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Faster-is-slower effect in escaping ants revisited: Ants do not behave like humans

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ABSTRACT

In this work we studied the trajectories, velocities and densities of ants when egressing under controlled levels of stress produced by a chemical repellent at different concentrations. We found that, unlike other animals escaping under life-and-death conditions and pedestrian simulations, ants do not produce a higher density zone near the exit door. Instead, ants are uniformly distributed over the available space allowing for efficient evacuations. Consequently, the faster-is-slower effect observed in ants (Soria et al., 2012) is clearly of a different nature to that predicted by de social force model. In the case of ants, the minimum evacuation time is correlated with the lower probability of taking backward steps. Thus, as biological model ants have important differences that make their use inadvisable for the design of human facilities.

1. Introduction

It is already known that under normal conditions, ant and human fundamental diagrams (FD) are different (John et al., 2009). While the former displays a constant velocity for all densities, the pedestrian and vehicular FDs always show a monotonically decreasing velocity for increasing density (see for example Seyfried et al., 2005). Moreover, ants do not produce jamming (Dussutour et al., 2004; John et al., 2009).

Contrary to what the title of Soria et al.'s paper (2012) would suggest, the authors claimed that there are differences between ants and humans in highly competitive situations such as emergency evacuation through narrow exits. They reported the observation of the faster-is-slower (FIS) effect in escaping ants stressed with a chemical repellent at different concentrations. Even though the FIS effect has been reported for simulated pedestrians via de social force model (SFM) (Helbing et al., 2000), it is not enough for justifying an analogy between ants and humans when egressing through a narrow door. One should not be misled by the title of the paper since the authors clearly state that the mechanisms causing the FIS effect in ants are not the same as those in the SFM simulations. So, although the "FIS effect" was reported in this paper, using it as a proof that ant and human egress is similar, it is not correct.

During different types of emergencies people can adopt different behaviors depending on the demand and capacity of the means of egress. The balance between the demand and capacity is given by several factors such as the kind of physical threat, information and subjective perception of danger, the number of people and the widths of the means of egress. As long as the physical threat is not imminent or not directly perceived (for example an alarm, but no smoke or fire), people tend to be cooperative (Kretz, 2010). The shorter the time (or the smaller the width of a door or stairway) available for a safe egress is, the lower the degree of cooperativeness results. As there is less time available for escape from danger, decisions under stress could be taken (Keinan et al., 1987), which could result, for example, in choosing the main entrance instead of the nearest exit as means of egress. In the extreme case that the time available is very scarce to escape from a sure death, the predominant behavior would be the individual self-preservation.

In such a situation, people could choose rushing or not rushing toward the exit. As this decision has an impact on the payoffs of each agent and the whole group, it can be studied from the point

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of view of game theory. Heliövaara et al. (2013) have shown that jamming and clogging may be caused by people acting rationally, even when this rational individual behavior results in a bad strategy for the group.

An example of such egressing behavior, which saturates the capacity of the egress door, is the fire at "The Station Night Club" (Rhode Island, USA, 20 February 2003), where an amateur camera recorded the tragedy (http://www.youtube.com/watch?v=OOz-fq9Egxeo). There, it can be seen that, at a given moment, most of the people tried to egress simultaneously through the main door, causing the blockage of that door (Fahy et al., 2012).

The behavior of rushing toward a door was also observed in animals in less frightening situations.

Saloma et al. (2003) found this response when studying the egress of mice from a water pool.

Zuriguel et al. (2013) also observed the same response when studying the anxious passage of sheep through a narrow door when they were to be fed.

Also, this selfish evacuation behavior is the one assumed in the paper where the FIS effect was first reported (Helbing et al., 2000). The cause of this effect is the high tangential friction between particles in contact (Parisi and Dorso, 2007). Moreover, the FIS effect was recently verified experimentally in granular media (Gago et al., 2013), herd of sheep (Zuriguel et al., 2013), and humans (Garcimartín et al., 2014). In all cases the FIS effect appears due to jamming and clogging at the door, producing high frictional forces.

On the other hand, the FIS effect reported for ants (Soria et al., 2012) was not caused by any kind of frictional contact, jamming or clogging. This behavior was also confirmed in another experiment with Argentinean ants stressed with temperature (Boari et al., 2013) in which, contrary to the FIS effect, the "faster-is-faster" effect was found, even when ants were close to dying by temperature (if it had risen a little bit further).

The present work is based on the video recording from the experiments performed in Soria et al. (2012). Here we used image processing technics for obtaining the individual trajectory of ants. From this information, velocities and densities can also be studied. These data allowed us to demonstrate the claim that ants do not jam nor clog near the exit and thus that the FIS observed has no relation to the FIS effect in other animals' systems. To be even more specific, we are going to compare the more relevant metrics obtained from ant data with the corresponding ones from simulations with the SFM producing the real FIS effect. As a consequence, it will be evident that the FIS effect in ants is not the same as in other systems relevant to the area of highly competitive egress.

2. Materials and methods

We analyzed the recorded video of the experiments reported in Soria et al. (2012) when studying the egress of *Camponotus mus* (*Roger*) ants stressed with aversive stimuli through a narrow exit. A detailed description of the experiments can be found in that paper; here we only summarize the main features.

Approximately one hundred ants were placed in a transparent arena consisting of a floor, walls and a ceiling so high that ants could not get on one another, thus maintaining the system two-dimensional.

In order to produce different degrees of repellency, ants were exposed to different concentrations of a repellent solution, made with water and citronella. The increasing degree of repellency mimics the increase of the desired velocity in the SFM simulation of the room evacuation problem (Helbing et al., 2000), where the FIS effect is observed. The repellent was placed at the wall opposite the door.

The geometry of the arena can be seen in Fig. 1A and it was designed to guide ants toward the door. Before the egress began, ants were allowed to enter the punishable chamber using the only exit from the non-punishable chamber. At the start of the evacuation, the citronella solution was placed and the door was opened simultaneously. Trials were recorded with a HD camera at 30 fps.

Image processing of the video recording was performed using the tool built by Liendro and Goldberg (2013), which allows one to obtain the position of each ant as a function of time.

As one of the main objectives of this work is to show that the FIS effect observed in ants has a different nature to that arising

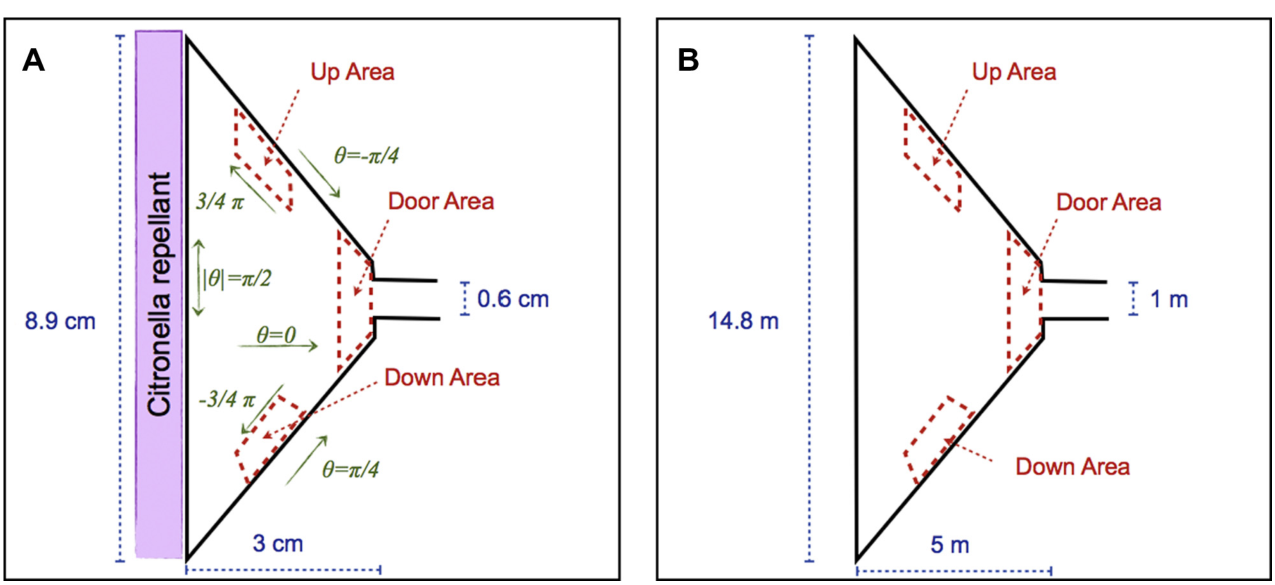

Fig. 1. Geometry for the evacuation process and the 3 areas for density measurements. (A) The punishable chamber of the arena used in the ant experiment (Soria et al., 2012). Definition of the direction angle of the velocity (θ) for individual ants. (B) Scaled geometry for simulating pedestrian egress using the social force model (Helbing et al., 2000).