Fundamental Evaluation of Decision-making Task for Development of Training Method

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To prevent decision-making errors through training and education, it is necessary to evaluate personal decision-making traits. Two decision-making tasks were developed which make it possible to identify individual differences in decision-making. A decision confirmation exercise was designed to assess the tendency to omit confirmation tasks, while a modified Iowa Gambling Task (work version IGT) was developed to estimate the degree of preference for short-term gains. The validity of these exercises was then tested using functional magnetic resonance imaging (fMRI).

Keywords: decision-making, fMRI, omitting confirmation, short-term gains

1. Introduction

Non-technical skills (decision-making, situation awareness, communication, and so on.) on which technical skills are based have been identified as a major factor to be tackled to improve safety. Decision-making is often regarded as a managerial skill. In psychology however, decision-making has a much broader meaning. Here the focus is on decision-making in the workplace. According to recent research, even in the workplace, every task involves decision-making and decision-making plays an important role in maintaining safety [1].

In order to develop a suitable training method for decision-making skills, work was launched to construct a decision-making skills model to develop a decision-making skills evaluation method. This paper reports on a series of decision-making tasks needed to develop these evaluation methods.

Decision-making in the workplace usually has to be fast. Some studies show however, that simple heuristic decision-making often leads to errors. To prevent bias in decision-making, decision makers first have to recognize that they are biased.

It is difficult create awareness of this and to identify how decision-making is swayed through outside observation. As such, two decision-making tasks were developed that reflect a workplace situation and the validity of these tasks was validated using functional magnetic resonance imaging (fMRI).

fMRI is widely used in the human sciences field as it can detect slight changes in blood flow. By using fMRI data, many researchers have identified the relationship between areas in the brain and cognitive functions such as decision-making. There are other neuroimaging methods (e.g. near infrared spectroscopy (NIRS), electroencephalogram (EEG) and so on), however, they only measure brain surface activity. A significant body of research shows that decision-making is associated with deeper parts of the brain [2] [3] [4]. Therefore, in the light of this, this research, it was decided to use fMRI.

2. Error inducing situations

The decision-making tasks for this study had to represent actual working conditions in the railways. Based on an analysis of 278 decision-making error reports collected from railway accident analysis data, situations particularly prone to decision-making errors and the behavioral tendencies in each decision-making scenario, were taken into consideration. The results showed that over 60% of the work situations examined involved decisions that required a final confirmation.

In order to clarify the behavioral tendencies in decision-making that induced errors, the correlation between typical cognitive biases and decision errors was examined. The cognitive biases investigated were as follows:

(1) Short-sightedness [5]
Tendency to prefer short-sighted aspects (not thinking of consequences)

(2) Normalcy bias [6]
Tendency to minimize a potential threat

(3) Representative heuristics [7]
Tendency to excessively generalize a case

(4) Availability heuristics [7]
Tendency to excessively generalize information easy to remember

(5) Anchoring and adjustment [7] [8]
Tendency to rely too heavily on first piece of information obtained

(6) Above-average effect [9]
Tendency to rate themselves as superior to others (over estimation of own ability)

The results that shows over 70% of the decision-making errors involved short-sightedness in decision-making.

3. Development of decision-making tasks and assessment of their validity

Based on these results, tasks were developed to estimate the tendency to omit final confirmation and a modified Iowa Gambling Task [10] (work version IGT) was designed to assess the degree of preference for short-term gain. These tasks were validated using fMRI.
The decision confirmation task consisted of a first phase involving a visual search exercise followed by a phase where results had to be confirmed. For the visual search phase, participants were required to check if any of the following Japanese syllables appeared more than once on the screen: "コ" (ko), "ウ" (u), "テ" (te), "ツ" (tsu). After 5 questions, the participant was asked to decide whether they wanted to confirm their answers or not, as shown in Fig. 1. If they chose to confirm their answers, two extra questions appeared. The settings simulated a real situation where a worker may often feel that confirmation is tedious and a waste of time. If they chose not to confirm their answers and the answer was correct, then there were no extra questions. If they chose not to confirm and but there was an error in their answer, they were given an extra 10 questions. The configuration simulated a situation where no confirmation may be allowed when no mistakes are made, whereas not confirming can lead to a significant disruption if the initial decision was incorrect. The participants were required to make a series of 25 decisions in this confirmation task.

In order to isolate the brain activity related to decision-making, control experiments were conducted. The collection of fMRI data when participants were carrying out the decision confirmation task alone was not enough since it included unnecessary data on other brain activity such as pressing the response buttons, watching the monitor etc., as shown in Fig. 2. Therefore, control experiments were carried out for all activities except decision-making, in order to identify brain activity related to all the other experimental conditions except decision-making.

As such for the control experiments, in order to avoid any decision-making activity, subjects were instructed simply to select whatever highlighted option appeared on the screen.

3.2 Validity of the decision confirmation task

To investigate the validity of the decision confirming task, fMRI experiments were conducted using a 3-T whole body scanner equipped with a volume head-coil (Verio, Siemens, Erlangen, Germany), as shown in Fig. 3.

Fifteen volunteers (8 men and 7 women) participated in the experiment (mean age=34.1, SD=7.7). The participants were given instructions about the task and the fMRI. After these detailed explanations, a written informed consent was obtained from each of the participants in accordance with the Declaration of Helsinki (Ethical Principles for Medical Research involving Human Subjects) (1975). The study protocol was approved by the ATR-Promotions Ethics Committee.
As shown in Fig. 4, the mean number of times where no confirmation was made, was 13.47(SD=4.56, min=6, max=21).

For the event-related fMRI analysis, only periods when participants were actually making decisions were focused on. The second-level analysis for the task conditions minus the control conditions revealed significant activation exclusively in the insula as shown in Fig. 5 and Table 1. A number of studies have reported activation of the insula during various decision making activities [11] [12] [13].

These results show it is possible to estimate the tendency to omit confirmation by using task performance and brain activity results, and show that the task was consistent with the intended purpose.

Task performance however does not only reflect tendency to omit confirmation, it also shows the confidence of the subject when completing the visual search task. This limitation would have to be solved by developing a task index. For example, it would be more effective to distinguish the numbers of times no confirmation was made with no mistake from those where no confirmation was made with mistakes in the visual search task.

Based on the above, the confirmation task will be improved for future tests.

### Table 1  Activity during decision confirmation task

| Regions                  | Cluster level | Size | Peak level | x y z  |
|--------------------------|---------------|------|------------|--------|
| Left anterior insula     | 31            | 0.001| 0.002      | -28 22 2 |

### 3.3 Workplace version of IGT

To estimate the degree of preference for short-term gains, the Iowa Gambling Task (IGT) as shown in Fig.6. In the original IGT, participants are instructed to maximize profit over the course of 100 trials by selecting a card from one of four decks. On each draw, decks A and B yield a profit of $100 on average, and decks C and D yield a profit of 50$ on average. But, in long run, deck C and deck D turn out to be advantageous, while deck A and deck B turn out to be disadvantageous due to penalties inflicted once in a while on the participant drawing the card.

The IGT was developed to simulate actual financial decisions. To adapt the IGT to a workplace scenario, a workplace version of IGT was developed, where participants were instructed to maximize the height of a tower as their goal. Instead of selecting a deck, the participants select blocks from one of four manufacturers. The ratio between the block height (profit) and the frequency of collapse (penalty) was the same as in the original IGT, shown in Table 2. Just as with the decision confirmation task, control conditions were set: participants were instructed to simply select the highlighted blocks.

### 3.4 Validity of the workplace version of IGT

The workplace version of IGT was also validated using fMRI experiments. The same volunteers from the decision confirmation task experiment with the fMRI, participated...
in this experiment. The mean number of times a disadvantageous selection was made (preference for short term gain selection) was 62.6 (SD=20.4) as shown in Fig. 7.

The second-level analysis for the task conditions minus the control conditions revealed significant activation exclusively in the Right Superior frontal gyrus and the Middle temporal gyrus as shown in Fig. 8 and Table 3.

Some studies have demonstrated that the Right Superior frontal gyrus is activated during ambiguous decision-making activity [14][15].

These results show that it is possible to assess tendencies to prefer short-term gains using this task performance exercise, while the fMRI results show that the task induces brain activity as planned.

The work version IGT made it possible to measure the number of times a disadvantageous selection was made, however this index not only indicated the degree of preference for short term gains, but also revealed in some cases a lack of understanding about the disadvantage of choosing the alternatives.

These results show that future methods for estimating decision-making skills in future, need to be improved, by for example, adding a condition where the characteristics or features of each alternative are displayed. Adding this new condition, would make it possible to discriminate between preference for short term gains and lack of understanding about the negative outcome of certain alternatives.

| Regions               | Cluster level | Peak level  | x y z |
|-----------------------|---------------|-------------|-------|
| Right superior frontal gyrus | 140 | <0.001 | 14 56 38 |
| Left middle temporal gyrus  | 66  | <0.001 | -62 -26 -12 |
4. Conclusion

This study extracted situations and cognitive conditions in which decision-making errors were likely to occur from 278 case reports where decision-making errors had been made. An analysis of these cases showed that in over 60% of work situations decisions required a final confirmation, whereas over 70% of these cases revealed short-sightedness (lack of vision with regards to negative consequences) in decision-making. Based on these results, a decision confirmation task and workplace version of IGT were developed.

In order to validate these tasks, fMRI experiments were performed. The resulting performance data showed that the tasks did indeed make it possible to estimate tendencies to omit confirmation and the degree of preference for short term gains. fMRI data showed that devised tasks generated brain activity related to decision-making, as planned.

The tasks simulated situations where decision-making errors were likely to occur. By using these tasks, it is possible to detect dangerous tendencies in decision-making which can lead to errors being made in the workplace.

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