Investigation of dynamic social influence in human crowd motions based on Crowdsourced VR experiments

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Abstract Social spread of behavioral change is a manifestation of dynamic social influence, which is frequent in nature and human society. However, the decision-making mechanism underlying the dynamic social influence in human crowd motions remain underexplored. A direction-change experiment based on crowdsourced virtual reality approach was conducted in this study. The preliminary results revealed the significant influence of initiator number and relative positions in the crowd. A Susceptible-Infective model will be employed in this study to reveal the dynamic social influence process in the crowd network.

Keywords Crowd motion, social influence, behavioral spread, crowdsourcing, VR

Introduction

The dynamic social influence in a swarm can manifest its as social spread of behavioral change, which is a common phenomenon in mobile animal swarm. It is typically initiated by several effective leaders and induces large rearrangements of the crowd's trajectory [1]. Previous research has revealed that the hidden networks of interactions within mobile fish swarm can predict complex behavioral spread [1]. However, compared to non-human animals, humans engage in more intricate cognitive decision-making processes, incorporating social, environmental, and psychological factors [2]. This complexity significantly increases the challenge of predicting behavioral spread in human motions. Prior simulation models can macroscopically replicate the behavioral spread wave [3, 4], but their underlying assumptions lack empirical calibration and validation. In addition, other empirical studies in social influence primarily focus on individual-level and static social influence and lack the understanding of the dynamic social influence process in crowd [5, 6]. Critical questions, such as the path of social information transmission during the process, the factors influencing the range and speed of behavioral spread, and the conditions under which large-scale behavioral spread occurs, remain unanswered. To fill in the gaps, this study conducted a direction-change experiment in walking crowds to examine the individual decision-making mechanism underlying the dynamic spread of behavioral changes in human motions.

A key challenge in the empirical study of pedestrian and evacuation dynamics is the difficulty of obtaining accurate large-scale trajectory data within a controlled experimental environment. In a recent publication, we proposed a novel methodology termed Crowdsourced Virtual Reality (CVR) experiments, which collect data by recruiting participants who own Virtual Reality (VR) headsets via online platforms [7]. The approach enables remote, synchronous and collaborative VR-based studies and offers a promising approach for collecting high-quality crowd behavioral data [8]. Compared to field experiments, CVR experiments have unique advantages, including a highly customized experimental environment, cost-efficient and diverse participant recruitment, and direct access to precise trajectory data without the need for additional extraction from video recordings [8]. Therefore, this study used the CVR experimental approach to conduct the direction-change experiment.

In the CVR experiment, participants were instructed to navigate toward the assembly point in the virtual environment, maintaining a straight trajectory at first unless they observed others changing direction. Two conditions were designed: an emergency condition, featuring virtual smoke, fire and an alarm, and a normal condition. In each condition, a varying number of initiators ranging from 1 to 6 were arranged either at the front or within the middle of the crowd with a total of 10 scenarios for each condition. A total of 23 participants were recruited to engage in 20 experimental scenarios, with 10 scenarios per condition. Each scenario was repeated twice or three times, resulting in a total of 54 trials.

A digital platform called CrowdVR [7] was used to conduct experiment and collect participants' behavioral data. Figure 1 illustrates cumulative trajectories from several trials. A total of 1025 trajectories

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were collected and 181 events of turning behavior were detected from the the trajectories. We examined the difference of direction changing probability in various conditions using Cox proportional hazard model. As shown in Figure 2, the number and positions of the initiators had a significant effect on response time of behavioral change ($ps < 0.005$), while the condition had no significant effect ($p = 0.29$). The statistical model with no interactions showed that the probability of a direction change when the initiators are positioned at the front of the crowd is 81% higher than when they are in the middle of the crowd (hazard ratio = 0.19). In addition, the probability of turning behavior is 26% higher for each unit increase in initiator number (hazard ratio = 1.26).

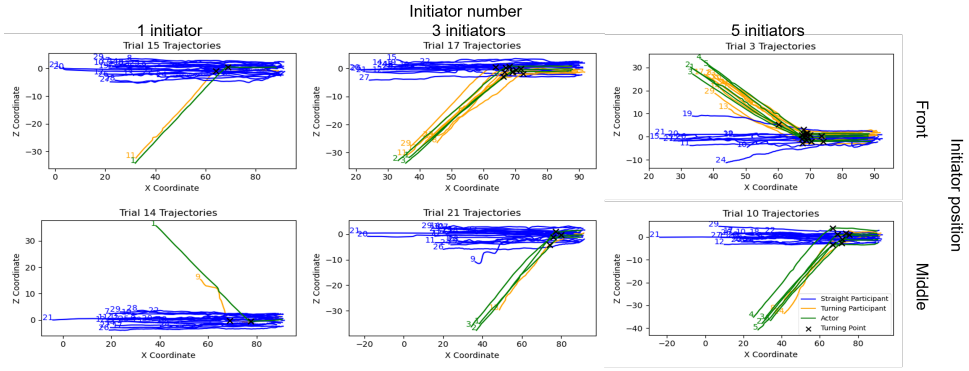

Figure 1: Results of the survival analysis by initiator number, position and condition

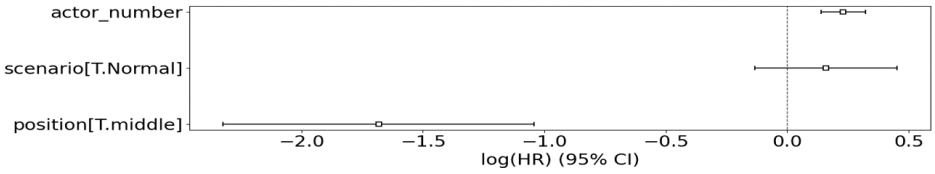

Figure 2: Results of Cox proportional hazard model by initiator number, position and condition

For further analysis in this study, the individual decision-making rule of turning behavior will be built and a Susceptible-Infective (SI) model will be employed to capture the dynamic spread process of behavioral change in the crowd network. The findings are expected to enhance the understanding of the interplay between cognition and collective behavior while contributing to the advancement of crowd dynamics modeling.

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