Collective Behavior in an Emergency: Escaping from a Human Maze

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ABSTRACT

The study investigated the effects of fear on collective escape from a computer simulated maze. TV monitors watched by subjects did not present a bird's eye view of the maze, but rather what they would see if they were actually inside the maze. In the maze, other body figures and behaviors were also shown. Subjects often got close, encountered, and collided with each other. The results were as follows: Fear (a) augmented traffic jams, (b) increased time and locomotion required to reach the exit, an effect that was especially prominent for those who escaped last, and (c) reduced rate at which the maze was learned.

Key words: collective behavior, maze escape, computer simulation, emergency situation, fear.

Spontaneous group behavior in an emergency situation is frequently in conflict with what would be considered an optimal course of action. For example, instead of utilizing all available exits, people evacuating a threatened building crowd around only a few.

In a number of cases, this tendency has taken its toll in lives. A fire in the Iroquois theater in 1903 cost approximately 600 lives because everyone in the building rushed to a few crowded exits and could not escape (Perry & Pugh, 1978). In the Cocoanut Grove Night Club fire in Boston in 1942, 448 people died because they jammed the exits (Veltfort & Lee, 1943). More recently, a fire in the cabaret named Play Town in the Sennichmae Building in Osaka, Japan in 1972 led to a high death toll because people rushed to only a few of the available exits (Abe, 1974).

These tragedies suggest that some emergency situations may produce competitive behaviors whereby individuals are motivated purely by the motives of their own survival without concern for the fate of others (Brown, 1954; Quarantelli, 1979). It is also possible that the emotional arousal experienced by people caught in emergency situations interferes with optimal decision making. At a loss for how to proceed, people may look to others for clues concerning the best path to choose. Several studies have shown that in threatening situations, when the course of action is not obvious, people tend to follow one another (Abe, 1974; Darley, 1966; Kugihara, 1984, 1989). This tendency to follow others in a fearful situation is likely to lead to a jam at a single exit, rather than dispersion to several different exits.

Another factor that could contribute to jammed exits in an emergency situation is that fear might lead individuals to persevere in one behavior pattern. Individuals repetitively attempt to move in a given direction, even though these efforts prove fruitless. These phenomenon may be instances of a more general tendency to fixate
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under fear. Maier (1949) showed that when faced with insoluble problems, animals show rigidity or abnormal fixation of behavior. Imada (1975) also reported fixated behavior in rats exposed to severe electric shock. Compared to rats exposed to lower shock levels, those receiving severe shock repeatedly jumped in the same direction to escape the shock, even though movement in any direction could lead to escape. With human subjects, Kugihara (1985, 1989) created an emergency situation where there were five equally available exits. He investigated the effect of fear induced by an ostensible threat of electric shock on choosing an exit. Results showed that frightened subjects tried repeatedly to escape through the same route, in spite of the fact that there were other outlets available.

Several laboratory experiments have attempted to reproduce emergency situations to examine collective escape behavior. Most of this research has focused on the effects that emotional arousal, namely fear, has on escape patterns. In an early study by Mintz (1951), subjects were required to remove from a bottle objects attached to a string. Because the neck of the bottle was narrow, only one object could be removed at one time. Thus a jam occurred if two or more subjects tried to remove their objects at the same time. In this setting, Mintz set up several experimental conditions. One of them was that confederates shouted, demonstrating a state of arousal to naive subjects. In another condition, subjects were motivated to remove their object quickly from the bottle by the promise of a monetary reward for escaping within a given time period. Only subjects in the reward condition produced bottle-neck jams, while emotional arousal, as operationalized by Mintz, did not lead to jams.

Kelley, Condry, Dahlke, and Hill (1965) argued that Mintz's study did not examine the effect of fear directly, and that to investigate the influence of fear on escape behavior fear and nonfear condition should be created. Fear was created by instructing subjects that they would receive electric shock if they failed to escape within a specified time period. Results showed that fear facilitated a jam occurrence. In addition, fear led to a slower escape rate.

Kruglanski (1969) set up a condition in which the later the subject escaped the greater the monetary reward they could receive. The subjects' level of motivation to postpone their escape was manipulated by the amount of money they received. The results showed that even under the condition of fear induced by electric shock, the degree of jam was low in the high monetary condition.

Gross, Kelley, Kruglanski, and Patch (1972) investigated whether the occurrence of a jam was caused by irrational emotional arousal such as fear, or by a rational response to an unstable reward structure of a emergency situation. However, They could not obtain clear results.

In contrast to Kelley et al. (1965), by setting up almost the same situation as the Mintz's experiment, Schultz (1966) showed that the degree of jam was actually lower when fear induced by electric shock was present than when it was absent. Schultz contended that in the fear condition subjects grasped the severity of the situation and behaved conservatively.

As this review demonstrates, the few studies conducted to date on the relationship between fear and escape behavior have failed to show consistent results. The major purpose of the present study is to examine this relationship with an experimental procedure that realistically portrays a disaster situation. In the experiments described above, subjects were able to observe the behavior of others. Thus, they were able to quickly grasp the impact of their behavior on others and they were keenly aware that their own behavior was observed by others. In these kinds of situations, subjects might find it difficult to behave in a self-serving fashion. In a real disaster, however, an individual's field of vision may be limited. Therefore, it may be difficult for individuals to see the impact of their own behavior on others. In addition, personal actions are somewhat anonymous.

In the present study, subjects were required to
escape from a maze in which others could be observed only when they shared the same passageway of the maze. Fear was induced through instructions that led some subjects to believe that they would receive painful electric shock if they did not exit the maze quickly. It was predicted that, compared to subjects in the nonfear control condition, subjects in the fear condition would spend more time in the maze in spite of moving at a faster pace, and would travel a longer distance before escaping from the maze. These subjects were also expected to spend more time involved in a jam. In addition, it was predicted that the order of escape would interact with fear, such that fear would have its greatest effect on subjects who escaped from the maze last. Strauss (1944) suggested that feeling of isolation from others can lead to a feeling of panic. Thus, subjects who are left in the maze after others have escaped might evidence poor escape behavior, especially by those in the fear condition. Finally, it was predicted that learning the shape of the maze would be slower for subjects in the fear condition. In other words, their walking distance and escape time would not be reduced across subsequent trials in the same maze.

METHOD

Subjects and Design

One hundred and sixty-eight male undergraduate students at Kyushu Institute of Technology participated in the study. Subjects were run in groups of six. The experiment was conducted in a 2 × 3 (Fear vs. Nonfear × Trial) factorial design.

Apparatus

Six booths were placed in a single room, each equipped with a desk, a TV monitor, a computer, a set of headphones, and electrodes. A control panel consisting of a button and a vertical control stick was also placed on each desk.

During the experiment the monitors displayed for the subjects what they would see if they were inside a maze (see Figure 1). Arrows were used to indicate the presence of others in the maze. Since the six computers were connected to one another, these arrows indicate the actual movement of the other five subjects in the experiment. If another subject came within a subject’s field of vision, a colored vertical bar appeared on the screen. The direction of movement was indicated by an arrow that pointed upward if the movement of this other subject was in the same direction as the subject himself was moving, and pointed downward if the subjects were moving in the opposite direction. The length of the bar indicated how far away other subjects were; as a subject got closer to another subject the bar got longer. Movement of another subject to the right or to the left was indicated by an arrow pointing in the direction of that subject’s movement. The statement, “Someone is just behind you.”, was flashed on the screen whenever a subject was approached from behind. Lines indicating the presence of others were only presented when subjects were in the same corridor. If a wall separated subjects, they could not see each other.

Subjects could control their movement within

Fig. 1. An example of a typical display seen by a subject. (The colored vertical bars seen by this subject correspond to other subjects. The length of the bar corresponds to the distance between the subject and the other subjects. The direction of the arrow corresponds to the other subjects' direction)
the maze by pushing or pulling the vertical control stick in direction labeled "backward", "turn right", and "turn left". Movement was produced by pressing the button on the control panel eight times. This moved the subject one block of the maze (the maze consisted of 93 blocks). To change direction, a subject had to first use the stick to choose a direction, and then press the button to move. Each subject's movements were recorded in a central computer.

The following additional constraints were imposed on the situation. Only one subject could occupy a particular position in the maze at any one time, and the passageways of the maze were too narrow for subjects to pass one another. Thus, subjects could not pass each other in the maze. Figure 2 presents an overview of the maze. The passageways were arranged such that when subjects reached a dead-end, it was necessary to backtrack and move toward the wall opposite the dead-end. The maze included a starting point, four T-shaped turning points, and an exit. Keep in mind that the subjects were never given this vantage point of the maze; they only saw the maze from the inside.

Procedure

Subjects were seated in one of the six booths, from which they were unable to see the other five subjects. It was explained that the purpose of the experiment was to examine behavior in an emergency situation such as a fire or an earthquake. At this point, subjects in the fear condition were asked if they would agree to receive electric shock. Before the experimental trials began, subjects were taken through a practice trial during which they were instructed in how to use their control instruments to progress through the maze. In addition, various aspects of the maze were described, including dead-ends, T-shaped passage, the exit, and the arrow indicating the presence of others. Subjects were informed of their inability to pass others in the maze and of the likelihood that a jam would occur if more than one subject tried to occupy the same position in the maze.

Subjects in the fear condition were told that to simulate a real-life emergency situation, they would receive an electric shock, and the strength of this shock would depend upon the speed of escape; the longer it took to escape, the greater the shock. Subjects were also told that the electric shock would be given to simulate a situation where someone was killed or injured because of a disaster such as a fire. An 80 volt sample shock was administered for a moment from the medical instrument for treating stiffness of the shoulders through electrodes attached to the second and third fingers of the left hand. Subjects were then told that the electric shock given after the three trials in the maze would be more than five times greater than this, causing a considerably stronger and unpleasant sensation.

Subjects in the nonfear condition were simply told that the purpose of the experiment was to simulate a real-life disaster situation, such as a fire or an earthquake. No instructions concerning electric shock were given.

Each of the three trials consisted of a 30 minute time period during which the subjects attempted to escape from the maze. During each trial the room was darkened. To inform subjects
of a time elapsed, the synthesizer's sound coming through the subjects' headphone become increasingly higher as each session progressed.

Dependent measures

At the end of the third session, subjects completed a questionnaire asking them to rate on a 5-point scale how fearful and disturbed they felt during the trials, how nervous they were about the movements of others, and how difficult they judged the maze to be.

A central computer recorded the distance (in blocks) each subject moved during each trial, the speed at which subjects traveled through the maze, the amount of time spent in the maze, and the amount of time spend in a jam.

RESULTS

Manipulation checks

The questionnaire item concerning the degree of fear experienced during the trials served as a check for the fear manipulation. The data were evaluated by $2 \times 6$ (Fear $\times$ Escape Order) analyses of variance (ANOVA). Escape order was determined by adding the total time taken to escape during the three trials. The subject who took the least time to escape across the three trials was considered the first subject to have escaped and subject who took the most time to escape across trials was considered the last subject to have escaped. The analyses revealed that subjects in the fear condition reported greater fear than subjects in the nonfear condition, $F(1,156) = 37.54$, $p < .01$. There was no main effect for escape order, nor was there a significant interaction.

The analyses of the items on nervousness about other's movement and on feeling of disturbance caused by others' behaviors also revealed the significant main effects for fear, $F(1,156) = 3.51$, $p < .06$, $F(1,156) = 11.94$, $p < .01$, respectively.

Locomotion distance

The number of blocks traveled by the subjects during each trial served as a measure of locomotion distance. The horizontal axis of Figure 3 indicates, in ascending order, the locomotion distance of the subjects. That is to say, the locomotion distance of the subject on the left end of this axis was the shortest among the distance of the members of his group. On the other hand, the right-end subject's locomotion distance was the longest in his group. The data was evaluated by separate $2 \times 3 \times 6$ (Fear $\times$ Trial $\times$ Locomotion-distance order) ANOVA. The trial factor was treated as a between-subject measure because subjects' order concerning the locomotion distance

![Fig. 3. Mean locomotion distance as a function of fear, trial, and order of locomotion distance of subjects.](image-url)
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was sometimes changed from trial to trial. As a result of analysis, significant main effects for fear, trial, and order were obtained, $F(1,468)=26.04, p<.01$, $F(2,468)=18.58, p<.01$, and $F(5,468)=44.87, p<.01$, respectively. These main effects indicate that subjects in the fear condition locomoted further than subjects in the nonfear condition, and locomotion distance was reduced over trials. Furthermore, a significant Fear × Trial interaction emerged, $F(2,468)=3.43, p<.05$, indicating that the reduction in locomotion distance that took place in later trials was more prominent for subjects in the nonfear condition than for subjects in the fear condition. This suggests that subjects in the fear condition were slower in learning the shape of the maze than subjects in the nonfear condition. The questionnaire analysis concerning the feeling of maze difficulty also showed a significant difference between the fear condition and the nonfear condition, $F(1,156)=23.37, p<.01$. In addition, a significant interaction between fear and order, $F(5,468)=2.68, p<.05$, indicates that, as predicted, fear had its greatest impact on subjects who took the longest to escape. No other interactions were significant.

**Time spent in the maze**

Figure 4 shows the time it took from the starting point to the exit. The horizontal axis corresponds to the order of escape. Subjects on the left end of this axis were the first to escape in every group. On the other hand, subjects on the right end were the last to escape. The data was analyzed by $2\times3\times6$ (Fear × Trials × Escape order) ANOVA. Significant main effects for fear, trial, and order were obtained, $F(1,468)=13.64, p<.01$, $F(2,468)=17.76, p<.01$, and $F(5,468)=41.09, p<.01$, respectively. Subjects in the fear condition spent more time in the maze than subjects in the nonfear condition, time spent in the maze lessened subsequent trials, and not surprisingly, subjects who were among the last to escape spent more time in the maze. In addition, there was a marginally significant Fear × Order interaction, $F(5,468)=1.76, p<.12$, indicating that fear had its greatest impact on subjects who took the longest to escape from the maze.

**Locomotion speed**

Locomotion speed was computed by dividing the number of blocks subjects traveled by the amount of time(s) it took to exit the maze. The data was evaluated by separate $2\times3\times6$ (Fear × Trial × Escape order) ANOVA. As a result of analysis, significant main effects for fear, trial, and order were obtained, $F(1,468)=9.63, p<.01$, $F(2,$
These main effects indicate that subjects in the fear condition traveled at a higher speed than subjects in the nonfear condition, that speed increased over trials, and subjects who escaped early locomoted at a high speed than those who escaped later.

**Jam seconds**

Jam seconds was the sum over the various Ss of the time they adjoined each other in the maze. In other words, it reflects the length of jam and the number of persons contributing to them. For example, in the case in which three persons were involved in a jam for three seconds, the jam seconds equaled nine. As shown in Figure 5, the degree of jam seconds was almost the same in all conditions just after the start of the experiment. As time passed, however, the degree of jam seconds was gradually differentiated in accordance with condition. The data was at first transformed logarithmically. For reason of analysis of the time series data, jam seconds data were divided into every 30 seconds. A 2 x 3 (Fear x Trial) ANOVA for every 30 seconds revealed significant main effects for fear on 120s, 150s, 180s, 210s, 240s, and 270s, F(1,26)=11.09, p <.01, F(1,26)=22.88, p <.01, F(1,26)=4.79, p <.05, F(1,26)=4.86, p <.05, F(1,26)=4.61, p <.05, and F(1,26)=5.05, p <.05, respectively.

**DISCUSSION**

As mentioned above, although the few studies conducted to date on the relationship between fear and escape behavior have failed to show consistent result, the present study clarified the negative effect of fear. The difference between the result of this study and prior reports would be mainly caused by experimental situation. In the prior experiments, subjects were able to observe the behavior of others. Thus, they were able to quickly grasp the impact of their behavior on others and they were keenly aware that their own behavior was observed by others. In these kind of situations, subject might find it difficult to behave in a self-serving fashion. In a real disaster and in the present experiment, however, an individual's field of vision may be limited. Therefore, it may be difficult for individual to see the impact of their own behavior on others. In addition, personal actions are somewhat anonymous.

The difference in speed of locomotion demonstrates that motivation toward early escape was greater in the fear condition than in the nonfear condition. In spite of the fact that the locomotion speed was higher in the fear condition than in the nonfear condition, it was also found that escape time for subjects was longer in the fear condition than in the nonfear condition. It appears that one cause of these effects was that fearful subjects were apt to be involved in the jams, and once this occurred, they could no extricate themselves as easily as those in nonfear condition. The second reason may be due to the fixation of fearful subjects to a certain area within the maze. That is to say, fear produces impatience, which in turn degrades decision making. As a result, subjects tend to go around and around in the same area of the maze at high speed.

The places where a jam was apt to break out most frequently were in corners from which dead-
ends were five blocks away (i.e., A, B, C, and D of Figure 2). From these places, subjects could not judge whether the dead-ends existed in front of them, because they could not see the front wall of the dead-end. If subjects could have moved one block further in the direction of the dead-end, they could have seen the front wall and therefore could have identified the dead-end in front of them. Generally, subjects who arrived in these corners tended to proceed to the dead-end. But unfortunately, in the case where another subject backtracked from the dead-end, they were apt to bump against each other and could not move at all. They then tried to push away each other in order to move from their position. Soon, other subjects who followed these two subjects arrived in this area and participated in the jam one after the other. The analysis of the item on nervousness about other's movement in the questionnaire indicated that the tendency to follow others was greater in the fear than in the nonfear condition.

A subject who was sandwiched between others could not move forward or backward. The subject turned around and around frantically because he or she was at a loss for what to do. Moreover, a subject who followed others involved in the jam became irritated because these others did not move forward and because there was no information why this was so. This is supported by the finding that fearful subjects reported being more disturbed by others' behavior than were nonfearful subjects.

For a while almost all subjects gathered in a certain corner and struggled. After a while, a subject who stood in the tail of jam group gave up following others, and ceased movement toward the dead-end. Then the subject began to go in the opposite direction. After that, others followed. Consequently, the jam group disappeared gradually, but reappeared in another corner where subjects concentrated. In the fear condition, the same type of phenomenon as mentioned above occurred repeatedly.

On the other hand, in the nonfear condition, a jam occurrence was relatively rare. If a subject could think and behave rationally, he could soon understand that the behavior of others is important information. If a person in front of a subject turned back, the subject might become aware that a dead-end existed in front of him.

In this study, fixated behavior was shown to be greater in the fear condition than in the nonfear condition. Subjects in the fear condition had a tendency to go around and around in the same area within the maze. Figures 3 and 4 show this phenomenon clearly. The locomotion distance and the time subjects took to reach the exit were greatest in the fear condition. It seems that to grasp the entire shape of the maze was more difficult for subjects in the fear condition than in the nonfear condition because of the long locomotion distance and the long locomotion time subjects took to reach the exit and because of high frequency and length of jam situations in the fear condition. So, as shown in the Figure 3, it is also evident that subjects in the fear condition were inferior to subjects in the nonfear condition. The questionnaire analysis concerning the feeling of maze difficulty also showed a significant difference between the fear condition and the nonfear condition.

Furthermore, such a phenomenon as mentioned above was prominent especially for subjects who escaped later in the fear condition. That is to say, while the locomotion distance of first escaped subject was almost the same in both conditions (i.e., fear and nonfear condition), the distance traveled by the last escaped subject varied by condition. According to these result, it is likely that fear magnified individual differences. One person may behave coolly and rationally even in an emergency. On the other hand, other persons, who are frightened in a dangerous situation, can not make rational judgments about the surrounding circumstance. It was said that the value of a person or true personality is measured most precisely when he or her is in a difficult situation. The results of the present experiment seem to suggest this phenomenon.

In addition, it seems that the person who escaped later was greatly affected by fear. As
Strauss (1944) indicated, the feeling of isolation amplifies fear, leading to irrational behavior.

Future research should develop a time series method or mathematical model which is able to analyze or express the dynamic movement of subjects in the maze. In the present study, a simple method which cut the time series data into 30 seconds blocks was used. Thus, an important aspect of the data might have been neglected. Furthermore, a model which expresses the relationship between the shape of a maze and the degree of escape difficulty to escape should be developed. There is a related network model which uses graph theory (Yoshimura, 1988). This model may provide useful new tools for analysis of maze evacuability.

REFERENCES


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