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Study on effect Size of Walking Speed According to Corridor Shape

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Abstract

Background/Objectives: The walking speed is not steady and is influenced by corridor shapes. Most of evacuation simulations are using fixed walking speed, and it possible to cause an erroneous value. **Methods/Statistical Analysis:** In order to determine the changes and influence of walking speed depending on the shape of the pathway and the type of the crossroads, the maze-set experiment is conducted. Total 30 participants recruit as experimental subjects, and ratio of gender is same (male: 15, female: 15). The experimental site has 5 types of crossroad and all pathways of participants recorded that used experimental cameras. Findings: The average walking speed of participants is 1.08 m/s (male: 1.12 m/s, female: 1.04). The result of walking speed is lower than speed in general situation which is 1.40m/s and can form the hypothesis on walking speed affected by corridor shapes. The walking speed change by each shape corridor has meaningful difference. Based on this, the cause of different walking speed estimates that corridor shape has various effect sizes and through one-way ANOVA, it can compute by using eta squared. **Application/Improvements:** Corridor shapes used in paper is not representing as all of actual building. From the result, however, walking speed is not fixed value and interacts with corridor shapes.

Keywords: Corridor Shape, Effect Size, Maze-set Experiment, One-way ANOVA, Walking Speed

1. Introduction

With the horizontal spatial expansion and systems of complex walkways which come about as structures become enlarged, the walking speed of their occupants has become affected directly. Peoples' walking speeds generally reflect their inherent characteristics such as age, sex, disabled, environmental factors, purpose for movement, etc[1].; but also fluidly changes due to external, artificial factors such as crowd density[2]. Walking speeds generally range between 0.76m/s and 1.76m/s when there is no obstruction in the pathway, and when a pedestrian density is 2.3m^2/person and there is no oncoming pedestrian traffic, pedestrians move at an average walking seeped of 1.37m/s. Also, when people move at an average walking speed, they spend the least amount of energy[3], and walking speed varies between national cultures and GDP (Gross Domestic Product)[4]. The results for the measured average walking speed in each country are listed in Table 1.

Meanwhile walking speed is fluidly changed in accordance with the characteristics of the walking location, the building uses as well as the size and shape of the space. Fruin[2] refers to different walking speeds according to the walking locations used by unspecified people, such as bus terminals or train stations. Zhang et al.[6] found a close correlation between changes in walking speed and walking density at a T junction. Even outside of changes in the

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Table 1. Walking Speed Observed in Literature [5]

Source	Measured Walking Speed			Source	Measured Walking Speed		
	Mean speed (m/s)	Standard deviation	Country		Mean speed (m/s)	Standard deviation	Country
CROW	1.40	-	NLD	Morrall et al.	1.25, 1.40	-	LKA
Dammen	1.41	0.215	NLD	Navin and Wheeler	1.32	-	USA
Daly et al.	1.47	-	GBR	O'Flaherty and Parkinson	1.32	1.00	GBR
FHWA	1.20	-	USA	Older	1.30	0.30	GBR
Fruin	1.37	0.15	USA	Pauls	1.25	-	USA
Hankin and Wright	1.60	-	GBR	Roddin	1.6	-	USA
Henderson	1.44	0.23	AUS	Sarkar and Janardhan	1.46	0.63	IND
Hoel	1.50	0.20	USA	Sleight	1.37	-	USA
Ins. of Trans. Engineers	1.20	-	USA	Tanariboon et al.	1.23	-	SGP
Knoflacher	1.45	-	AUS	Tanariboon and Guyano	1.22	-	THA
Koushki	1.08	-	SAU	Tregenza	1.31	0.30	GBR
Lam et al.	1.19	0.26	HKG	Virkler and Elayadath	1.22	-	USA

physical environment, during movement people continually collect information from things such as directional signs, and at every moment they engage in decision making regarding the path they will take, in accordance with the changes in their cognitive environment. During this process, the pedestrian's walking speed decreases even unintentionally[7]. Along these lines, research into the variability of peoples' walking speeds has continued in diverse fields, and it is necessary to correct the research into walking speeds currently being undertaken in traffic engineering, ergonomics and fire protection engineering.

The corridor is primary pathway between room and room or room and other space, and occupants should be spent their time on there. Therefore, this paper is limited to the corridor within a structure and compares walking speeds according to the shape of the pathway and crossroads with those on a straight line. The fact that walking speeds result from and change according to the corridor shape is a premise condition, and in order to determine what influence pedestrian space had on walking speed, sets in the form of pathways were made and the experiment conducted. Using experimental cameras, the moving route is recorded and turned into data to measure walking speed changed every moment, after which the video data is converted into numerical data for post-analysis. These results are subject to statistical methodology, and the influence exerted by the corridor shape is deduced from these analyses.

2. Methodology

2.1 Participants

The participants are university students in their 20s (average age: 23.0, range: 20-29), and a total of 30 participants are recruited (15 males, 15 females). Participants were selected at random and their way-finding and related abilities were considered so as to be standardized if possible. Before the experiment, all participants had their free walking speed measured for 20m, without being controlled, and the result was that their average free walking speed was 1.35m/s (1.37m/s for males, 1.33m/s for females). Crossroads were included among the experiment sets, and it was hypothesized that the setup of the pathways would affect walking speed. Subsequently, the experiment staff did not give any information regarding the pathway to the exit of the set to the participants, and participants were separated before and after the experiment to prevent any sharing of information on the pathways between the participants.

2.2 Experimental Site and Recording Equipment

Because walking speed is influenced by specific objects which can serve as a landmark, such as exit signage or other visual attraction, all other variables outside of the pathways proposed as the experimental variable need to be controlled. During the experiment, the corridor shape is maintained for consistency, and, in order to control other factors, copies of standard corridors are constructed as experimental set. Because participants move along with the constructed corridors, any external force is not applied to the walls of the experimental set, and so they are made using a thick paper material which can maintain their form while being as light as possible. The height of the walls was set at 2.2m so that participants could not predict the pathway while moving, and, to prevent discomfort while walking, the width of pathways was set at 1.20m. The total size of the experimental set is 13.20m in width and 10.80m length, with a total area of 142.56m^2, and the shortest pathway from the experimental set's starting point to its finishing point, if walking in the middle of the pathway, is 44.0m. The total shape of the corridors can be shown in Figure 1 (Right), and the shape and number of the corridors can be found in Table 2. Figure 2 is snap shots for experimental set-up recorded by camera which left image is overall scene and right image is closing-up scenes focused on pathway.

Table 2. Experimental Set-up for Corridors

Shape of Corridor	'+'	'L'	'T'	'Blacked'	'Hall'
No. of Corridor	1	13	3	7	1

2.3 Experimental Procedure

Before this experiment is conducted, the free walking speed of all participants were measured. The free walking speeds is used as a control group with which to compare the walking speeds inside the experimental set. The free walking speed for each participant measures in a place where physical factors would not interfere, and the measurement distance set as 20m. Measured walking time can calculate the free walking speed for measurement distance. The participants began walking from 2m away from the starting point, and their walking speed is measured as they moved at an even pace through the 20m measurement interval. In order to identify each participant and conduct a video analysis, all participants get a experimental numbered sign, and only one participant is instructed to enter the experimental set and try to find the final exit. After experiment, an explanation of the experimental goals and content are given to participant and staff instructed to him/her to leave the experimental area immediately.

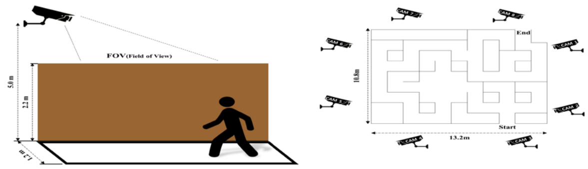

Figure 1. Specification of Experiment (L: Experimental Corridor size, R: Shape of Maze-set and Location of Camera).

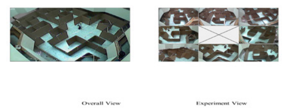

Figure 2. Snap Shot for Experimental Recording.

2.4 Data Analysis Procedure

In order to analyze the walking speed of the participants, prior procedures regarding the use of video have to conduct, and the content of these procedures are listed below (Figure 3).

(1) Making framed Video – The video recorded during the experiment process exports to a video file from the DVR(Digital Video Recorder) itself. If the video is played, the overall form of movement can be checked, but it is unsuited to assigning location coordinates over a same time interval. Subsequently, this research divided the video into images, with 4 frames per second.

(2) Setting fields for data extraction – In order to determine the walking speed for each corridor shape, the fields for data extraction concerning each of the planned corridor shapes is set ahead of time.

(3) Assignment of two-dimensional location coordinates – Because of the camera angle, the images retrieved by divided the experiment video has in 3 dimensions. In order to resolve this, coordinates are assigned to each participant in the image, and the proportion of a reference

length in each photograph is applied to the participant's coordinates, changing them to coordinates on a 2-dimensional floor plan.

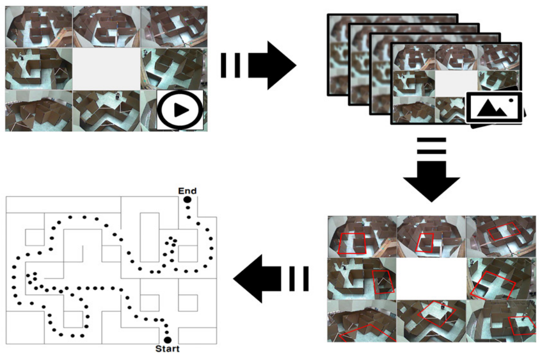

Figure 3. Experimental Analysis Process.

The location coordinates assigned to the 2-dimensional floor plan is subject to statistical analysis, and the tool used for this statistical analysis is the SPSS ver.22, with the reliability of all statistics set to 95%(p=0.05). The methods for data analysis are as follows:

(1) Descriptive statistics - the properties of the data were produced for the dependent variables from among the experimental variables, including average, range, and standard deviation, among others.

(2) A variance analysis was conducted for each corridor shape and walking speed, and the difference between dependent variables is examined according to experiment variable.

(3) In order to determine the amount of change in the walking speed according to the changes in the corridor shape, one-way ANOVA (analysis of variance) is conducted.

(4) The amount of influence of each walking speed by corridor was set based on the results of these analyses.

3. Result

3.1 Moving Route in Experimental Set

When the lines are connected between the location coordinates created in equal time intervals through the beforehand processing of the experiment video, the results are shown in Figure 4. Through figure 4, it is possible to tell that the participants, who had no way of knowing the pathway to the exit, made a number of errors in path choice. Of the total 30 participants, 17% turned around and went out the path that they had come, and though this it is possible to judge that the participants had lost their sense of direction due to failed path choices. If the free walking speed were not reduced inside the experiment set, then the total movement time would take around 32.6 s (32.41s for males, 33.38s for females), with a shortest distance of 44.40m and an average free walking speed of 1.35m/s).

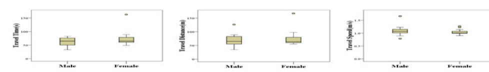

Figure 4. Experimental Results (L: Average Travel Time, M: Average Travel Distance, R: Average Travel Speed).

The average movement time for the participants in the experiment set was 61.35s (σ=17.3) for males and 73.06s (σ=27.5) for females; the average movement time for the 95% average confidence interval was 61.93s for males and 69.41s for females, and within the 95% significance level this was 61.93 for males and 69.41 for females. The average movement time according to the confidence interval was 1.91 times longer than the movement time at free walking speed for males and 2.8 times for females. The average movement distance was 68.68m (σ=23.71) for males and 75.80m (σ=28.27) for females, and within the 95% confidence interval, these figures were 67.38m and 71.89m, respectively. It is possible to determine that the participants moved a farther distance than shortest distance because of the intersecting corridors, and that the reason the males' movement distance was shorter than the females' movement distance was because of the choice of path and adherence to the shortest route. Finally, an average walking speed was 1.12 m/s (σ=0.24) for males and 1.04 (σ=0.10) for females was deduced, and participants moved at slower walking paces than free walking speed. These results support the idea of changes in walking speed with a same space, as proposed in the outline.

3.2 Walking Speed Changed by Corridors Shape

This chapter seeks to meticulously follow the change in walking speed according to the shape of the corridor statistically. First, in order to compare the walking speeds of each of the participants according to the shape of the

Table 3. Result of Descriptive Statistics and Variance Analysis

Shape of Corridor	'+'	'L'	'T'	'Blacked'	'Hall'
N(Person)	30	30	30	30	30
Mean(m/s) (5% Trimmed Mean)	0.72[a] (0.72)	0.89[bc] (0.88)	1.00[c] (0.98)	0.79[ab] (0.78)	0.95[c] (0.93)
Median(m/s)	0.7	0.86	0.78	0.78	0.91
Variance	0.02	0.02	0.01	0.01	0.07
Std. Deviation	0.15	0.14	0.11	0.11	0.27
Minimum(m/s)	0.38	0.66	0.61	0.61	0.35
Maximum(m/s)	0.98	1.43	1.59	1.14	1.97
F	12.777***				
P	0.000				
*** p<.001					

corridor, descriptive statistics were performed on each corridor shape. Through the descriptive statistics alone, an overall difference could be seen, but the walking speed according to corridor shape could not be verified for each group (N=30). Subsequently, in order to verify whether or not there was a significant difference in walking speed by corridor shape, a variance analysis was conducted. To carry out this variance analysis, a check of the equal variance in the dispersion of walking speed by corridor shape must first take place, and so a Levene Test was conducted.

As a result of the Levene Test, a statistical value of 0.068, higher than significance level of 0.05 was found, and the null hypothesis of 'the dispersion of the five walking speeds is equal' was adopted. The statistical value of the variance analysis was F=12.777, with a significance probability of 0.000, meaning that the null hypothesis that there was no difference in each walking speed was dismissed. In other words, it was found that there is a statistically significant difference in walking speed according to the shape of the corridor (Table 3).

3.3 Effect Size of Corridor Shape

As seen in chapter 3.2, walking speed was diminished according to the shape of the corridor, and the level of change was also different, as verified by the variance analysis. In this chapter, we will conduct an analysis of just how much the shape of the corridor was actually involved in walking speed, and on the basis of this an effect size will be determined for each corridor shape. The fact that the F value resulting from the variance analysis in Table 3 is significant means that the difference in walking speed for each corridor shape is above the margin of error, however this cannot explain how much influence the shape of the corridor has on free walking speed. Subsequently, the index[8] which can explain the influence exerted on free walking speed by the shape of the corridor, the eta squared (η^2), was used on the statistical analysis. Eta squared refers to the ratio between the entire variance squared and the difference between the variance squared of each group in the variance analysis, and, along with the coefficient of determination (R^2), means the variance explained. However, the difference between the coefficient of determination (R^2) and eta squared(η^2) is that eta squared is only possible through correlation coefficient between the nominal scale and interval scales, whereas the coefficient of determination (R^2) is possible only through correlation coefficient between the interval scale and interval scale.

In order to determine the effectiveness of each corridor shape on free walking speed, a univariate analysis of the free walking speed and the walking speed of each corridor shape was conducted. The nominal scale by the corridor shape, and the interval scale by the walking speed of each corridor shape were divided, and a Levene test was conducted, after which the eta squared value was calculated.

As per the results of the equal variance test on the free walking speed and the walking speeds of each corridor shape, the equal variance of each group were all verified, and the partial eta squared of each corridor shape satisfied all the conditions defining the effect size. Comparing the effect size of each of the corridor shapes, the blocked corridor had the largest effect on free passage, followed by the '+', 'L', 'T', and hall shaped corridors, in that order. It is possible to determine that the blocked passage had the largest effect size because walking speed had to be diminished in order to turn around and by the path of entry, and many location coordinates were assigned to the blocked paths on a 2-dimensional location coordinate floorplan.

The value of eta squared is the effect of the difference between free walking speed and the walking speed in each corridor shape, and so it is difficult to consider each of their values as an effect size. Subsequently, each eta squared was generalized on a scale of 100 and converted into an effect size. The results of this are in Figure 5.

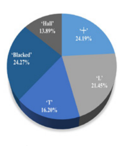

Figure 5. Effect Size for Each Corridor Shape.

4. Conclusions

The ultimate of this research was to calculate an effect size for the walking speed of each corridor shape. Among the many factors influencing the fluidity of walking speed, the shape of the corridor limits the pathway of the occupant, is a directly influential factor, and, as prior research has also indicated, walking speed decreases around corners. Subsequently, in this research, corridor shapes were created, and in order to eliminate interfering factors affecting walking speed, an experimental set was built. A total of 30 people participated in the experiment, and as they were moving through the experimental set, the changes in their walking speed were analyzed. The results included: 1) In the experimental set, average speed was 0.27 m/s slower than free walking speed, and the reason for this is judged to be the shape of the corridors. 2) ' ', 'L', 'T', blocked, and hall shaped corridors were constructed, and each of these had an average walking speed of 0.72m/s, 0.88m/s, 0.98m/s, 0.79m/s, and 0.95m/s, respectively. (Confidence interval: 95%) 3) As the result of a variance analysis of walking speed by corridor shape, each walking speed showed a significant change, and a one-way ANOVA was conducted in order to determine the effect size on free walking speed. 4) The influence exerted by independent variables on the dependent variables is expressed in the eta squared values, and the eta square of the walking speed in each corridor was calculated, and the result of their generalization whose that a blocked corridor has the largest effect on walking speed, whereas the hall shaped corridor has the least effect.

Places like large retail facilities have wide horizontal spaces, and, because of the circulation, the change in walking speed is inevitably determined by the flow of human traffic in a given location. This research is limited in scope to the effect of corridor shape on walking speed; however additional research into various locations is needed, and, moreover, additional research into the other factors affecting walking speed is needed.

5. Acknowledgment

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6. References

1. Prestopnik JL, Roskos–Ewoldsen B. The relations among wayfinding strategy use, sense of direction, sex, familiarity, and wayfinding ability. J Environ Psychol. 2000; 20(2):177–91.
2. Fruin J. Designing for Pedestrians: A Level-of-Service Concept. New York Metropolitan Association of Urban Designers and Environmental Planners. Highway Research Record. 1971(355).
3. Browning RC, Baker EA, Herron JA, Kram R. Effects of obesity and sex on the energetic cost and preferred speed of walking. J Appl Physiol. 1985; 100(2):390–8.

4. Levine RV, Norenzayan A. The pace of life in 31 countries. Journal of cross-cultural psychology. 1999; 30(2):178–205.
5. Daamen W. Modelling passenger flows in public transport facilities. Doctoral Thesis, Delft University of Technology; 2004.
6. Zhang J, Klingsch W, Schadschneider A, Seyfried A. Transitions in pedestrian fundamental diagrams of straight corridors and T-junctions. Journal of Statistical Mechanics: Theory and Experiment. 2011; 2011(06):P06004.
7. Jong-Yeong S, Soo-Ho L, Jun-Ho C. Won-Hwa H. A study on the emergency light cognitive effects according to background luminance using regression analysis. Journal of Asian Urban Environment. 2015; 12(1):379–82.
8. Levine TR, Hullett CR. Eta squared, partial eta squared, and misreporting of effect size in communication research. Human Communication Research. 2002; 28(4):612–25.
9. Eun-Myeong J, Jun-Ho C, Won-Hwa H. Analysis on characteristics of human behavior and cognitive effects according to types of egress route instruction in a large-scale mazy facility. Journal of the Architectural Institute of Korea (planning and design). 2011; 27(10):51–8.
10. Kyu-Hun J, Soo-Ho L, Ju-Ho C, Won-Hwa H. A study on the corner walking speed for drawing pedestrian characteristics in indoor space. Proceeding of Spring Annual Conference of KHA. 2013; 25(1). p. 203–6.