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A study of sense of self-agency focused on cross-correlation and delay between action and effect in continuous operation

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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. We discuss it on continuous operation to find out the transition of the sense for a change of delay and cross-correlation that is the degree of noise between an action as an input signal and its effect as an output signal. We conclude that sense of self-agency is affected by both of a cross-correlation and a delay, human gets stronger sense of self-agency when cross-correlation between action and effect is higher, and an acceptable noise and delay to feel enough good operational feeling may be predicted.

Categories and Subject Descriptors (according to ACM CCS): H.1.2 [Information Systems]: User/Machine Systems—Human factors

1. Introduction

Sense of self-agency which is the sense that I am the initiator or source of the action has been proposed in psychology field [Gal00], and is spotlighted in ergonomics and interface design fields [MW*15]. It is important to consider the human perception in order to design a better interface and develop a VR system. However the researches about sense of self-agency have focused on discrete operation like turning indication on at the pressing of a button [FVH13]. In this study we discuss sense of agency on continuous operation 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 and its effect as an input and output signal [KFTY16]. First some kinds of operation were observed to compare the difference of sense of agency. And we considered an acceptable degree of noise and delay to feel the sense of self-agency, in other word good operational feeling. It is expected that this is useful for ergonomics interface design.

2. Experiment 1: sense of self-agency and cross-correlation in continuous signals

It was reported that human obtains sense of self-agency when actual results of their action matches the expectation [BWF02]. First we made the following hypothesis: human gets stronger sense of self-agency when cross-correlation between continuous action and effect gets higher. Here a coefficient of cross-correlation is defined as follow:

$$C = \max_{\tau} \frac{\sum_{t=1}^{T} \{X(t)Y(t+\tau)\}}{\|X(t)\|\|Y(t)\|}. \quad (1)$$

X and Y are signals between which cross-correlation is determined, and τ is delay between them. We performed the following experiment. 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. Participants operated a force feedback device Geomagic Phantom (Fig. 1) in three ways; (1) stroke – back and forward movement, (2) twist – rotation of a stylus device, and (3) push – apply pressure forward. Then four outputs selected from eight types of output were displayed; (1, 2) linear and circular gauges (Fig. 2), (3, 4) circles that size and brightness are changed, (5) one digit like seven segment arabic numerals, (6, 7) sounds that frequency and volume are changed, and (8) push-pull force feedback. Two types of sound output were not presented at the same time, and push

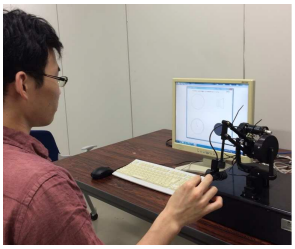

Figure 1: *Appearance of experiment*

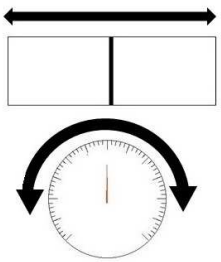

Figure 2: *Linear and circular gauges*

operation and force feedback were not combined together. Only one of the outputs was synchronized with the input, it means the cross-correlation was strong and the coefficient is 1.00. The others were moved randomly, not synchronized, the cross-correlations were weak and coefficients were set around 0.3 for the sing curve input with frequency $1/2\pi$ and amplitude 1 (same as the range of input operation) in this experiment, and without any delay. Participants answered which they think they were operating. The number of combinations of input and output was $3 \times 8 - 1 = 23$, total trial number was $23 \times 14 = 322$. The trials were divided almost equally and randomly for 20 participants. They answered it in about 10 seconds for each trial. The correct answer rate in each combination of their input operation and operation target was approximately 100 %. Therefore the hypothesis has been validated. There was no significant difference in the combination and its correct answer rate ($\chi^2(22) = 21.23, p > 0.05$). It does not mean that the strength of sense of self-agency was dependent on the operation form and the presentation type of the target. Especially human also feels certain sense of self-agency operating a concept as a number that requires higher processing of information.

3. Experiment 2: sense of self-agency for cross-correlation and delay

Next we performed the experiment to examine how sense of self-agency was affected by changes of cross-correlation and delay. Participants operated the target bar to follow the example bar (Fig. 3). The output signal as the target was affected by noise and delay, then it was difficult to follow the example exactly. They evaluated sense of self-agency 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 can operate it by themselves because we considered that they were not familiar with the word, sense of self-agency. The delay levels were four as 0.0, 0.2, 0.4 and 0.6 seconds, and the cross-correlation coefficient levels were five as 1.00, 0.98, 0.96, 0.94 and 0.92. The noise was implemented by addition of sing curve with random frequency and amplitude that change every period, the parameters were set empirically. Before the experiment participants experienced the configurations delay 0.0 – coefficient 1.00, and delay 1.0 – coefficient 0.80 for references. They operated it for 30 seconds for each trial, total trial number was $4 \times 5 \times 10 = 200$. The trials were divided equally and randomly for 20 participants. Figure 4 shows the result of the evaluation value of sense of self-agency. Both of cross-correlation and delay had a significant effect to the sense ($(F_{4,180} = 40.468 > 3.425, p < 0.01)$, $(F_{3,180} = 7.688 > 3.892, p < 0.01)$). The multiple regression equation for the value of sense of self-agency (S) was obtained as follow:

$$S = 23.88 \times C - 1.18 \times D - 19.41, \quad (2)$$

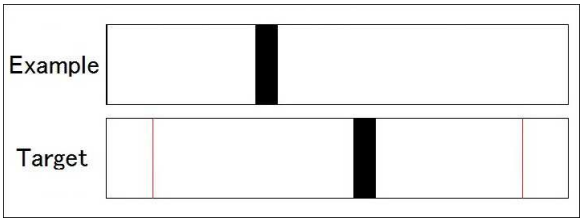

Figure 3: *Visual outputs of example and target*

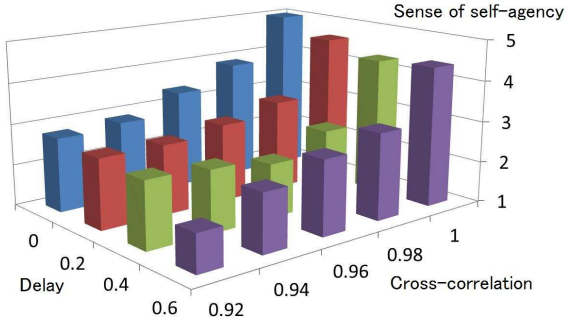

Figure 4: *Evaluation value of sense of self-agency*

where C is cross-correlation coefficient and D is delay. The multiple correlation coefficient was 0.63. The result suggests that the degree of sense of self-agency can be predicted from cross-correlation and delay.

4. Conclusion

In this study, we researched the transition of sense of self-agency focused on delay and cross-correlation that was the degree of noise between the continuous action and its effect. Our experiment results validate and suggest as follows. Human gets stronger sense of self-agency when cross-correlation between action and effect gets higher. Human also feels certain sense of self-agency operating a concept that requires higher processing of information. Both of a cross-correlation and a delay have a significant effect to sense of self-agency. The degree of sense of self-agency can be predicted from cross-correlation and delay. An acceptable noise and delay to feel enough sense of self-agency may be predicted. In the future we would like to research the changes of sense of self-agency for various factors in terms of increasing the type and number of input, the form of output and type of sensory organs to receive it. We also would like to compare the accuracy of the operation and sense of agency, and consider the situation where their transitions are different.

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