Experimental investigation on information provision methods and guidance strategies for crowd control

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Abstract. Recent improvements in crowd sensing and dynamic signage are paving the way for automatic crowd control, in which real-time information is used to steer crowds of people. However, little is known on the impact that automatic information provision has on crowd dynamics. In this study, pedestrians moving in a two-lane fork loop were given different types of information and were guided using different strategies. Our analysis focused on which combination had the best performance and was perceived as comfortable from the participants. Results indicate that a human guidance is preferred when comfort is concerned, but providing real-time traffic information is more efficient in terms of pedestrian flow. It is speculated that the processing of a large volume of information limits the perceived comfort when real-time data are provided. As a consequence, people prefer the less effective human guidance in which decision-making is entrusted into others. With this said, the speculative nature of this conclusion puts emphasis on future studies which will need to investigate more in detail how information provision affects pedestrians' behavior and comfort perception in public spaces.

Keywords: crowd control, information provision, dynamic signage, real-time sensing, supervised experiment

1 Introduction and background

Pedestrian guidance and crowd control are the key elements to ensure safe and smooth mass events and are also an important aspect in the design of urban infrastructures dealing with a large number of people [6, 3]. In the recent years, advances in pedestrian sensing technology [4] and computational performances are making it possible to simulate large crowds on real-time, thus increasing the volume and the type of information which can be used to guide people.

Nowadays, expected waiting time is often provided at the entrance of security screening in airports and, in the context of vehicular traffic, dynamic routing is increasingly used to avoid congestion. However, there is only little experimental knowledge on which type of information can help efficiently guiding people and to which extent will people follow instructions given.

A number of studies considered the case of a fork road and investigated its dynamics in regard to real-time information in the frame of vehicular traffic, both theoretically [7, 8] and experimentally [11, 10, 9]. However, to the knowledge of the authors, no study has been performed to date for the case of pedestrian traffic.

In our previous research [5], we investigated the effect between information provision and compliance by means of simulation and found that information is beneficial to the overall crowd dynamics, but high levels of compliance can be an issue if guidance is not performed in the proper way. However, as the study only considered a simple simulation model, the validity of the conclusions is questionable.

Bode and Codling [1] considered how information affects the way in which people make decisions in virtual evacuations, concluding that stress contributed in making less rational choices and people did not prefer familiar routes. However, also in their study, non-real conditions were tested, thus showing the need to collect experimental data on the relation between information provision and crowd dynamics.

In this study, different methods to guide crowds of people are considered in a supervised experiment, where both efficiency and perceived comfort for different solutions are investigated.

2 Experimental and technical setup

To study experimentally the above topics a course like the one schematically presented in Fig. 1 was built. The course consisted of two lanes, clearly divided by a wall. People were allowed to move from the internal to the external lane (or vice-versa) only in two locations, where an opening of 80 cm was provided. Participants to the experiments were asked to avoid unnecessarily wasting time and had therefore to chose the fastest lane when necessary.

Sensors were installed to measure in real time walking speed in different locations and obtained speed could be displayed on PC displays provided along the course. Speed shown in the display was relative to the average in the inner and outer course (two measuring locations were used to get each average). We also tested the case in which people are guided by staff on-site and rely on their decisions to change lane or not. In this case, guidance staff (students belonging to the group organizing the experiment) was located at each lane-change location and was requested to guide participants showing left/right arrows on a dedicated PC display (different from the ones used for speed). In a first experimental trial, guidance staff had to rely only their local vision (limited to 90 degrees by internal walls), while in a later trial they had access to the real-time video stream of the experiment, entirely showing the course (the video offered the same view to what is seen on Fig. 1).

Each experiment started with 35 participants in the inner loop and 5 in the outer loop and lasted 3 minutes (start and stop signal were given by a programmed clock). Three variables were varied to study crowd behavior: availability and timing of information provision (either real-time/present or predicted/future speed), availability and strategy employed for staffed human guidance (direct visual inspection or use of the overhead camera stream) and compliance (participants could choose by their own or had to obey to the instructions/information given them). Predicted (future) speed was obtained

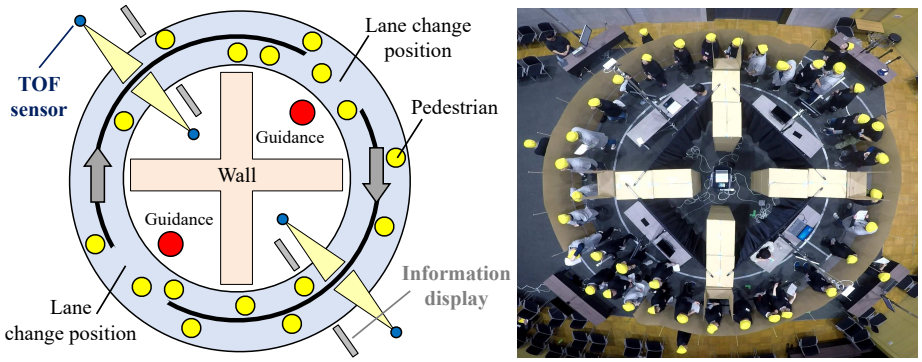

Fig. 1. Experimental setup employed: schematic representation (left) and top-view snapshot (right).

by means of a simulation model [5] using the speed measured by sensors as initial conditions. Speed predicted 10 seconds ahead in time was computed in less than one second and promptly displayed on the PC displays along the course.

Videos of the experiments were taken using a camera fixed directly above the center of the experimental course (see Fig. 1) and pedestrians' positions were later obtained using PeTrack software [2]. A comparison between the ground truth speed obtained from video recordings and sensor measurements gained during the experiments revealed that sensors' accuracy was about 3% for speeds between 0.5 and 1.2 m/s and generally above 10% for lower and higher speeds. We can thus assume that speed measurement was accurate when both lanes moved at similar speed and differences in speed were difficult to notice by visual inspection. When one lane was slow (and congested) the other one was always much faster (as a consequence of the experimental design), thus making inaccuracy at low and high speed of little concern.

3 Results

To evaluate the efficacy and suitability of different strategies of information provision and crowd control, two criteria have been used: the average flow of people transiting over a single lane during each trial and the comfort perceived by the participants. For the latter measure we provided participants with a questionnaire and asked them to indicate at the end of each experimental trial the level of comfort using a score varying from 1 to 7 and based on their own perception. We did not give instructions on how to judge the perceived level of comfort, but simply asked to participants to provide a score for it. Results for different experimental conditions are given in Table 1.

Results presented in Table 1 clearly indicate that the type of information provided, the inspection method used by the staff to guide crowds of people and the degree of compliance among participants clearly affect the overall dynamics of the group. In particular,

Table 1. Average pedestrian flow per lane and perceived comfort for different experimental conditions. N/A is used when the indicated mean was not provided (either information was not available or guidance was not given). "Visual range" refers to the situation in which guidance staff only relied on their (limited) vision, "real-time video" refers to the case in which they were able to see the real-time footage from the overhead camera. Under the "free choice" condition participants were allowed to ignore information/orders if they judged them as incorrect; under the "must obey" condition they had to choose the fastest lane or the one indicated by guidance staff.

Information provided	Guidance	Compliance	Flow [s^{-1}]	Comfort [1–7]
N/A	N/A	Free choice	0.789	3.775
Present speed	N/A	Free choice	0.851	3.875
Present speed	N/A	Must obey	0.770	3.375
Predicted speed	N/A	Free choice	0.772	4.049
Predicted speed	N/A	Must obey	0.492	2.829
N/A	Visual range	Free choice	0.794	4.436
N/A	Visual range	Must obey	0.769	4.175
N/A	Real-time video	Free choice	0.780	4.100
N/A	Real-time video	Must obey	0.749	3.950

it seems there is a discrepancy between what is efficient from a physical/engineering perspective and what people perceive as comfortable. While real-time speed information achieved the highest flow, the highest degree of comfort was recorded when human guidance was provided along the course.

Although the reasons for this difference are not completely clear, a few participants interviewed after the experiments stated that a continuous stream of information forced them to make very often decisions on which lane to use, thus creating a sort of psychological stress, related to the constant pressure on taking the right choice. Also, since some participants were elderly in their 60s, they did not perceive the computer system constantly providing numbers as user-friendly . On the other side, human guidance was more accepted and more warmly perceived. Also, since decisions were entrusted into guidance staff, participants simply had to follow them, reducing their pressure on making prompt decisions.

When information timing is considered, real-time information seems to be slightly better than the predicted one. However, on this topic, further investigations will need to assess the accuracy of predicted speed.

Finally, it can be seen that differences also appear in regard to compliance. An hypothesis to explain those differences is that in the "must obey" case a sort of resonance may have formed in the control system thus amplifying the fluctuations in speed and worsening the outcome.

The relation with compliance is illustrated better in Fig. 2 which provides the speed change in the inner and outer lanes for two selected cases. As it is seen, when people were allowed to use the real-time speed only as an information (which could have been disregarded), both the inner and outer speeds rapidly converged to similar levels and stood almost constant for the length of the experiment. On the other side, the constraint

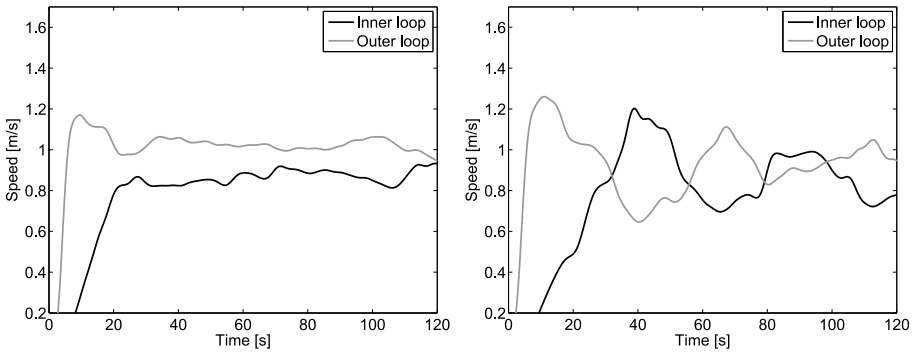

Fig. 2. Speed profile for the two cases where real-time speed is shown to pedestrians. Left: signage has only an informative nature, people are able to act or not in regard to the information given (free choice); right: people must compulsory move to the lane which has the highest speed (must obey). Speed shown here is computed from video processing (ground truth).

on moving into the faster lane led to strong oscillations. The cause for this oscillations may be related to the slowing down created by a large number of people changing lane and the small distance between the speed signage and the lane change position, thus creating a sort of delay in the control loop.

4 Conclusions and future work

Effect of information provision on an infinite fork path has been experimentally studied for the pedestrian case. This study showed that type of information provided to people and crowd control strategy can influence the overall dynamics of the crowd. While directly providing information to pedestrians is surely important and was found being the best solution in terms of traffic flow, our results also showed the importance that guidance staff has on the comfort perceived by people.

It is therefore our belief that having an informed and trained staff/guidance personnel is of central importance in crowd management. In this regard, the development of a system able to provide guidance staff and security personnel with relevant information and possibly also predicting changes occurring in the near future, would allow them to perform an efficient work and should be one of the goals in the frame of research on crowd management. As this research showed, benefits would be reflected in pedestrian traffic efficiency, but also and mostly in regard to user satisfaction.

It is nonetheless necessary to add that despite our experiments being designed to reproduce conditions close to reality and to avoid learning effect by participants, there are still limitations given by the supervised nature of the experiments. In particular, it is possible that participants were not as motivated toward choosing the fastest route as they would in real conditions.

In the future, suitability of the experimental setting to describe real conditions should be further studied, possibly conducting similar experiments in a real environment. Additional investigations on the experimental data are also required, considering for example the reliability of the predicted speed and the local relationship between information provided and pedestrian decision-making. It could be also interesting investigating whether there is a relationship between speed profiles and comfort perceived by participants.

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