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Article

Influence of Cognitive Biases in Distorting Decision Making and Leading to Critical Unfavorable Incidents

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Abstract: On the basis of the analyses of past cases, we demonstrate how cognitive biases are ubiquitous in the process of incidents, crashes, collisions or disasters, as well as how they distort decision making and lead to undesirable outcomes. Five case studies were considered: a fire outbreak during cooking using an induction heating (IH) cooker, the KLM Flight 4805 crash, the Challenger space shuttle disaster, the collision between the Japanese Aegis-equipped destroyer "Atago" and a fishing boat and the Three Mile Island nuclear power plant meltdown. We demonstrate that heuristic-based biases, such as confirmation bias, groupthink and social loafing, overconfidence-based biases, such as the illusion of plan and control, and optimistic bias; framing biases majorly contributed to distorted decision making and eventually became the main cause of the incident, crash, collision or disaster. Therefore, we concluded that, in addition to human factors or ergonomics approaches, recognition and elimination of cognitive biases is indispensable for preventing incidents, crashes, collisions or disasters from occurring.

Keywords: cognitive bias; confirmation bias; groupthink; fallacy of control; fallacy of plan; framing

1. Introduction

Unlike in traditional economics, bounded rationality is commonly assumed in behavioral economics [1–9] in that decisions cannot be made rationally, thereby resulting in cognitive biases, as pointed out by Kahneman [1], Tversky and Kahneman [2] and Kahneman and Tversky [3]. Kahneman and Tversky [3] stated that the cognitive information processing in humans is conducted through either of the following processes. System 1, where the operation is quick, automatic, without much time consumption and intuitive, with little or no effort, and System 2, which requires effortful, demanding and deliberate mental activities. Nevertheless, a heuristic approach of cognitive information processing, which is adopted when there is a time constraint, is based on System 1 and is simple and intuitive. However, such approaches constantly suffer from cognitive biases.

One of the major causes of the Challenger space shuttle disaster [10,11] is regarded to be due to groupthink or, specifically, the illusion of unanimity [12–14]. In this case, although the manufacturer of the O-ring recognized the risk of malfunction of the O-ring under severe cold conditions, the manufacturer agreed with the launch of the Challenger space shuttle owing to an illusion of unanimity. After a serious disaster, collision or crash occurs, one tends to overestimate the occurrence probability of such an event. For example, one generally hesitates to use an airplane immediately after a serious incident of crash, because he/she tends to overestimate the occurrence probability of a crash. This type of cognitive bias is called the hindsight bias and is suggested to become an obstacle in the objective analysis of incidents, crashes, collisions or disasters.

Reason [10] enumerated judgmental heuristics and biases, irrationality and cognitive ‘backlash’ as potential risk factors of human errors or mistakes leading to unfavorable or unexpected incidents. However, a systematic model of how such cognitive biases and backlashes are related to distorted decision making and how they become a trigger of incidents, crashes, collisions or disasters is not provided. Moreover, this study does not address how cognitive biases distort decisions irrationally. Dekker [15] pointed out a situation of developing a vicious circle of repeated occurrences of similar unfavorable incidents. He also suggested that the cause of such a vicious circle is hindsight bias, pointed out by Fischhoff [16], or outcome bias, noted by Mackie *et al.* [17], which places greater emphasis on outcomes than processes. In other words, he suggested that the analysis of incidents, crashes, collisions or disasters conducted without hindsight bias or considering outcomes, but with foresight or in consideration of processes, will aid in proper safety management and in drastically disconnecting a situation of a vicious circle of repeated occurrences of similar incidents. Therefore, it is important to gain insights into how cognitive biases are related to and lead to critical incidents.

In this paper, we first discuss how cognitive biases potentially induce critical incidents by distorting decision making. By using five examples, (i) a case of a fire breakout during cooking with an IH cooker, (ii) the KLM Flight 4805 crash, (iii) the Challenger space shuttle disaster, (iv) the collision between a Japanese Aegis-equipped destroyer and a fishing boat and (v) the Three Mile Island nuclear power plant disaster, we demonstrate how cognitive biases are related to these incidents. Some implications of our findings for preventing incidents, crashes, collisions or disasters in consideration of cognitive biases are given.

2. How Cognitive Biases Lead to Unsafe Behaviors or Events

As shown in Figure 1, cognitive biases are hypothesized to cause distortion of decision making, thereby leading to human errors in judgment, decision making and behavior, eventually (in the worst case), triggering incidents, crashes, collisions or disasters if the commitment to the biased judgment, decision making and behavior is escalated (Murata and Nakamura [18]).

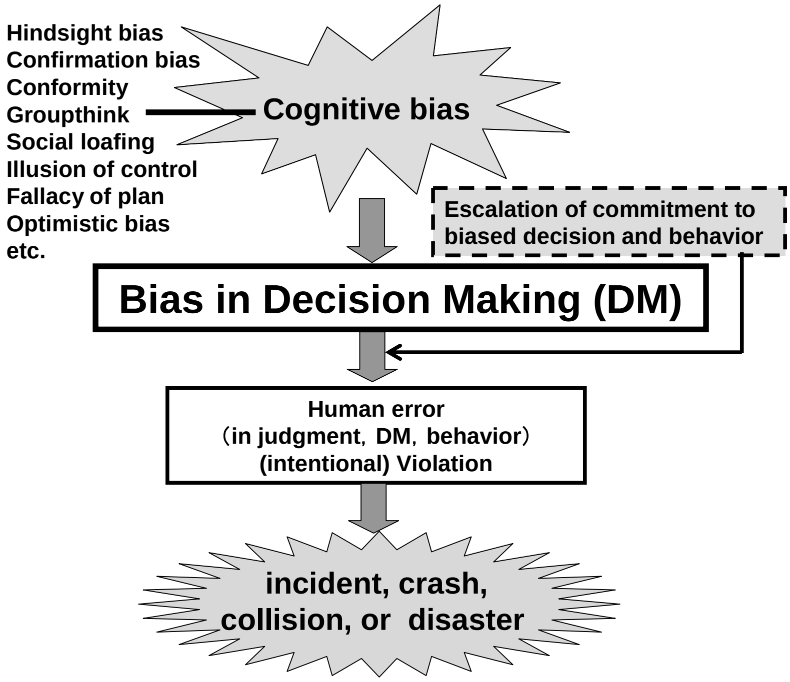

Figure 1. Relational model between cognitive biases and unsafe behaviors, incidents, crashes, collisions or disasters.

Bazerman and Moore [6] hypothesized that heuristics, such as availability, representativeness, confirmation or affect, cause biases, including confirmation biases, anchoring and adjustment, hindsight, availability bias and conjunction fallacy. An event easily imaginable is more available than an event that is difficult to imagine. For example, the availability of the vividness of imaginable events biases our perception of the occurrence frequency of similar events. This might lead to wrong decision making on the frequency of such events. Managers predict a salesperson's performance on the basis of an established category of salespeople. This corresponds to the representativeness heuristic. While this heuristic offers a proper approximation of salespeople in some cases, it can induce a biased understanding of salespeople and lead to serious errors in other cases. Such errors include ignorance of base rate or insensitivity to sample size pointed out by Tversky and Kahneman [2] and Kahneman and Tversky [3]. People naturally tend to seek information that confirms their expectations and hypotheses, even though information disconfirming their expectations and hypotheses is actually more useful. This induces a biased recognition of causality and leads to serious errors.

Figure 2 shows not only heuristics, but also overconfidence and framing as causes of biases. Bounded awareness prevents one from focusing on useful, observable and relevant information. Due to such bounded awareness, it is valid that we occasionally cannot behave rationally. Moreover, it is assumed that our bounded awareness and uncertain (risky) situations form the basis of heuristics, overconfidence and framing.

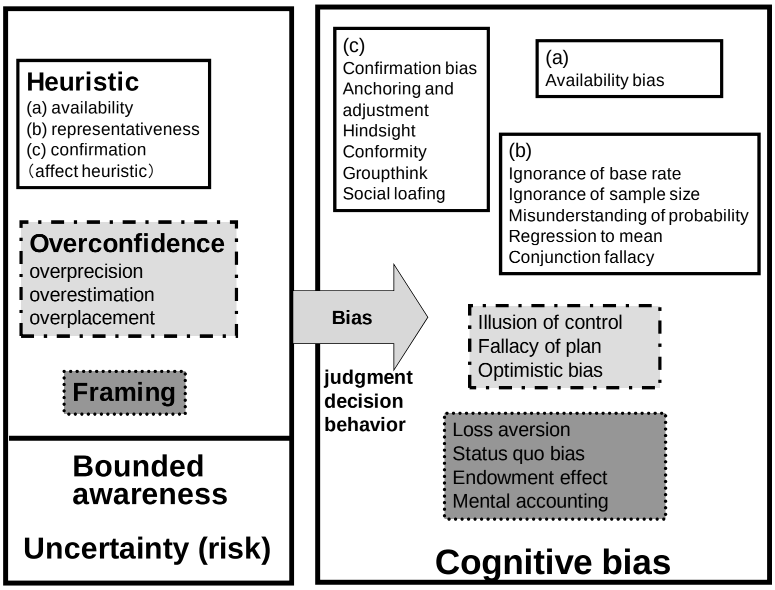

Figure 2. Mechanism of cognitive biases due to heuristics, overconfidence and framing.

As mentioned above, we frequently tend to behave irrationally and are, in most cases, unaware of how and to what extent these irrational behaviors influence us. Such irrational tendencies definitely distort our decisions and, in the worst cases, lead to incidents, crashes, collisions or disasters, according to the model shown in Figures 1 and 2. Without the consideration of our bounded rationality (irrationality) in our approach, we cannot analyze and prevent the main (root) cause of a disaster.

Further analysis on the basis of case studies is required for how cognitive biases distort decision making, induce preconception and become a trigger of an incident, a crash, a collision or a disaster. To this end, we aimed to further clarify the mechanisms related to why we suffer from cognitive biases, under what conditions we are vulnerable to cognitive biases, what type of cognitive bias is potentially dangerous and readily leads to an unfavorable and unexpected incident and when or how cognitive biases distort decision making and become a trigger of errors, violations and critical incidents. Moreover, we aim to identify what is in common for the undesirable stream that cognitive biases induce errors or violations of regulations or safety rules and how this leads to an incident, a crash, a collision or a disaster.

3. Analyses of the Cause of an Incident, a Disaster, a Collision or a Crash from the Perspective of Cognitive Biases

3.1. Outbreak of Fire during Cooking with an IH Cooker

A fire outbreak incident occurred in April 2008 due to the misuse of an IH cooker (from Encyclopedia of Accidents II (Nikkei BP)). When a woman was making a deep-fried dish, a fire broke out during her absence from the kitchen for a while. Although the woman attempted to fight the fire, she suffered from burns on the hand, and the cooking range hood was partly damaged. The following three points are the precautionary measures a user must take when using an IH cooker, and violations of these notices occurred in this case.

(1) When preparing a deep-fried dish, the user must select the "deep-fried dish" mode. For heating a cooking pot on an IH cooker, an eddy current is produced inside the pot by means of a magnetic-generation coil. Using the "deep-fried dish" mode and setting up the oil temperature is effective to some extent to prevent overheating of the pot. The woman, however, selected the "manual" mode.
(2) When using an IH cooker, the user must use the pot exclusively provided with the cooker. The IH cooker has a built-in temperature sensor at the location corresponding to the center of the exclusive cook-pot that will sense the temperature of the pot and thus avoid overheating of the oil. However, the woman used a different commercial cooking pot.
(3) When using an IH cooker, the user must not cook or prepare a deep-fried dish using an amount of oil of less than 500 g. Less oil makes it impossible to measure the temperature of the oil accurately as there can be an abrupt increase in the temperature. The woman cooked using an amount of oil of less than 500 g.

A reproducibility experiment of this incident conducted by the National (Japanese) Institute of Technology and Evaluation (NITE), Japan, verified the following results. When the exclusive cooking pot was used with 600 mL of oil, a fire did not break out. In contrast, when a commercial pot with a caved center was used, combustion occurred in approximately 6 min.

Now, we consider the cause of the incident from the perspective of cognitive biases. Optimistic biases correspond to the tendency to overestimate the rosiness of our future (occurrence of a likable event) and to avoid facing inconvenient events. This may be due to the fact that imagining a favorable future provides us with a feel-good experience. We tend to believe that we are less at risk of experiencing a negative event than others and that we exaggerate less than others.

Normalcy biases represent our propensity to regard minor abnormalities as normal. By this phenomenon, we try to prevent ourselves from reacting excessively to various changes or new events and becoming impoverished. Normalcy bias in excess becomes hazardous in that we do not seriously consider a warning presented to us and may delay in escaping from a disaster, such as a Tsunami or landslide. Normalcy bias is in fact a coping mechanism we adopt while attempting to register and deal with stressful events or impending disasters. Because fears change, one tends to resist them, and in turn, the brain tries to simulate a normal environment. This resistance to a change is a considerably common and normal response and can occur even during the first phase of stressful events or disasters. However, risk can stem from this bias, as we usually become accustomed to normal situations or states and thereby tend to overestimate optimistically that the situations surrounding us will continue to be normal.

In summary, the violation of the aforementioned precautionary measures, (1) and (2), probably stemmed from the optimistic and normalcy biases. The possibility of overheating was regarded optimistically. We must also regard the minor abnormality (violation of Measures (1) and (2)) as normal due to the normalcy bias. Concerning Measure (3), along with optimistic and normalcy biases, loss aversion might have played a role, because the woman tried to save cooking oil. Thus, cognitive biases contributed mainly to the occurrence of the incident. The analysis of this incident is summarized in Figure 3.

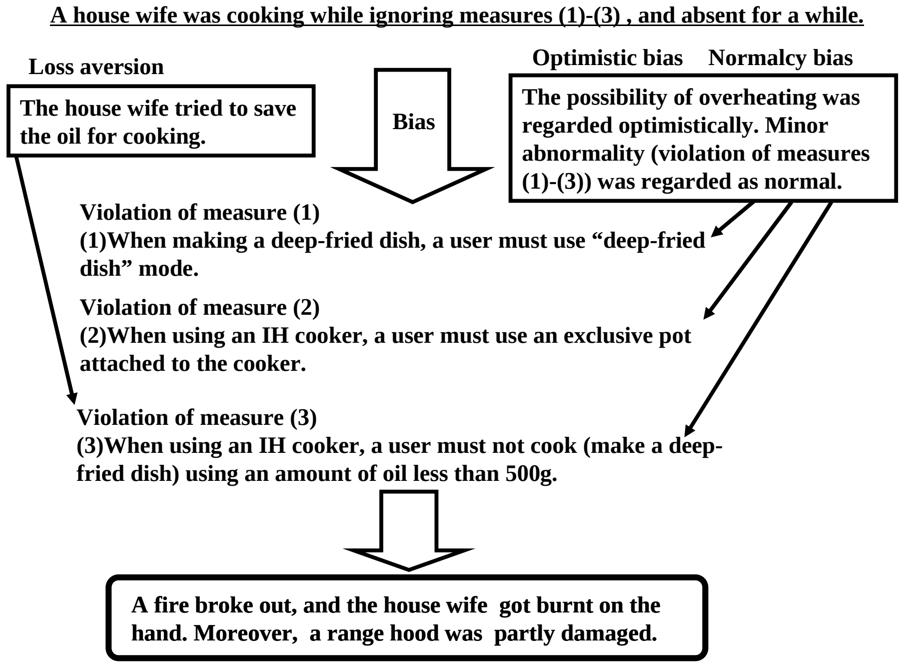

Figure 3. Summary of the analysis of an IH cooker incident.

3.2. KLM Flight 4805 Crash

In March 1977, a Boeing 747 KLM Flight 4805 left Amsterdam and was bound for Las Palmas Airport on the Canary Islands. A terrorist bomb explosion occurred at a flower shop in Las Palmas Airport, and so, the flight, along with a few others, was diverted to Tenerife Airport. After landing at the airport, the flight waited for clearance from the ATC (air traffic controller) to take off, but because of reduced visibility due to fog at the airport, the clearance was delayed. The captain, however, decided to take off without permission from the ATC, and he turned the throttles to full power on the foggy runway. Unfortunately, a Pan Am 747 plane was parked across the runway as the KLM Flight 4805 approached it at take-off speed. Although the captain attempted to avoid a collision by trying to take off as early as possible, the underside of KLM flight's fuselage ripped through the Pan Am plane, and the KLM plane burst into a fiery explosion. All crew and passengers of the KLM plane and many passengers of the Pan Am plane lost their lives.

Brafman and Brafman [19] pointed out that loss aversion strongly contributed to the KLM Flight 4805 crash. In this case, the losses for the captain of the flight include a reduced mandated rest period due to the flight delay, the cost of accommodating the passengers at a hotel until the situation improves and a series of consequences of the flight delay, such as stress imposed on the captain and a blot on the captain's reputation of being punctual. The complicated interaction of these factors probably triggered and escalated the captain's feeling of loss aversion. The more significance we attach to potential loss, the more loss aversive we tend to be. The captain must have been preoccupied with the urge to reach the destination as early as possible and must have lost his sense of safety, resulting in his decision to take off without clearance from the ATC. For no apparent logical reason, we tend to get trapped in such a cognitive bias. The phenomenon of loss aversion apparently unexpectedly affected the decision making skills of a seasoned flight captain and caused the critical crash. The analysis of the crash is summarized in Figure 4.

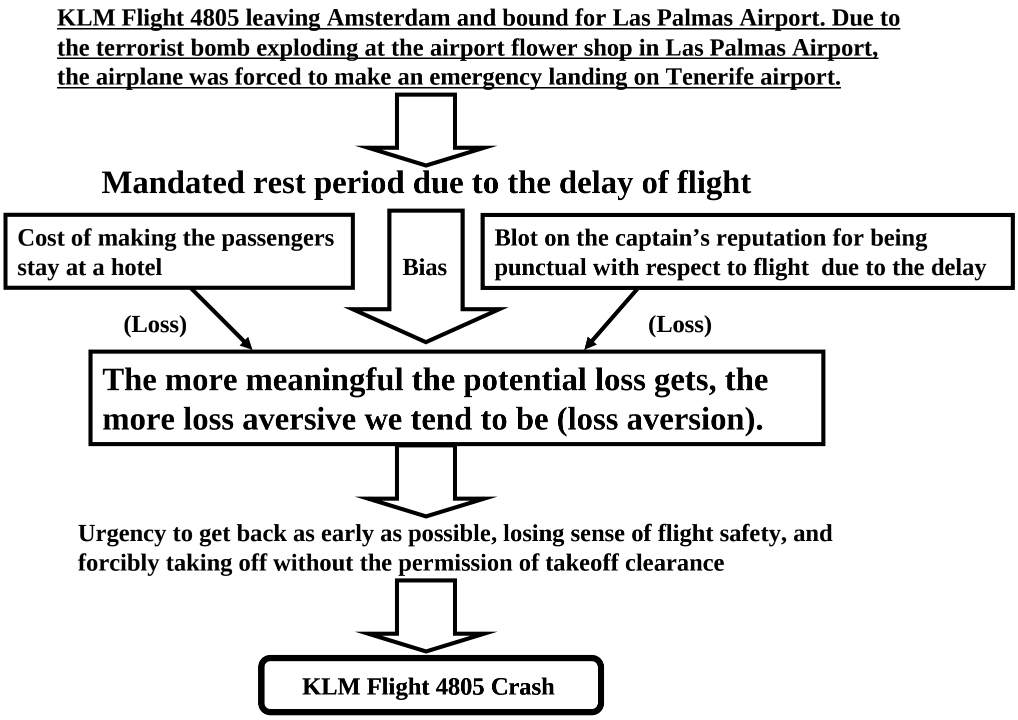

Figure 4. Summary of the analysis of the KLM Flight 4805 crash.

3.3. Challenger Space Shuttle Disaster

One of the major causes of the Challenger space shuttle disaster, in January 1986, is regarded to be the phenomenon of groupthink, especially the illusion of unanimity (e.g., Reason [10] and Vaughan [11]). The illusion of unanimity implies that the group decision conforms to the majority view. When such a cognitive bias occurs, the majority view and individual judgments are assumed to be unanimous. As shown in Figure 2, groupthink stems from the confirmation heuristic. As stated by Janis [12–14], groupthink is explained by the following three properties: overestimation of the group, closed mindedness and pressure toward conformity. These properties will potentially distort the group's decision toward the wrong direction.

Although the manufacturer of the O-ring (a component of the space shuttle) recognized the risk of a malfunction of the O-ring under severe cold temperature, the manufacturer agreed with the launch of the Challenger space shuttle because of groupthink. Specifically, the factors that contributed to this irrational behavior include direct pressure on dissenters (group members are under social pressure to not oppose the group consensus), self-censorship (doubts and deviations from the perceived group consensus are not accepted) and the illusion of unanimity. Turner *et al.* [20,21] also showed that groupthink is most likely to occur when a group experiences antecedent conditions, such as high cohesion, insulation from experts and limited methodological search and appraisal procedures, and leads to symptoms, such as the illusion of invulnerability, the belief in the inherent morality of the group, pressure on dissenters, self-censorship and the illusion of unanimity. More concretely, the symptoms of groupthink, *i.e.*, (1) incomplete analysis of the alternatives, (2) incomplete analysis of the objectives and (3) failure to examine the risks of the preferred choice, were observed during the occurrence of the Challenger space shuttle disaster. The group, as a whole, did not consider the opinion of the manufacturer that the O-ring might not properly work under a severely cold environment and did not carry out a complete analysis of this opinion. This eventually led to the critical disaster. The analysis of this incident is summarized in Figure 5.

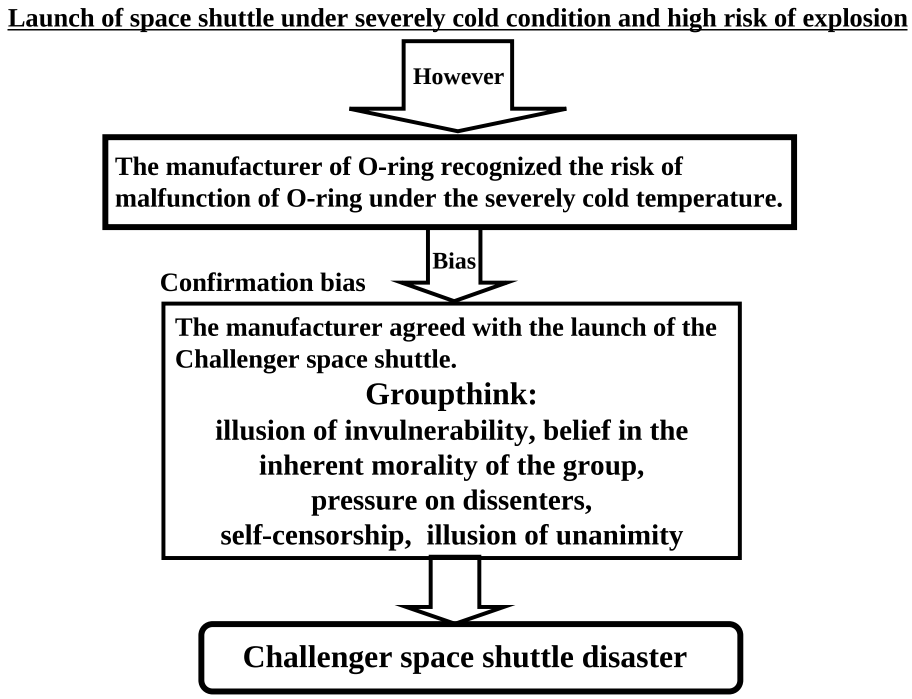

Figure 5. Summary of the analysis of the Challenger space shuttle disaster.

3.4. Collision between the Japanese Aegis-Equipped Destroyer "Atago" and a Fishing Boat

At dawn on 19 February 2008, the Japanese Aegis-equipped destroyer "Atago," which belonged to the Japanese Ministry of Defense, collided with the fishing boat "Seitokumaru." Consequently, two crew members of the fishing boat were missing and thereafter declared dead.

Social loafing, which stems from confirmation bias or optimistic bias, possibly led to this critical incident. Social loafing [22,23] corresponds to a defective behavior in a social dilemma situation. This phenomenon also potentially leads to an undesirable event under the cooperative working condition of a group. Therefore, organizational managers must take appropriate measures to prevent social loafing from leading to undesirable outcomes. Latané *et al.* [22] showed that social loafing is a tendency of an individual to exert less effort when carrying out a job in a group than when working individually. Murata [24] showed that due to social loafing, the performance of a secondary vigilance (monitoring) task tends to decrease as the number of members increases. Moreover, he presented insights into the prevention of social loafing and demonstrated that the feedback of the information on each individual member's performance and the group's performance of both primary and secondary tasks is effective for restraining social loafing.

One of the main causes of the collision of the Japanese Aegis-equipped destroyer and the fishing boat is as follows. According to the announcement of the investigation committee of the collision, although twenty-four crew members were working on the Aegis-equipped destroyer at the time of collision, nobody properly noticed the fishing boat and, thus, could not take proper countermeasures against the collision. Every crew member must have optimistically reckoned that someone would notice an abnormal situation. The crew members may have failed to take into account the poor visibility due to the cold weather conditions while estimating the likelihood that some crew member will detect an anomaly or an obstacle. This corresponds to the social loafing phenomenon [22–24], which stems from confirmation or optimistic bias. In other words, the lack of motivation to detect the likelihood of a collision occurred due to social loafing. The analysis of this collision is summarized in Figure 6.

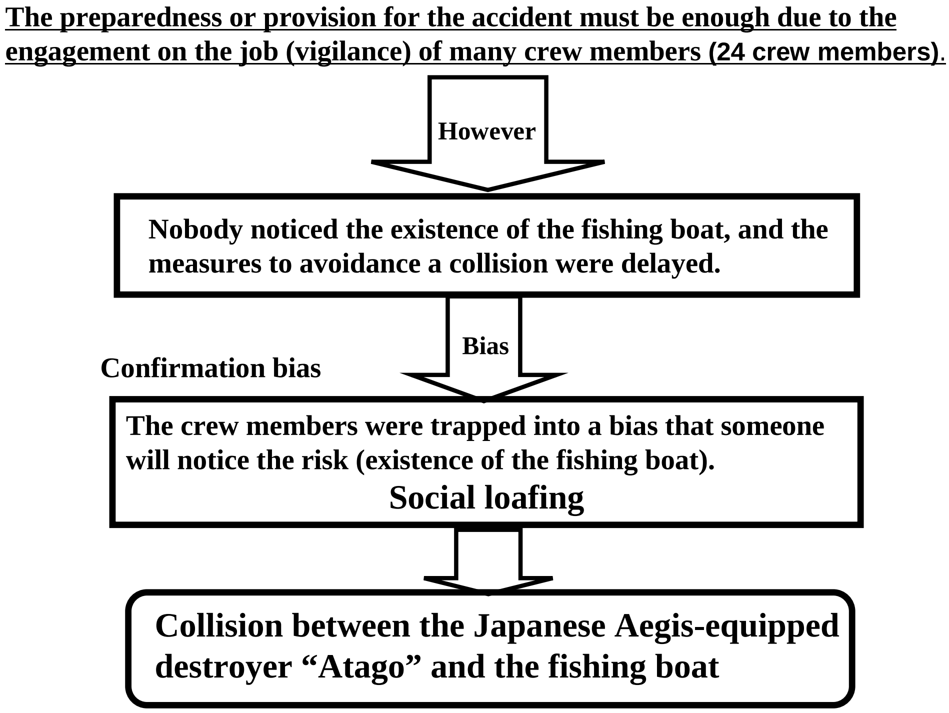

Figure 6. Summary of the analysis of the collision between the Japanese Aegis-equipped destroyer "Atago" and a fishing boat.

3.5. Three Mile Island Nuclear Power Plant Disaster

The main cause of the nuclear meltdown that happened at the Three Mile Island nuclear power plant in March 1979 is that the operators forgot to open the valve of an auxiliary (secondary) water feeding pump after maintenance and did not notice this error for some time [25–27]. This incident is possibly related to confirmation bias (see Figure 2), which made the operators believe that such a subtle error would not be the cause of any critical disaster. The confirmation bias makes us seek information that confirms our expectations (in this case, the expectation that a subtle error would not be the cause of a critical disaster), even though information that contradicts the expectation is available. In spite of the automatic operation of the ECCS (Emergency Core Cooling System), the operators did not notice the malfunction of the nuclear reactor because of the availability heuristic (*i.e.*, Halo effect), which biases our judgments by transferring our feelings or beliefs about one attribute of something to other unrelated attributes. For example, a good-looking person is likely to be perceived as a competent salesperson, even though there is no logical reason to believe that a person's appearance is related to his/her sales achievements. The operators' thinking process could have been biased, such that their belief about the normally-operating plant was transferred even to the malfunctioning plant. Due to confirmation and availability biases, the plant operators could not have identified the root cause of the meltdown. They must also have optimistically believed that such a minor lapse of not opening the valve of the auxiliary water feeding pump would not lead to a crucial disaster (optimistic bias stems from overconfidence).

On the basis of the past reports on the malfunction of the pilot relief valve, it is expected that the pilot relief valve cannot be closed in emergency situations. The confirmation bias that leads the operators to believe that such a trouble would not occur in the Three Mile Island nuclear power plant also prevented them from noticing and identifying the malfunction of the pilot relief valve.

It took a long time to identify the cause of the rapid and abrupt increase of the reactor core temperature, which led to the meltdown of the reactor core. This was probably because of the framing effect (bias) that generally makes operators not analyze and identify the cause of a disaster from multiple perspectives, especially under emergency situations. The operators adhered to the narrow frame that they usually used and could not apply another frame for solving the problem (identification of the cause).

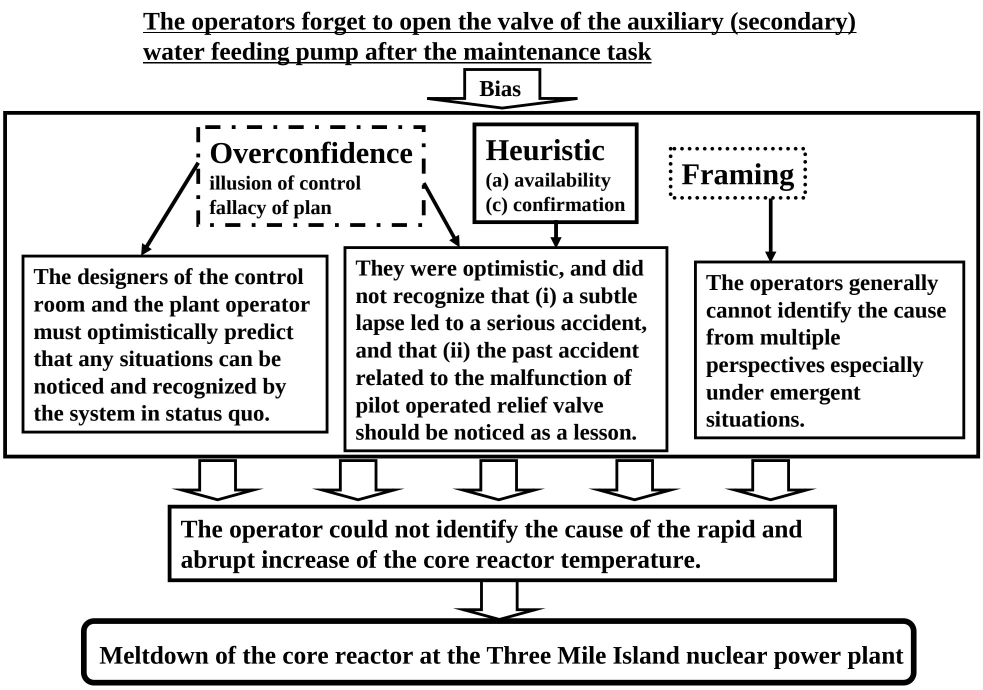

Figure 7. Summary of the analysis of Three Mile Island nuclear power plant disaster.

The design of the central control room must have also been another main cause of the criticality of the disaster. The display system of the central control room was not designed in such a way that the states of the nuclear power plant components, such as the pilot-operated relief valve, the emergency feedwater pump and the drain tank, could be easily monitored. Eventually, the cause of the rapid and abrupt increase in the reactor core temperature could not be identified until the meltdown of the reactor core occurred. The optimistic bias, the fallacy of plan and the fallacy of control (see Figure 2 for the details) were the main causes of the disaster. The designers of the control room and the plant operators must have optimistically predicted that any situations could be noticed and recognized by the system in status quo. Therefore, they did not consider the worst situations in designing the central control room owing to both the fallacies of plan and control. The analysis of this disaster is summarized in Figure 7.

3.6. General Discussion

The framework of the traditional analysis of unexpected incidents or events does not focus on how the distortion of decision making due to cognitive biases is related to critical human errors and, eventually, to crashes, collisions or disasters. Although Reason [10] describes judgmental heuristics and biases, irrationality and cognitive "backlash," he has not demonstrated systematically how such biases and cognitive backlash are related to distorted decision making, which eventually becomes a trigger of crashes, collisions or disasters. Therefore, we presented a systematic approach based on the human cognitive characteristics that we frequently tend to behave irrationally and are, in most cases, unaware of how and to what extent these irrational behaviors influence the decisions we make (Figure 2). In addition, we assumed that such irrational behaviors definitely distort our decisions and, in the worst cases, lead to crashes, collisions or disasters, as shown in Figure 1.

From the analyses of the five case studies presented in Sections 3.1 to 3.5, we note that three major types of cognitive biases (Figure 2) manifest themselves as causal factors of crashes, collisions or disasters. In the discussion of the cases presented in Sections 3.2 and 3.5, framing is shown to contribute to the occurrence of the crash or disaster. Overconfidence and, in particular, optimistic bias lead to the errors or mistakes we discussed in the cases presented in Sections 3.1 and 3.5. Heuristics, that is, groupthink and social loafing, are found to be causal factors in the cases presented in Sections 3.3 and 3.4, respectively. This suggests that we must identify where and under what conditions these heuristic-, overconfidence- and framing-based cognitive biases are likely to come into play within specific man-machine interactions. This way, we can introduce an appropriate safety intervention to avoid these biases from becoming causal factors of crashes, collisions or disasters.

We have demonstrated how cognitive biases can be the main cause of incidents, crashes, collisions or disasters throughout our analysis of the five case studies. The observations emphasize the significance and criticality of systematically building the problem of cognitive biases into the framework of a man-machine system, as shown in Figure 8. Moreover, our findings call attention to addressing human errors and preventing incidents, crashes, collisions or disasters more effectively by considering cognitive biases.

If designers or experts of man-machine (man-society, man-economy or man-politics) systems do not understand the fallibility of humans, the limitation of human cognitive ability and the effect of emotion on behavior, the design of the systems could pose incompatibility issues, which, in turn, will induce crucial errors or serious failures. To avoid such incompatibility, we must focus on when, why and how cognitive biases overpower our way of thinking, distort it and lead us to make irrational decisions from the perspective of behavioral economics [1,6–8], as well as the traditional ergonomics and human factors approach. The design of man-machine (society, economy, or politics) compatibility (compatible technology) must be the key perspective for a preventive approach to human error-driven incidents, crashes, collisions or disasters.

As mentioned in Section 3.3, it is reasonable to think that a cognitive bias (in this case, groupthink) became a trigger of the NASA Challenger disaster. On the other hand, referring to the concept of normal accidents proposed by Perrow [28], Gladwell [29] pointed out the fact that there were many other shuttle components that NASA deemed as risky as the O-ring. Given this view, the case also seems to be the result of an optimistic bias that stems from overconfidence, that is where one thinks optimistically that a malfunction seldom occurs in spite of recognizing defects in numerous components, such as the O-ring. Gladwell [29] warned that a disaster, such as the NASA Challenger disaster, is unavoidable as long as we continue developing large-scale systems with high risks for the profit of humans. Such a situation corresponds to a vicious circle (repeated occurrences of similar critical incidents), as pointed out by Dekker [15].

Cognitive biases lead to such situations being unresolved and, thus, hinder the progress of safety management and technology. A promising method to address such a problem might be to take into consideration and steadily eliminate cognitive biases that unexpectedly and unconsciously interfere with the functioning of large-scale systems, so that man-machine compatible systems can be established and maintained. Introducing appropriate safety interventions that ensure that cognitive biases do not eventually manifest themselves as causal factors of incidents, crashes, collisions or disasters would enable one to address a cognitive-bias-related safety problem appropriately and to develop a man-machine compatible system.

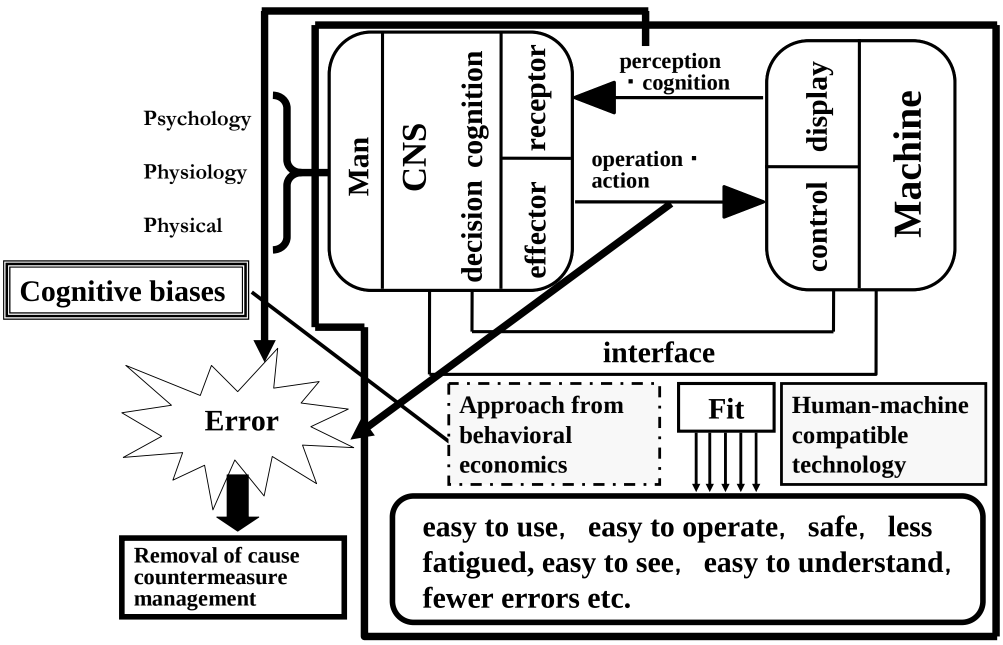

Figure 8. Proposal for a preventive approach to incidents, crashes, collisions or disasters and human error by human-machine compatible technology that takes cognitive biases into account.

4. Conclusions

Throughout the analysis of five case studies, we recognized that the main causes of incidents, crashes, collisions or disasters include cognitive biases. The correction or modification of a bias in decision making is one of the promising measures for preventing such undesirable events. If designers, engineers and managers of modern technologies, such as transportation systems, nuclear power plants and social inflation systems, fail to understand human fallibility (the characteristic of being error-prone) related to irrational thinking, they will tend to design new systems that do not take human limitations (irrationality) into account. Consequently, the distortion of decisions occurs inevitably, escalating human errors and eventually leading to incidents, crashes, collisions or disasters. The lack of such an understanding of human irrationality leads to the repetition of errors unconsciously, resulting in vicious circles of similar crucial incidents, as pointed out by Dekker [15]. Therefore, understanding how cognitive biases distort decision making and lead to critical incidents is essential to avoid such situations of vicious circles.

How cognitive biases can be removed must be examined, as discussed by Gigerenzer [30], who showed that cognitive biases, that is conjunction fallacy and ignorance of the base rate, can be suppressed to some extent by changing the representation of information from a probability-based to a frequency-based representation. Todd and Gigerenzer [31] showed that simple (fast and frugal) heuristics perform better compared to complex and deliberate algorithms in situations where simplicity leads to robustness. Haselton *et al.* [32] suggested that the research on cognitive biases might be well understood through an evolutionary perspective on cognitive bias. Such a perspective might be helpful to gain insight into the mechanism by which we suffer from cognitive biases and under what conditions we are vulnerable to cognitive biases.

Future research should analyze the feasibility of countermeasures to avoid cognitive biases or irrational and distorted decision making by means of check sheets for cognitive biases or irrationality in the processes related to industrial or transportation systems. If we can identify cognitive biases and determine where they may be inherent or likely within specific systems or procedures by using a check sheet of cognitive biases or the accumulated statistics of cognitive biases, we can introduce appropriate safety interventions or countermeasures that will ensure that the recognized cognitive biases do not eventually manifest themselves as causal factors of unfavorable critical incidents. As Gigerenzer [30] demonstrated that the representation of information can be effective for suppressing cognitive bias-related errors, we also aim to establish a useful representation method of information within specific man-machine systems. This will prevent the cognitive biases originating in the information representation from manifesting themselves as contributing factors of incidents, crashes, collisions or disasters.

Author Contributions

Atsuo Murata contributed to making a plan of this research, investigating the relationship between cognitive biases and critical disasters, crashes, and collisions, analyzing five cases, and discussing the results, leading to conclusions and providing some implications for safety management. Tomoko Nakamura contributed to the analysis of five cases, and relating these results to the cognitive biases in

cooperation with Atsuo Murata. Waldemar Karwowski contributed to making a plan of this research, discussing the analysis results, and summarizing the results as findings of this study in cooperation with Atsuo Murata during his research visit to the University of Central Florida, Orlando, USA.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Kahneman, D. *Thinking, Fast and Slow*. Penguin Books: New York, NY, USA, 2011.
2. Tversky, A.; Kahneman, D. Judgment under Uncertainty: Heuristics and Biases. *Science* **1974**, *185*, 1124–1131.
3. Kahneman, D.; Tversky, A. Choices, Values, and Frames. *Am. Psychol.* **1984**, *34*, 341–350.
4. Altman, M. *Behavioral Economics for Dummies*; John Wiley & Sons Canada, Ltd.: Toronto, ON, Canada, 2012.
5. Angner, E. *A Course in Behavioral Economics*; Palgrave Macmillan: London, UK, 2012.
6. Bazerman, M.H.; Moore, D.A. *Judgment in Managerial Decision Making*; Harvard University Press: Cambridge, MA, USA, 2001.
7. Ariery, D. *Predictably Irrational—The Hidden Forces that Shape our Decisions*; Harper: New York, NY, USA, 2009.
8. Ariery, D. *The Upside of Irrationality—The Unexpected Benefits of Defying Logic at Work and at Home*; Harper: New York, NY, USA, 2010.
9. Ariery, D. *The (Honest) Truth about Dishonesty: How We Lie to Everyone—Especially Ourselves*; Harper: New York, NY, USA, 2012.
10. Reason, J. *Human Error*; Cambridge University Press: Cambridge, MA, UK, 1990.
11. Vaughan, D. *The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA*; University of Chicago Press: Chicago, IL, USA, 1997.
12. Janis, I.L. *Groupthink: Psychological Studies of Policy Decisions and Fiascoes*; Wadsworth Cengage Learning: Boston, MA, USA, 1982.
13. Janis, I.L. *Crucial Decisions: Leadership in Policy Making and Crisis Management*; The Free Press: New York, NY, USA, 1989.
14. Janis, I.L. *Decision Making: A Psychological Analysis of Conflict, Choice, and Commitment*; The Free Press: New York, NY, USA, 1977.
15. Dekker, S. *The Field Guide to Understanding Human Error*; Ashgate Publishing: Farnham, UK, 2006.
16. Fischhoff, B. Hindsight≠Foresight: The Effect of Outcome Knowledge on Judgment under Uncertainty. *J. Exp. Psychol. Hum. Percept. Perform.***1975**, *1*, 288–299.
17. Mackie, D.M.; Worth, L.T.; Allison, S.T. Outcome-biased Inferences and Perception of Change in Groups. *Soc. Cogn.* **1990**, *8*, 325–342.
18. Murata, A.; Nakamura, T. Basic Study on Prevention of Human Error—How Cognitive Biases Distort Decision Making and Lead to Crucial Accidents. In Proceedings of the 5th International

Conference on Applied Human Factors and Ergonomics, Krakow, Poland, 19–23 July 2014; pp. 136–141.
19. Brafman, O.; Brafman, R. *Anatomy of Accident*; In Sway: The Irresistible Pull of Irrational Behavior; Crown Business: New York, NY, USA, 2008; pp. 9–24.
20. Turner, M.E.; Pratkanis, A.R.; Probasco, P.; Leve, C. Threat, Cohesion, and Group Effectiveness: Testing a Social Identity Maintenance Perspective on Group Think. *J. Personal. Soc. Psychol.* **1993**, *61*, 50–67.
21. Turner, M.E.; Pratkanis, A.R. Twenty-five years of Groupthink Theory and Research: Lessons from the Evaluation of a Theory. *Organ. Behav. Hum. Decis. Process.* **1998**, *73*, 105–115.
22. Latané, B.; Williams, K.D.; Harkins, S. Many Hands Make Light the Work: The Causes and Consequences of Social Loafing. *J. Personal. Soc. Psychol.* **1979**, *37*, 822–832.
23. Williams, K.D.; Harkins, S.; Latané, B. Identifiability as a Deterrent to Social Loafing: Two Cheering Experiments. *J. Personal. Soc. Psychol.* **1981**, *40*, 303–311.
24. Murata, A. Effects of Information Feedback of Task Performance on Social Loafing. *Psychol. Res.* **2014**, *4*, 734–741.
25. Walker, J.S. *Three Mile Island: A Nuclear Crisis in Historical Perspective*; University of California Press: Oakland, CA, USA, 2004.
26. Stephens, M. *Three Mile Island*; Random House, Inc.: New York, NY, USA, 1980.
27. Gray, M.; Rosen, I. *The Warning: Accident at Three Mile Island: A Nuclear Omen for the Age of Terror*; W. W. Norton & Company: New York, NY, USA, 2003.
28. Perrow, C. *Normal Accidents-Living with High-Risk Technologies*; Princeton University Press, Princeton, NJ, USA, 1999.
29. Gladwell, M. The Ethnic Theory of Plane Crash. In *Outliers*; Little, Brown and Company: New York, NY, USA, 2008; pp. 206–261.
30. Gigerenzer, G. Why the Distinction between Single-event Probabilities and Frequencies is Important for Psychology. In *Subjective Probability*; Wright, G., Ayton, P., Eds.; Wiley: Chichester, UK, 1994; pp. 129–161.
31. Todd, P.M.; Gigerenzer, G. Precis of Simple Heuristics that Makes Us Smart. *Behav. Brain Sci.* **2000**, *23*, 727–780.
32. Haselton, M.G.; Bryant, G.A.; Wilke, A.; Frederick, D.A.; Gelperin, A.; Frankenhuis, W.E.; Moore, T. Adaptive Rationality: An Evolutionary Perspective on Cognitive Bias. *Soc. Cogn.* **2009**, *27*, 733–763.