A Study of Sense of Self-Agency Focused on Noise and Delay in Multiple Input Operation

Toshiki Kataoka*, Kenji Funahashi*, Koji Tanida† and Katsuya Yashiro‡

*Department of Computer Science, Nagoya Institute of Technology, Japan
†Department of Mechanical Engineering, Kindai University, Japan
‡Automobile R & D Center, Honda R & D Co., Ltd., Japan

***Abstract*—Sense of self-agency has been proposed in psychology field, and it is the sense that I am the initiator or source of the action. Human perception should be considered to design a better interface, so that sense of agency is spotlighted in ergonomics and robotics interface design field. In previous study we concluded that sense of agency is affected by both of a noise and a delay in the case of an operation between an action (input signal) and its effect (output signal). In this study we tested the sense in the situation that required multiple inputs like car driving operation. We considered that the behavior of sense of agency by each of a noise and a delay for each of multiple input. The knowledge may be applicable to an interface required complex operations.**

***Keywords*—Ergonomics; Robotics Interface; Psychology; Sense of self-agency;**

I. Introduction

The operational feeling is deteriorated by noise and delay in interactive operation due to the performance of the interface. Usability is generally evaluated by various factors, and the degree of operational feeling affects user's satisfaction for the interface. Incidentally, sense of self-agency which is the sense that I am the initiator or source of the action has been proposed in psychology field [1]. Human perception should be considered to design a better interface, so that sense of agency is spotlighted in ergonomics and robotics interface design fields [2]. The researches about the sense of self-agency have focused on discrete operation like turning indication on at the pressing of a button [3]. Therefore we have focused on continuous operation. In previous study we discussed the sense of self-agency to find out the change of the sense for a change of delay and cross-correlation, which is the degree of noise between an action as an input signal and its effect as an output signal. We concluded that the sense of self-agency is not dependent on the operation form and the presentation type of the output and is affected by both of a cross-correlation and a delay in the case of an operation between input and output [4]. However there are interfaces that required multiple inputs and multiple outputs like car driving operation. In this study we considered the sense of self-agency in the situation of car driving that require two inputs (steering wheel and accelerator pedal) and two substantial outputs (the amount of change in front-back direction and left-right direction, we do not consider that driver feel to control revolution of engine and steering angle). Here each of the left-right direction and the front-back direction is affected by both inputs. A similar result was obtained for multiple inputs, the knowledge may be applicable to interfaces requiring complex operations like car driving. It is expected that this is useful for ergonomics and robotics interface design.

II. Experiment

We consider sense of agency in car driving operation as one of the interfaces that require multiple inputs. We also consider sense of security because it is an important factor to evaluate interface performance in the case of operation involving risks such as car driving operation. We performed the following experiment.

A. Participants

Participants who had been sought from the public and took part in this experiment of their own free will were 10 men and 10 women, and about 20 years old. They received explanations of this research contents orally and through documents, and gave informed consent in writing. This experiment is accepted by the bioethics review of Nagoya Institute of Technology and Honda R & D Co., Ltd.

B. System

Participants used GT Force Pro that was a steering control device (Fig. 1). They operated steering wheel and accelerator pedal to control a target car to trace the locus of an example car, and to keep the specified distance between the target and the example. In figure 2, we drew the road width at 2.0. The smallest black circle (radius is 0.1) is a target that they operated. The black line in the front-back direction is the locus of an example car, and the black line in the left-right direction is the line that is the specified distance away from an example car. We drew two circles (radii are 0.2 and 0.5) centered on the intersection of the two black lines. Participants substantially operated the target to overlap these circles. The example car motion was calculated randomly in specified range. The behavior of the target was determined by the turning radius R (Fig. 3), that is defined as follows:

$$R = A\frac{V}{\theta}, \tag{1}$$

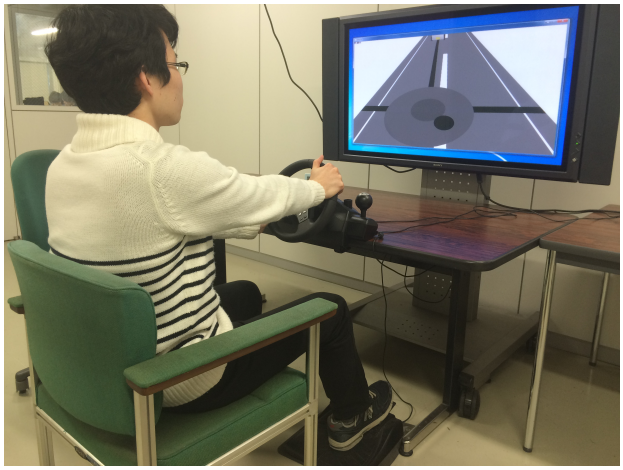

Fig. 1. Appearance of experiment

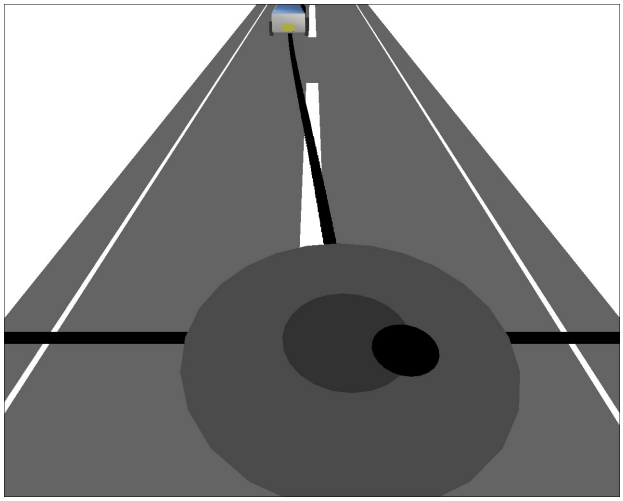

Fig. 2. Example of screen to present

where V is the velocity of the target in the travel direction, θ is the angle between the travel direction and the tire, and A is a constant. For simplification we assumed that the target always faces forward without considering the direction and displayed it as a circle. Moreover V was obtained from the input value of an accelerator pedal, and θ was obtained from the input value of a steering wheel. The moving distance in front-back direction Δz and left-right direction Δx in a very small time Δt are obtained from the following equation:

$$\Delta z = R sin \Delta\varphi, \quad (2)$$

$$\Delta x = R(1 - cos\Delta\varphi), \quad (3)$$

where $\Delta\varphi$ is the center angle of the turning circle and obtained from the following equation:

$$\Delta\varphi = \frac{V}{R}\Delta t. \quad (4)$$

From equations (1) to (4), the moving distance in a very small time is as follows:

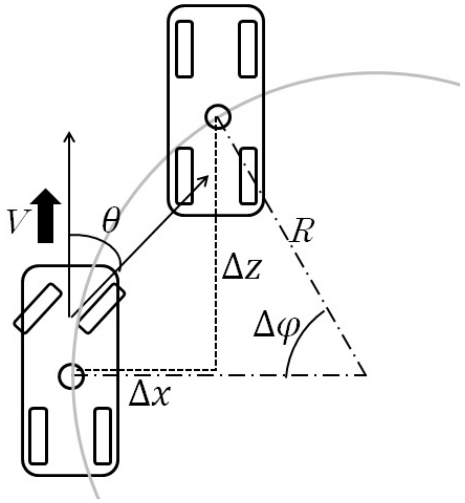

Fig. 3. The behavior of the target

$$\Delta z = A\frac{V}{\theta} sin\frac{\theta}{A}\Delta t, \quad (5)$$

$$\Delta x = A\frac{V}{\theta}(1 - cos\frac{\theta}{A}\Delta t). \quad (6)$$

The target moves sequentially according to the equation (5) and (6). Here V and θ were affected by noise and delay, then it was difficult to follow the example exactly. The degree of noise is represented by a coefficient of cross-correlation that is defined as follows:

$$C = \max_{\tau} \frac{\sum_{t=0}^{T}\{X(t)Y(t+\tau)\}}{\|X(t)\|\|Y(t)\|}, \quad (7)$$

where X and Y are signals between which cross-correlation is determined, and τ is delay between them. In this experiment X and Y were input signal (the value of an accelerator pedal or a steering wheel) and output signal (V or θ that was affected by noise), and τ was different from the delay time we decided.

In past experiment [4], we experimented with combination of five degree of noise (coefficient of cross-correlation is 1.00, 0.98, 0.96, 0.94 and 0.92) and four delay time (0.0, 0.2, 0.4 and 0.6 seconds). However if we applied in the same way in this experiment, the combination became enormous. Therefore we limited the combination of noise and delay as follows.

1) We arranged all combinations in descending order of the evaluation value of sense of agency in past experiment.
2) We compared each combination with the combination of highest sense of agency in descending order.
3) We extracted a combination that had significant difference for the first time.
4) We compared each combination with the combination that were extracted in 3), and repeat 3).

We extracted three combinations ((coefficient of cross-correlation, delay time (second)) = (1.00, 0.0), (0.96, 0.0), (0.92, 0.6)). We further adopted a median value ((1.00, 0.6), (0.98, 0.4)) between them and decided a total of five combinations.

We adopted Perlin Noise as noise [5]. It is a noise obtained by randomly generating a gradient for each control point at intervals and complementing between points according to the gradient. We set each parameter empirically and made several stages of noise.

C. Procedure

Participants evaluated sense of agency and sense of security in five steps subjectively for each combination of cross-correlation and delay. It should be noted that we instructed them to answer whether they felt they could operate it by themselves because we considered that they were not familiar with the word, sense of self-agency. Before the experiment participants experienced the configurations coefficient 1.00 – delay 0.0, and coefficient 0.92 – delay 0.6 for each input. They operated it for 30 seconds for each trial, total trial number was $5 \times 5 \times 14 = 350$. The trials were divided equally and randomly for 20 participants.

III. Result

The figure 4 and figure 5 show the result of the evaluation value of the sense of self-agency and the sense of security for changes of noise and delay for steering wheel and accelerator pedal. This is similar to the result of the previous study for single input experiment. The change of noise and delay for steering wheel had a significant effect to the sense of agency ($F_{4,325} = 62.186, p < 0.01$) and the sense of security ($F_{4,325} = 61.447, p < 0.01$). The change of noise and delay for accelerator pedal also had a significant effect to the sense of agency ($F_{4,325} = 71.635, p < 0.01$) and the sense of security ($F_{4,325} = 58.803, p < 0.01$). The effect of noise and delay to the sense of agency and the sense of security did not show significant difference between accelerator pedal and steering wheel ($t(38) = 0.604, p > 0.05$), ($t(38) = 0.131, p > 0.05$). It was suggested that the effect of noise and delay to the sense of agency did not depend on the operation form of the target. We defined P as an operation score that indicates the accuracy of the operation. We calculated P as follows. First we calculated $\overline{D_t}$ that is the value of the average distance between the target and the example for each trial from the following equation:

$$\overline{D_t} = \frac{\sum_{t=0}^{N} |D_t|}{N}, \tag{8}$$

where D_t is the value of the distance between the target and the example at time t and N is the total number of frames for each trial. The trial time is 30 seconds and the frame rate is 60 fps so that N is $30 \times 60 = 1800$ in this experiment. We normalized P according the following equation so that $P = 100$ when $\overline{D_t} = 0$ and $P = 0$ when $\overline{D_t} = 0.5$.

$$P = -200 \times \overline{D_t} + 100. \tag{9}$$

The figure 6 shows an operation score for changes of noise and delay for steering wheel and accelerator pedal. As the noise and delay increase, a operation score is lower. We compared the sense of agency, the sense of security and operation score.

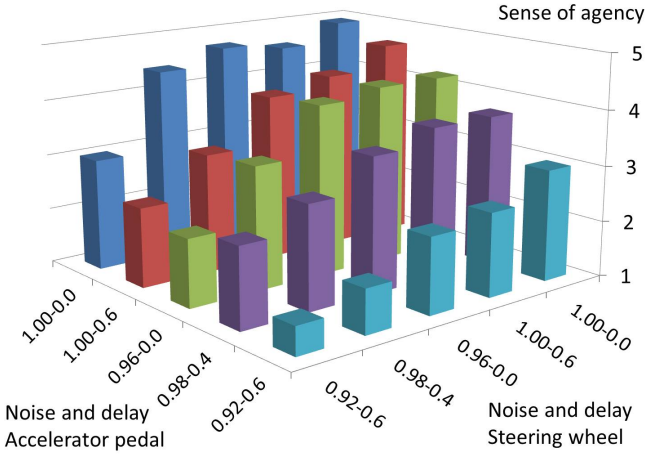

Fig. 4. Evaluation value of sense of self-agency

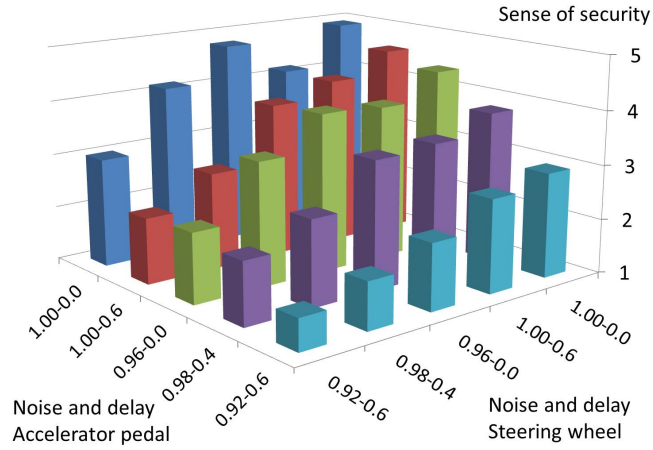

Fig. 5. Evaluation value of sense of security

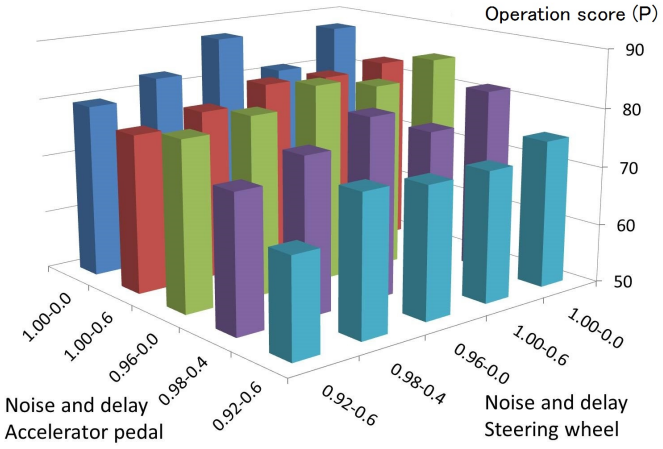

Fig. 6. Operation score

There was a strong correlation between them (correlation coefficient is about 0.9 in any combination). Participants

probably evaluated the sense of agency based on the operation accuracy felt by themselves in this experiment.

IV. Conclusion

In this study we considered sense of agency in the situation of car driving that required multiple input. Our experiment results validate and suggest as follows. The effect pattern of noise and delay to the sense of self-agency for single input operation is probably applied to multiple input operation. The strength of the effect does not depend on the operation style probably. There was a strong correlation between the sense of agency and the accuracy of the operation. In the future we would like to consider the situation with an exhaust sound that might affect sense of self-agency and sense of security, and compare them each other, and with the accuracy of the operation.

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