Playing with Mobile Phones: Investigation from Pedestrian Flow Experiments

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Abstract-In order to investigate the pedestrian behaviors, four large-scale pedestrian flow experiments were organized from 2016 to 2019, and different corridor widths of ring road were adopted. During the uni-directional experiments, it was observed that some pedestrians played with mobile phones (PPM). And then, some statistical results under high densities are collected, and the average proportions of PPM (AP-PPM) are calculated. It is found that in most runs, the numbers of PPM keep nearly constant and the AP-PPMs gradually decrease with the growth of densities. At the same time, the AP-PPMs increase with the growth of flow rates, which implies that AP-PPM could be considered as one important indicator for the states of pedestrian flow. This work can help to build the relationship between microscopic behaviors and macroscopic dynamics in the field of pedestrian flow.

Keywords-pedestrian flow; pedestrian behavior; experiment; playing with mobile phones

1 INTRODUCTION

The study of pedestrian flow has a very long history [1-3]. As one low-carbon transportation mode, it attracts the attention of many researchers from various fields. In order to make pedestrian movement efficient and safe, these researchers tried to investigate the properties of pedestrian flow by different methods. In recent days, more and more researchers conducted different types of pedestrian flow experiments [4-9], including the uni-directional flow, bi-directional flow, intersecting flow and bottleneck flow, etc. Since many parameters and conditions could be controlled in the experiments, it is easier to study the basic mechanisms of pedestrian movement by this method. Therefore, in this paper the experimental approach is followed.

Although lots of findings have been revealed in the previous papers [4-9], most of them just focus on the macroscopic and microscopic properties of pedestrians. The former level includes the averaged flow rates, speeds and densities of many pedestrians, etc. The latter one includes

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the speeds and trajectories of each pedestrian. However, the individual behaviors of pedestrians are usually ignored, which is one common deficiency of many researches.

For such a situation, it is necessary to do some investigations on the details of pedestrians' behaviors. At 2016, one large-scale pedestrian flow experiment on one ring road was performed, including the uni-directional and bi-directional conditions. The corridor width was 1.5m. During the experiments, one new phenomenon was observed: some Pedestrians Played with Mobile phones when moving forward (we will call it as PPM). This was beyond our expectations before the experiment, but also not strange in the current era, especially when the pedestrians thought the experiment was a little boring. After the experiments, some statistical results about this interesting phenomenon were collected, and it was found that the important relationship between the results of PPM and the collective dynamics of pedestrians. Thus we showed some preliminary conclusions about this topic in our previous paper [10].

But the main disadvantage of Ref. [10] is: the data collected is not enough for a comprehensive study. Therefore, in the following three years (from 2017 to 2019), three new pedestrian flow experiments with different corridor widths (1m, 2m and 2.5m) were conducted. Although our main goal was to study the macroscopic and microscopic features of pedestrian flow, the investigation of PPM was also important. In this paper, we will further study the data of PPM in the other three uni-directional experiments, and try to make one comparison between different groups of data. The findings may be helpful for understanding more about the essence of pedestrian flow.

This paper is organized as follows. The configurations of the four uni-directional experiments are introduced in Section 2. The statistical results of PPM and some related discussions are presented in Section 3. Finally, the conclusion is given in Section 4.

2 CONFIGURATIONS OF THE PEDESTRIAN FLOW EXPERIMENTS

In this section the configuration of all the pedestrian flow experiments is briefly introduced. From 2016 to 2019, a series of uni-directional and bi-directional experiments were conducted in the Jiulonghu Campus of Southeast University of China. In this paper the experiments conducted in 2017/2018/2016/2019 are named as Experiment A/B/C/D. Experiment A has the largest corridor width (2.5m), while Experiment D has the smallest one (1m), as shown in Table 1. The durations for all the experiments were about 2~3h. All of them were performed on one ring road, which can make the global density unchanged. Some plastic stools were used to form the boundaries, as shown in Fig.1. The inner radius of the ring road was always 2.0m, while the outer radius was determined by the corridor width used.

TABLE.1. THE BASIC INFORMATION OF ALL THE EXPERIMENTS

Name	Year	Corridor width (m)	Number of Participants	Maximum density (ped/m^2)
A	2017	2.5	358	7
B	2018	2.0	296	8
C	2016	1.5	278	9
D	2019	1.0	274	8

In each experiment, the total number of the participants was about 270~360, since it was very difficult to recruit more people at one time. This also makes the differences between the global maximum densities: for example, in Experiment A the global maximum density is only 7 ped/m^2. All the participants were the students from Southeast University, and their ages were between 18~24. In Experiment A, B, D (from 2017 to 2019), in order to save time, some other bottleneck experiments or single-file experiments were also performed on the same day. These experiments have no relationship with the uni- and bi-directional experiments mentioned in this paper, and the related discussion could be found in Ref. [11-12].

Figure 1. The configuration of the uni-directional experiments: Run B-5-2 at 2018, T=2:15.

During the experiments, one unmanned aerial vehicle (UAV) was used to record the data. It always hovered over the center of the ring road, which can minimize the errors. The experimental video is 25 frames per second, and the resolution is 2704*1520. Therefore, the details of each pedestrian could be identified in the video.

In all the experiments, firstly the uni-directional experiment was performed, and all the pedestrians just moved forward together. After some minutes, the participants were asked to stop, and then, the bi-directional experiment started. This is the reason why these pedestrians wear caps of different colors in Fig.1: the ones with blue caps would turn around and move, while the ones with red caps continued moving forward. Since the bi-directional experiments are much more complex than uni-directional ones, in this paper only the results of PPM in the uni-directional experiments are discussed.

The details of some uni-directional runs are shown in Table 2. The name of each run means “name of the experiment-predetermined density-order of the run.” For example, “A-7-2” means that the predetermined density of the second run was ρ_p=7 ped/m^2 in the uni-directional Experiment at 2017. For all the high-density experiments ($\rho_p \geq 5\mathrm{ped/m^2}$), two rounds were conducted: the moving direction of 1st/2nd round in the uni-directional situation is anti-clockwise/clockwise. For all the low-density experiments ($\rho_p < 5\mathrm{ped/m^2}$), only one round is enough. Note that the actual density and the number of pedestrian used in some runs are a little different from the predetermined values. The reason is that there were too many participants, and we did not have enough time to count the number of participants before each experimental run. These differences have no influence on our experimental results. Besides, in Table 2 only the runs under high densities were presented, which are more important for our study.

TABLE 2. THE DETAILS OF SOME UNI-DIRECTIONAL RUNS IN THE EXPERIMENTS

Run number	Actual Density (ped/ m^2)	Number of pedestrians used	Run number	Actual Density (ped/ m^2)	Number of pedestrians used
D-8-1	8.03	126	C-8-1	7.69	200
D-7-1	6.50	102	C-7-1	6.27	163
D-6-1	5.67	89	C-6-1	5.65	147
D-5-1	4.27	67	C-5-1	4.85	126
D-8-2	7.45	117	C-8-2	7.65	199
D-7-2	6.69	105	C-7-2	6.42	167
D-6-2	5.61	88	C-6-2	5.69	148
D-5-2	5.03	79	C-5-2	4.73	123
B-8-1	7.8	294	A-7-1	6.99	357
B-7-1	7.09	267	A-6-1	5.79	296
B-6-1	5.94	224	A-5-1	4.85	248
B-5-1	4.64	175	A-7-2	7.01	358
B-8-2	7.83	295	A-6-2	5.89	301
B-7-2	6.66	251	A-5-2	4.87	249
B-6-2	5.55	209			
B-5-2	4.72	178			

In the experimental video, the phenomenon of PPM can be observed. At one given time instant, the pedestrians can be marked by yellow circles, as shown in Fig.2. Sometimes it is not easy to make a judgement on a static snapshot (especially when the density is very high). For such a situation, we try to check more details by playing the video for several times.

Figure 2. One example for marking the pedestrians who are playing with mobile phones in the uni-directional experiments: Run B-5-2 at 2018, T=2:15.

3 STATISTICS OF PEDESTRIANS WHO PLAYED WITH MOBILE PHONES

Firstly, some microscopic results are shown. The time series of the numbers of PPM in some typical runs are presented in Fig.3, and the time interval for collecting data is 15 seconds. Here the predetermined density is 7 ped/m^2, and the differences between four curves mainly come from the corridor widths and the total pedestrian numbers. It can be seen that in these runs, although the time durations are quite different, all the numbers of PPM keep nearly constant with time. This situation is similar to that of the averaged flow rates in the uni-directional experiments: usually their fluctuations are low.

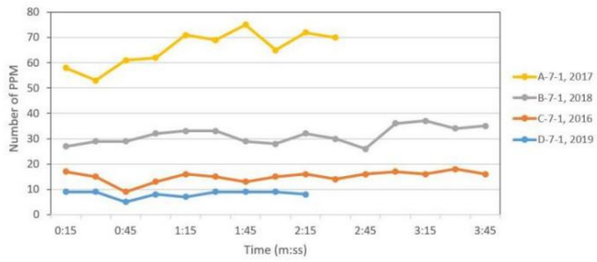
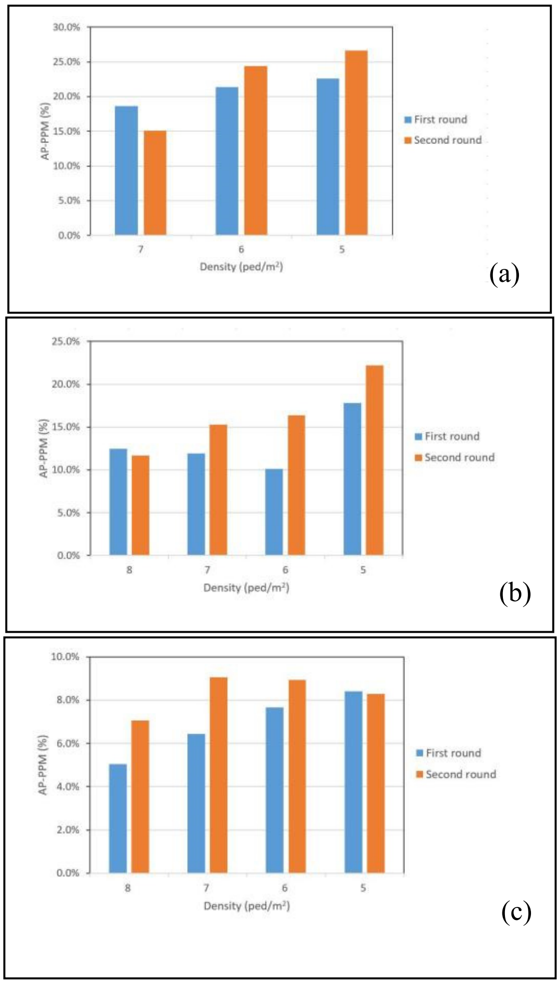


Figure 3. The numbers of PPM in some typical runs when . (a) A-7-1 at 2017; (b) B-7-1 at 2018; (c) C-7-1 at 2016; (d) D-7-1 at 2019.

Therefore, it is possible to use the average values to represent the results. Here we call the Averaged Proportion of PPM in one uni-directional run as AP-PPM. It is calculated by the average number of PPM divided by the total pedestrian number. In Fig.4 it is found that for most cases, the AP-PPMs in the second round are larger than that in the first round. It is not strange that in the second round, pedestrians gradually become familiar with the experimental configuration. Thus more pedestrians choose to do something else. Besides, the density has important influence on the results: for most cases, AP-PPM grows when the density decreases. It is easy to understand that under high densities, pedestrians may feel uncomfortable. Thus it is much more difficult to move forward when playing with mobile phones.



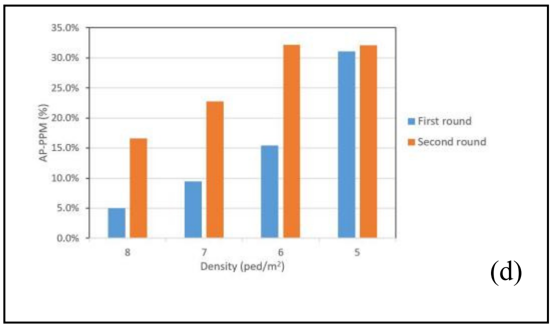


Figure 4. The results of AP-PPM in the runs under high densities. (a) Experiment A at 2017; (b) Experiment B at 2018; (c) Experiment C at 2016; (d) Experiment D at 2019.

Next, the relationship between the results of AP-PPM and other traffic flow parameters will be discussed. Here the results of linear regression by four straight lines are shown in Fig.5. The relationship between AP-PPMs and densities is not linear, but we just want to emphasize the general tendencies of these data by this approach. Similar to Fig.4, it could be found that the AP-PPM decreases when the density grows. And then, it is clear that the AP-PPMs of 2016 are much lower than all the others, and the maximum values of AP-PPMs are reached at 2019. This could reveal the fact that during the four years, mobile phones become more and more popular among the young students. Besides, the distribution of data points also show that the influence of corridor widths on PPM is not significant in the experiments, especially when the statistical results of W=1m (Experiment A) and W=2.5m (Experiment D) are similar.

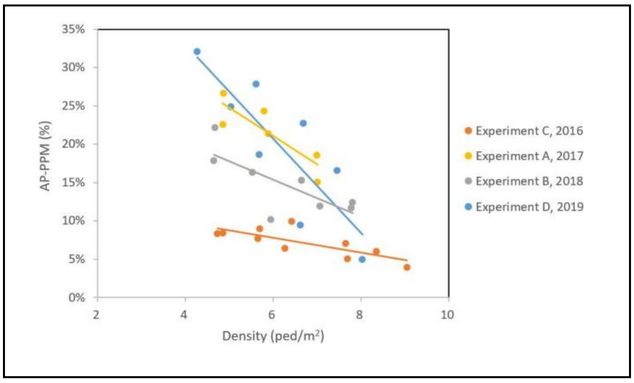


Figure 5. The relationship between AP-PPMs and densities in the four experiments.

Finally, the relationship between flow rates and AP-PPMs is shown in Fig.6. Here the results of linear regression are also shown. Although the data are obtained from four different groups of pedestrians, it is interesting that the slopes of four straight lines are all positive, and the values are close to each other. Usually some people think “playing with mobile phones make pedestrian walk more slowly”. However, in our experiments the conclusion is different: under high densities, more pedestrians play with mobile phones when they can move faster. This is one reasonable result: in other words, the change of AP-PPMs can indicate the change of traffic flow states. For such a situation, the bridge between microscopic behaviors and macroscopic states is built in the field of pedestrian flow.

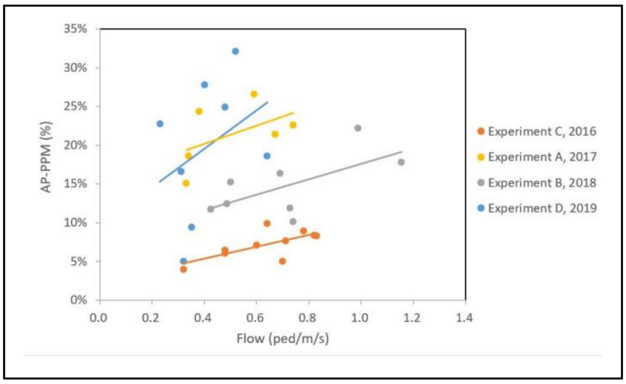


Figure 6. The relationship between AP-PPMs and flow rates in the four experiments.

4 CONCLUSION

In this paper the phenomenon of "pedestrians playing with mobile phones" (PPM) in four pedestrian flow experiments is discussed. The data of PPM under high densities are extracted from the video of the uni-directional experiments. For most runs, the numbers of PPM keep nearly constant from the beginning to the end. And then, the AP-PPMs in different runs are compared and discussed. They gradually decrease with the growth of densities, while the influence of corridor widths is not significant. Finally, it is found that under high densities, the AP-PPMs increase with the growth of flow rates. It implies that AP-PPM could be considered as one important indicator for the states of pedestrian flow.

Although lots of findings have been presented in this paper, there are still some problems. For example, in this paper only the uni-directional flow is considered. In the future, it is necessary to consider some more complex situations (including the bi-directional flow, bottleneck flow, etc.), and try to check whether the phenomena and conclusions qualitatively change or not. Besides, whether the pedestrians choose to play with mobile phones not only depends on the surrounding traffic states. It is also related to their personal preferences. In the future it will be helpful to collect more data about the pedestrians' own characteristics, and check their influences on these behaviors. Maybe questionaries could be useful.

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