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Research on continuity among assistive devices for personal mobility of visually impaired persons around crossings*

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***Abstract*— There are several assistive devices for personal mobility of visually impaired person around crossings. To safely access the crossing, it is very important to maintain continuity between Tactile Walking Surface Indicators and audible traffic signals. This study evaluates the continuity among devices around crossings.**

I. INTRODUCTION

There are about 31,000 visually impaired persons in Japan, and this number increases year-by-year. Implementing a barrier-free environment is motivated by the "Barrier-Free Transportation law." However, crossings are place where visually impaired persons are aware of the danger. Traffic density and inconvenience are a couple of the causes. An independent experiment has already been conducted to evaluate the walking characteristics of the crosswalk. Experiments have also been conducted on many electronic travel aids such as Talking Signs[1]-[7]. Assistive devices for visually impaired person are installed at crossings. Specifically, there are audible traffic signals, pushbuttons for signals, and Tactile Walking Surface Indicators (TWSIs). Securing continuity among assistive devices for personal mobility is essential for visually impaired persons to access the crossing. Securing continuity among assistive devices for personal mobility means supporting visually impaired persons transiting such devices after mobility is interrupted. TWSIs and audible traffic signals are installed on both sides of a pedestrian crossing for guiding visually impaired persons. In this case, an audible traffic signal mediating walks between TWSI on both sides of pedestrian crossings helps ensure continuity. If continuity is not ensured between TWSIs and audible traffic signals, visually impaired persons may veer onto the wrong side of pedestrian crossings. Therefore, audible traffic signals play an important role as assistive devices for mobility at crossings. However, the lack of a uniform speaker location is a problem.2 Furthermore, the National Police Agency has jurisdiction over audible traffic signals and crossing pushbuttons, and the Ministry of Land has jurisdiction over TWSIs; this may be one of the problems.

This paper seeks to evaluate the change of the continuity between Tactile walking surface indicators and audible traffic signals by changing the position of installed audible traffic signals and to determine the most suitable speaker location.

II. EXPERIMENT

In this experiment, we studied the optimum assistive device arrangement for visually impaired persons. In an area simulating a crossing, we examined how different locations of audible traffic signals at pedestrian crosswalks influenced visually impaired persons.

This experiment added setting patterns used in the preceding study ([center(C)-center(C')], [right(R)-right(R')], and [center(C)-right(R')] to the setting pattern [left(L)-left(L')]. Table 1 lists the setting patterns for the audible traffic signal experiment. Figure 1 depicts the setting position of corresponding to it.

Table 1 Speaker location patterns.

	Near side	Far side	Location in Fig. 1
Speaker setting position	Center	Right	A
		Center	B
		Left	C
	Right	Right	D
	Left	Left	E

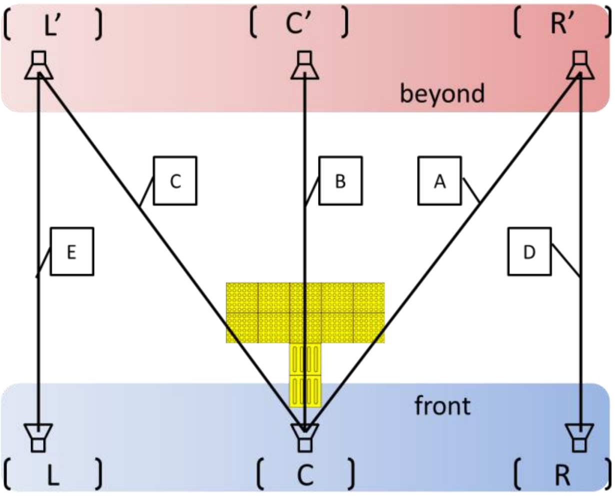

Fig. 1 Speaker position patterns.

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III. EXPERIMENT CONDITIONS

Our laboratory can reproduce a crosswalk and an intersection (Figure 2). These speakers in Figure 2 reproduce the noise in an actual intersection. This laboratory facilitates safe and reproducible experiments. We installed audible traffic signal speakers, TWSIs, and noise speakers as illustrated in Fig. 3 in order to reproduce a space simulating a real crossing in an indoor laboratory. The sound field of the crossing of one side traffic lane was reproduced by a speaker playing traffic noise at a volume of 59 to 79dB. Audible traffic signal speakers were installed in two patterns, [left(L)-left(L')] and [center(C)-left(L)]. In addition, the setting height was 3m, and the audible traffic signal speakers were set to warble to each other.

Fig. 2 Indoor laboratory

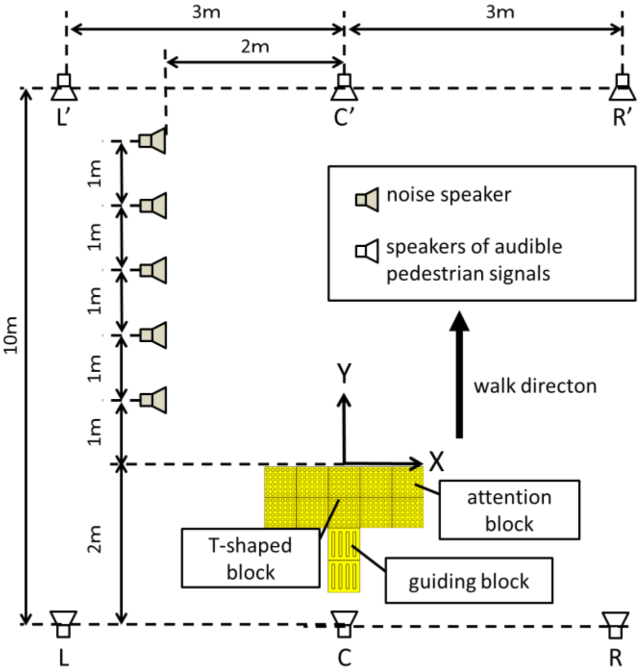

Fig. 3 Experiment setup.

IV. EXPERIMENTAL PROCEDURE

The experiment procedure is as follows.

1. Place a subject in front of a T block.
2. Let the subject determine the crossing direction from the indication block.
3. Stop the subject on the attention block.
4. Let the subject cross as soon as the subject confirms the tone of audible traffic signal.
5. Tell the subject to stop after walking 6m.

Have the subject repeat the above procedure 20 or 30 times per pattern.

At this time, we informed the subjects that conscious the direction that confirming indication block and walk and explained that the audible traffic signal ??is assistance to the last should be used last. Therefore, we made the following experiment rules.

- Admission to the laboratory

We had subjects enter the laboratory one at a time while other subjects waited outside, thus preventing subjects from exchanging information.

- Use of white canes

In this experiment, we had subjects walk without white canes to eliminate influence of positional information obtained through the cane.

V. SUBJECTS

We selected ten visually impaired subjects and had them repeat two setting patterns ([left(L)-left(L')] and [center(C)-left(L')]), performing one experiment 40 times. We asked 10 subjects to repeat the pattern with no signal sound (only noise) 20 times.

The number of data samples for each setting pattern is listed in Table 2.

Table 2 Number of subjects for each setting pattern.

Speaker position	Near	Far	Subjects	Samples
	Center	Left	20	400
	Left	Left	20	400
	None	None	10	200

VI. EVALUATION METHOD

In this experiment, we measured the distance from the central axis to the position where the subject stopped. We assumed a subject's starting position was $(x_0,\ \ 0)$ and the stopping position was $(x,\ \ y)$. The starting position doesn't correspond to the origin $(0,\ \ 0)$, and the stopping position is not 6m to the distance walked. In addition, we shifted the starting position to the origin as depicted in Fig. 4. Therefore, the vertical distance from the central axis in pedestrian crossing to the 6m stopping position that I estimated linearly from the starting position and stopping position is the distance the subject veered from the crosswalk. Equation (1) calculates veering distance L(cm).

$$\mathrm{L} = 600 \times (x - x_0/y) \cdot \cdot \cdot \cdot \cdot \cdot \cdot \quad (1)$$

VII. EXPERIMENTAL RESULTS

In setting pattern of audible traffic speaker, Fig.5 shows boxplot of [center(C)-left(L')], [left(L)-left(L')] and [no sound signal (only noise)][8]. The horizontal axis indicates the setting pattern, and the vertical axis indicates the veering distance. Therefore, median line of the boxplot corresponds to the median value. In addition, the upper side of the box represents the third quartile, and the lower side represents the first quartile. The top and bottom of the error bar are defined by equations (1) and (2). The points outside of the error bar outliers. Boxplots of [center(C)-left(L')], [left(L)-left(L')], and [no signal sound (only noise)] setting patterns are each medians exit around 0cm. In contrast, the distribution tendency reveals that setting pattern [center(C)-left(L')] and [left(L)-left(L')] is distributed significantly more to the more negative side than no signal sound (only noise). Therefore, the probability of missing the pedestrian crossing was 8% for center(C)-left(L'), 7% for left(L)-left(L'), and 13% for no signal sound (only noise).

$$(\text{ Top end of error bar }) = Q_3 + 1.5 \times (Q_3 - Q_1) \cdot \cdot \cdot (2)$$

$$(\text{ Bottom end of error bar }) = Q_1 - 1.5 \times (Q_3 - Q_1) \cdot \cdot (3)$$

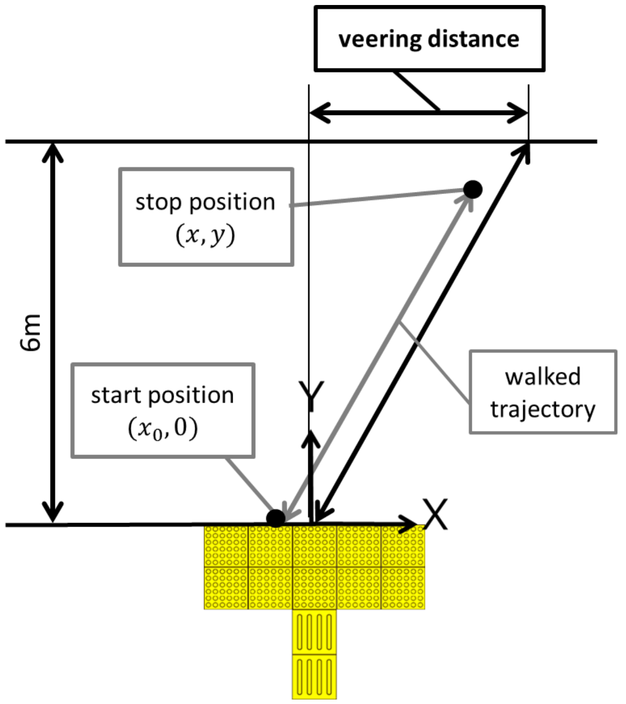

Fig. 4 Veering distance and walking trajectory

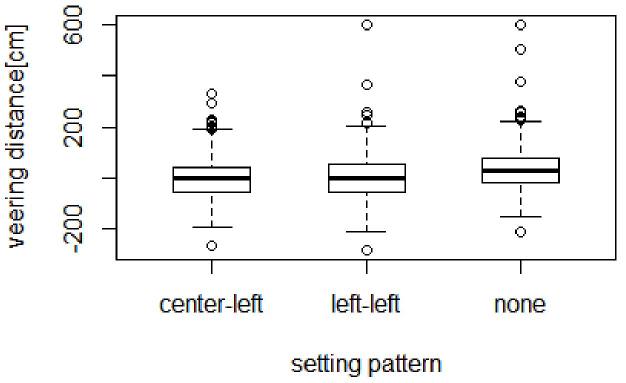

Fig.5 Relation between boxplots of veering distance and signal speakers position.

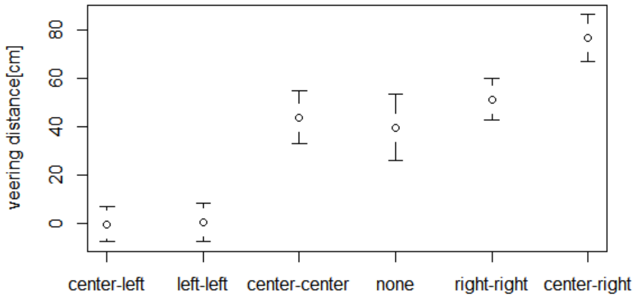

Fig. 6 Relation between veering distance and (Mean S.D.) and signal speaker position.

VIII. DISCUSSION

We now consider the data obtained in the preceding study and the data obtained in this experiment.

Figure 5 presents the mean and standard deviation of veering distance in each pattern acquired by the preceding study and by this one. Figure 1 indicates that the inductivity of the setting pattern of [center(C)-left(L')] and [left(L)-left(L')] is relatively high in all setting patterns. In particular, [left(L)-left(L')] has highest inductivity because its mean value is the closest to 0.

The probability of missing the pedestrian crossing were 8% for [center(C)-left(L')], 7% for [left(L)-left(L')], 13% for [no signal sound (only noise)], 23.5% for [center(C)-center(C')], 23% for [center(C)-right(R')], and 17.8% for [right(R)-right(R')].

From result of [no signal sound (only noise)] in Fig. 6, the noise speaker caused the subjects to veer right, indicating a tendency for subjects to avoid traffic noise. Thus, value of this veering distance added other pattern. Consequently, veering distance data is distributed around the center because the noise and signal tone cancel each other in the pattern with signal speakers installed on the left side.

IX. CONCLUSION

This paper seeks to establish guidance for installing assistive devices for personal mobility of visually impaired persons around crossings and to examine continuity among assistive devices for personal mobility. As a result, we found that traffic noise influences visually impaired persons. We assumed that traffic noise causes visually impaired persons to veer right when audible traffic signal speakers are installed on the left of a subject. Therefore, we estimated veering distance of each setting pattern of audible traffic signal speakers was that the noise and the inductivity were included. In the future, we will obtain data in an experiment environment of the same sort without noise speakers because to so as to distinguish between the noise and setting pattern of audible traffic signal speakers.

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