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# Pedestrians' Microscopic Walking Dynamics in Single-File Movement: The Influence of Gender

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**Abstract:** Demographics of individuals could largely influence their behaviors and interactions with surrounding pedestrians. This study investigates the influence of pedestrians' gender on microscopic walking dynamics of single-file movements using the trajectory data collected from a controlled experiment conducted under different density levels. Instantaneous acceleration (with a time lag that varied from 0.12 s to 0.68 s) versus relative speed between the subject pedestrian and the pedestrian in front of him/her plots displayed significant correlations, which is analogous to the car following behavior, indicating that the relative speed is a key determinant of pedestrians' acceleration behavior. Time-delayed instantaneous accelerations and decelerations of pedestrians were modeled as functions of relative speed and spacing that are used in microscopic behavior models and gender using multiple linear regression. The outcomes revealed that in addition to relative speed, gender has a significant influence on instantaneous acceleration and deceleration for all density levels. Spacing displayed significant influence on acceleration and deceleration only for several density levels, and that influence was not as strong as relative speed. Males were likely to accelerate more and decelerate more compared to females for all density levels. The findings of this study provide important insights into gender dependence on microscopic walking dynamics. Furthermore, the results emphasize the importance of considering gender influence in microscopic behavior models.

**Keywords:** pedestrian behavior; gender effect; single-file movements; microscopic models; microscopic-walking dynamics; linear models

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## 1. Introduction

It is well known and generally agreed upon that the behavior of an individual in a crowd is determined by the interactions between individuals in the walking environment. As a result, local interactions between individuals lead to the emergence of global patterns of motion in a crowd [1]. This feature is used by the majority of microscopic pedestrian simulation models to predict the future state of a crowd, given its current state. In addition to interactions between individuals, geometric settings in walking environments could also influence walking behaviors [2]. Studies on how pedestrian crowds interact with various geometrical settings are of particular interest due to their prevalence in pedestrian facilities. To this end, a number of experimental studies have been carried out to explore the influence of common geometrical settings in the walking space, e.g., crossing [3–7], merging or T-junction [8–13], and turning [14–17] configurations under microscopic as well as macroscopic levels. In addition to these geometries, the influence of the width of the corridors [18–20] and exits [21–25] on pedestrian behaviors has also been well studied. Comprehensive reviews on experiment-based studies can be found in Shi et al. [26] and

Haghani [27]. These studies have mainly emphasized the microscopic behaviors specific to different geometric configurations, fundamental relationships, the bottleneck effect of different geometric features, and the self-organized phenomena arising as a result of the interactions between individuals moving through such configurations. Based on the outcomes of such empirical studies, several previous studies have attempted to incorporate the influences of different geometrical settings in microscopic behavior models [28–31]. As mentioned in Duives et al. [32], a crowd simulation model should be capable of reproducing the motions, which are specific to the geometrical settings of the walking space, and self-organized phenomena that might arise during crowd movements. Most of the time, these studies have treated different pedestrians similarly without taking into account their specific characteristics, e.g., age, gender, cultural background, etc. Individual behaviors and interactions could be significantly influenced by the characteristics of the individuals. Previous studies have highlighted that demographics, i.e., gender and age, have direct influences on walking speed [33–35]. These studies have shown that, in general, men walk faster than women, and younger people walk faster than older people. In addition to the studies on walking speed, several previous studies have investigated the influence of age, gender, and cultural background on walking behaviors. Using the data collected from a walking experiment on single-file movements, Zhang et al. [36] compared the fundamental diagrams and time-space diagrams for middle- and old-aged adults. They concluded that, although the trends were similar, the fundamental diagrams of these two groups were significantly different. Cao et al. [37] compared the fundamental diagrams of three groups, i.e., the young student group, the old people group, and the mixed group. The outcomes of this study indicated that the fundamental diagrams of the three groups cannot be unified into one diagram as there were significant differences between those three fundamental diagrams. Their results further indicated that the congestion occurred more frequently in the mixed group. Ren et al. [38] compared the walking dynamics of elderly people and other-aged people using the data collected from an experiment on single-file movement. Their results indicated that when changing speed, younger pedestrians are less sensitive to the space headway compared to older pedestrians. Furthermore, they claimed that not only age but also heterogeneity in terms of gender or culture could affect the walking dynamics. Subaih et al. [39] studied the effect of gender on the fundamental diagram using the data obtained from a single-file walking experiment conducted in Palestine. The results indicated that the gender effect on pedestrian fundamental relations was insignificant. Later, using the same empirical data, Subaih et al. [40] compared the speed-density diagrams for exclusive males, exclusive females, and mixed groups. This comparison revealed that because of social customs, male and female pedestrians tend to walk slowly when they are in a mixed-gender group. The outcomes of this study further indicated that factors, such as age and culture, could affect the movement of pedestrians. The outcomes of the study by Cao et al. [41] also highlighted that there was no significant effect of gender on fundamental diagrams. The recent study by Paetzke et al. [42] also examined the age and gender influences on pedestrian fundamental diagrams. The outcomes of this study explained that even though age could influence the fundamental diagrams, gender has no influence. Xue et al. [43] investigated the time-delayed speed correlation between consecutive leading and following pedestrians in a single-file crowd. They used the data collected from a single-file experiment conducted with German students in the 5th and 11th grades (11–12 years old and 17–18 years old, respectively). Their results indicated that the characteristic delay time depends only on the crowd density. However, demographics (age and gender) of the leading, and following pedestrians did not show any significant influence on it.

It can be noted that almost all these studies have focused on macroscopic characteristics, i.e., mainly related to fundamental diagrams of pedestrian dynamics. The influence of gender on microscopic behaviors has not been comprehensively studied so far. Microscopic walking dynamics are the underlying mechanics of microscopic pedestrian simulation models. This study aims to explore the effect of gender on microscopic walking behaviors when people walk in a mixed crowd. The data were obtained from a walking experiment on single-file maneuvers conducted under controlled conditions.

The paper is organized as follows: The next section will discuss the methods that include a description of the data and microscopic variables. This is followed by the results of the study. Finally, a discussion and conclusions are presented.

## 2. Methods

### *2.1. Data*

This study uses the data of the single-file walking experiment conducted by Subaih et al. [40] at the Arab American University in Palestine. The experiments' participants consisted of 26 females and 21 males from various university departments. A schematic diagram of the experiment setup is shown in Figure 1.

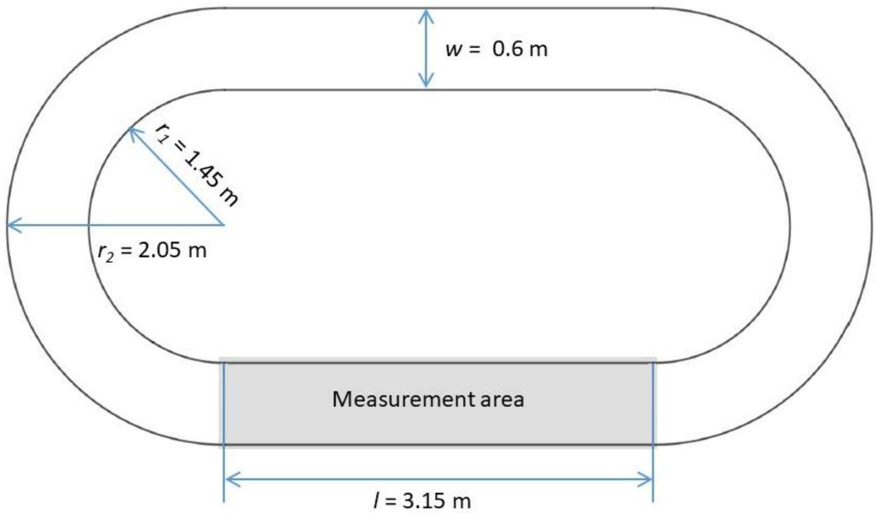


**Figure 1.** Schematic representation of the experiment setup (redrawn from Subaih et al. [40]).

The participants were placed one after another in an alternative way based on their gender and instructed to walk normally and not to overtake. That is, a male participant is led by a female, and a female participant is led by a male. Four experimental scenarios were considered depending on the total number of pedestrians walking within the experimental walkway, namely 14 (7 males and 7 females), 20 (10 males and 10 females), 24 (12 males and 12 females), and 30 (15 males and 15 females) participants on the walkway. These scenarios were named as N = 14, N = 20, N = 24, and N = 30, respectively. Global densities for these cases were 0.81 $m^{-1}$, 1.16 $m^{-1}$, 1.38 $m^{-1}$, and 1.73 $m^{-1}$, respectively. Several snapshots taken during each experiment scenario are shown in Figure 2. The entire series of experiments was video recorded, and the trajectories were extracted at 25 frames per second using an automatic tracking tool called PeTrack [44]. More details about the experiment setup and procedures can be found in Subaih et al. [40].

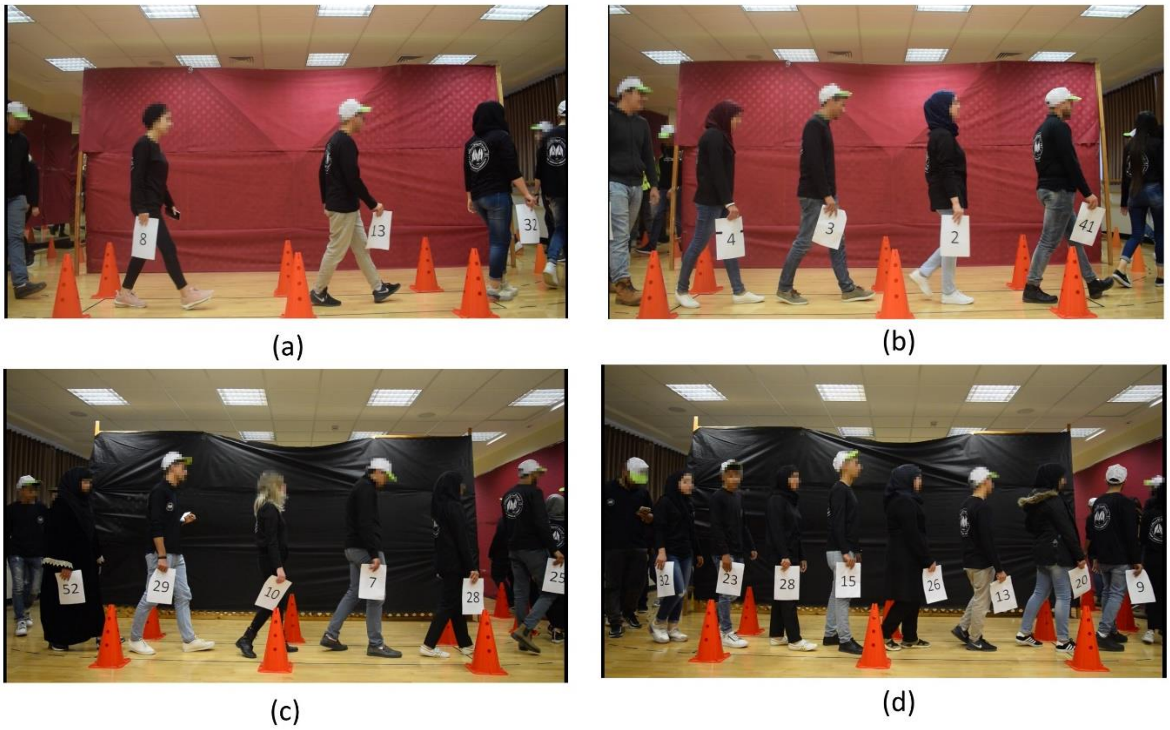


**Figure 2.** Snapshots taken during the experiment: (**a**) N = 14; (**b**) N = 20; (**c**) N = 24; (**d**) N = 30.

### *2.2. Microscopic Variables of Walking Behaviors*

The key assumption of this study, where a single-file movement is considered, is that the walking behavior of the pedestrian under consideration is determined by his/her interaction with the pedestrian in front. It should be noted that this is the key assumption of microscopic behavior models, e.g., the social force model.

From individual trajectories, microscopic variables are derived as follows:

$$s_{i,i+1}(t) = x_{i+1}(t) - x_i(t) \tag{1}$$

where, $s_{i,i+1}(t)$ is the spacing between leading and following pedestrians, $x_i(t)$ is the x-coordinate of the positions of pedestrian $i$, who is under consideration, at time $t$ and $x_{i+1}(t)$ is the $x$-coordinate of the positions of pedestrian walking in front of the pedestrian $i$ at time $t$.

$$v_i(t) = \frac{x_i(t + \Delta t/2) - x_i(t - \Delta t/2)}{\Delta t} \tag{2}$$

where, $v_i(t)$ is the instantaneous speed of the pedestrian $i$ at time $t$, $\Delta t$ = 0.4 s is the sampling interval.

$$a_i(t) = \frac{v_i(t + \Delta t/2) - v_i(t - \Delta t/2)}{\Delta t} \tag{3}$$

where $a_i(t)$ is the instantaneous acceleration of the pedestrian $i$ at time $t$.

### *2.3. Modeling Pedestrians' Interactions Using Multiple Linear Regression*

Instantaneous acceleration and deceleration of individual pedestrians were modeled as functions of several variables, i.e., the instantaneous walking speed of the pedestrian, the relative speed between the pedestrian under consideration and the pedestrian in front of him/her, spacing, and gender, using multiple linear regression. It should be noted that the instantaneous walking speed, relative speed, and spacing are widely used in microscopic simulation models, e.g., the social force model [45], to predict the motion of pedestrians. The general form of a linear regression model can be given as:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n \quad (4)$$

where, $y$ is the predicted or the dependent variable, $\beta_0$ is the intercept, $\{\beta_1, \beta_2, \ldots, \beta_n\}$ are the regression coefficients, $\{x_1, x_2, \ldots, x_n\}$ are predictor or independent variables.

In this study, the predicted variable is the instantaneous acceleration ($a_i(t+\tau)$), where $\tau$ is a time lag that was obtained using instantaneous acceleration versus relative speed plots for each individual. The independent variables are spacing ($s_{i,i+1}(t)$), instantaneous speed ($v_i(t)$), relative speed ($v_{i+1}(t) - v_i(t)$), and gender. Previous studies have also used linear relationships in microscopic behavior models. For example, Helly's car-following model [46] used a linear model to predict the acceleration behavior of a vehicle, and Duives et al. [47] modeled pedestrians' acceleration behaviors using linear models.

## 3. Results

### *3.1. Characteristics of the Microscopic Interactions*

The relative speed versus acceleration plot for an individual is shown in Figure 3. This is called the Lissajous diagram, and it can be observed that the correlation between instantaneous acceleration and relative speed improves when a time lag ($\tau$) is introduced to the acceleration. These plots are analogous to drivers' acceleration behaviors during car-following situations [48,49].

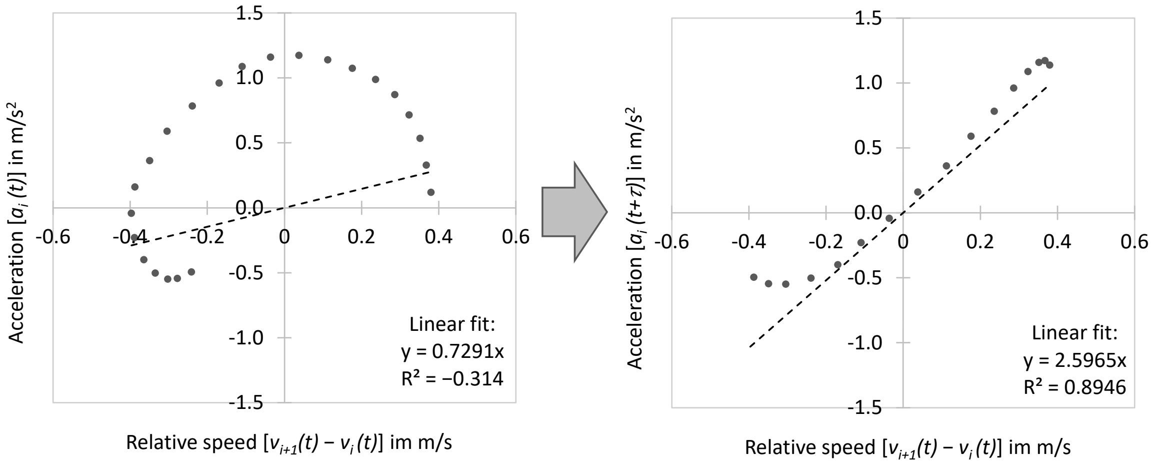


**Figure 3.** Relative speed versus acceleration plots for an individual pedestrian without and with a time lag.

For each individual, Lissajous diagrams were constructed, and relative speed versus acceleration plots were obtained. In this study, the time lag varied from 0.12 s to 0.68 s, and this difference could be due to individual characteristics. Even though such a time lag is incorporated in car-following models as "the reaction time", pedestrian simulation models do not specify such a time lag or reaction time. In pedestrian dynamics, this time lag may be comparable to the time delay specified as "visual-motor delay" in previous studies, e.g., Le Runigo et al. [50] and Rio et al. [51]. This value varied depending on the individual characteristics and was approximately set as 0.40 s [50,51]. However, Xue et al. [43] reported a higher average delay time for the speed correlation between leading and following pedestrian dyads, and the average time delay value in that study ranged from 0.75 to 0.84 s. Furthermore, according to Xue et al. [43], this time delay did not have any gender dependence.

Aggregated time-delayed acceleration versus relative speed plots for different density levels and genders are compared in Figure 4. As can be observed from the figure, the acceleration tends to increase with increasing relative speed for both genders. This means that people accelerate or decelerate more when the speed difference between him/her and the leading pedestrian is larger. Further, it can be observed that the accelerations (and decelerations) of males are higher than females in all cases, which indicates that the acceleration (and deceleration) capacities of males are higher.

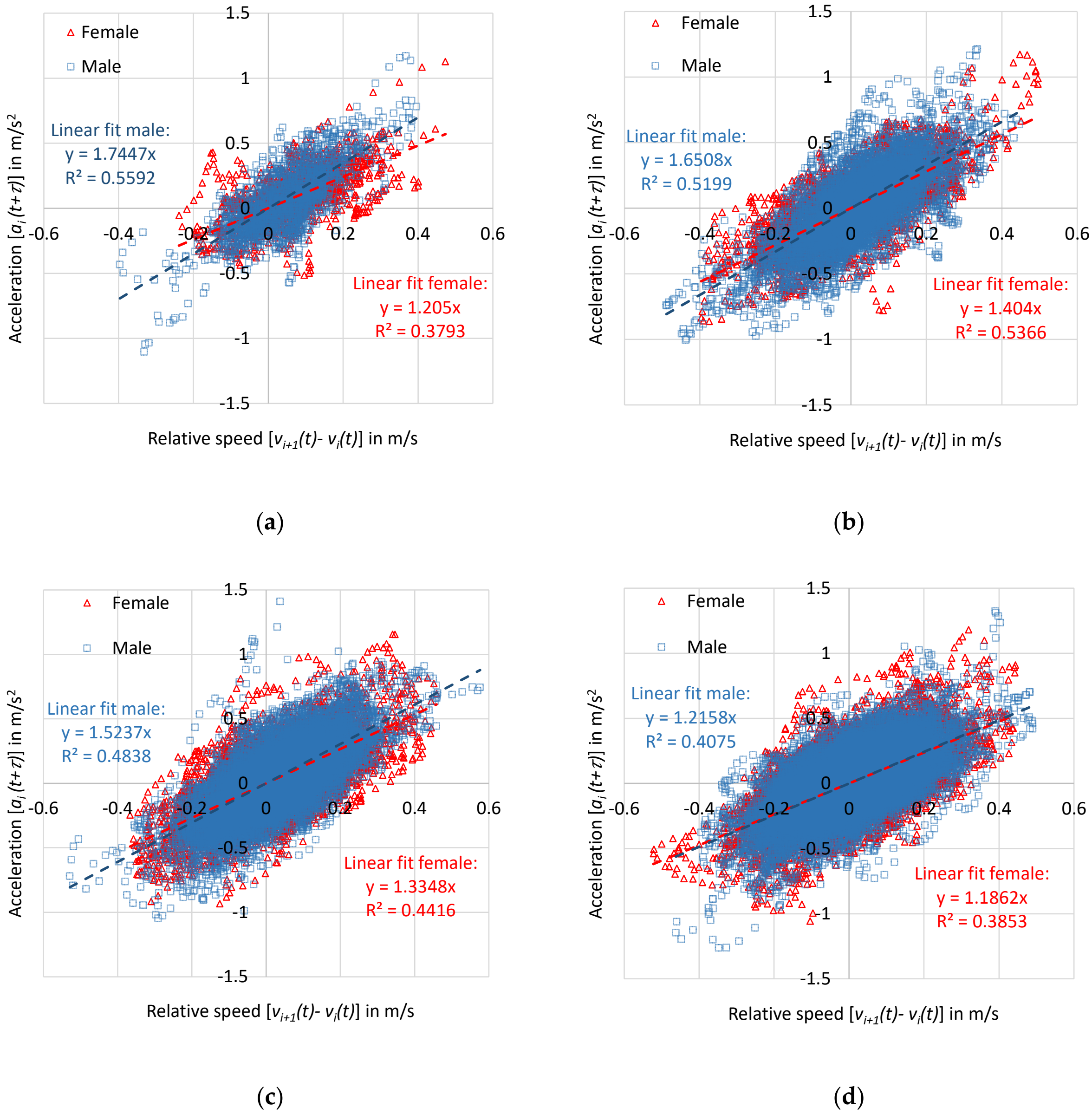


**Figure 4.** Relative speed versus time-delayed instantaneous acceleration plots for different density levels: (**a**) N = 14; (**b**) N = 20; (**c**) N = 24; (**d**) N = 30.

ANCOVA (analysis of covariance) tests were performed to compare the regression lines for males and females for the four density levels separately. The test results indicated that, for all density levels, there is a significant difference between the slopes of the regression lines for males and females. The test statistics, i.e., ($F$, $p$), for N = 14, N = 20, N = 24, and N = 30 scenarios were (12.14, 0.0005), (29.77, <0.0001), (42.66, <0.0001), and (16.97, 0.000038), respectively. It can further be noted that the slopes of the lines tend to decrease when the density level increases. This means that for a given relative speed, the acceleration and deceleration capacities decrease with increasing density.

Relationships between acceleration and walking speed for different density levels and genders are compared in Figure 5. It is clear that the walking speeds decreased with increasing density. Further, it can be observed that for all density levels and both genders the accelerations decrease with increasing instantaneous walking speed. In particular, when the speed is higher, people tend to decelerate more, and when the speed is lower, people tend to accelerate more. This observation is logical when general microscopic walking dynamics are considered. However, it should be noted that only walking speed may not determine the acceleration behaviors and the speed of the leading pedestrian, which is considered in relative speed, could also play a significant role.

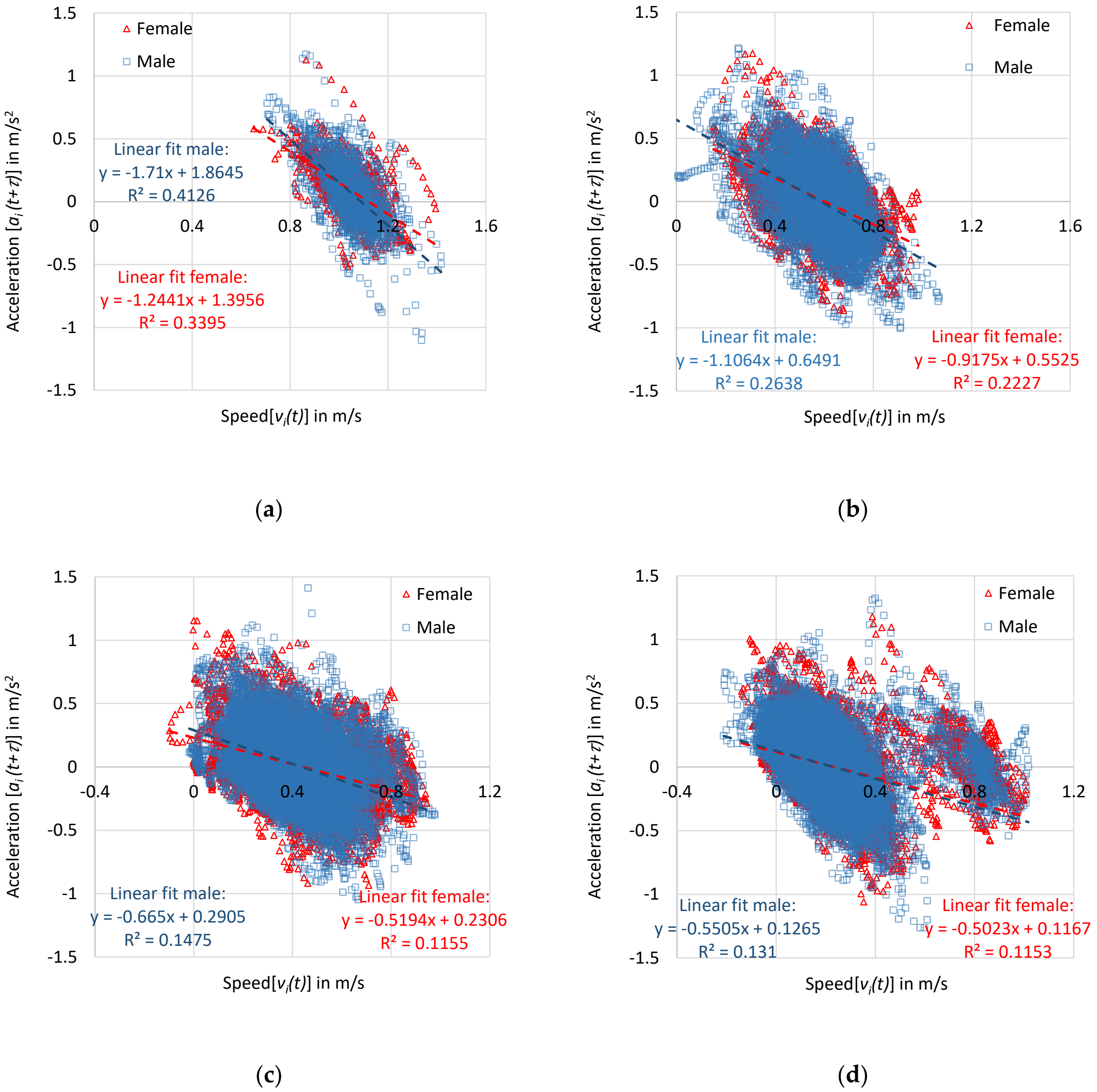


**Figure 5.** Instantaneous speed versus time-delayed instantaneous acceleration plots for different density levels: (**a**) N = 14; (**b**) N = 20; (**c**) N = 24; (**d**) N = 30.

As verified with the *t*-test, the slopes of the regression lines for males and females were significantly different for all cases. The test statistics, i.e., (*t-stat*, *p*), for N = 14, N = 20, N = 24, and N = 30 scenarios were (7.138, <0.001), (5.512, <0.001), (7.771, <0.001), and (3.576, <0.001), respectively. This outcome indicates that for a given walking speed level, gender has a significant influence on acceleration behavior and the acceleration (and deceleration) capacities are higher for males compared to females.

### 3.2. Outcomes of the Multiple Linear Regression Model

Eight multiple linear regression models were developed for acceleration and deceleration behaviors for four different density levels. It should be noted that the acceleration and deceleration were modeled separately to prevent the averaging effect of positive and negative values of the acceleration when they are modeled together. The predictor variables of the model were relative speed (DV), which was calculated as the speed of the leading pedestrian minus the speed of the pedestrian under consideration (i.e., $v_{i+1}(t) - v_i(t)$), spacing (DS), and gender, while the dependent variable was time-delayed instantaneous acceleration ($a_i(t+\tau)$). Males and females were coded as "0" and "1", respectively. To avoid multicollinearity, instantaneous speed ($v_i(t)$) was not used as a predictor variable because it had a significantly high correlation with relative speed and spacing. Outcomes of the linear regression models for acceleration and deceleration behaviors are described below.

- Models for acceleration behavior

Only the positive values of instantaneous acceleration ($a_i(t+\tau)$) were considered in these models, and four models were developed for the considered density levels. As shown in Table 1, the ANOVA results indicated that all four models for acceleration behavior were significant. The R-squared values were 0.428, 0.288, 0.243, and 0.189 for N = 14, N = 20, N = 24, and N = 30 cases, respectively. The highest R-squared value was found for N = 14 case (global density = 0.81 $m^{-1}$). All the predictor variables were found to be significant for all the density levels except spacing, which was not significant for N = 24 cases (global density = 1.38 $m^{-1}$). Gender was significant for all the density levels. The unstandardized coefficients for all the significant predictors are shown in Table 2. For all four density levels, relative speed and spacing had a positive association with instantaneous acceleration. That is, people tend to accelerate when the relative speed is increasing, or in other words, when the leading pedestrian's speed is higher. This is logical that an individual tends to accelerate to gain speed to reach the leading individual and to move ahead with the crowd when the individual's speed is lower than the leading pedestrian. The negative sign of the gender indicates that males are likely to accelerate significantly more than females for all the density levels. Spacing also had a positive association with instantaneous acceleration, which is logical that people tend to accelerate to gain speed when the spacing in front of them increases. Gender had the greatest significant effect on acceleration behaviors for the lowest density level, which decreased with increasing density levels.

**Table 1.** ANOVA results for the multiple regression models for acceleration.

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| N = 14 | Regression | 26.229 | 3 | 8.743 | 541.478 | 0.000 |
| | Residual | 35.086 | 2173 | 0.016 | | |
| | Total | 61.315 | 2176 | | | |
| N = 20 | Regression | 40.382 | 3 | 13.461 | 757.273 | 0.000 |
| | Residual | 99.719 | 5610 | 0.018 | | |
| | Total | 140.100 | 5613 | | | |
| N = 24 | Regression | 66.333 | 3 | 22.111 | 1433.751 | 0.000 |
| | Residual | 207.021 | 13,424 | 0.015 | | |
| | Total | 273.353 | 13,427 | | | |
| N = 30 | Regression | 64.867 | 3 | 21.622 | 1701.145 | 0.000 |
| | Residual | 278.269 | 21,893 | 0.013 | | |
| | Total | 343.136 | 21,896 | | | |

**Table 2.** Coefficients in the multiple regression models for acceleration.

| Model | | Coefficients | | t | Sig. |
|---|---|---|---|---|---|
| | | B | Std. Error | | |
| N = 14 | (Constant) | 0.048 | 0.014 | 3.480 | 0.001 |
| | DS | 0.067 | 0.011 | 6.295 | 0.000 |
| | DV | 1.072 | 0.027 | 39.274 | 0.000 |
| | gender | −0.050 | 0.005 | −9.214 | 0.000 |
| N = 20 | (Constant) | 0.085 | 0.010 | 8.539 | 0.000 |
| | DS | 0.088 | 0.012 | 7.607 | 0.000 |
| | DV | 0.791 | 0.017 | 46.529 | 0.000 |
| | gender | −0.027 | 0.004 | −7.418 | 0.000 |
| N = 24 | (Constant) | 0.134 | 0.005 | 24.581 | 0.000 |
| | DS | 0.009 | 0.007 | 1.286 | 0.198 |
| | DV | 0.706 | 0.011 | 64.663 | 0.000 |
| | gender | −0.010 | 0.002 | −4.539 | 0.000 |
| N = 30 | (Constant) | 0.110 | 0.003 | 42.342 | 0.000 |
| | DS | 0.036 | 0.004 | 9.916 | 0.000 |
| | DV | 0.523 | 0.008 | 69.504 | 0.000 |
| | gender | −0.003 | 0.002 | −1.960 | 0.050 |

- Models for deceleration behavior

In these models, negative values of instantaneous acceleration ($a_i(t + \tau)$), i.e., decelerations, were considered without the negative sign. Four models were developed for the considered density levels. All four multiple linear regression models of deceleration behaviors corresponding to the four different density levels were significant, as indicated by the ANOVA results (see Table 3). The R-squared values were 0.244, 0.343, 0.254, and 0.225 for N = 14, N = 20, N = 24, and N = 30 cases, respectively. All the predictor variables were found to be significant for all the density levels except spacing, which was only significant for N = 24 cases (global density = 1.38 $m^{-1}$). Further, gender was found to be significant for all the density levels. Table 4 shows the unstandardized coefficients for all the significant predictors. For all four density levels, relative speed had a negative association with instantaneous deceleration. Moreover, deceleration increases with decreasing relative speed. Decreasing relative speed means that the speed of the following pedestrian or the one under consideration is higher than the speed of the leading pedestrian. In such circumstances, pedestrians tend to decelerate or decrease their speed to avoid a collision with the leading pedestrian. The negative sign of the coefficient of the gender indicated that males were likely to decelerate significantly more than females for all the density levels (note: males were coded as "0" and females were coded as "1"). Gender had the greatest significant effect for N = 20 cases (global density = 1.16 $m^{-1}$). The spacing was significant (at 0.05 level) only for N = 24 cases, and the sign is negative, which indicates that pedestrians tend to decelerate more when the spacing is decreasing. However, it can be noted that the spacing is not significant for other density levels, and the influence is weak even for N = 24 cases as compared to other variables.

**Table 3.** ANOVA results for the multiple regression models for deceleration.

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| N = 14 | Regression | 3.099 | 3 | 1.033 | 124.576 | 0.000 |
| | Residual | 9.584 | 1156 | 0.008 | | |
| | Total | 12.683 | 1159 | | | |
| N = 20 | Regression | 46.374 | 3 | 15.458 | 893.690 | 0.000 |
| | Residual | 88.974 | 5144 | 0.017 | | |
| | Total | 135.348 | 5147 | | | |
| N = 24 | Regression | 52.049 | 3 | 17.350 | 1394.864 | 0.000 |
| | Residual | 153.253 | 12,321 | 0.012 | | |
| | Total | 205.302 | 12,324 | | | |
| N = 30 | Regression | 61.715 | 3 | 20.572 | 2027.086 | 0.000 |
| | Residual | 212.323 | 20,922 | 0.010 | | |
| | Total | 274.038 | 20,925 | | | |

**Table 4.** Coefficients in the multiple regression models for deceleration.

| Model | | Coefficients | | t | Sig. |
|---|---|---|---|---|---|
| | | B | Std. Error | | |
| N = 14 | (Constant) | 0.135 | 0.012 | 10.910 | 0.000 |
| | DS | 0.003 | 0.010 | 0.260 | 0.795 |
| | DV | −0.585 | 0.032 | −18.269 | 0.000 |
| | gender | −0.027 | 0.006 | −4.967 | 0.000 |
| N = 20 | (Constant) | 0.182 | 0.009 | 19.570 | 0.000 |
| | DS | 0.003 | 0.011 | 0.270 | 0.787 |
| | DV | −0.852 | 0.017 | −49.695 | 0.000 |
| | gender | −0.064 | 0.004 | −17.193 | 0.000 |
| N = 24 | (Constant) | 0.163 | 0.005 | 32.863 | 0.000 |
| | DS | −0.013 | 0.006 | −2.025 | 0.043 |
| | DV | −0.677 | 0.011 | −64.249 | 0.000 |
| | gender | −0.020 | 0.002 | −10.133 | 0.000 |
| N = 30 | (Constant) | 0.129 | 0.002 | 57.295 | 0.000 |
| | DS | 0.000 | 0.003 | −0.072 | 0.942 |
| | DV | −0.554 | 0.007 | −77.549 | 0.000 |
| | gender | −0.011 | 0.001 | −7.694 | 0.000 |

## 4. Discussion and Conclusions

Crowds in public places are diverse in terms of demographics, such as gender, age, culture, and socioeconomic characteristics, such as income level, occupation, travel purpose, and so on. The interactions between individuals in a crowd determine the global movement patterns of the crowd motion. Characteristics of the individual pedestrians could largely influence the microscopic interactions between individuals, and as a result, that will affect the macroscopic and global patterns of motion.

The purpose of this study was to determine whether pedestrians' gender influences the microscopic walking dynamics when they walk in a mixed-gender crowd. The trajectory data was obtained from an experiment on single-file movement that was conducted under four different global density levels. Key microscopic variables of walking dynamics, i.e., spacing, speed, and acceleration, which are widely used in microscopic pedestrian behavior models, were derived from these trajectory data. Multiple linear regression was used to model individuals' acceleration and deceleration behaviors as functions of relative speed, spacing, and gender. Eight regression models were obtained for acceleration and deceleration behaviors and for the four considered density levels separately. The gender and the relative speed were significant in all models, which indicated that these two variables are the key determinant of individual acceleration and deceleration behaviors. In particular, males are more likely to accelerate and decelerate than females when they are interacting with the opposite gender. Spacing was significant only for several models that indicated that the spacing was not a strong predictor of the acceleration or deceleration of a pedestrian in a single-file crowd of mixed genders.

In this study, individual pedestrians' time-delayed instantaneous accelerations were used as the dependent variable as it is the commonly used predicted variable in microscopic behavior models, such as car-following models [52] and force-based pedestrian simulation models [45]. One key outcome of the current study was that relative speed is the main determinant of acceleration and deceleration behaviors. Spacing displayed a marginal influence on acceleration and deceleration behaviors. These findings are consistent with the findings by Rio et al. [51], who modeled pedestrians' following behaviors using six car-following models. The outcomes of Rio et al. [51] indicated that the speed matching model [53], which explained that if the follower is traveling slower than the leader, they should accelerate, and if they are traveling faster, they should decelerate, performed better as compared to distance-based models. The spacing between the leading and the following pedestrian had no influence on the follower's behavior. However, simplified versions of the social force model used the spacing or the distance between pedestrians to predict interactive repulsive forces or accelerations, and relative speed is used to estimate pushing force when simulated agents are physically contacting [54]. Nevertheless, recent specifications of the social force model consider relative speed to estimate repulsive forces more realistically [55]. The behavior model proposed by Tang et al. [56] to simulate pedestrian following behaviors when they board an aircraft also considered the relative speed in addition to the optimal speed and the current walking speed of the pedestrian. The numerical results of this study indicated that the model that used the variables mentioned above could reasonably reproduce the dynamics of aircraft boarding behaviors.

Duives et al. [47] derived several linear regression models to predict change in speed, which can be considered a proxy for the acceleration and walking direction of a pedestrian. The outcomes of this study indicated that the absolute speed, distance headway (spacing), time headway, number of pedestrians located nearby, angle of sight, and angle of interaction are significant predictors of the change in speed and direction of a pedestrian. As can be noted, the result that the space headway or spacing is a significant predictor of the change in speed partially agrees with the outcomes of the current study. However, as we noted, spacing was not a strong predictor of acceleration behavior. Even though the absolute walking speed was not considered in the regression models presented in our study (as it had a high correlation with spacing), as shown in Figure 5, walking speed displayed a strong negative correlation with acceleration. This finding also agrees with the findings by Duives et al. [47], who established that absolute speed is a strong predictor of the change in speed.

There are several limitations to this study. Instead of a single model to predict acceleration behaviors, eight separate models were obtained in this study. As mentioned earlier, to avoid the averaging effect, acceleration and deceleration behaviors were considered separately. A single model should be able to predict pedestrian walking dynamics as most microscopic behavior models do. However, different density levels and acceleration and deceleration behaviors were considered separately to comprehensively explore the gender influence on walking dynamics. Furthermore, walking speed was omitted in the regression model due to multicollinearity. The linear relationship between spacing and speed, particularly when the spacing is less than 1.5 m, is well-studied in previous studies, e.g., Jelić et al. [57], Cao et al. [37], Cao et al. [58], and Paetzke et al. [42].

Culture may significantly influence the interactions of pedestrians in a crowd [40,59]. This study did not consider the cultural dimension of the gender influence on microscopic interactions, and future studies may explore such aspects. Furthermore, it should be noted, however, that the microscopic simulation models and statistical regression models perform differently. Thus, future studies may explore the acceleration (and deceleration) behaviors using microscopic simulation models incorporating gender as well as other parameters, including walking speed, relative speed, and spacing.

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