repeated Measure Difference Test Results Navigation Duration Score*

The results of the repeated measure ANOVA difference test on the processed navigation task duration data are shown in Table 4, Table 5, and Table 6 including the Test of Within-Subjects Effects, Estimate Marginal Means, and Pairwise Comparison tables. Table 4 presents the results of the overall difference of the three conditions, Table 5 displays the average data between the three conditions, and Table 6 shows the cross comparison between variables, along with the average difference of these variables. The basis for the decision in the difference test results is determined through the difference test hypothesis including:
H0 = There is no significant difference between the duration of the navigation task of the three conditions (RL, TX and EG)
Ha = There is a significant difference between the duration of the navigation task of the three conditions (RL, TX and EG)

Table 4. Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Conditions	Greenhouse-Geisser	4388,424	1,974	2223,422	6,106	0,009

Once the test hypothesis has been established, the basis for the decision to reject or accept H0 is shown in the alpha value. If the p-value < alpha = 0.05 then H0 is indicated. Based on the results of the analysis that has been carried out through the Repeated Measure ANOVA Difference Test, it shows that the navigation process duration data has a significant difference ($F(1,974) = 6.106$; $p\text{-v} = 0.009 < 0.05$), with the highest mean value obtained in the EG condition ($M_{EG} = 104.9$) and the average value of the RL and TX conditions has a fairly similar achievement ($M_{RL} = 80.09$ & $MTX = 80.82$). The high mean value in the duration aspect concluded that the navigation duration in the EG condition was slower than the RL and TX conditions.

Table 5. Estimates Marginal Means

Conditions	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
RL	80,091	5,554	67,716	92,466
TX	80,818	8,990	60,788	100,849
EG	104,909	9,889	82,875	126,943

Table 6. Pairwise Comparison

(I) Conditions	(J) Conditions	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
RL	TX	-0,727	7,700	1,000	-22,827	21,373
	EG	-24,818*	8,029	0,034	-47,863	-1,774

TX	RL	0,727	7,700	1,000	-21,373	22,827
	EG	-24,091	8,501	0,053	-48,489	0,307
EG	RL	24,818*	8,029	0,034	1,774	47,863
	TX	24,091	8,501	0,053	-0,307	48,489

The second parameter in the navigation task is duration. Referring to the results of the repeated measure ANOVA difference test conducted on the calculation of time based on the three design conditions has a significant difference (See Table 4, Table 5, and Table 6). The large average value obtained by the Elevated Graphics condition in the duration calculation indicates that participants spent a long time in the navigation process. The difference in results on navigation duration is related to the design aspect, because during the navigation process, participants do most of the activities on the hand area that performs the trailing process of the tactile design, by looking at the difference in navigation time that is quite different, it indicates the distraction or obstacles of participants during the orientation process in the Elevated Graphics condition. When looking at the other two conditions, the Rised Lines and Texture conditions have a tendency for simple shapes and minimalist shape details. In contrast to the design in the Elevated Graphics condition which has a variety of complex shape features, where this prominent relief graphic has a depth aspect in each gap.

In line with what is described by Schiff & Foulke (1982), the use of excessive detail inhibits the effectiveness of the performance of the sense of touch in visually impaired individuals. In addition, the shape with the addition of details becomes a complexity factor accepted by visually impaired individuals (Theurel et al., 2013). Therefore, the aspect of simplicity in a tactile object is important (Gual et al., 2015). Responding to the function of symbols that are widely applied in embossed map techniques, linear symbols have a tendency to identify connectivity, and areal symbols identify area differences (Lee, 2019) This is related to the Rised Lines condition which has two main forms, namely smooth raised lines and broken raised lines. For Texture conditions that have textural properties with two clear differences in texture types, where texture form 1 tends to be smoother, and texture form 2 has a surface that contrasts with the previous form, which is bumpy but has a fairly low height.

CONCLUSIONS

The results of the ANOVA analysis showed that there was no significant difference in navigation experience among the three different tactile design conditions. All participants demonstrated good navigation skills, with measured aspects including ease of routing, comfort of travel, ability to determine directions and turns, ability to remember objects and environmental features, and confidence during navigation. This suggests that the three tactile design conditions functioned effectively as non- visual information that assisted participants in the navigation process. The well-designed simulation environment, including the relatedness of objects and features and consistency of markings, contributed to these results.

A repeated measure ANOVA analysis showed significant differences in navigation duration among the three tactile design conditions. The Elevated Graphics condition had the highest mean navigation duration, indicating that participants spent more time navigating this environment. Obstacles and distractions in the trailing process to the more complex tactile design of Elevated Graphics affected the navigation duration. The Rised Lines and Texture conditions, which had simpler shapes and minimalistic details, showed shorter navigation durations. This suggests that simpler and minimalist tactile designs are more effective in supporting the navigation of visually impaired individuals.

Tactile design plays an important role in aiding the navigation of visually impaired individuals in new environments. Simpler and more minimalistic designs, such as in the Rised Lines and Texture conditions, are more effective in reducing obstacles and improving navigation efficiency. Excessive complexity in design, such as in Elevated Graphics, can hinder the performance of the tactile sensors and prolong the duration of navigation. Therefore, simple and clear tactile designs are preferred to support effective navigation for visually impaired individuals.

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