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Formula for Panic: Crowd-motion findings may prevent stampedes

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Wherever dense crowds gather, an eruption of panic can have deadly consequences, as in the stampede that killed hundreds during a mass pilgrimage to Mecca in 2006. With methods from the physics of fluids, scientists have now dissected the events of that tragic day and come up with recommendations that may have contributed to making this year's pilgrimage proceed smoothly.

DANGEROUS BRIDGE. Every year, millions of Muslim pilgrims walk across the Jamarat Bridge near Mecca, Saudi Arabia, for the stoning of the pillars ritual. New research may have prevented catastrophic stampedes this year.
Zainal abd Halim/Reuters/Corbis

Every year toward the end of the week-long Hajj pilgrimage, millions of pilgrims visit the place in the desert outside Mecca, Saudi Arabia, where Abraham is said to have thrown stones at the devil. Every able-bodied Muslim is supposed to make the trip at least once. When they arrive, pilgrims throw pebbles at three walls, which symbolize three apparitions of the Evil One.

Catastrophic stampedes have periodically afflicted the event. The most recent one, on Jan. 12, 2006, killed 345 people and injured 289.

In collaboration with Saudi authorities, physicists at Dresden University of Technology in Germany studied video recordings of the 2006 stampede. They wrote visual-recognition software to track and measure the motion of individuals in the crowd and, by following those individuals, analyzed the crowd's movements as the disaster unfolded.

In normal conditions, pedestrians tend to spontaneously fall into ordered patterns, such as lanes going in opposite directions, previous research had shown. As crowds get denser, stop-and-go patterns begin to propagate in waves, as is typical for cars on heavily trafficked highways. But in critical situations—as when cars get into gridlock—people can break out in panics that result in random patterns of motion, similar to the turbulence of water in the wake of a boat. Crowd members can get squeezed and asphyxiated or fall and be trampled.

The video recordings enabled the Dresden team to identify for the first time a factor that correlates with these transitions in crowd behavior. It can be regarded as a thermometer of chaos.

"We tried dozens of different measurements," says team member Anders Johansson, but he and his colleagues found only one factor, which they called crowd pressure, that proved useful. It combines crowd density and the rate of change in the velocity of the flow.

The team found that critical thresholds in crowd pressure correlate with the onset of stop-and-go patterns and turbulence. The findings are due to appear in *Physical Review E*.

The results are "remarkable," says Hani Mahmassani, a traffic-dynamics expert at the University of Maryland at College Park. "It sheds incredible light on the anatomy of a major crowd disaster." But Mahmassani, who has also advised the Saudi government on preventing stampedes during the Hajj, warns that understanding the dynamics of crowd panic is not the same as preventing it. "Panic has a psychological dimension," he says.

However, Salim Al-Bosta, a civil engineer in the Saudi government, says that measures based on the research helped the Hajj run smoothly this year. Image-recognition software now tracks the flow of pilgrims and warns organizers to slow the influx of pilgrims to the site when crowd pressure approaches a critical value, he says.

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Further Readings:

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