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Experimental study of the effects of culture and location on single-file fundamental diagrams

Nashiru Mumuni Daniel Bilintoh, Jun Zhang *, Rehmat Karim, Warda Rafaqat

State Key Laboratory of Fire Science, University of Science and Technology of China, Hefei, 230027, China

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A B S T R A C T

Empirical observation, controlled experiments, and pedestrian dynamics models are used to research pedestrian movement. These studies rely on single-file fundamental diagrams. Experiments were conducted in Ghana, and African students in China and Germany undertook experiments (Seyfried et al., 2005) [1]. Different groups of pedestrians were tested, and then told the entrance group conducted three corridor rotations. A *t*-test and z-test were employed to compare all measurement findings statistically. The study found significant spatial and cultural implications on single-file pedestrian travel. African pupils in China have an R^2 of 0.63 (63%), while Ghanaians have an R^2 of 0.77 (77%). Both groups are African, suggesting that location influences single-file pedestrian principles. According to a comparable study, Indian and German pedestrian fundamental diagrams [2,3], German and Brazil [4,5] show considerable variances. This research examines whether locations and culture affect single-file pedestrian travel.

1. Introduction

Researchers of pedestrian behaviour and crowd modelling have recently taken notice of the importance of studying and modelling social group behaviour [1–5]. It is critical to understand and model groups to recreate crowd behaviour during normal and emergencies since groups make up a significant proportion or even the majority of urban pedestrian crowds [6,7] and exhibit group-specific behaviours [8–10]. In response, several numerical, mathematical, and statistical models of group behaviours were developed [8,11,12]. The group's makeup and relationships among its members will likely influence group dynamics related to human social behaviour [13,14].

Introducing more mechanized and non-mechanized vehicles into Ghana's cities and regions has expanded the country's adaptability. Even though we drove by car most of the way, we had to walk in some areas. Walking is the most fundamental and primary mode of human locomotion. It is critical for the advancement of human civilization. Walking is the major mode of transportation for humans. However, motorized travel is prioritized over all other forms of transportation. It can provide better mobility if the pedestrian flow is understood clearly. Separate routes are set up for vehicular and pedestrian traffic. Pedestrians move freely depending on their trip's object, purpose, vehicle lanes, and flows. There are two kinds of pedestrian traffic flow: unidirectional (where pedestrians move in one direction), single-file (where pedestrian movement is bi-directional), or bi-directional [15,16] (where pedestrian movement is unidirectional) [17–19]. Pedestrian movement is chaotic, complex, and highly vulnerable [20]. To avoid delays due to obstacles and passing pedestrians, a pedestrian will try to have the most convenient way for movement to achieve their destination as quickly as

* Corresponding author.
E-mail address: junz@ustc.edu.cn (J. Zhang).

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possible.

In recent years, pedestrian movement studies have attracted increasing attention, as they can improve safety and efficiency in emergency evacuations. Researchers conducted experiments [21–23]under diverse conditions to learn pedestrian group characteristics by considering several indicators that influence statistics collection methods, such as gender, age, building structure, and motivation.

This research [1,24,25] on single-file pedestrian movement focused on specific factors influencing pedestrian movement characteristics by reducing the experiment conditions and cross-interactions between pedestrians. There has been much research on pedestrians moving in single-file pedestrian fundamental, mainly focusing on time space and the relationship between speed and headway using limited visibility [26]. They investigated the speed distribution while moving in single-file under different conditions and found that it complies with a Gaussian distribution. The field observations and controlled experiment [27] revealed differences in the single-file motion. This argument is based on their observation of the boundary's potential influence.

The study explores the impact of pedestrian movement characteristics, emphasizing culture and prominent location. Using data archives from dynamic pedestrian groups in Germany [1] compared the findings to those from similar studies based on single-file movement experiments. Velocity, densities, and headway, a comparative analysis of pedestrian movement quantity data from Germans, Ghanaians, and African students in China, will be conducted.

2. Methodology

The research uses a single-file fundamental diagram to evaluate an experiment conducted in Ghana and a similar experiment conducted by African students in China and compare it with research conducted in Germany [1]. The study used originPro software to determine if there is any location and cultural impact on pedestrian behaviours.

3. Perform an experiment

In June 2021, an experiment was conducted at a senior high school in Ghana's upper west region, and a similar experiment involved African students in China in February 2021. A replicated experiment by Refs. [16,21,28] All instructions and guides were the same based on the research objectives (comparative analysis). The only difference was the location and pedestrians involved in the experiment. Fig. 1 below shows the shape and dimensions of the experiment setup.

About 35 volunteers from senior high schools in Ghana participated in the experiment with ages ranging from 18 to 35 years, while the experiment in China involved African Students ages 22–35 years. By widening the path in the curve and placing the examination part in the middle portion directly to the passageway, the measurement is reduced by reducing the influence of curves. The measured section had a length of 2 m, and the entire corridor had a length of 17.3 m. Table 1 shows the results of the study. A total of six different types of experiments were conducted for the research. Throughout all runs, participants received the exact instructions. A minimum of 3 min of walking without overtaking was required for the results to be repeatable and meaningful. Based on the different numbers (N) of pedestrians in each run, the global densities are calculated $\rho_g = N/_L$, 2.02 m^{-1} were the ranges for all the setups; We considered no gender of pedestrians N = 1, 15,20, 25, 30, and 35.

4. Collection of data

Fig. 1Reflect the configuration of a camera set to 25fr (frame rate) and a resolution of 640 × 480 to measure the speed-density data. Pedestrian movements were recorded using the video. The observations section was marked as measured using two ranging rods, shown in Figs. 1 and 2(a), separately. The video data shown in Fig. 1 above generates a snapshot of the measured section. Using the observations section, we note every individual's entry time (t_{in}) and exit time (t_{out}). Information about speed and density can be derived from these time points. As noted above, collected data. Used these data to determine each pedestrian's speed and density. Finding the reciprocal of the density can determine the distance headway. During data collection, it took appropriate precision as pedestrians were moving so slowly.

We manually calculated the entry and exit time t_{in} and t_{out}. This way, the individual speeds $v = \frac{l_m}{t_{out}-t_{in}}$, while $n(t)$, representing a

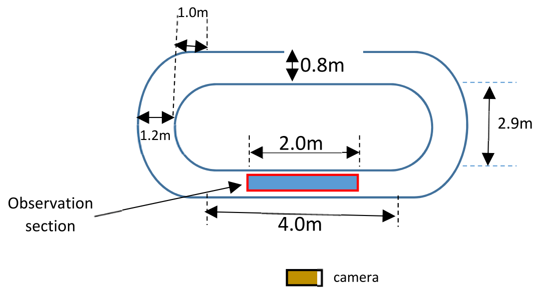
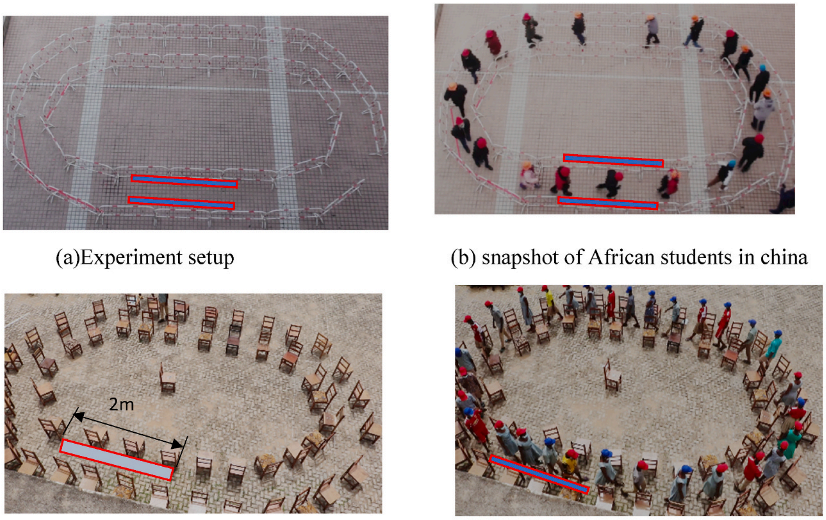


Fig. 1. An illustration of the corridor used for the experiments [3].

Table 1
Experiment details.

No. sets	Number of participated		Total	Global density (m^{-1})
	Males	Females		
2	5	10	15	0.87
3	10	10	20	1.16
4	15	10	25	1.44
5	15	15	30	1.73
6	20	15	35	2.02



(a)Experiment setup (b) snapshot of African students in china

(c)Experiment setup (d) snapshot of Ghanaian students in Ghana

Fig. 2. (a) and (c)show the setup of the experiment, and (b) and (d) screenshots of the experiment performed in China and Ghana, while in the German experiment, we pedestrian dynamic data archive. Ref. [18].

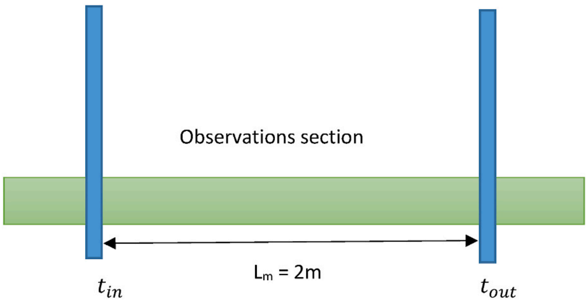


Fig. 3. Illustrates the observation section for data collection.

temporary number at time t in the observation part, can be calculated. Because of the low number of subjects involved (one to five), the temporary density calculation sometimes needs to be revised. $\rho = n(t)/_{l_m}$, ref [24]. The flow per second is manually calculated after the pedestrian speeds have been determined. Flow is the number of people passing through the observation area every second. The three parameters (density, speed, and headway) are interconnected. The equation below can determine density by finding speed and flow [1].

$$\rho = n(t)/_{l_m} \quad (1)$$

Density is represented by (p) and $n(t)$, representing several persons in the observation part at a time, and l_m is the length of the observation section of the experiment.

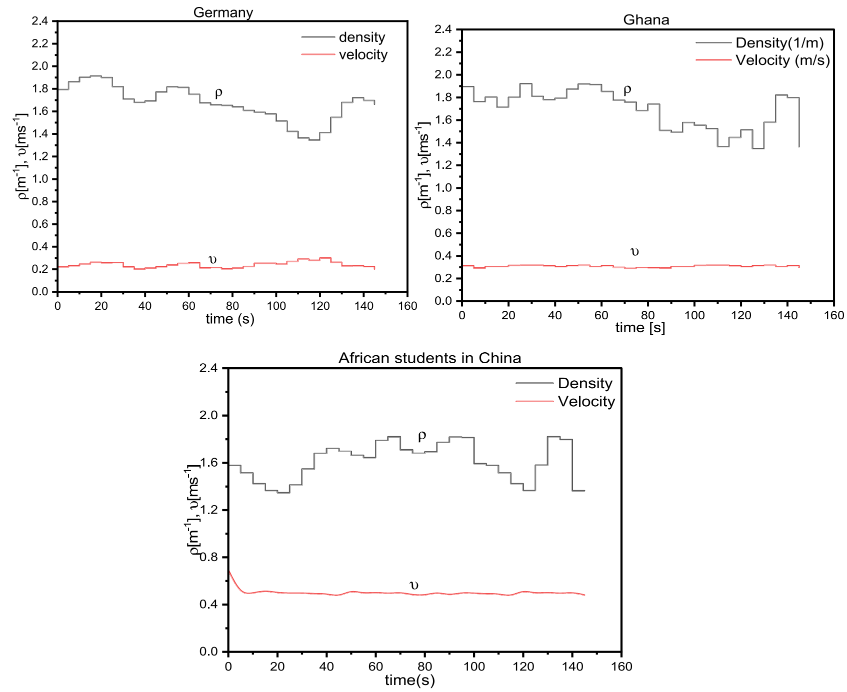


Fig. 4. Based on N = 30, the velocities *v and densities ρ developed progressively. The length of line v. determines a pedestrian's time inside the measurement area. In contrast, ρ, the density defined by* Refs. [1,3]*, shows smooth fluctuations.* The upper line illustrates density; the lower bars indicate the intervals when a pedestrian is in the measured section, and the lower bars indicate an associated mean velocity. The fluctuations in individual velocities show this correlation.

$$v = \frac{l_m}{t_{out} - t_{in}} \tag{2}$$

(v) Is individual velocity, with t_{in} representing time in the observation section and t_{out} is the time of exit from the observation section.

5. Density-speed and speed-headway relations comparison

Each experiment's mean velocity for Germany and the Ghanaians and their t-Value, the intercept, slope, and statistics R^2 values, are

Table 2
shows the parameters and summary of the linear regression for Germans and Ghanaians.

Parameters		Value	Standard Error	t-Value	Prob>|t|
Germany	Intercep	0.365	0.012	29.573	1.75577E-57
	Slope	1.042	0.027	37.519	7.63461E-69
		Value	Standard Error	t-Value	Prob>|t|
Ghana	Intercept	0.210	0.028	7.291	3.36533E-11
	Slope	1.273	0.061	20.810	5.9439E-42

Summary	Intercept		Slope		Statistics
	Value	Standard Error	Value	Standard Error	Adj. R-Square
Germany	0.365	0.012	1.042	0.027	0.919
	Intercept		Slope		Statistics
	Value	Standard Error	Value	Standard Error	Adj. R-Square
Ghana	0.210	0.028	1.273	0.061	0.77

ANOVA		DF	Sum of Squares	Mean Square	F Value	Prob > F
Germany	Model	1	7.738	7.738	1407.687	7.63487E-69
	Error	122	0.67	0.005		
	Total	123	8.409			
		DF	Sum of Squares	Mean Square	F Value	Prob > F
Ghana	Model	1	7.751	7.751	433.058	5.94391E-42
	Error	122	2.183	0.017		
	Total	123	9.93			

displayed in Table 2. There is a difference in velocity between German and Ghanaian inflows based on statistical analysis. The findings differ from those of the studies mentioned above since they were made under density flows.

The study represents German and Ghanaian in Fig. 5 (a) (see Fig. 4). Germans always have a higher speed for density, despite the basic shape being similar. The data is presented here as density versus speed in the rest of the analysis. The study did it because a linear fit seemed more likely to be achieved with such a representation than with the speed-density data Fig. 5 (b) shows that the slope and intercept parameters of the linear regression fit to the Germans and Ghanaian data are significantly different in Table 2. In this article, we will find out the difference and provide a basis for understanding how these relationships are shaped across cultures and locations and how they differ.

The study represents African students in China and Germans in Fig. 6 (a). African students in China have a higher speed for a density; for example, with a low density of 0.624 (1/m), the velocity is 1.106±0.01 m/s, and when a dense density of 1.956 (1/m), the velocity is 0.311±0.02 m/s. At the same time, with the same densities for the Germans, velocities are 0.926±0.02 m/s and 0.154±0.01 m/s, respectively, regardless of the basic shape is similar—Table 3. Shows the summary of the analysis of African students in China R^2 is 0.631 (63%) while the Germans are 0.920 (92%); this research will find out the difference and provide not only a basis for understanding how these relationships are shaped across cultures and geographical location but also how they differ among them.

Similar to the analysis between African students in China and Germans, Germans and Ghanaians in Figs. 5 and 6, the study compared African students in China as Ghanaians here to understand, using the same densities, low density of 0.624 (1/m), velocity is 1.106±0.01 m/s. When the dense density of 1.956 (1/m), the velocity is 0.311±0.02 m/s, as again Ghanaians with the same densities, the velocities are 0.775±0.03 m/s and 0.225±0.03 m/s correspondingly. From the analysis, the study almost has the same shape. Fig. 7 (b) shows that the slope and intercept parameters of the linear regression fit to the data of African students in China and Ghanaians are significantly different.

6. Speed-headway analysis across

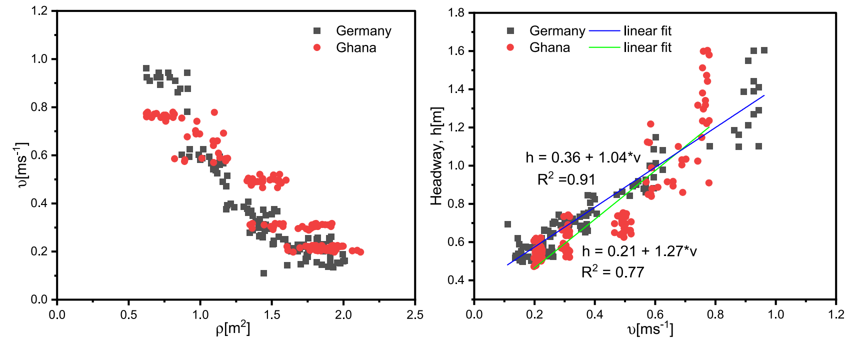
According to Ref. [1], Inverse density was used to define headway. In Figs. 5 (b), 6(b), and 7(b), the researchers present the velocity-headway relationships between the African students in China, Germans, and Ghanaian experiments form $h = a + bv$ for linear fitting where a and b represent the intercept and slope as shown in Tables 2–4 above with all the statistics, included t-statistic and R^2, as well as the velocity-headway relationships for several densities. Compared to Ghanaians who walk closely together in corridors with velocities of 0.775±0.03 m/s and 0.225±0.03 m/s, German maintains a greater distance of 0.926±0.02 m/s and 0.154±0.01 m/s. African students in China are 1.106±0.01 m/s and 0.311±0.02 m/s with the data provided. The following observation was made;

1. African students in China maintain a better distance in the experiments (between 0.51 m and 1.60 m) than Ghanaians.
2. German pedestrians kept a long distance in the experiments (0.68 m–1.7 m) than African students in China and Ghanaians.

According to Refs. [29–31] pedestrians, headway space is approximately 1.2 m–1.8 m, as shown in Fig. 9 with different scenarios. As a result, based on the experiment data, both location and cultural factors may have influenced pedestrian dynamics.

7. Location/cultural differences in speed–density relation

A culture factor is one of the factors that influence the fundamental diagrams (FDs) [3–5]. However, the study also wants to consider geographical location in this experiment. By comparing Ghanaian experiments and African students in China experiments with similar ones conducted by German [1] and Indian [2,3] researchers, the study could get a better understanding of how culture and geographical location affect behaviour [1,1,1]. Measurements can find density and velocity from the German experiments on the pedestrian dynamics data archive [1]. To make comparisons more straightforward same method is used. The study kept other comparable factors in evaluating the influence of geographical location and culture. The research compared India and Germany [2] with about the same density and Germany and Palestine with just about the same density, taking into account the differences in pedestrian



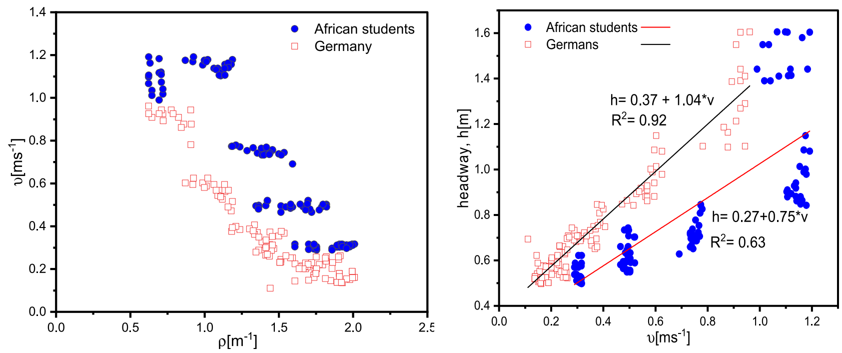
(a) Density-Speed relation (b) speed-headway relation

Fig. 5. (a) German and Ghanaian Speed-density data; (b) The distance headway-speed relationship is fitted linearly for German and Ghanaian data.

Table 3
shows the parameters and summary of the linear regression for African students in China and Germans.

Parameters		Value	Standard Error	t-Value	Prob>|t|
African students	Intercept	0.277	0.038	7.264	3.85553E-11
	Slope	0.748	0.051	14.637	1.24681E-28
		Value	Standard Error	t-Value	Prob>|t|
Germany	Intercept	0.365	0.012	29.573	1.75577E-57
	Slope	1.042	0.027	37.519	7.63461E-69

Summary	Intercept		Slope		Statistics
	Value	Standard Error	Value	Standard Error	Adj. R-Square
African students	0.277	0.038	0.748	0.051	0.634
	Intercept		Slope		Statistics
	Value	Standard Error	Value	Standard Error	Adj. R-Square
Germany	0.365	0.012	1.042	0.027	0.919



(a) Density-Speed relation (b) Headway-speed relation

Fig. 6. (a) Germans and African students in China Speed-density data; (b) For Germans and African students in China data, the distance headway-speed relationship is fitted linearly.

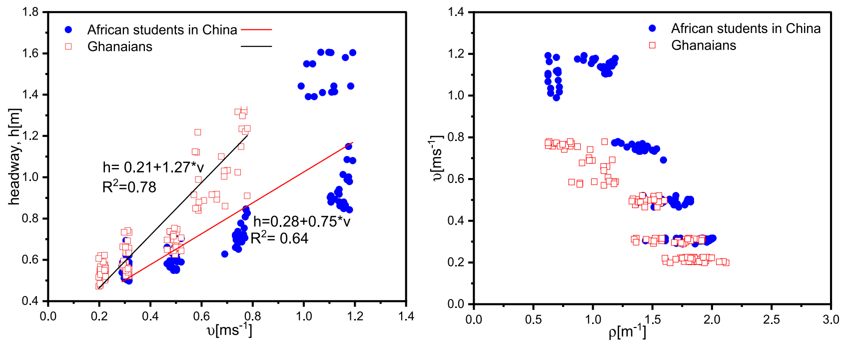
Table 4
shows the parameters and summary of the linear regression for African students in China and Ghanaians.

Parameters		Value	Standard Error	t-Value	Prob>|t|
African students in China	Intercept	0.277	0.038	7.264	3.85553E-11
	Slope	0.748	0.051	14.637	1.24681E-28
		Value	Standard Error	t-Value	Prob>|t|
Ghanaians	Intercept	0.210	0.028	7.291	3.36533E-11
	Slope	1.273	0.061	20.810	5.9439E-42

Summary	Intercept		Slope		Statistics
	Value	Standard Error	Value	Standard Error	Adj. R-Square
African students in China	0.277	0.038	0.748	0.051	0.634
	Intercept		Slope		Statistics
	Value	Standard Error	Value	Standard Error	Adj. R-Square
Ghanaians	0.210	0.028	1.273	0.061	0.77

dynamics based on the composition of the groups [32]. One noticed that the pedestrians were arranged systematically during Ghanaian experiments and African students in China. The numbers were the same as in the German experiment since we will use that data for comparison. German experiments downloaded data from the pedestrian dynamics data archive [1], an analysis of the fundamental diagram (FD) relationships between Palestinian and German experiments ref. [32] Of the report.

Fig. 8 illustrates each run of the German, Ghanaian, and African students in China experiments. All the densities were the same throughout all runs; for example, the study compared experiments, with 0.7 (1/m), the velocity for Germans was 0.940±0.02 m/s, Ghanaians velocity was 0.762± 0.01 m/s, and African students in China is 1.121± 0.01 m/s Compared to the Germen's. The Ghanaian's speed zone is tiny when walking. A second observation is that the Ghanaian's walking speed is heavily influenced by their density, but not the Germen's, since the spaces between individual runs seem to be shrinking. However, African students in China maintain a constant level of space.



(a) Density-Speed relation (b) Headway-speed relation

Fig. 7. (a) Ghanaians and African students in China Speed-density data; (b) For Ghanaians and African students in China data, the distance headway-speed relationship is fitted linearly.

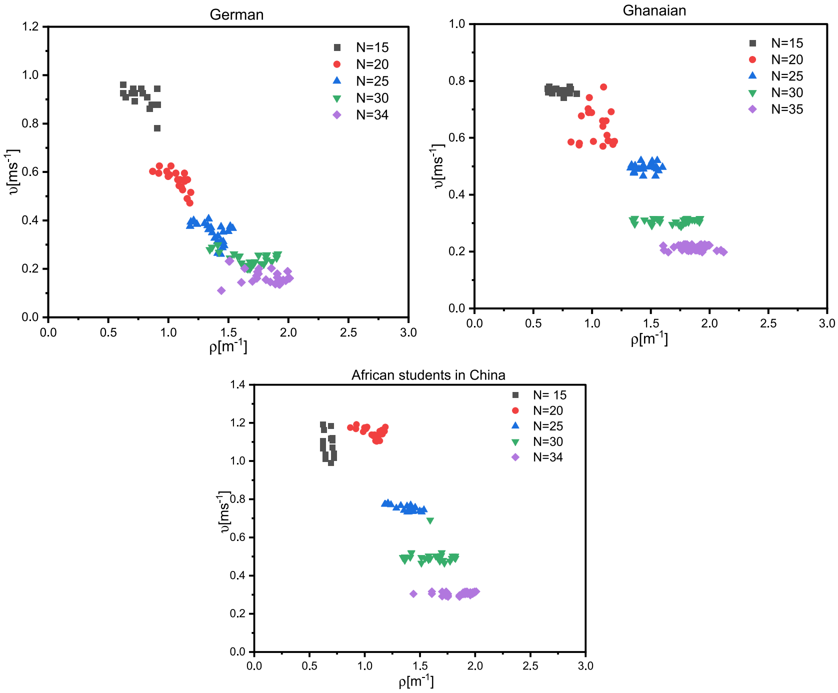


Fig. 8. Identify the density-speed distributions among German, Ghanaian, and African students in China.

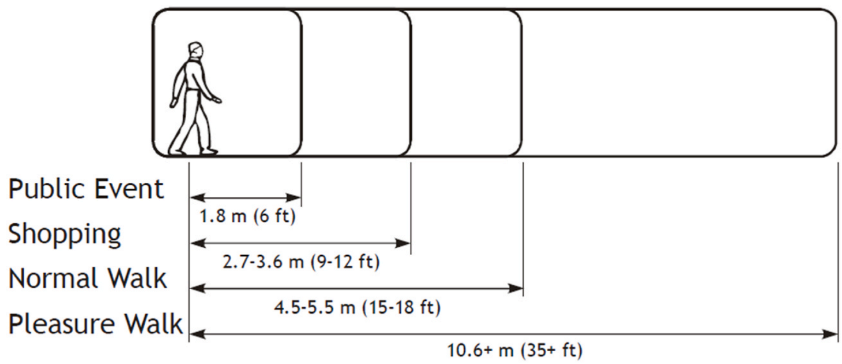


Fig. 9. An illustration of walking patterns among pedestrians in a variety of situations [19].

8. The flow rate

Throughout the experiment, they monitored flow rates at 0.8 m with a 17.3 m and 2 m circumference (observation section). The flow rate was determined by dividing the duration between the first and last pedestrians. Slow-moving pedestrians' flow rates were least affected by the circular—measured pedestrians' time and pace from a 2 m stretch of 17.3 diameters. As the quantity of pedestrians rises, the speed slows, and their combination slows the average pedestrian's flow. Slower pedestrians tend to have this propensity more.

In scenarios with more pedestrians, the flow rate decreases less. So, normal pedestrians must slow down to pass slower ones—narrow space limits path traffic and density.

Focus on pedestrian flow rate in groups (1, 15,20, 25, 30, and 35) with 0.8 m path width and 2 m observation section. African students in China pedestrians had a flow rate of 71% compared to 68% and 15–20 for Ghanaians, while the German flow rate was above 82%. But there was a similarity when pedestrians' numbers (density) were between 30 and 35; we have a 60–61% flow rate for all. If detour-distributed pedestrians have the same effect as a single-lane block, the flow rate should be around 80% without slow-speed pedestrians. The results reveal that pedestrians walk predictably, occupy a specified path area, and alter their walking behaviour based on speed, distance, and walking course. Around each density, the flow rate is high or low, but at 35, it lowers dramatically for both countries due to density disparity and pedestrian culture. High density means typical pedestrians can't pass strollers. Dense cases have a slightly lower flow rate than less dense instances. Since the way isn't thorough, normal pedestrians can't pass slow-speed pedestrians.

Repeated experiments under the same settings yielded similar findings. Density, cultural beliefs, and geographical location all affect the flow rate.

9. A study of the personal space across

9.1. Between Germans and Ghanaians

Table 5 below shows German personal space (a) to be 0.36 m with 0.21 m for Ghanaians. According to the standard errors, $S_{a^{Ger}}$ and $S_{a^{Gh}}$, respectively, for Germany, are just 0.01, and for Ghanaians, it is just 0.02. In this study, we tested the hypothesis that German minimum personal space, a^{Ger}, and Ghanaians' minimum personal space, a^{Gh}, are significantly different a^{Ger}-$a^{Gh}=0$ and the alternate hypothesis (H_1: $a^{Ger} \neq a^{Gh} = 0$). Because of the data obtained from experiments and the normality assumption, the research can presume that the expression is usually distributed.

The standard error for German is $S_{a^{Ger}}$, and the standard error for Ghanaians is $S_{a^{Gh}}$. When the calculated z value exceeds the table's z-critical value, it can reject the null hypothesis; otherwise not. According to formula (3) below, the z-value for a^{Ger}, a^{Gh}, $S_{a^{Ger}}$, and $S_{a^{Gh}}$ is 3.46. The confidence level of 91% means that 3.36 is more significant than 1.96, thus rejecting the null hypothesis. There is little difference between Germany and Ghanaians. Therefore, one should observe some jam-density similarities between Germans and Ghanaians.

$$z = \frac{a^{Ger} - a^{Gh}}{\sqrt{S^2_{aGer} + S^2_{aGh}}} \tag{3}$$

9.2. Between Germans and African students in China

Germans' personal space (a) is 0.36 m, and that of African students in China is 0.27 m reference Table 4. The standard error for Germans ($S_{a^{Ger}}$) is 0.01, and for African students in China ($S_{a^{ASC}}$) is 0.03 m independently, we tested the hypothesis of German personal space a^{Ger} and that of African students in China minimum space (a^{ASC}), which are the same a^{Ger}-$a^{ASC}=0$ and the alternate hypothesis (H_1: $a^{Ger} \neq a^{ASC} = 0$). As a result of the data obtained from experiments and the normality assumption, it can be presumed that the expression is usually distributed.

If the calculated z value exceeds the z-critical value from the table, the null hypothesis can be rejected; otherwise, it cannot. According to the above formula (3), the z-value for a^{Ger} a^{ASC}, $S_{a^{Ger}}$, and $S_{a^{Gh}}$ is 7.26. The null hypothesis is rejected because 7.26 is more significant than 1.96 at a 63% confidence level. There is a statistical difference between Germans and African students in China.

9.3. Between Ghanaians and African students in China

Using 8.1 and 8.2, the study obtained Ghanaians' personal space (a) to be 0.21 m with 0.27 m for African students in China. Ghanaians' standard errors ($S_{a^{Gh}}$) are 0.02, and African students in China's standard error ($S_{a^{ASC}}$) is 0.03; the tested hypothesis and personal space obtained from African students in China and Ghanaians were the same (a^{ASC}-$a^{Gh}=0$), and the alternate hypothesis (H_1: $a^{ASC} \neq a^{Gh} = 0$). They are using equation (3) for normal distribution and assumption. Can reject the African students in China Standard error and Ghanaians' standard error from the table above Null hypothesis if the z-value exceeds the z-critical value from the table; otherwise, not. From the table, all the value was used, and the z-value for all was 7.26, confidence was 77% level, the expression value was 5.13, and the null hypothesis was rejected since it is greater than 1.96. Therefore, there is a significant difference between Ghanaians and African students in China; consequently, one should observe the intense density difference between African students in

Table 5
Illustrating headway-velocity relationship with statistical measures.

		Value	Standard Error	t-Value	Prob>|t|
Germany	a(m) Intercept	0.365	0.012	29.573	1.75577E-57
	b(s). Slope	1.042	0.027	37.519	7.63461E-69
		Value	Standard Error	t-Value	Prob>|t|
Ghana	a(m) Intercept	0.210	0.028	7.291	3.36533E-11
	b(s). Slope	1.273	0.061	20.810	5.9439E-42

	Intercept		Slope		Statistics
Germany	Value	Standard Error	Value	Standard Error	Adj. R-Square
	0.365	0.012	1.042	0.027	0.91
	Intercept	Slope	Statistics	Intercept	Slope
Ghana	Value	Standard Error	Value	Value	Standard Error
	0.210	0.028	1.273	0.210	0.028

China and Ghanaians.

10. Distance-headway with speed changes

Based on distance headway (h) versus speed (v), coefficient b represents the change in speed. It is also possible to calculate this coefficient to measure the speed at which people react to constrained spaces. According to Tables 3–5, the analyses show that for Ghanaians , $b^{Gh} = 0.78$, Germens $b^{Ger} = 0.92$, and African students in China $b^{ASC} = 0.74$. The standard error of b is 0.06 for Ghanaians; in Germany, it is 0.02, and for African students in China, it is 0.03 separately. The null hypothesis ($H_o = b^{Ger} - b^{Gh} = 0$),the alternative hypothesis ($H_1 = b^{Ger} - b^{Gh} \neq 0$), ($H_o = b^{Ger} - b^{ASC} = 0$),the alternative hypothesis ($H_1 = b^{Ger} - b^{ASC} \neq 0$) and ($H_o = b^{ASC} - b^{Gh} = 0$),the alternative hypothesis ($H_1 = b^{ASC} - b^{Gh} \neq 0$)were tested. Similar to the previous section, the test proceeds along the same lines. For a two-tailed test, the z-critical at a 91% confidence level in the previous case is the same, with a z value of 3.36. Because z > z-critical, if there is no difference, can reject the null hypothesis between Ghana and Germany, the same test was conducted for African students in China and Germans with the two-tailed test z-critical at 63% confidence level and z-value of 7.26 and African students in China and Ghanaians similarly two-tailed test z-critical of 77% confidence level was obtained with z-value of 5.13. From the analysis, Ghanaians need more space to increase their speed than Germans, but African students in China have more superior to the two comparable. During increasing densities, Ghanaians decrease their speed more quickly than Germans and African students in China, which can be attributed to their more sensitive response to density.

11. The experimental groups' differences were compared using Hypothesis Testing

The *t*-test was used to demonstrate the location and cultural differences. An ANOVA (Nonparametric Repeated Measures) was conducted using the Friedman effect test. The p-value is, therefore, less than 0.0001 ($p<0.0001$), which is considered highly significant. Based on the chi-square distribution, the p-value is approximate. The speed of Germans, Ghanaians, and African students in China significantly differs ($p<0.001$). In comparing the three, namely Germans, Ghanaians, and African students in China, distance headway, the p-value is less than 0.001 ($p<0.001$), which is considered significant. Significant results are obtained from the hypothesis test.

12. Conclusion

The research examined the impact of location and cultural differences in fundamental pedestrian diagrams. The Fundamental diagrams that were study, for these research were from German, Ghanaian, and African students in China. A *t*-test and z-test were used to compare the results of all measurements statistically. A comparative analysis of three locations, Ghanaians, Germans, and African students in China, was done in a single-file movement. During this experiment, the following observation was made; The data revealed that locations and cultures differ in mobility. The pace of Ghanaian pedestrians is slower, with velocity 0.741 ± 0.01 m/s and 0.231 ± 0.02 m/s than that of German pedestrians, with 0.921 ± 0.02 m/s and 0.152 ± 0.03 m/s and African students in China 1.110 ± 0.01 m/s and 0.311 ± 0.03 m/s with density 0.62 (1/m) and 0.95 (1/m). However, with dense density, the Germans are faster than Ghanaians and African students in China.

Therefore, Ghanaians require a smaller personal space zone, enabling them to travel quicker than a similar density of German pedestrians and African students in China. The following information has been discovered by experiments on how locations/cultural factors have impacted pedestrians' movement behaviour: it has previously been believed that women move differently from men due to their cultural backgrounds [32]. However, this research could not verify this assumption in the study because the focus was on the locations and cultural impacts; although males and females displayed similar features, the study needed help digging deep into it.

12.1. *The experiments and data analysis show significant locations/cultural impacts on single-file pedestrian fundamentals*

The impact of culture/locational difference was the main purpose of the research, conducted between two countries located at a great distance [2,4], and significant differences were observed. In the future, more studies will be conducted to determine whether the different factors, such as education level, belief, convention, etc., between different countries of the same continent, can dissolve this assertion.

Author contribution statement

1 - Conceived and designed the experiments
2 - Performed the experiments
3 - Analyzed and interpreted the data;
4 - Contributed reagents, materials, analysis tools or data
5 - Wrote the paper.

Data availability statement

The data that has been used is confidential.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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