Influence of selfish and polite behaviours on a pedestrian evacuation through a narrow exit: A quantitative characterisation

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Abstract

We study the influence of selfish *vs.* polite behaviours on the dynamics of a pedestrian evacuation through a narrow exit. To this end, experiments involving about 80 participants with distinct prescribed behaviours are performed; reinjection of participants into the setup allowed us to improve the statistics. Notwithstanding the fluctuations in the instantaneous flow rate, we find that a stationary regime is almost immediately reached. The average flow rate increases monotonically with the fraction c_s of vying (selfish) pedestrians, which corresponds to a "faster-is-faster" effect in our experimental conditions; it is also positively correlated with the average density of pedestrians in front of the door, up to nearly close-packing. At large c_s, the flow displays marked intermittency, with bursts of quasi-simultaneous escapes.

In addition to these findings, we wonder whether the effect of cooperation is specific to systems of intelligent beings, or whether it can be reproduced by a purely mechanical surrogate. To this purpose, we consider a bidimensional granular flow through an orifice in which some grains are made "cooperative" by repulsive magnetic interactions which impede their mutual collisions.

Keyworks pedestrian, evacuation, behaviour, experimental,

1. Introduction

In Boris Vian's *Froth on the Daydream*, the main character witnesses a massive collision on an ice skating rink; no sooner have the skaters tumbled into a deadly pileup than housekeepers enter the rink and sweep away their corpses while singing. In real life, crowd disasters are not taken so light-heartedly; recent examples during the emergency evacuation of a nightclub in Bucharest (October 2015) [1] or the massive stampede in Mina during the Muslim Hajj (September 2015) [2], which resulted in thousands of casualties, demonstrate how tragic these events can be. The issue of evacuation in public facilities and, more generally, questions related to pedestrian flows are therefore of paramount importance.

It is needless to say, though, that the description or modelling of the dynamics of crowds is, at the very least, challenging. Since first-principles approaches are hopeless in any conceivable future, models have to rely on a combination of assumptions and empirical observations. Fortunately, the success of rather simple physical models in describing increasingly complex entities (complex fluids, bacteria [3], birds and fish [4]) bolsters the desire for similarly successful models for pedestrian crowds. *But how detailed, or "realistic", need these models be to appropriately describe the flow of pedestrians in a given situation?* The numerous existing models and simulation software [5, 6] vary greatly as regards their sophistication, from minimalistic cellular automata [7] to continuous agent-based models incorporating a large number of parameters. Even if we explicitly bypass the psychological intricacy of the human mind and take for granted the pedestrians' choice of a target point and his or her behaviour, the dynamics that result from these choices, and how simple or complex they are, remain mostly unknown.

The flow of pedestrians at a constriction, *e.g.*, the disordered egress through a narrow exit, seems to be largely governed by physical constraints and is therefore worth studying from a mechanical perspective

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(not to mention its importance for safety science). Still, one can expect the attitude of pedestrians to play an important role in the dynamics.

Our objectives are two-fold. First, we wish to characterise the influence of prescribed polite (cooperative) and selfish (vying) behaviours, regardless of their psychological origins, on the evacuation process of a heterogeneous crowd. Second, we investigate whether the observed characteristics are tied to the inherent complexity of intelligent beings or whether they can be reproduced in a simple granular system. To this end, repulsive magnetic interactions are introduced between some grains to mimic the avoidance of physical contact presumably associated with polite behaviour.

We have chosen to divide the presentation of our work as follows. In this contribution, we shall expose the underpinning of the granular analogy and its "behavioural extension", present our original setups in detail and expose the global flow properties of pedestrians and grains. The *microscopic* characterisation of the flows and a more thorough analysis of the granular analogy shall be published separately, in a companion paper [8].

2. Underpinning of the work

In the last decade, large-scale experiments of pedestrian flows through bottlenecks have been conducted. Within the framework of a German collaborative project, the flow of voluntary pedestrians under normal (cooperative) conditions was studied at the abrupt narrowing of a corridor, from $4\,\mathrm{m}$ to a variable width $w \in [0.8\mathrm{m}, 1.2\mathrm{m}]$ [9]. Contrary to perhaps less exhaustive earlier measurements [10], the flow was observed to increase monotonically with w, instead of undergoing a stepwise growth. For $w \gtrsim 0.9\mathrm{m}$, a "zipper effect" is visible, whereby two lanes form in the narrower corridor and entrances tend to be grouped in pairs, one pedestrian on either lane, with a short headway to avoid physical contact; this, claim the authors, leads to anticorrelated time headways Δt between successive passages. More recently, a Spanish-Argentine collaboration performed evacuation drills through a narrow (69cm-wide) door with almost 100 participants and revealed robust statistical features. In each realisation, a given degree of competitiveness was imposed on the whole crowd, from low (*i.e.*, avoidance of all contacts) to high (mild pushes) [11, 12]. These experiments provided evidence for the so called "faster-is-slower" effect, whereby a crowd made of individuals eager to move faster actually needs longer to evacuate than a less competitive crowd, due to the formation of clogs. Furthermore, the distributions of time lapses Δt between successive egresses were found to be heavy-tailed and well described by power laws at large Δt, viz.

$$p(\Delta t) \sim \Delta t^{-\alpha}. \tag{1}$$

These features, along with a couple of others, appear to be universal to flows of particles through narrow bottlenecks, as they have also been reported for sheep entering a barn, granular hopper flows, and colloids flowing through an orifice [13, 14]. This analogy between pedestrian evacuations and granular flows through a bottleneck suggests that the dynamics of pedestrians in such situations are governed by the following few key mechanisms:

Excluded volume. Clogging occurs in granular hopper flows because of the formation of arches bridging the gap between walls at the outlet; these arches resist pressure thanks to the solid contacts between the grains that constitute them [15]. For orifices smaller than 3 or 4 particle diameters in two dimensions (2D), permanent clogs almost surely occur and the flow halts [15, 16]. To et al. rationalised the probability of permanent clogging in 2D by calculating the probability of formation of a convex arch between the walls. In addition, contrary to the case of liquids, anisotropic force chains develop in the granular system, so that the height of the granular column is not transmitted down to the bottom; most strikingly, the pressure measured at the outlet is virtually independent of the height of the granular layer; this is the so called Janssen effect [17].

Fluctuations or vibrations. Arch-like structures are also observed in pedestrian flows through bottlenecks, but they lead to non-persistent (although potentially long) clogs, responsible for the existence of relatively large time lapses Δt between successive egresses and intermittency [12]. In granular flows, too, arches can be broken provided that the system is vibrated strongly enough [16]. Therefore, in a model, such fluctuations should be present in order to avoid permanent clogs; they are generally described by a noise term.

As the orifice size D_0 is increased, at a given small vibration amplitude, the importance of vibrations is reduced as the flow transits from a regime of intermittent flow dominated by the time needed for vibrations to break clogs, to a regime of continuous flow. The latter regime is the usual range of applicability of Beverloo's relation between the flow rate and D_0 [18, 16]. A parameter controlling the transition between

these regimes is Φ, the fraction of time during which the system flows [13]. Note that, according to Eq. 1, $\Phi \to 0$ if $\alpha < 2$. For pedestrian flows, as long as the door is wide enough for agents to go through, $\Phi > 0$.

Frictional contacts vs. no contacts. In competitive evacuations, people will be in contact. Conversely, under normal conditions collisions are avoided and contacts are rare. One may reasonably think that this lack of contacts will strongly affect the flow [19]. Indeed, in granular systems, simply replacing frictional grains with frictionless ones reduces the probability of clogging, insofar as arches become less stable [15]. For slighlty deformable frictionless particles (surfactant-coated emulsion droplets), clogging only occurs at very narrow outlets, only slightly larger than the particle diameter [20]. To go beyond frictionless contacts and really investigate systems with no particle contacts, Lumay et al. recently studied the 2D hopper flow of repulsive magnetic discs [19]. It is noteworthy that even without contacts clogs were observed for aperture sizes significantly larger than the particle diameter, through the formation of arches held by magnetic repulsions. But, in the absence of a vibrating device in the setup, the authors rather focused on wider apertures. Thus, the following question is still open: *does the preclusion of contacts between grains in a hopper flow suffice to reproduce the change from a competitive evacuation through a narrow door to a cooperative one?*

Overall, the aforementioned experiments deal with relatively homogeneous crowds or systems. Here, in order to better illuminate the effect of individual behaviours, we shall consider heterogeneous systems.

3. Description of the setups

3.1. Pedestrian evacuation experiments

Setup

We performed evacuation experiments involving more than 80 voluntary participants on the premises of Centro Atómico Bariloche (CAB), Argentina. The participants were students and researchers, aged 20 to 55 for the greatest part, with a woman/man ratio of about 1:3. They were asked to evacuate a delimited space through a 72 cm-wide door, with the specific instructions exposed below. The geometry of the setup is sketched in Fig. 1.

In light of its potential risks, the experiment was validated beforehand for ethical issues and prepared in collaboration with the Safety and Hygiene group of CAB. The doors and the walls were protected with paddings and the whole evacuation process was supervised by 3 staff members who could stop it at any moment by blowing a whistle. No incident whatsoever was reported during or after the drill.

This experimental setup is directly inspired from [11, 12], but some significant changes were introduced. All participants were instructed to "head for the door purposefully (*con ganas*), but without running, pushing or hitting others", but in each evacuation drill, a fraction c_s of participants was randomly selected to behave selfishly while the rest should behave politely. Selfish participants were told to wear a red headscarf to be recognisable on the videos and allowed to "elbow their way through the crowd, with mild contacts but no violence whatsoever". Their polite counterparts, on the other hand, were to "avoid any contact and try to keep their distance".

Moreover, an innovative trick was devised to curb finite-size effects: egressing participants were reinjected into the room, as if there were periodic boundary conditions. To maintain homogeneity in the system and limit the clustering of, say, fast participants, two reinjection circuits were set up, a short one and a longer one, and the evacuees were directed to either one alternatively.

These experiments were briefly described in (China)

Data analysis

The flow at the exit was filmed by two video cameras (acquisition rate: 60Hz) placed just above the door while a third camera provided a more global view.

To study the dynamics at the individual scale, time frames of escapes were constructed, following Refs. [11, 12], by extracting a line of pixels just past the door from every frame of the video and stitching these lines together: an example of such a time frame is shown in Fig. 3. The individual escape times were collected semi-manually by clicking on each pedestrian, with the help of a home-made computer routine. The reproducibility of the experimental results was tested by performing two runs in nominally identical conditions, but at different times and with different individuals as selfish agents; the results were in fair agreement (7% difference in the global flow rate, similar - though not identical - distributions of time lapses between escapes, *data not shown*).

Figure 1: (*Left*) Sketch of the experimental geometry, with $a = 7.3\,\text{m}$, $b = 3.5\,\text{m}$, and $c = 4.3\,\text{m}$. (*Right*) snapshot of an evacuation.
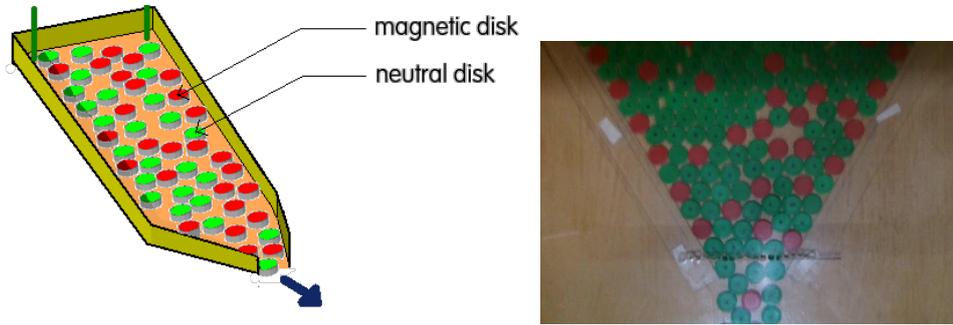

Figure 2: (*Left*) Sketch of the experimental geometry and (*right*) snapshot of an experiment. The chipwood panel is inclined by about 18° and vibrates.

3.2. Two-dimensional granular hopper flow

Setup

To investigate the analogy between pedestrian and granular flows, we also conducted experiments on constricted flows of non-magnetic (green) and magnetic (red) granular discs (see Fig. 2). The discs are about 1 mm-thick and confined between a vibrated chipwood panel at the bottom and a plastic sheet. Thin plastic bars placed between the plates delimit a 2D funnel-like region, with an aperture of variable width w =3, 4 or 5cm and an opening angle of 58°.

Both types of discs consist of a circular plastic cap of 13mm of diameter, mounted on a narrower bronze washer for the non-magnetic ones, or a narrower neodyme magnet otherwise. Their total weights are $0.545\text{g} \pm 0.01\text{g}$ and $0.582\text{g} \pm 0.01\text{g}$, respectively. The chipwood panel was carefully polished and varnished to reduce the friction coefficient and make it less heterogeneous. At rest, *i.e.*, without vibrations, the static friction coefficient was about $\mu \simeq 0.32 = \tan{(18°)}$. The chipwood panel was inclined by an angle roughly equal to the friction angle, 18°, or perhaps slightly smaller, but the vibrations produced by an unbalanced motor attached to the panel allowed sliding. At the beginning of each experiment, the discs were inserted from the top of the setup, in a relatively homogeneous fashion.

In the following, the aperture width w and the relative fraction of magnetic discs in the system are varied; all other parameters are kept constant.

Data analysis

The granular flow was filmed with a 60Hz camera placed above the aperture. The analysis is very similar to that performed for the pedestrian experiments (see Fig. 3).
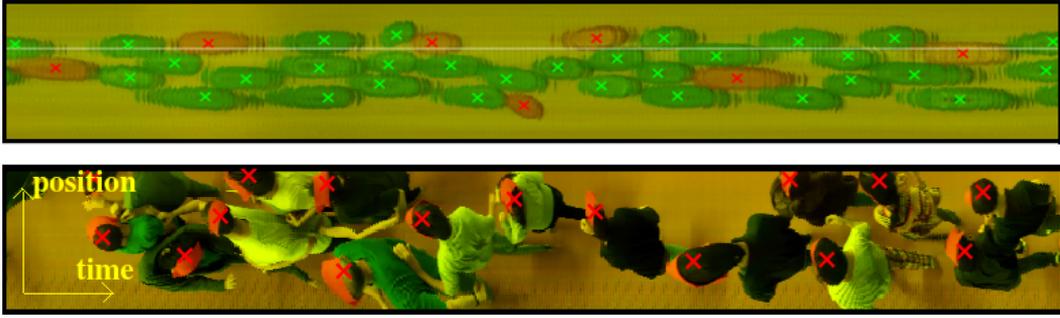
Figure 3: Time frames (zoom) for a granular experiment (*top*) and a pedestrian evacuation experiment (*bottom*). The vertical axis represents the position along the direction of the door and the horizontal coordinate is time.

c_s	Effective fraction $c_s^\star$	Flow rate J (s^{-1})	Density ρ ($\approx$ m^{-2})
0%	0%	1.26 ± 0.07	3.70
10%	18%	1.39 ± 0.09	4.49
60%	71%	2.20 ± 0.09	7.63
90%	90%	2.36 ± 0.15	8.26
100%	100%	2.41 ± 0.17	8.98
0%†	0%†	1.01 ± 0.05	2.69
30%†	46%†	1.41 ± 0.08	4.94
60%†	68%†	1.71 ± 0.12	6.04

Table 1: List of the performed evacuation experiments, with the prescribed fraction of selfish agents c_s, the effective fraction $c_s^\star$, the average flow rate J and the density ρ in front of the exit. Note that, for J, a confidence interval of $\frac{2\sigma}{\sqrt{n}}$ on either side is given, where σ is the standard deviation of $\bar{j}(t)$ averaged over $\delta t = 7$ s and n the number of (independent) sampling points.
† In these runs, participants were asked to "head for the door", and not to "head for the door *purposefully*".

4. Experimental results for the pedestrian evacuation

Let us start with the study of the pedestrian flow. We recall that the participants are prescribed either a polite or a selfish behaviour. Here, we present results with c_s = 0%, 10%, 60%, 90%, and 100% of selfish participants. Generally, we only have data for one run for each c_s, but, thanks to the recirculation, each run comprises about 200 to 300 passages through the door.

4.1. General observations

As expected, no collisions or contacts are observed with crowds of polite agents ($c_s = 0\%$). On the contrary, cooperative behaviour is witnessed in front of the exit, with, e.g., sometimes one participant waving to a neighbour to go ahead. As the fraction c_s of selfish agents increases, more and more contacts and soft collisions occur, either on purpose or because of the pressure exerted by the neighbours. At the same time, the density of participants in front of the exit rises markedly. At high c_s, in regions of low density, vying agents walk visibly faster on average than their polite counterparts and some align in files of 2-3 selfish agents.

Since selfish agents reach the door faster, they pass more times through the door in each run. Therefore, the prescribed concentration c_s of selfish agents should be replaced by an effective concentration $c_s^\star$, corresponding to the number of passages. Table 1 gives the correspondence between the nominal and effective concentrations.

4.2. "Instantaneous" flow rates and the question of stationarity

To get rid of the dependence on the initial position and of the finite crowd size effects at the end of the evacuation, it is preferable to collect data in the stationary state. To ascertain stationarity, we compute the time-dependent flow rate $\bar{j}(t)$, averaged over a sliding time window δt, an example of which is plotted in Fig. 4(left). Clearly, for relatively small δt, of order 1s, the flow rate fluctuates considerably.
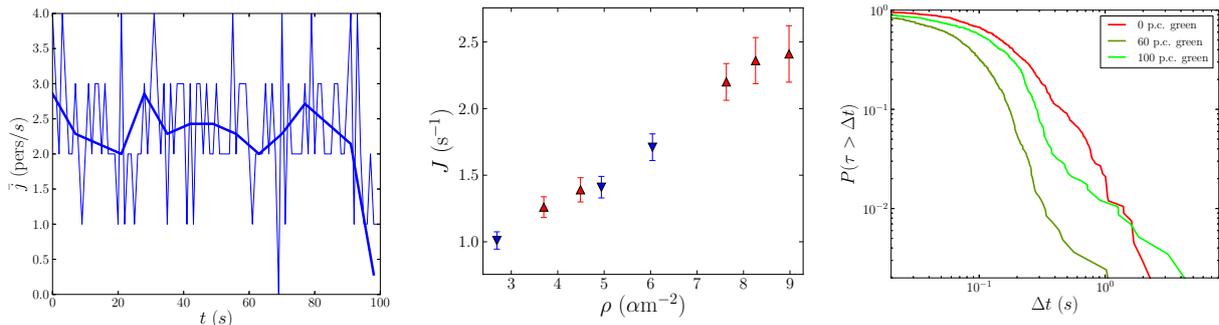
Figure 4: (*Left*) Time-dependent flow rate $\bar{j}(t)$ in an experiment involving $c_s = 90\%$ of selfish **pedestrians**. The thin lines are the data averaged over $\delta t = 1$ s, whereas the thick lines are for $\delta t = 7$ s.
(*Centre*) Dependence of the average flow rate J on the **pedestrian** density ρ in front of the exit. The blue downwards triangles correspond to a set of evacuation drills in which the participants were just asked to "head for the door" (see footnote in Table 1).
(*Right*) Complementary cumulated distribution $P(\tau > \Delta t)$ for the **granular flow** with $w = 4$ cm; the data have been cumulated over two to three experiments for each fraction of non-magnetic (*green*) discs, as indicated in the legend.

Averaging over larger time windows, *e.g.*, $\delta t = 7$ s, tends to wash out these fluctuations, even though the curve remains noisy. Nevertheless, beyond this noise, the data clearly point to the almost immediate attainment of a steady state (for $\bar{j}(t)$), that persists until (nearly) the end of the experiment. This contrasts with the bottleneck flow experiments conducted by Seyfried et al. [21], which involved up to 60 participants and did not quite reach a steady state. However, in their case, the crowd was initially positioned 3 meters away from the bottleneck and no recirculation contrivance was used.

Taking a closer look at our time series $\bar{j}(t)$, we realise that, in the experiment with 10% of selfish agents in particular, the flow rate decreases moderately 30 to 40 seconds before the end of the evacuation (which lasted 190 s overall). In the videos, we notice that most selfish agents have already escaped by this time, hence an excess of polite pedestrians, the last of whom display no sign of hurry whatsoever.

4.3. Average flow rate

Turning to the *average* flow rate J, we notice that it increases monotonically with c_s (see Table 1): the more selfish agents there are, the faster the evacuation. As a corollary to this statement, no "faster-is-slower" effect is observed, unlike in [11, 12], where long jams at the door were found to delay significantly the evacuation for the most competitive crowd. This discrepancy is not necessarily a contradiction. Instead, we suspect the precise instructions given to the participants to have mattered: for safety reasons, we insisted repeatedly that the participants should not to push each other (although soft contacts were allowed). It follows that we also observed some jams at the exit for selfish crowds, but they never lasted long, because there was not enough mechanical pressure to stabilise them. We shall come back to this issue in the light of the results for the granular system.

Let us now put in perspective the values we obtained for J, which range from 1.26 to $2.37\,\text{s}^{-1}$. Using a door of almost identical width (69 cm instead of 72 cm), Pastor et al. measured global flow rates[†] $J = 2.63\,\text{s}^{-1}$, $2.56\,\text{s}^{-1}$ and $2.43\,\text{s}^{-1}$ for homogeneous crowds of moderate, medium, and high competitiveness, respectively [12]. The fact that these values lie at the upper range of our range of flow rates (corresponding to $c_s = 100\%$) supports the idea that the three situations considered in [12] were more competitive than ours, hence at higher pressure. On the other hand, Seyfried et al. measured specific capacities J_s (defined as the average flow rate per meter of door width) of about $1.9\,\text{s}^{-1} \cdot \text{m}^{-1}$ in their setup, with a value relatively independent of the bottleneck width w in the range $[0.9\text{m}, 1.2\text{m}]$ (in fact, J_s was found to decrease slightly for smaller w) [21]. For $w = 0.72\,\text{m}$, $J_s \lesssim 1.9\,\text{s}^{-1} \cdot \text{m}^{-1}$ yields a flow rate slightly smaller than $1.37\,\text{s}^{-1}$, which corresponds to the case of our polite crowds ($c_s^\star = 0\%$ or 18%). Noticing that Seyfried et al.'s experiments were performed under normal conditions, with no contact between the participants, we conclude that our results are perfectly consistent with theirs.

[†]Note that $J = \frac{1}{\langle \Delta t \rangle}$, where $\langle \Delta t \rangle$ is the average time lapse between sucessive escapes in an experiment.

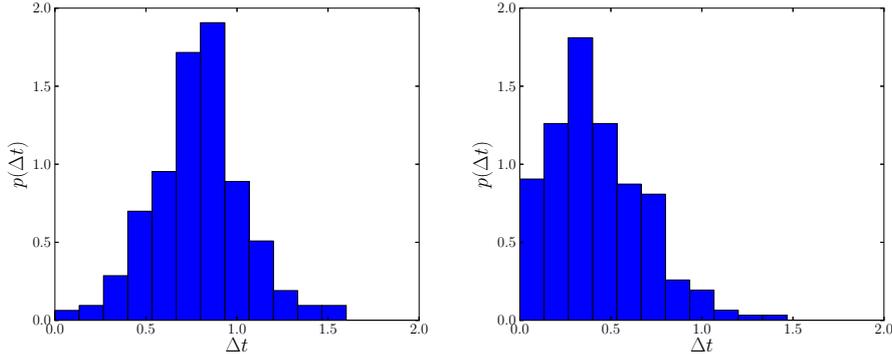Figure 5: Histograms of time lapses Δt between successive escapes in the experiment with $c_s^\star = 0\%$ of selfish agents (*left*) and $c_s^\star = 90\%$ (*right*).

4.4. Density in front of the door

On the basis of a comprehensive comparison with the literature, Seyfried et al. claimed that the main parameter controlling the flow rate J was the density ρ in front of the door, while the other parameters such as the position of the bottleneck or its length were of minor importance. In spite of their considerable divergences, most models in the literature, whether empirical or not, predict a quasi-linear increase of J at low densities, followed by a peak and a decrease at high densities, due to hampered motion.

Does this apply to our experiments? We compute the average density ρ in a $\approx 0.5 \mathrm{m}^2$ zone in front of the exit and find values ranging from 4 to 10 $\alpha \mathrm{m}^{-2}$, approximately, as listed in Table 1. Here, α is a numerical factor close to unity that is mainly due to the optical distortion of the images; we should also mention that our measurement method may slightly overestimate the higher range of densities. Going beyond these caveats, we observe a monotonic increase of J with the density ρ. This holds even for the highest density, $\rho = 9.5 \, \alpha \mathrm{m}^{-2}$ at $c_s = 100\%$, where people are closely packed in front of the door, whereas the models reviewed in [21] predict a decreasing $J(\rho)$ curve in this range of densities.

Whether the prescribed behaviours affect the flow rate exclusively indirectly, via the density at the door, or also directly, can only be settled by a more local analysis of our experiments [8]. Nevertheless, we would like to remark that at very high densities the body resistance limits the crowd's compressibility. Accordingly, an increase of mechanical pressure, *e.g.,* due to people pushing at the back, will only moderately raise the local density, but it is expected to generate significantly longer clogging events.

4.5. Is a small fraction of selfish people beneficial for the evacuation?

At the 2010 Love Parade in Duisburg, "pushers" were recruited to push the crowd entering the festival area in order to enhance the inflow [22]. As a side question, we wonder whether selfish agents, when they are scarce, act in this way and accelerate the flow of the lagging polite crowd. Comparing the flows with $c_s^\star = 0\%$ and 18%, we find that the vying behaviour of some is inefficient for the rest of the crowd: although their presence increases the global flow rate J, the specific flow rate of polite agents is reduced with respect to the situation without selfish agents. But more extensive data at lower values of $c_s^\star$ would be required to reach a robust conclusion.

4.6. Distribution of time lapses between escapes

In Fig. 5, we plot the distributions of time lapses Δt between successive escapes through the door for $c_s^\star = 0\%$ and 90%. For the polite crowd, the distribution is peaked at a value of Δt slightly below 1 s. This peak is shifted to lower value for $c_s^\star = 90\%$ and, above all, the distribution broadens and the probability of very small values $\Delta t \approx 0$ is strongly enhanced. This feature turns out to be characteristic of flows with a significant fraction $c_s^\star$ of selfish agents and reflects bursts of quasi-simultaneous escapes through the door.

5. Experimental results for the granular flow

5.1. General observations; (non)-stationarity

Having analysed the global statistics of pedestrian evacuations through a narrow door, we turn to the granular flow. In systems of only magnetic discs ($c_s = 0\%$, with c_s now referring to the fraction of non-magnetic grains), the density increases gradually, but quite visibly, with the depth: at the bottom, the discs are much closer to each other than at the top, but still non-touching. This separation gets larger as the experiment proceeds and the weight of the granular layer decreases. In other words, there is no Janssen effect. It also follows that the flow is non-stationary at $c_s = 0\%$: the flow rate $\bar{j}(t)$ slows down with time (*data not shown*). Besides, no persistent clog is observed, even for the narrowest door, $w = 3\,\mathrm{cm}$. We ascribe this difference with respect to Lumay et al.'s recent experiment with magnetic discs [19] to the absence of vibrations in their setup.

On the other hand, in systems with a significant fraction of non-magnetic discs ($c_s = 60\%$, 100%), persistent clogs occur for $w = 3\,\mathrm{cm}$, which have to be broken manually. For larger doors, the vibrations suffice to unclog the system. Besides, there is not so prominent a decrease of the flow rate $\bar{j}(t)$ with time and a quasi-stationary regime seems to be reached for $c_s = 100\%$ (as expected in a non-vibrated system), even though fluctuations blur the picture.

5.2. Average flow rates

For the narrow door, $w = 3\,\mathrm{cm}$, magnetic grains flow faster overall than neutral ones, which undergo severe clogs. It is tempting to draw a parallel with the pedestrian evacuation experiments of [12], in which the collision-prone competitive crowd evacuated more slowly than the less competitive one. We should however remark that, here, the isolated neutral discs do not slide faster than their magnetic counterparts.

The situation differs for $w = 4\,\mathrm{cm}$. In this case, the global flow rate J is larger for the system which exhibits contacts and collision, *i.e.*, here, the non-magnetic one ($J = 6.2\,\mathrm{s}^{-1}$ at $c_s = 100\%$ *vs.* $J = 4.7\,\mathrm{s}^{-1}$ at $c_s = 0\%$). This echoes our observations in the pedestrian experiments. Nevertheless, contrary to these, the flow rate J for an intermediate fraction of non-magnetic discs, $c_s \simeq 60\%$, is by far larger ($J \approx 11\,\mathrm{s}^{-1}$) than that at $c_s = 100\%$; the non-stationarity of the flow at $c_s = 0\%$ makes another difference.

5.3. Time lapses

Figure 4(right) presents the complementary cumulated distribution $P(\tau > \Delta t)$ of time lapses between successive egresses.

As in the pedestrian experiment, the more negative slope of $P(\tau > \Delta t)$ at small Δt indicates that there are more quasi-simultaneous egresses at large c_s than at $c_s = 0\%$, where grains are separated. On the other hand, the softening of the slope at large Δt reveals the presence of long clogs at large c_s, which are indeed observed in the videos. This is in line with the stronger flow intermittency in the presence of many vying pedestrians.

6. Discussion and outlook

We have studied the influence of polite *vs.* selfish behaviours on the evacuation of pedestrians through a narrow door. We have observed a monotonic increase of the global flow rate with the fraction c_s of selfish agents, *i.e.*, a "faster-is-faster" effect, and with the density ρ in front of the door, up to $\rho \approx 9 - 10\,\mathrm{m}^{-2}$. In parallel, evacuations at high c_s display stronger intermittency and are characterised by the presence of quasi-simultaneous escapes. Under the hypothesis that the absence of mutual contacts characterise the motion of polite pedestrians, we have proposed to model them as repulsive magnetic discs in a granular hopper flow. This analogy helps us explain some features observed in the pedestrian evacuation in mechanical terms, but also suffers from some deficiency, such as the absence of stationarity in the contact-free flow.

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