THE EFFECT OF PATH ENVIRONMENT ON PEDESTRIANS' ROUTE SELECTION: A CASE STUDY OF UNIVERSITY OF CINCINNATI

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Abstract. The present study on the influence of the path environment on pedestrians' route selection is mostly concentrated on the urban level while rarely discussed from the architectural level. Taking the University of Cincinnati (Ohio, US) as an example, this study aims to investigate whether the difference in the environmental settings of the route will affect pedestrians' walking experiences and future route selection, with the ultimate goal of ascertaining the underlying relationship between the route environments and the user behavior in the process of route selection and implementation. This study selected three routes from the Langsam library to the CEAS library. The research methods included data analytics, questionnaires, and comparative analysis. Firstly, through surveys and an E4 wristband, psychological and physiological data were collected. Secondly, Analysis of Variance (ANOVA) was used to examine whether there was a significant difference in pedestrians' walking experience among the three routes. Thirdly, through the analysis of questionnaires, the factors that play an important role in pedestrians' route selection were determined. It can be concluded that the three routes with different environmental settings bring a different experience to participants. More specifically, the level of comfort and openness of the route significantly affects the route selection of pedestrians, while the degree of fatigue during walking does not. To sum up, for the transition space from outdoor to indoor, the factors affecting pedestrian route selection include the route's degree of comfort and openness.

Keywords. Path Environment; Route Selection; Pedestrian; Data Analysis; Sustainable Built Environment; SDG 11.

1. Introduction

Many scholars have begun exploring the relationship between the pedestrian environment and human behavior. It contributes to building more walkable cities once we know how the environment affects pedestrians' route selection or sensory experience. Cepolina et al. use the scale of pedestrian comfort to assess whether a

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facility's design impacts human comfort (Cepolina, Menichini, & Rojas, 2018). Guo et al. evaluates the environmental situation by analyzing the path selection of pedestrians (Guo & Loo, 2013). Isaacs explores how the environment of a path, such as the width and height of the elevation along the road, affects people's time perception during the walking journey (Isaacs, 2001). Miller and Laurie interview and observe the experience of pedestrian accessibility in high-density urban areas (Miller & Buys, 2013). Calvert explores urban walking experience holistic and multi-faceted experience (Calvert, 2020). Barros et al. try to determine which factors interfere with the choices people make about modes or transport of walking paths (Barros, Martínez, & Viegas, 2015). Hollmann reviews "how individual pedestrian behavior and the pedestrians' environment usage are realized in current pedestrian behavior simulation models has been undertaken"(Hollmann, 2015). Martínez and Ana present a Structural Equations model to assess pedestrian environment satisfaction (Martínez & Barros, 2014). Guo proposes a new method (based on path choice) to investigate the causal effect of the pedestrian environment on the utility of walking (Guo, 2009).

Also, more and more cities are increasingly considering the impact of path environment on the pedestrian's walking experience to improve the image and liveliness of a city. Many cities issued a corresponding urban street environment design manual to guide urban planners and urban designers to improve the community environment, comfort, and walkability. The design guidelines for street and sidewalk construction and retrofit design is also adopted by the cities such as Pennsylvania, Burlington, Vermont, Tacoma, Washington, Minneapolis, and Phoenix.

However, the present study on the influence of the path environment on pedestrians' route selection is mainly concentrated on the urban level while rarely discussed from the architectural level. Few studies have investigated the transition space from outdoor to indoor, and whether environment settings between the outdoor and indoor space affect pedestrians' walking experiences and route selections.

In this case, this study aims to investigate whether the difference in the environmental settings of each route would affect pedestrians' walking experiences and future route selection, Researcher conducts an experiment and collect pedestrians' psychological and physiological data while they are walking from the Langsam library to the CEAS library at the University of Cincinnati (Ohio, US). Then the collected data was analyzed to see whether path environmental settings affect pedestrians' experience and route selection. Three routes with different environmental settings from the Langsam library to the CEAS library are selected as the research testbeds. In this pilot study, a total of nine students participated the experiment. Their physiological data was obtained through an E4 wristband while the psychological data was collected through a questionnaire. Finally, through analysis of the questionnaire, data shows that the factors including comfort and openness of the transition space will affect pedestrians' route selection. However, the limitation of the study is the small sample size. Unfortunately, due to Covid-19, the researcher's ability to collect a larger research sample was restricted. In the future, there would be more generalizable and convincing results if larger sample size is used. It is hoped that this pilot study can ascertain the underlying relationship between the route environment and user behaviors in route selection and implementation.

2. Experiment Design

2.1. SITE SELECTION

The experiment site is located at the UC campus. For research purposes, two points were considered while selecting the routes: 1) the routes should share the same start point and endpoint; 2) environmental settings among the routes have significantly different characteristics. Based on the selection standards above, the gate of the Langsam library (outdoor) is set as the start point and the gate of the CEAS library (indoor) as the endpoint. Three routes connect these two points. These three routes have apparent characteristic differences in the setting of the roof garden, elevator, stairs, art installations, plaza, etc (Figure 1).

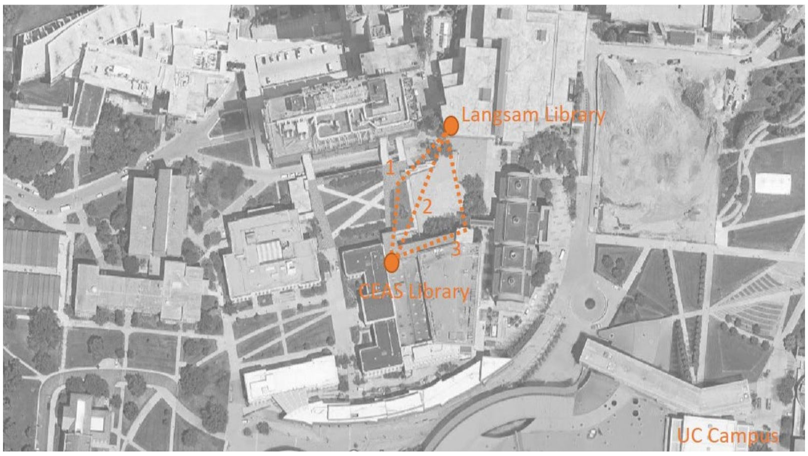

Figure 1: Site Location (Source: Author)

2.2. ROUTE ANALYSIS

The three routes from the Langsam library to the CEAS library have different outdoor and indoor space ratios, the proportion of stairs, and environmental settings (including plants and artwork) (Table 1). Route 1 has a total length of almost 155 m and the ratio of outdoor and indoor space is 2:1. The percentage of greenery and stairs are 28% and 40%, respectively (Figure 2). Route 2 has a total length of almost 157 m and the ratio of outdoor and indoor space is 1:2. The percentage of greenery and stairs are 3% and 42.7% (Figure 3). For route 3, the length is around 135 m and the ratio of outdoor and indoor space is 1:1. The percentage of greenery and stair is 14.8% and 2% (Figure 4).

Table 1: Routes Comparison (Source: Author)

Route No.	Length (≈)	Ratio of Outdoor and Indoor Space（≈）	Percentage of Greenery（≈）	Percentage of Stairs（≈）

Route 1	155m	2:1	28%	40%
Route 2	157m	1:2	3%	42.7%
Route 3	135m	1:1	14.8%	2%

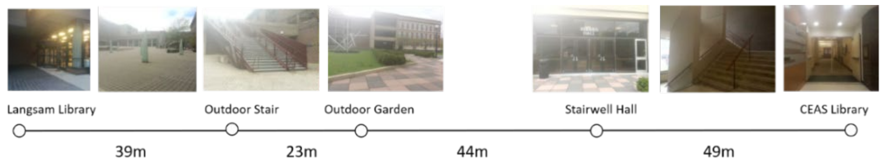

Figure 2: Overview of Route 1 (Source: Author)

Figure 3: Overview of Route 2 (Source: Author)

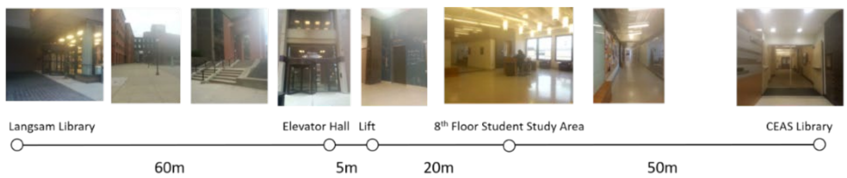

Figure 4: Overview of Route 3 (Source: Author)

Besides the physical indicators, we also consider the environmental factors of each route that may cause different psychological feelings. The route environment settings should afford the pedestrian with security or protection from injury in terms of the safety factors. In this study, the illumination and people flow are used to evaluate the safety of each route. There is a difference in illumination setting and pedestrian flow for these three routes. Route 1 offers greater security because it has much more outdoor space full of natural light, including a plaza, outdoor staircase, and roof garden. Even the staircase area is filled with natural light due to the huge glass windows. Meanwhile, a considerable crowd on the plaza and roof garden increase the route safety. Route 2 offers lower security. Besides the plaza, the whole route is very tortuous and dim due to a fire safety door and closed stairwell. Most places along the way are installed with artificial illumination. Very few people walk this route, which further weakens the safety of the route. Route 3 offers relatively higher security compared to route 2. Only the elevator and corridor place need artificial illumination and the remaining area of the route is full of natural light. There is many people on the route because of the existence of an elevator hall and study area, which helps enhance the route's safety.

In terms of continuous variables, it is about the possibility of constant involvement in various activities along the route. The types and diversity of events allowed in each route are different. Diversity activities allow for an array of visual possibilities. Due to the plaza and roof garden, pedestrians may encounter all kinds of events while walking on route 1, such as a party on the plaza, photography at the art installation, chatting with friends, resting beneath the shade of trees, reading, etc. For route 2, the richness level of route activities is relatively low. There are a few spaces on the route that allow for any activities. Also, very few people walk on the route. Route 3 is easy for people to run into friends because of the elevator hall and study lobby. The richness level of route activities is relatively high. Students can carry out various activities in the study lobby.

2.3. EXPERIMENT SETUP

The experiment was conducted at the UC in the summer. Participants were asked to walk these three routes sometime from 12pm to 8pm on a sunny day. There was a total of 9 participants and 3 for each route. To avoid affecting the experimental results due to the different expectations and requirements of different participants (Faculty/Staff/Student) for the path environment, all participants in this experiment were students.

All participants need to walk from the Langsam library to the CEAS library through a different route. During the walking process, all of them need to wear an E4 wristband to record their changes in physiological data. The E4 is a medical-grade wearable device allowing us to collect real-time physiological data and conduct in-depth analysis and visualization ("E4 Wristband," n.a.). The data collected by E4 Wristband includes Electrodermal Activity (EDA), Blood Volume Pulse (BVP), Accelerometer (ACCE), and Skin Surface Temperature (TEMP). The data recorded through the E4 Wristband is synchronized to the E4 cloud storage and can be retrieved anytime.

After arriving at the destination, the participants were asked to complete a questionnaire similar to the Likert Scale. The questionnaire helped the researcher collect the psychological data regarding pedestrians' feeling and experience while walking the route. The questions included mainly care about the following indicators: comfort level, openness level of environment setting, fatigue level while walking, possibility to choose the same route later, ventilation quality, visual quality, temperature, walking time, etc. At the end of the questionnaire, participants could give some advice on the improvement of route environmental settings, which was optional. The whole questionnaire took an average of 2-3 minutes to complete. In addition, the researcher followed the participant and recorded the time when the participant arrived at a specific node of each route by a stopwatch. The timestamps helped to study whether the physiological characteristics vary with the environmental settings.

3. Analysis and Discussion

3.1. DATA ANALYSIS

Based on the analysis, pedestrians have a different experience while walking on route 3 compared to the other two routes. People feel more satisfied with route 3. In other words, the various environmental settings of different routes trigger changes in the physiological characteristics of the participants, which further cause the different experiences of the three routes. However, more analysis of physiological data is still needed to increase the credibility of the conclusion.

3.1.1. Identify the Indicator and Analysis Method

For the indicator, the Electrodermal Activity (EDA) of all participants is for data analysis. EDA is used to measure the constantly fluctuating change at the surface of the skin. It will arise when the skin receives innervating signals from the brain. For example, if a person experiences emotional activation, the brain will send signals to the skin to used increase the level of sweating. We can measure how pedestrian feel while walking on each route based on the indicator.

For the analysis method, the Analysis of Variance (ANOVA) is used to determine whether differences between groups are statistically significant by comparing their means ("Understanding Analysis of Variance (ANOVA) and the F-test," 2016). First, the ANOVA tests whether there are noticeable differences among these three data sets in terms of EDA. Then, the F-test is used to compare every two groups of data to analyze whether there is a significant difference in experience between the two routes. "The null hypothesis for ANOVA is that the mean (average value of the dependent variable) is the same for all groups."(Creech, n.d.) If the P-value from the F-test is more than 0.05, the result supports the null hypothesis at the 95% confidence level. If the P-value is less than 0.05, then the result rejects the null hypothesis. This means there is a significant difference between these data sets, further indicating the differences in environmental settings of each route cause physiological characteristics change.

Table below is the mean of each participant's EDA (Table 2). ANOVA is used to examine these groups of data. Before the ANOVA test, all of these groups of data show normal distribution through the Shapiro-Wilk Normality test. The P-value of the three sets of data is 0.488, 0.976, and 0.28 respectively. All of them are greater than 0.05, indicating that the data shows a normal distribution with a 95% confidence level (Table 3).

Table 2: EDA Mean of Each Participant (Source: Author)

	Partici-pant	Route 1	Route 2	Route 3
EDA Mean (μs)	A	0.583	1.294	0.856
	B	0.11	1.576	3.543
	C	0.459	1.438	0.34

Table 3: Normality Test Result (Source: Author)

Shapiro–Wilk Normality Test		
Data: R1_EDA	Data: R2_EDA	Data: R3_EDA
W =0.92986, P-Value = 0.4881	W =0.99985, P-Value = 0.9765	W =0.8672, P-Value = 0.2876
Route 1	Route 2	Route 3

Then, according to the Test of Homogeneity of Variances, three data groups meet the requirement of homogeneity. The result of Fligner-Killeen Test, which is used to test the homogeneity of the variance, shows that the P-value is 0.4191 (>0.05). This result indicates that the variance in EDA mean of each participant is statistically significantly the same for these three routes (Table 4).

Table 4: Result for Fligner-Killeen Test of Homogeneity of Variance (Source: Author)

Fligner-Killeen Test of Homogeneity of Variance
Data: Values by ind
Fligner-Killeen: med Chi-squared – 1.7395, df = 2, P-Value = 0.4191

3.1.2. Variance Comparison Among the Three Routes

The ANOVA result suggests that the participants' experience in the three routes are not completely significantly different. The P-value, by the ANOVA test, is 0.34 (>0.05), which cannot reject the null hypothesis (Table 5). That is, the three sets of data are very similar, indicating the three routes give people a similar experience. Thus, we need to further explore the difference between every two groups of data.

Table 5: ANOVA Result for Three Groups (Source: Author)

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Ind	2	2.557	1.278	1.263	0.349
Residuals	6	6.075	1.012		

Through F-test analysis to examine the difference between every two groups, route 3 brings different experience to people compared to routes 1 and 2 (Table 6). When analyzing the Route1 and 2, the 0.496 P-value (> 0.05) suggests that pedestrians' experiences on these two routes are quite similar. Through analysis of Route 3 verse Routes 1 and 2 respectively, the 0.039 and 0.013 P-value (<0.05) indicates Route 3 provides a different experience to people compared to the other two routes.

Table 6: P-value of F-test for Every Two Groups (Source: Author)

P-value	Route1_EDA	Route2_EDA	Route3_EDA
Route 1_ EDA		0.4969	0.0398
Route 2_ EDA	0.4969		0.0134
Route 3_ EDA	0.0398	0.0134	

3.2. SURVEY ANALYSIS

The questionnaire reveals that the difference in environmental settings of each route result in a difference in walking experience (Table 7). First, the comfort level while walking directly affects pedestrians' route preference: the more comfortable they feel during walking, the more likely to choose the same route. The comfort level of each route is ranked as: Route 3 (100%) > Route 2 (0%) > Route 1 (-33.3%). The participants' route preference is Route 3 (22.2%) > Route 2 (-22.2%) > Route 1 (-33.3%). Then, when selecting the route, the degree of openness of the environment (from the pedestrians' evaluation) and the pedestrians' route preference shows a negative correlation — the more open the route, the less likely to choose the route.

Although Route 1 has the most open environment settings (openness: Route 1 (66.6%) > Route 2 (-11.1%) > Route 3 (-33.3%)), people are the least likely to take this route (route preference: Route 3 (22.2%) > Route 2 (-22.2%) > Route 1 (-33.3%)). Even though Route 3 has the least open environment, it provides the best experience for people. The rating of Route 3 ranks No. 1 when asking people which route they prefer to choose again. But for Route 1, people feel uncomfortable and unlikely to choose it again, and for Route 2, people hold a neutral attitude to its comfort level and state they don't want to choose this route again. Finally, compared to the tired feeling while walking, the degree of openness and comfort of route play a more crucial role in pedestrians' route selection. Although participants feel more tired while walking on the Route 2 compared to Route 1 (tired level: Route 2 (44.4%) > Route 1 (33.3%)), they are more likely to select Route 2 (route preference: Route 2 (-22.2%) > Route 1 (-33.3%)).

Table 7: Route Evaluation from Participant (Source: Author)

Route No.	Participant (Age/Gender)	Comfort Level (3 Comfortable ~ -3 Uncomfortable)	Environment Setting (3 Open ~ -3 Closed)	Tired Level (3 Relaxed ~ -3 Tired)	Choose Same Route (3 Yes ~ -3 No)
Route 1	24/F	-1	3	-1	-1
	27/M	-1	2	-1	-1
	26/F	-1	1	-1	-1
Route 2	27/M	-1	1	-1	1
	29/F	-1	-1	-2	-2
	25/M	2	-1	-1	-1
Route 3	32/F	3	-2	0	-1
	19/M	3	-2	3	2
	24/F	3	1	0	1

4. Conclusion

For the transition space from outdoor to indoor, the three routes' different environmental settings provide participants with different experiences that can affect their future route selection. Data Analysis indicates that the pedestrian's Route 3 experience is totally different from Routes 1 and 2, but the experience of Route 1 is similar to Route 2. This means that the different environmental settings between Route 3 versus Routes 1 and 2, such as the elevator hall and study area, cause these distinct experiences. Route 3 is more psychologically satisfying and leads to more significantly physiological changes in participants when compared with Routes 1 and 2. From the lens of subjective psychological experience, although the environmental setting of Route 3 is the least open, it makes people feel comfortable and relaxed. Thus, there is a 22.2% probability of them selecting Route 3 again.

Meanwhile, the willingness of pedestrians to choose specific routes depends on the level of comfort and openness of the route. The comfort level is positively correlated with the path preference: the more comfortable the route, the more likely a pedestrian tends to choose that route. Conversely, the openness level is negatively correlated with the path preference: the less open the route, the more likely the pedestrian is to choose the route. Compared with the comfort and openness indicator, the degree of fatigue caused by walking on a specific route has fewer effects on people's route preferences and selection. According to the survey, Route 3 is the most popular route among the three routes because of the highest comfort level, the lowest tiredness level, and the lowest openness.

One of the limitations of this research is the small sample size. Unfortunately, due to Covid-19 (2020), the researcher's ability to collect a larger research sample was restricted. Future research might have more generalizable and convincing results if a larger sample size from the UC is used. This could be accomplished by adding more sites and assessing a greater number of environmental settings. This would allow further discussion about what environmental factors impact route selection when pedestrians move from outdoor to indoor.

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