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Statistics of a variety of cognitive biases in decision making in crucial accident analyses

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Abstract

Due to bounded rationality, we cannot make decision rationally. Our cognitive information processing is conducted by System1 or System2. While System2 requires us to conduct effortful, demanding and deliberate mental activities, System1 operates quickly, automatically, without time consuming, and intuitively with little or no efforts. Although heuristic approaches that we adopt when we have no time to deliberate are based on System1, and are very simple and intuitive, such approaches constantly suffer from cognitive biases. In this study, using about 190 crucial accident analyses, it was explored how cognitive biases are include as a major causes of crucial accidents. It has been clarified that optimistic bias and loss aversion are more frequently observed in the range of this study. In conclusion, we are susceptible to cognitive biases, and never behave rationally. Due to such property (irrationality), we repeatedly commit similar error as we see in the statistical analysis of 190 cases of crucial accidents. This means that how we actually behave (irrationality) is more important than how we should behave (rationality).

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Keywords: Decision making; Bounded rationality; System1; Crucial accident; Cognitive biases

1. Introduction

Different from the traditional economics, the bounded rationality is commonly assumed in behavioral economics [1]-[9]. Due to bounded rationality, we generally cannot make decision rationally, and thus suffer from cognitive biases pointed out by Kahneman [1], Tversky and Kahneman [2], and Kahneman and Tversky [3]. Kahneman and

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Tversky [3] states that our cognitive information processing is conducted by System1 or System2. While System2 requires us to conduct effortful, demanding and deliberate mental activities, System1 operates quickly, automatically, without time consuming, and intuitively with little or no efforts. Although heuristic approaches that we adopt when we have no time to deliberate are based on System1, and are very simple and intuitive, such approaches constantly suffer from cognitive biases.

One of the major causes of the Challenger space shuttle disaster is regarded to be due to groupthink, especially illusion of unanimity. In this case, although the manufacturer of O-ring recognized the risk of malfunction of O-ring under the severely cold temperature, the manufacturer agreed with the launch of the Challenger space shuttle because of illusion of unanimity. In this study, using 190 crucial accident analyses in Japan, it was explored how cognitive biases are include as a major causes of crucial accidents.

2. Cognitive biases

As shown in Fig.1 (Murata et al. [10]), it is hypothesized that cognitive biases cause the distortion of decision making, and thus that this leads to human errors in judgment, decision making, and behavior and eventually (at the worst case) triggers crucial accidents if the commitment to the biased judgment, decision making, and behavior is escalated.

According to Bazerman and Moore [6], we summarized how cognitive biases are induced. It is hypothesized that the heuristics such as availability, representativeness, confirmation, or affect cause the biases such as confirmation biases, and anchoring and adjustment. In Fig.2 (Murata et al. [10]), not only heuristics but also overconfidence and framing are shown as causes of biases. Moreover, it is assumed that our bounded awareness and uncertain (risk) situations form the basis of heuristics, overconfidence, and framing. Due to such bounded awareness, it is valid that we humans cannot behave rationally but irrationally.

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 are sure to distort our decisions, and in the worst cases leads to crucial accidents according to the model in Figs. 1 and 2. Without consideration of our bounded rationality (irrationality), we cannot approach the prevention of crucial accidents and analyze the true (root) cause (source) of accidents.

In the next chapter, it is demonstrated how the cognitive biases form the main cause of crucial accidents using examples of crucial accidents.

3. Example of accident analysis

The accident (occurred on April, 2008) due to the misusage of IHI cooker is demonstrated to point out that cognitive biases are included in this accident (from Encyclopedia of Accidents II (Nikkei BP)). When a housewife was making a deep-fried dish, a fire broke out during her absence from a kitchen for a while. Although the housewife attempted to fight a fire, she got burnt on the hand and a range hood was partly damaged. When using an IHI cooker, the following three notices must be observed.

(1)When making a deep-fried dish, a user must use “deep-fried dish” mode. An IHI cooker produces an eddy current inside a pot by means of magnetic-generation coil in order to heat up a pot. Using a “deep-fried dish” mode and setting up the oil temperature is effective to some extent to prevent overheating of a pot. In spite of this, the housewife selected not a “deep-fried dish” mode but a “manual” mode.

(2)When using an IHI cooker, a user must use an exclusive pot attached to the cooker. The IHI cooker builds in a temperature sensor at the location corresponding to the center of an exclusive cook-pot in order to avoid overheating of oil. The exclusive cook-pot enables us to know the temperature of oil accurately, and thus to prevent overheating of oil. In spite of this, the housewife used not the exclusive pot but a commercial cook-pot.

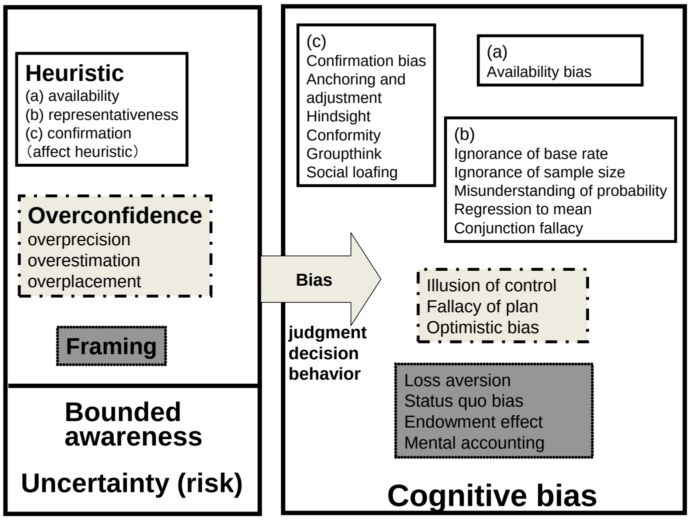

Fig. 1. Mechanism of cognitive biases due to heuristics, overconfidence, and framing (Murata et al. [10]).

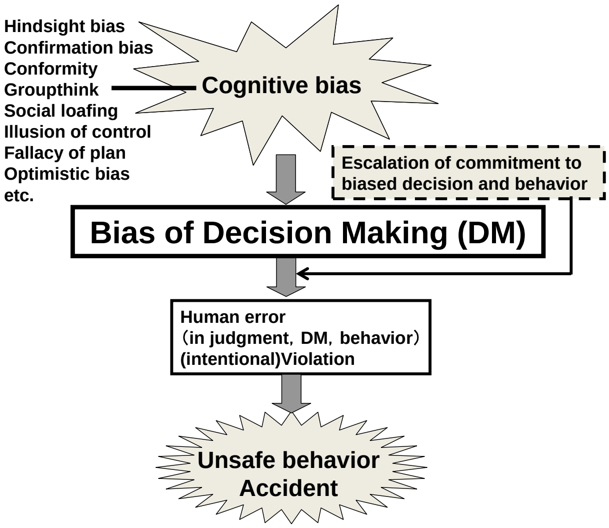

Fig. 2. Relational model between cognitive biases and unsafe behaviors or accidents (Murata et al. [10]).

(3)When using an IHI cooker, a user must not cook (make a deep-fried dish) using oil less than 500g. Less oil makes it impossible to measure the temperature of oil accurately, because it allows abrupt increase of temperature. In spite of this, the housewife cooked using oil less than 500g.

A reproducibility experiment of this accident conducted by National Institute of Technology and Evaluation (NITE) verified the following result. When the exclusive cook-pot was used with oil of 600ml, the production of fire did not occur. When not the exclusive pot but a commercial cook-pot with a cave in its center was used, combustion occurred in about 6 minutes.

The cause of the accident is considered from the perspective of cognitive biases. Optimistic biases correspond to the tendency to overestimate the rosiness of our future (occurrence of likable event) and not to face inconvenient events. This may be due to the fact that imaging of rosy future makes us feel good. We generally believe that we are less likely than others to live past 100 years old. We also expect people to consistently exaggerate their ability, their control, their performance, and their luck.

Normalcy biases represent our propensity to regard minor abnormalities as normal. Due to this, we can prevent ourselves from reacting excessively to a variety of changes or novel events and becoming impoverished. If carried too excessively, normalcy bias becomes a hazard. Even if a warning was being presented, we don't take this seriously and are late to escape from the disaster such as Tsunami or landslide disasters. Normalcy bias is actually a coping mechanism that occurs when we attempt to register and sort out stressful events or impending disasters. We have a tendency to resist disastrous events and, in turn, our brains try to simulate normal environment. This resistance to change is quite common and can occur even during the first phase of stressful events or disasters. Although this bias is a considerably normal response, there are risks that stem from this bias. This bias causes us to underestimate the possibility of a disaster such as Tsunami or earthquake. As we are usually accustomed to normal situations or states, we tend to think optimistically that the situations surrounding us will continue to be normal.

Loss aversion can be explained as follows. As Brafman and Brafman [11] also pointed out, loss aversion strongly contributed to the KLM Flight 4805 crash. On KLM Flight 4805, the Boeing 747 was leaving Amsterdam and bounding for Las Palmas Airport in Canary islands. Due to the terrorist bomb exploded at the airport flower shop in Las Palmas Airport, they were emergently forced to land on Tenerife airport.

In this accident, the losses of the captain of the flight were the downside of the mandated rest period due to the delay of flight, the cost of accommodating the passengers for making them stay at a hotel until the situation improves and the flight gets possible, the chain reaction of delayed flight such as time pressing stress imposed on the captain, and the blot on the captain's reputation for being punctual in his flight. The more meaningful the potential loss gets, the more loss aversive we tend to be. Therefore, the captain must be preoccupied with the urge to getting back as early as possible, lose his sense of safety flight, and be forced to take off without the permission of takeoff clearance by the air traffic control. For no apparent logical reason, we tend to fall trapped to such a cognitive bias. Our aversive property to loss apparently unexpectedly affected the decision making of the seasoned captain of the flight, and induced a crucial crash.

In summary, the violation of the notices (1) and (2) above must stem from optimistic bias and normalcy bias. The possibility of overheat was regarded optimistically. We must also regard minor abnormality (violation of notices (1) and (2)) as normal due to being carried too excessively. Concerning the notice (3), as well as optimistic bias and normalcy bias, loss aversion might work.

Judging from the two examples above, it can be predicted that the cognitive biases contribute mainly to the occurrence of accidents.

4. Method

Using 190 examples (nuclear power plant, aviation, fire, and transportation, etc.) of crucial accidents occurred in Japan, it was investigated how cognitive biases or irrational behaviors were included in the process leading to the crucial accidents. In other words, it was examined to what extent the cognitive biases in Fig.1 contributed to the occurrence of accidents as shown in Fig.2. The sources of accident analyses were from Encyclopedias of Accident I (2009) and II (2012) issued by Nikkei BP.

We regarded that cognitive biases stems from the following three mechanisms: (a) heuristics, (b) overconfidence, and (c) framing as shown in Fig.1. The first cause of cognitive bias, that is, (a) heuristics included availability, representativeness, and confirmation (affect heuristics). The second cause ((b) overconfidence) included over-precision, over-estimation, and over-placement. The third cause (framing effect) occurs when transparently and objectively identical situations generate spectacularly different decisions depending on how the situations are viewed. Analyzing the occurring event and people involved in it with the elapse of time, it was explored to what extent the classified cognitive biases (a), (c), and (c) were involved in each event.

Table 1. Classification of causes of accidents (causes attributed to products and causes not attributed to products).

Accidents attributable to products	A	Malfunctioning of design, manufacturing, or display of information
	B	Malfunctioning of products, or improper usage of products
	C	Deterioration of product performance or efficiency
Accidents not attributable to products	D	Problems or malfunctioning during construction, repair, or transportation
	E	Misusage or inattention of users
	F	Causes not attributable to products, or related to susceptibility of users
	G	From an unknown cause
	H	Under investigation

National Institute of Technology and Evaluation

5. Results

As a result, cognitive biases (a)-(c) were frequently observed and contributed to the occurrence of crucial accidents for all of 190 cases. Especially, the heuristic bias (a) and the overconfidence (c) were ubiquitous in all of 190 cases. The frequency distribution of cognitive biases obtained from 190 samples of accidents is plotted in Fig.3.

Main causes of accidents and its proportion are shown in Fig.4. Fig.5 classifies fatal accidents and its causes. Table 1 classifies the causes of accidents on whether the causes are attributable to products or not. Fig.6 shows the frequency distribution of cognitive biases according to the classification of causes of accidents A-E in Table 1 (A: Malfunctioning of design, manufacturing, or display of information, B: Malfunctioning of products, or improper usage of products, C: Deterioration of product performance or efficiency, D: Problems or malfunctioning during construction, repair, or transportation, and E: Misusage or inattention of users).

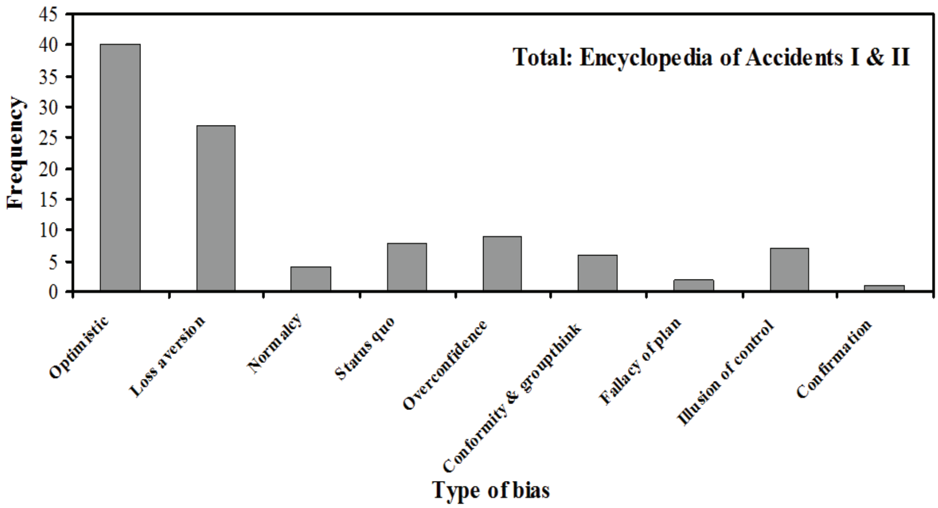

Fig. 3. Frequency distribution of cognitive biases obtained from 190 samples of accidents (Encyclopedia of accidents I and II).

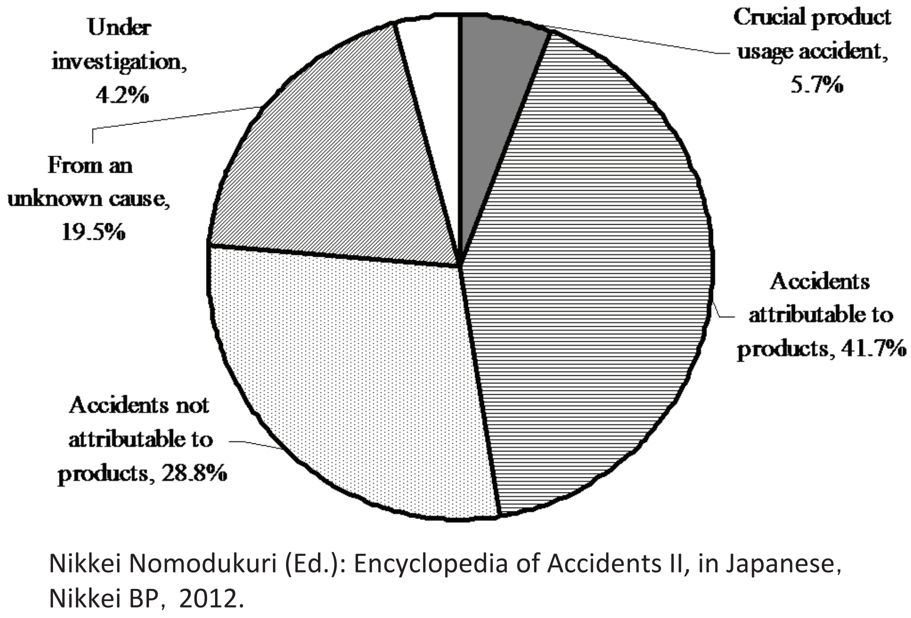

Fig. 4. Main causes of accidents and its proportion.

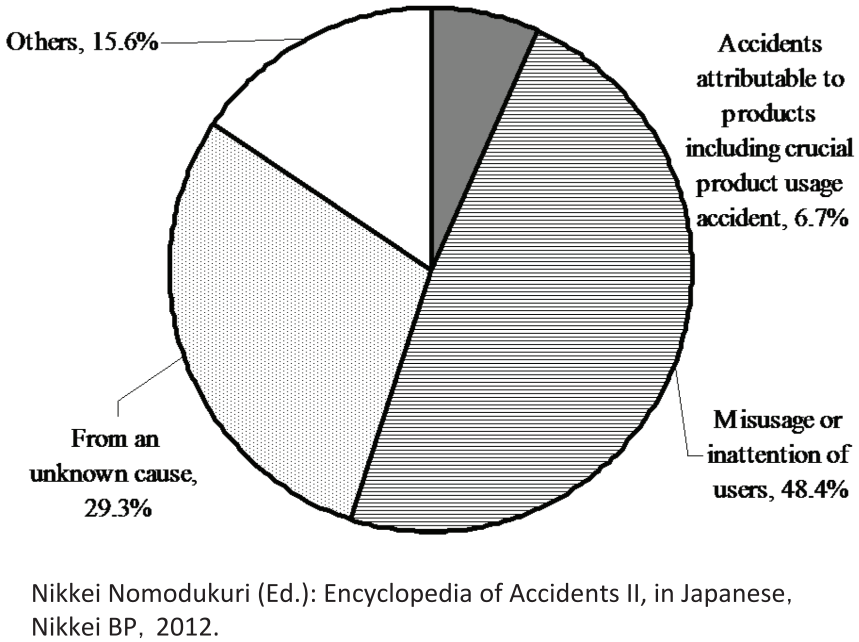

Fig. 5. Classification of fatal accidents and its cause.

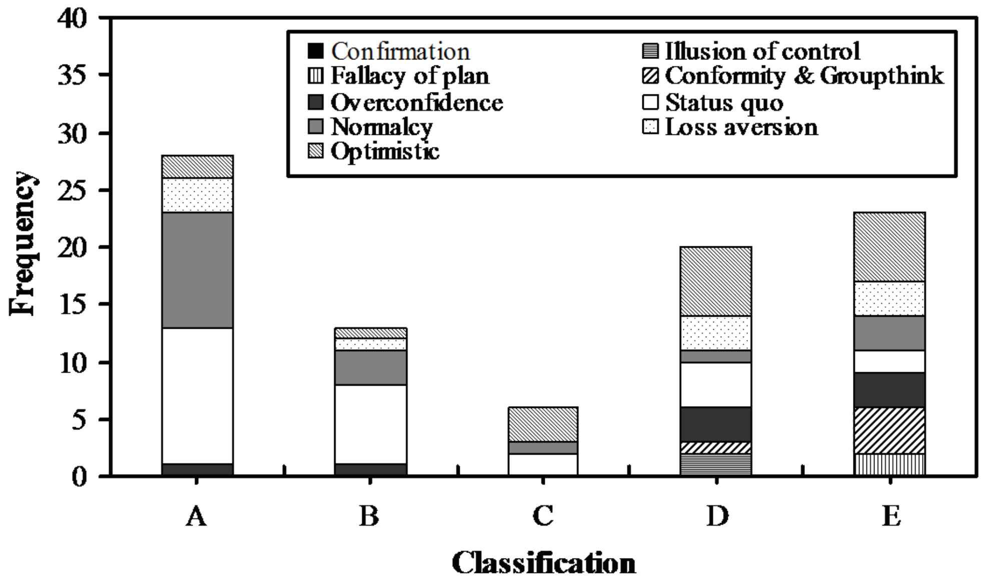

Fig. 6. Frequency of cognitive biases according to classification of causes of accidents A-E in Table 1. A: Malfunctioning of design, manufacturing, or display of information, B: Malfunctioning of products, or improper usage of products, C: Deterioration of product performance or efficiency, D: Problems or malfunctioning during construction, repair, or transportation, and E: Misusage or inattention of users

6. Discussion

Although it might be difficult to reach a conclusion, it seems that optimistic bias and loss aversion are more frequent in the range of this study (see Fig.3). Optimistic bias is related to overconfidence in Fig.1. Due to our tendency to overestimate the rosy prospect of future, overestimation such as planning fallacy and illusion of control occurs. It is sure that such a bias becomes a trigger of unsafe behavior when using a product or a system, or interacting with a system. As seen in the example of KLM Flight 4805 crash accident, loss aversion also seems to contribute to a lot of accidents. Many of the options we face in our daily activities are the mixture of a risk of loss and an opportunity of gain. As prospect theory predicts, loss looms larger than gain, and thus we unconsciously tend to be loss aversive. The data in Fig.3 shows that we frequently become a victim of loss aversive bias.

Fig.6 suggests that the cognitive biases are more frequently observed in causes A, D, and E. All of these causes are related to human activities, and are inseparable with human errors. As for the cause A (malfunctioning of design, manufacturing, or display of information), human errors or cognitive biases such as misconception or confirmation bias, or optimistic bias can induce malfunctioning of design, or improper display of information. It is also likely that the causes B (malfunctioning of products, or improper usage of products) and E (misusage or inattention of users) stem from human errors or cognitive biases.

On the basis of Figs.3 and 6, it can be concluded that we are susceptible to cognitive biases, and never behave rationally. Due to such property (irrationality), we repeatedly commit similar error as we see in the statistical analysis of 190 cases of crucial accidents. This means that how we actually behave (irrationality) is more important than how we should behave (rationality).

In the traditional framework of man-machine system, such an approach is impossible. In order to address properly and prepare for the repeated and frequent occurrence of similar crucial accidents, it is essential to understand our irrational property (cognitive biases) and develop strategies, tools, and method to overcome such biases in our judgment and decision making processes.

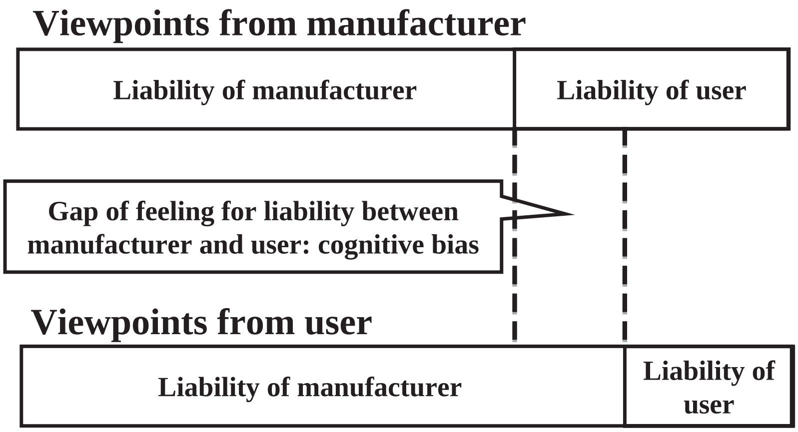

Fig. 7. Gap of feeling for liability between manufacturer and user due to cognitive biases.

Beyond the man-machine compatibility, we should aim at more interdisciplinary man-machine-economy (social system) compatible system that pays emphasis on fallibility of human, behavioral economics, and cognitive behavioral (irrational) characteristics or property. Cognitive bias (irrationality) is more powerful and pervasive than we realize. In the safety management, we must shed light on such irrational characteristics potentially hiding behind our behavior.

Fig.7 conceptually represents the gap of feeling for liability to products between manufacturers and users, which must occur due to cognitive biases. As we have shown, using 190 analytical examples of Japanese accidents, that cognitive biases are ubiquitous in the interface of systems or products related to humans, cognitive biases works for both manufactures or service providers (such as railway transportation or airline service) and users as in Fig.7. Future research should develop a systematical method for removing cognitive biases in accidental causes pointed out here, and make efforts to get rid of the gap so that the product or the system safety can be enhanced. In such an approach, the removal of cognitive biases which stem from the cross-cultural differences such as the Korean Air Crash Accident, one of the main causes of which is regarded to be absolute obedience to positional rank (high-power distance culture) should also be essential.

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