

Investigating pedestrians' obstacle avoidance behaviour

Abdullah Alhawsawi^{1,2}, Majid Sarvi¹, Milad Haghani¹, Abbas Rajabifard¹

¹Transport Engineering Group, School of Engineering
Department of Infrastructure Engineering
The University of Melbourne
Victoria 3010 Australia

aalhawsawi@student.unimelb.edu.au¹; majid.sarvi@unimelb.edu.au¹
milad.haghani@unimelb.edu.au¹; abbas.r@unimelb.edu.au¹

²Hajj and Umrah Institute, Umm Al-Quran University,
Makkah, KSA,
E:anhawsawi@uqu.edu.sa

Abstract - Modelling and simulating pedestrian motions are standard ways to investigate crowd dynamics aimed to enhance pedestrians' safety. Movement of people is affected by interactions with one another and with the physical environment that it may be a worthy line of research. This paper studies the impact of speed on how pedestrians respond to the obstacles (i.e. Obstacles avoidance behaviour). A field experiment was performed in which a group of people were instructed to perform some obstacles avoidance tasks at two levels of normal and high speeds. Trajectories of the participants are extracted from the video recordings for the subsequent intentions:(i) to seek out the impact of total speed, x and y-axis (ii) to observe the impact of the speed on the movement direction, x-axis, (iii) to find out the impact of speed on the lateral direction, y-axis. The results of the experiments could be used to enhance the current pedestrian simulation models.

Keywords: (Evacuation, Modelling, and Simulation, Crowd dynamic, Motion, Obstacle avoidance)

1. Introduction

Modelling and simulating the interaction of people around the physical environment are important issues in the study of crowd dynamics. The key issue is to design and build safe venues wherever crowd management rules are applied. For example, large gathering venues, schools, theatres, mosques, railway stations and alternative places are designed to have an entry and exit point.

Using physical obstacles is a common crowd control and management tool to navigate pedestrian flows. These include crowd control barricades, line management systems, entry control systems, temporary fencing and barriers. It's widely accepted that these measures facilitate, particularly in increasing the security in mass events [4]. According to Oksana [4], crowd control should think about several details to organize a safe and secure indoor or outdoor event.

Understanding the way in which obstacles size will affect pedestrian behaviour is important in nowadays, which can provide better evacuation management plan, comfort, and safety for the crowd. Investigating the effects of the obstacles in human behaviour have commonly used in many crowd simulation models. Crowd simulation models assist in predicting the crowd threats and in doing so reduce the deaths that may occur [1]. Many researchers had focused on the interaction of human behaviour, characteristics and phenomena in a complex geometrical environment to find the most common variables that led to the death or injury [2-8].

Many models are developed to explain the interaction of people, e.g., physical primarily based models [9], Social force model [10, 11], social cellular automaton [12-14]. Per people may well be delineated as Newton-like particles driven by forces [2]. These particles describe the interaction amongst the crowd. Several researchers have used these models due to promising results or well-acceptance. There are some delusive results found in these models, like interaction forces or geometries environment associated with the relative position of people.

Factors affecting how pedestrians respond to the environment or to others are in the beginning stages and not fully understood, and more human experiments are needed [15]. To do that, several experimental studies have been conducted on how pedestrians avoid obstacles [15] and collisions during their movements [15-19] using the recent technological approach of image processing to extract the trajectories [20]. The trajectories of the participants were extracted from recorded videos and analysed in two different levels of speeds, normal and high. Therefore, this paper studies the impact of speed on how pedestrians respond to the obstacles (i.e. obstacles avoidance behaviour).

A field experiment was performed during which a group of people were instructed to perform some obstacles avoidance tasks at two levels of normal and high speeds. Trajectories of the participants are extracted from the video recordings for the following intentions: (i) to find the impact of total speed (ii) to observe the impact of the speed on the movement direction, (iii) to find out the impact of speeds on the lateral direction. The results of the experiments could be used to enhance the current pedestrian simulation models.

2. Related works

2.1. Microscopic models

In microscopic models, each pedestrian in a crowd is treated as an individual agent holding a certain area during each time instant. These models are able to offer valuable insight over a wide range of behavioural inputs. The microscopic models deal with all the factors that take the pedestrians towards their goals or destination by respecting the interaction between pedestrians. Such models provide a more realistic description of pedestrian movements. In the most recent microscope models, individuals avoid obstacles, by avoiding collisions based on their positions [10].

The physical based models were studied and developed by [11] Helbing and Molnar. The model has been widely used in indoor environments, particularly in emergency and panic conditions [1]. This model provides better capabilities to design a strategic plan for the evaluation of pedestrians. In this model, an optimal acceleration is determined based on totally different physical force to apply the motion equations; then the simulation will be updated from time to time based on different steps and models, social force - models [11]. Therefore, this model can facilitate to provide better results to attain the aims of this study.

Social force model (SFM) is one of the most frequently used models in microscopic pedestrian studies. With the help of the self-stopping mechanism, a modification for upgrading this method is done day by day. The forces in the social model are not related to the pedestrian's personal environment but incorporated with an individual's performance to complete a certain action [8]. The basic concept of this model is motivating pedestrians to reach their goals. But the main assumption force for this model is that each agent has his/her own goals to reach a certain point at the target time.

2.2. Factors behaviour

The basic dynamics of the crowd activity may be characterized and influenced by numerous factors involving movement, speed, interactions. Based on the various situations, design, planning layout can be determined. Some of the several factors may include social factors, physical factors, and psychological factors [21]. The physical aspects of an individual are the most important attribute in the simulation process. It is essential that the simulation model incorporates these factors to ascertain human behaviour and patterns [22].

3. Methods

An experiment has been performed to grasp the behaviour of pedestrians throughout their movement through obstacles within the sports centre at the University of the Melbourne on 06/03/2017. The experiment procedure was approved by the Engineering Human Research Ethics Advisory Group. The experiment involved over 110 students of both genders moving in 120 m² area of square shape. The age group was limited to 21-25 years.

The movement of the participants was recorded at 50 frames per seconds by a video camera straddled at the experiment site. Special software, PeTrack [20], was used for tracking the position of participants. The program parameters were calibrated according to the experimental environments in the field. The program was set at the colour match mode and instructed to them to wear yellow and green beanies. The software provided a mass trajectory file of each experiment as the raw output data, based on which the subsequent analyses are performed [24].

The objective of this study is to examine the characteristics of individuals walking through several obstacles sizes and to evaluate the impact of an obstacle on human moving speed and on the individual's movement behaviours during high and low-density conditions. The data was collected from these experiments with a group of people walking and running through several sizes of the obstacles with different desired speeds scenarios, as shown in Table 1. The participants were ordered to enter a 50 cm size door and visit the opposite aspect bypassing obstacles with different sizes (1.2, 2.4, 3.6, 4.8 meters wide). In Fig.1. an extracted trajectory from the interface of the tracking software on and the trajectories in X (the Moving Direction) and Y (Lateral Direction) for all the participants from one door size of 50 cm and different obstacles sizes (a) Walking 1.2 m. (b) Running 1.2 m. (c) Walking at 2.4 m. (d) Running 2.4 m. (e) Walking 3.6 m (f) Running 3.6 m. (g) Walking 4.8 m (h) Running 4.8 m.

Table 1: Experiments scenarios

Entrance door size	50 (cm)	
Speed	Walking	Running
Obstacle Size	1.2 m (a)	1.2 m (b)
	2.4 m (c)	2.4 m (d)
	3.6 m (e)	3.6 m (f)
	4.8 m (g)	4.8 m (h)

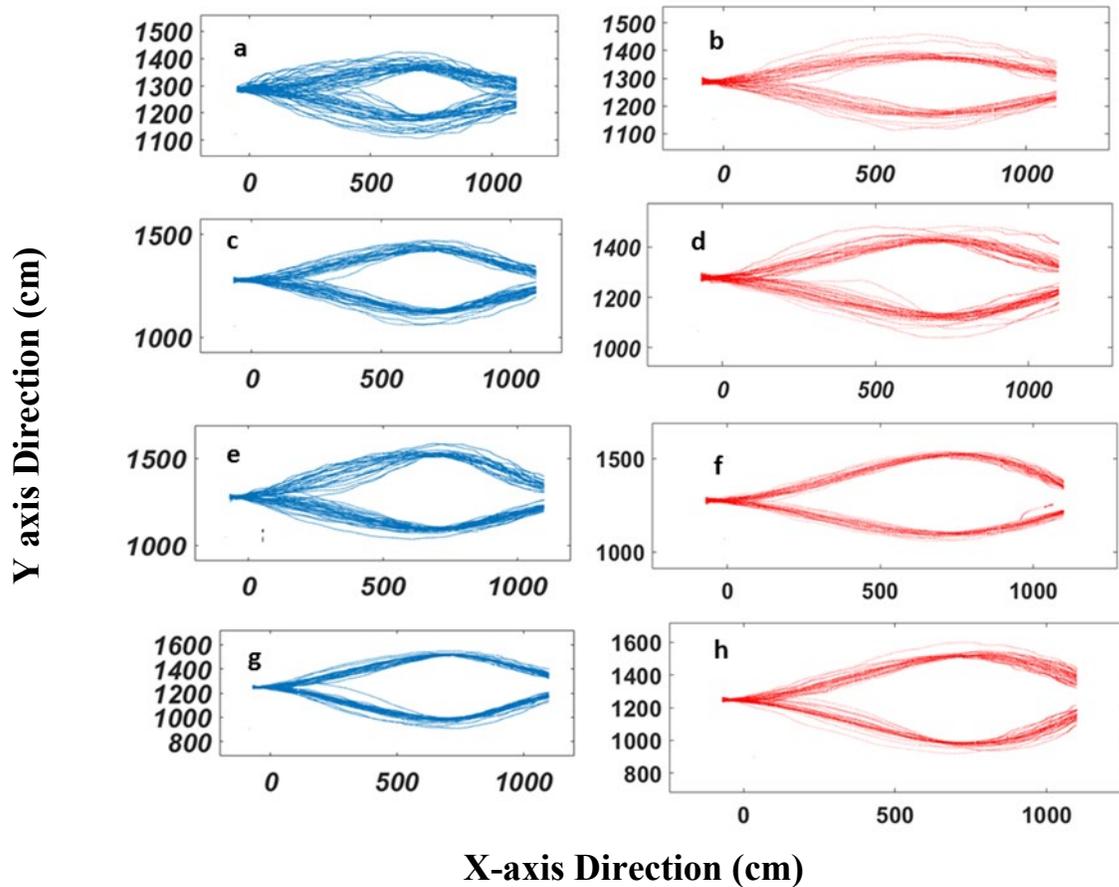


Fig. 1: Trajectories in X and Y direction for all the participants from one door size 50 cm and different obstacles sizes (a) Walking 1.2 m. (b) Running 1.2 m. (c) Walking at 2.4 m. (d) Running 2.4 m. (e) Walking 3.6 m (f) Running 3.6 m. (g) Walking 4.8 m (h) Running 4.8 m.

4. Results

4.1. Total speed

From the analysis of the extracted trajectories for all the participants, we have applied a method for measuring pedestrian speed in the direction with minimal scatter [23]. Then by averaging the area at every 10 cm managed to get all measurement within the whole area. A total speed (**x and y-axis**) was measured by applying the average speed in an ascertained area [23]. As can be seen in Fig 2. Walking speed was not significantly affected when participants moved towards the different obstacles ranged from the narrowest obstacle to the widest, as showing in fig 2 (a, b, c, and d) the total speed is not affected by the obstacles in the walking. The averages total waking speed in scenario (a) is 1.22 (m/s), (b) is 1.30 (m/s), (c) is 1.18 (m/s), and (d) is 1.31 (m/s). Obstacle had a more significant impact when subjects were running as showing in fig 2 (a, b, c and d). The total speed in scenario (a) is 2.66 (m/s), (b) is 2.16 (m/s), (c) is 2.55 (m/s), and (d) is 2.41 (m/s). From the results, walking speed has no significant variation in the walking scenarios (a, b, c, and d) which means moving towards different sizes of the obstacles is not affected by walking speed or obstacles had no significant impact when they were walking. On the other hand, the trends and patterns of speed in the running speed experiments as shown in (a, b, c, and d) had both changes meaning moving towards the different size of the obstacles affected the running speed. In summary, the results indicate that different obstacles size does not affect the participants while walking, but it does affect while the participants are running.

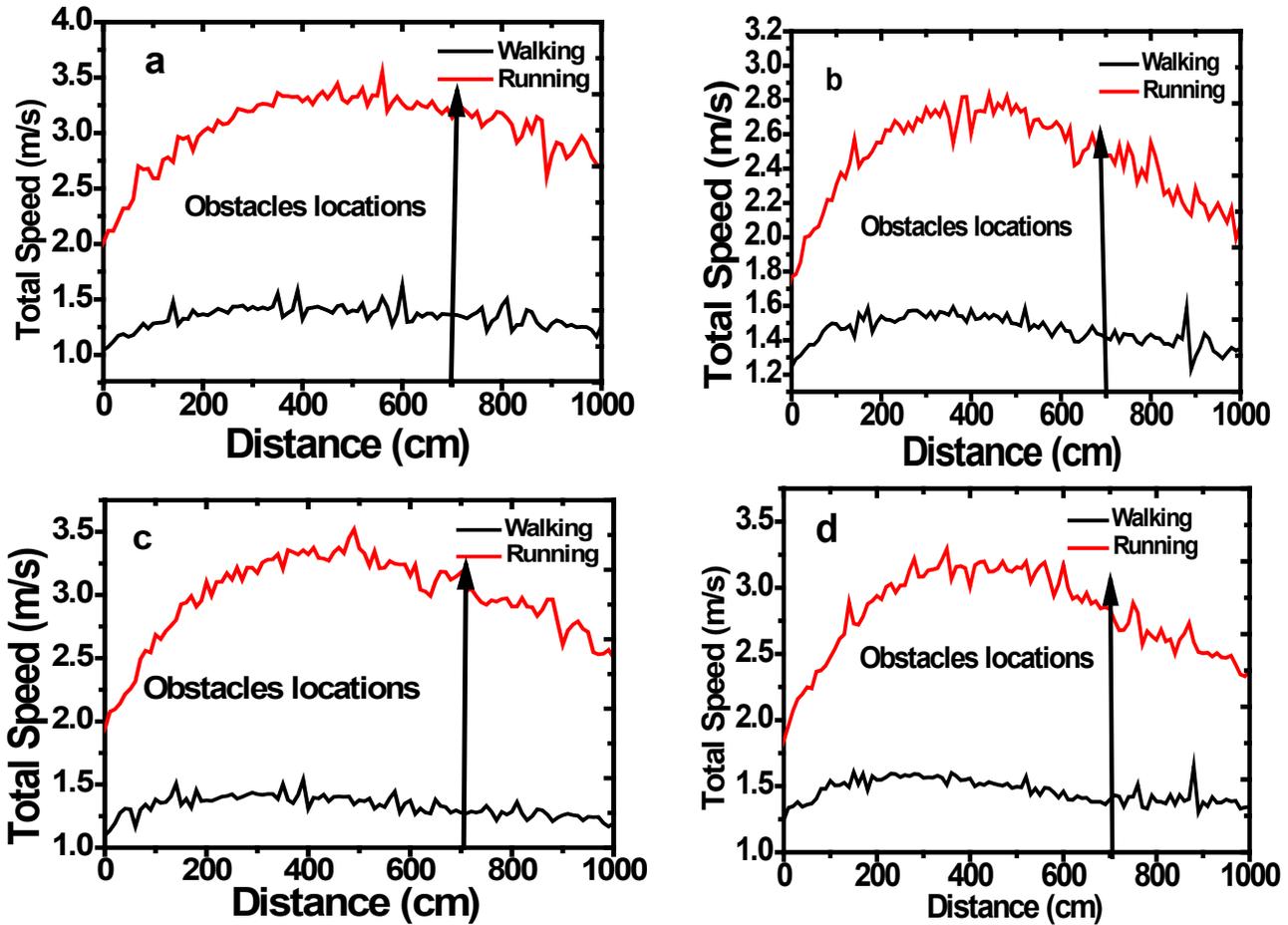


Fig. 2: Comparison of the total speed in (low vs high -speed) for difference obstacle size ((a) 1.2m, (b) 2.4m, (c) 3.6m, (d) 4.8m).

In Fig-3, we tend to additionally compare the impact of the size of the various obstacle in each low (a) high (b) speeds to visualize however the pedestrians responded to the various obstacles at the microscope level. The results show that in the low and high speeds, obstacle had an impression regardless of the speed. Most of the previous studies showed that there is no impact on walking. However, this study shows that even in low-speed condition, as shown in Fig 3 (a), there is an impact in both experiments. In low speed (a) experiments, obstacles had a less impact. Walking speed toward (1.2 and 3.6 (m)) obstacles have few speed changes that of (2.4 and 4.8(m)). In contrast, in the high-speed experiments in fig 3, (b) obstacle had a more impact, running speed toward (2.4 (m)) has few speed changes than that of (1.2, 3.6, 4.8(m)), therefore, more investigation is needed. In summary, results indicated that the total velocities are affected by the size of the different obstacle in both experiments walking and running.

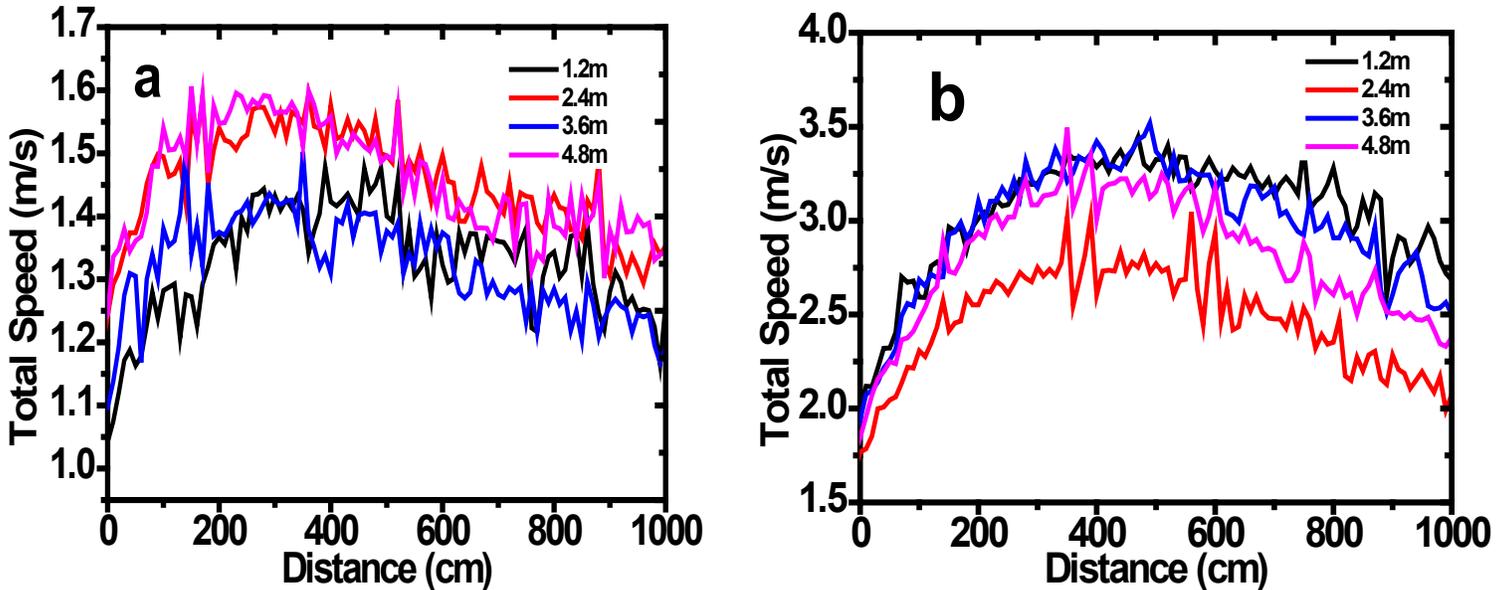


Fig. 3: Comparison of the total speed in all (low (a) and high (b)-speed) for difference obstacle size (1.2m, 2.4m, 3.6m, 4.8m.).

4.2. Speed in the Lateral Direction

In Fig 4, we also compared different speeds in low and high-speed experiments in the lateral direction. Obstacles had an impact on both cases. Walking and running velocities had the same impact when participants moved toward the different obstacles in the lateral direction (Y) axis. The obstacles arranged from the smaller obstacle to the largest, as shown in Fig 4 (a, b, c and d). In both experiments, the initial velocities have the same trends and patterns, they start to increase, then the speed drops down at the obstacles' locations, then the speed starts to increase to go back to the same trends and patterns. Our interpretation for that drop is that people are anticipating a collision point around them at the obstacle locations hence they would try to avoid the collision by dropping down their speed. In Fig 5, we compared, the low and high-speed experiments walking Fig 5 (a) and running Fig 5 (b) speeds to investigate more about the drop-down speeds at the location of the obstacle. The result shows that walking velocities had no impact when participants moved toward different obstacles. This means all the drop-down velocities are at the same point as shown in Fig 5 (a). In the running experiments, the drop-down velocities points are changed from point to another point based on the size of the obstacle as shown in Fig 5 (b). In Fig 6, we investigate the drop-down points by comparing the averages speed within the lateral direction, our results show a linear increased of the speed with the rise of the size of the obstacle in the path of the participants in low and high - speed experiments. The averages speed was impacted scientifically rise of the speed with obstacles size raised in low-speed experiments. However, in high-speed experiments, the averages speed had more affected when the participants were passing obstacles 3.6 -m and 4.8- m compared to the low speed -experiments, that was the reason for the previous drop-down points in Fig 5 (a) and (b). Therefore, high-speed experiments have more affected than low -speed experiments. In summary, the participants were affected by all the obstacles size at each experiment (walking and running).

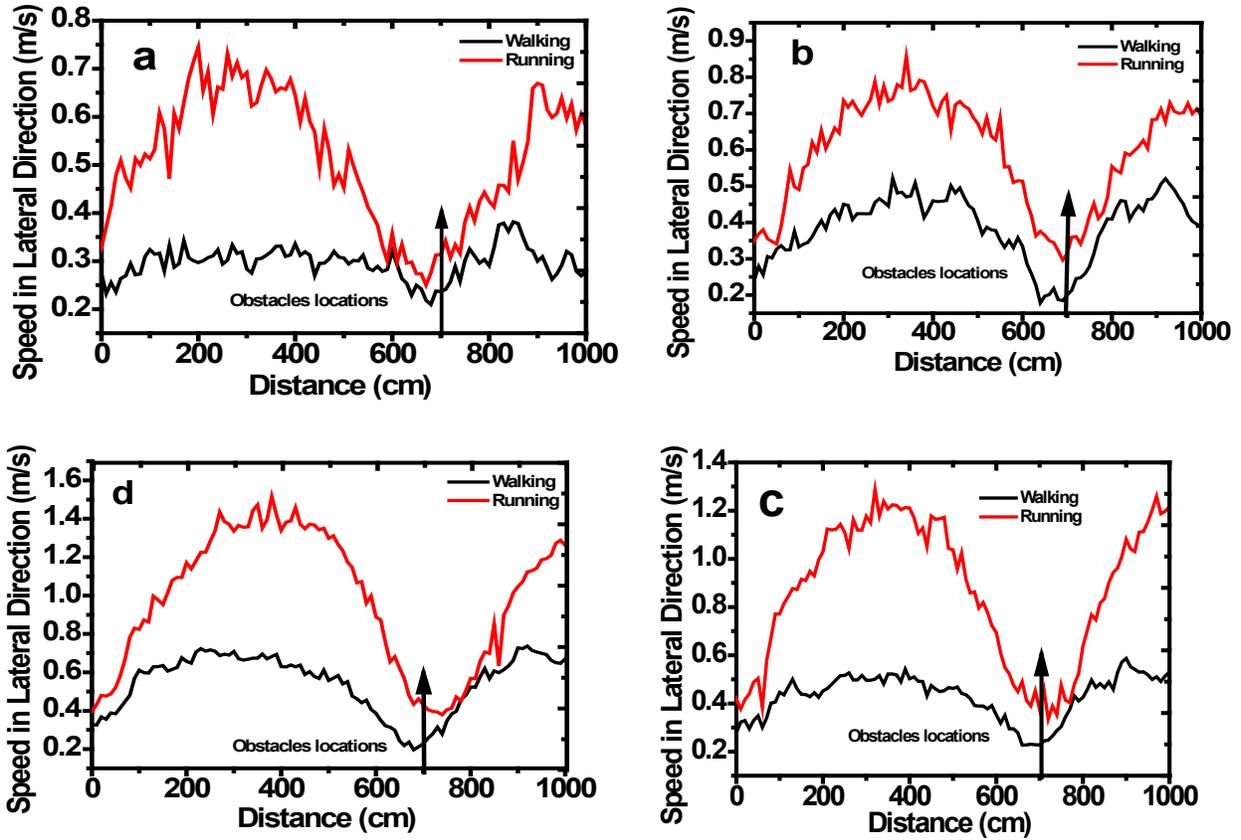


Fig. 4: Comparison of the speed - in (low- high) in the Lateral Direction (Y) axis, for difference obstacle size ((a) 1.2m, (b) 2.4m, (c) 3.6m, (d) 4,8m).

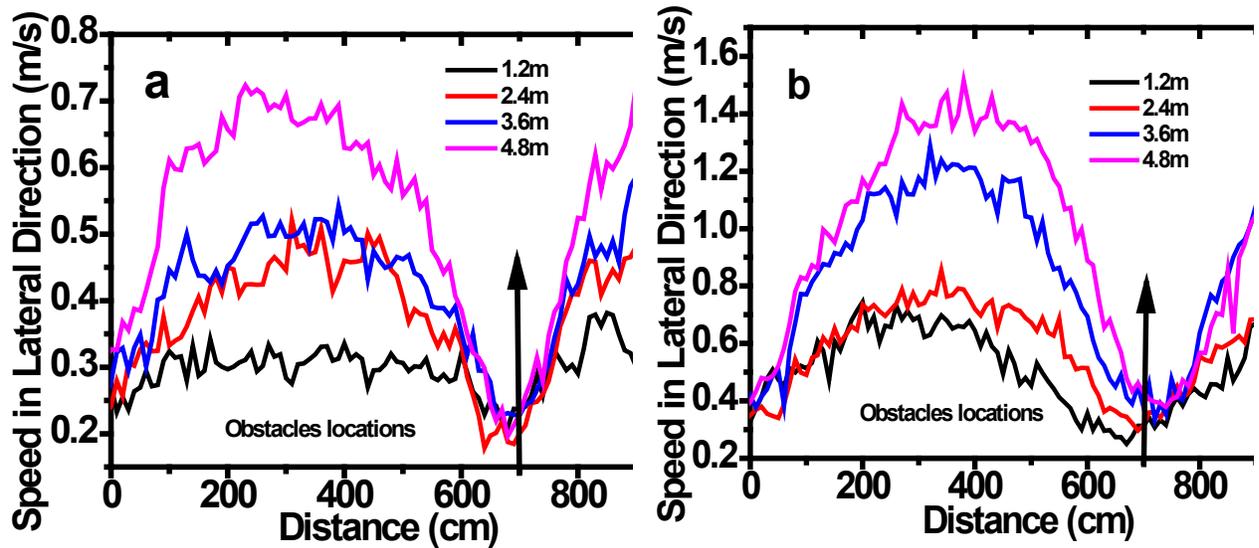


Fig. 5: Comparison of the Lateral speed in all (low (a) and high (b)-speed) for difference obstacle size (1.2m, 2.4m, 3.6m, 4,8m).

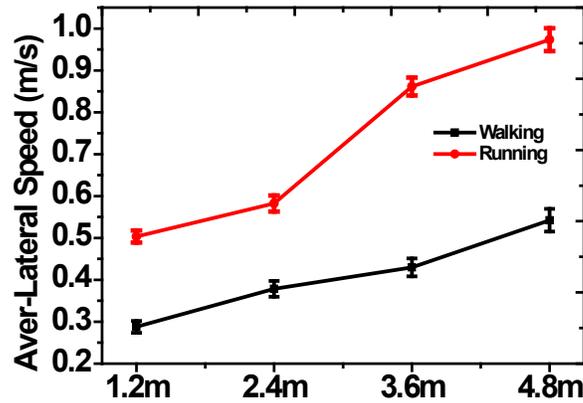
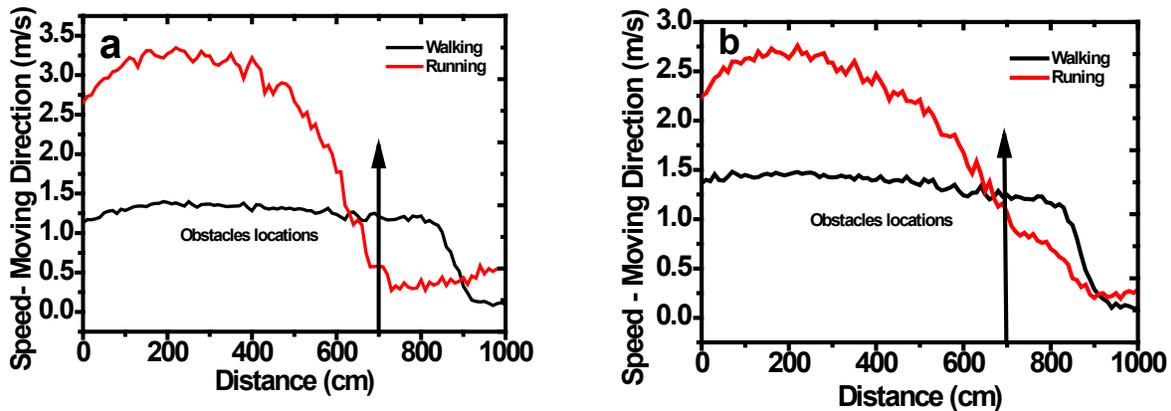


Fig. 6: Comparison of the Ave- speed in lateral speed - in (low-high) in the Lateral Direction (Y) axis, for difference obstacle size.

4.3. Speed in the Movement Direction

In this section Fig 7, we have a tendency to additionally compared the various speeds within the x-direction. It is found that obstacle had no impact on walking. There are similar trends and patterns for the velocities within the walking experiments in all eventualities (see Fig 7). However, obstacle had a lot of prevalent impact throughout running experiments. Running speed has a lot of affected within the trends and patterns in running experiments as shown in Fig 7 (a, b, c, and d) concluding moving toward completely different size of the obstacles is affected by running speed. Also, in Fig 8, we compared the effect of the size of the various obstacles in both experiments in the moving direction (X) axis, low (a) and high (b) speed to see how the pedestrians will respond to the different obstacles at the microscope level. The results show that within the low and high speed at Fig 8 (a and b) walking and running velocities are stricken by completely different obstacles. In low speed (a) experiments, walking speed have an impacted when participants moved toward the different obstacles. Walking speed toward (1.2 and 3.6 (m)) obstacle have few speed changes compared to that of 2.4 and 4.8- (m). However, within the high-speed experiments (b), running speed toward (2.4 and 4.8 (m)) has few speed changes compared to 1.2 and 3.6-(m) obstacle.



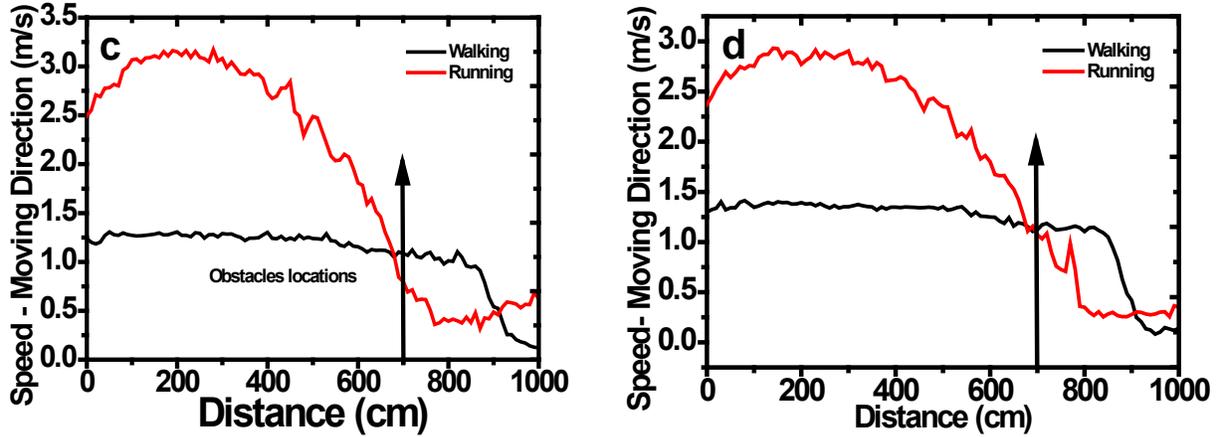


Fig. 7: Comparison of the speed - in (low Vs high) in the Moving Direction (X) axis, for difference obstacle size ((a) 1.2m, (b) 2.4m, (c) 3.6m, (d) 4,8m).

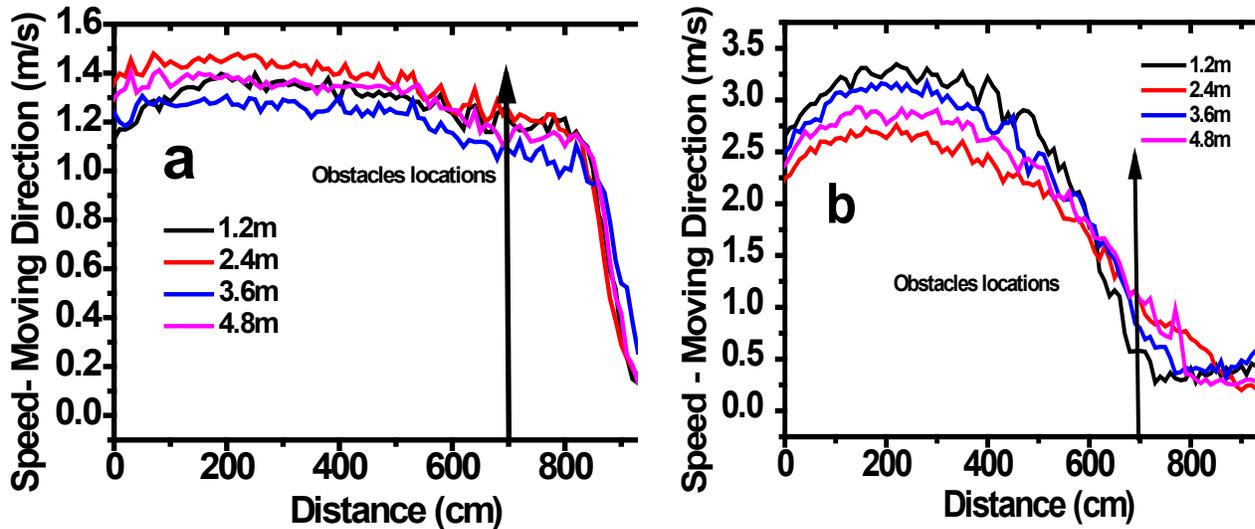


Fig.8: Comparison of the speed - in All (low (a)high(b)) in the Moving Direction (X) axis, for difference obstacle size (1.2m, 2.4m, 3.6m, 4,8m)

5. Conclusion

We experimentally investigated the walking characteristics of individuals through several obstacle sizes to evaluate the impact of an obstacle on human moving speed for both walking and running. We centred totally on the impact of the overall speed, speed within the moving direction, lateral speed. Our results show that obstacle had no vital impact on the overall speed once the participants were walking, in contrast, this impact was obvious for high-speed experiments (i.e. running). Results showed that obstacles would have an impact on lateral movements and it varies based on the speed of pedestrians.

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