Thesis title: Cognitive processes involved in the perception of operation-response variance

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The term “operation-response” system refers to the input/output system, consisting of operation, processing and response output. Thus, “perception of operation-response variance” refers to perceiving the variance of system responses resulting from observer operation and noise. In this thesis composing six chapters, I investigate cognitive processes involved in perception of operation-response variance using psychophysical approach and model simulation.

The study has tow main aims. First, it investigates the information-processing mechanisms underlying the perception of operation-response variance clarifying the characteristics of perceiving operation-response variance compared with passive variance perception. Second, it investigates whether operator ability to perceive operation-response variance influences the decision to stop the operation of the system in a condition wherein it becomes gradually uncontrollable. These purposes correspond to investigating “information processes undergirding the perception of operation-response variance” and “information processes in which perceived variance connects with higher cognitive processes such as decision-making” respectively. This study investigates cognitive processes involved in the perception of operation-response variance comprehensively by dealing with both of the processing stages.

In Chapter 1, I refer to the necessity of this study in real life; additionally, I introduce relevant previous studies. Groups of objects or creatures show a tendency to exist in the environment following certain distribution patterns, while they consist of complex and various stimuli. In such an environment, human observers have the ability to rapidly extract summary information about many items’ features. Regarding “average,” many studies have shown that people accurately perceive and estimate it over different feature dimensions in various sensory modalities. Regarding “variance” perception, however, there has been little research, and several information-processing mechanisms underlying these processes remain unclear. Nonetheless, they are worthwhile given the representative value of statistical properties. Furthermore, previous studies have focused on situation in which statistical information of stimuli was perceived passively. In real life, however, human operators actively interact with the environment and deal with specific objects or systems. It is conceivable that operators can obtain useful information about the conditions of the operating system by accumulating information over time about the relationship between their operations and the system’s responses. In particular, variance of operation-response variance is important because it can indicate abnormal and possible high-risk operating system conditions. For example, as operation-response variance increases, the operating system becomes uncontrollable, and the operator may be exposed to a significant risk. Based on the above, this study investigates fundamental information-processing mechanisms of operation-response variance, which have not previously

been focused on in research the field of statistical summary representation. Subsequently, in the latter half of this thesis, this study investigates how perceived operation-response variance is utilized and connected to higher cognitive processes, such as decision-making.

Chapter 2 describes the reasons for selecting the methods of measurement used in this study, and it explains its outline.

Chapter 3 indicates the relationship between pedestal variance and just noticeable difference (JND) in variance discrimination of operation-response noise. When the observers discriminate the orientation variance passively, it has been shown that low pedestals improve variance discriminability relative to the absolute JND (negative masking), and that high pedestals impair stimulus discriminability. This relationship is known as "dipper function." Negative masking, however, disappears when data are plotted in terms of variance (σ^2) instead of standard deviation (σ). However, dipper function does not disappear when data are plotted in terms of variance (σ^2) in discrimination of operation-response variance. In addition, the original non-linear transducer model depicting relationships between stimulus magnitude and the response of the sensory mechanism was fitted to the experimental data to explain information-processing mechanisms underlying perception of operation-response variance.

Chapter 4 shows the effect of active observation of variance perception. In this experiment, an operation-response system with the goal of operation was used. The results suggest that active operation-based observation facilitates the perception of the variance of visual motion, compared with passive observation. In addition, the JND first fell and then rose as pedestal variance increased, which produced a "dipper" function in both conditions.

Chapter 5 investigates whether operators' ability to perceive operation-response noise influences the decision to stop the operation of the system under the condition in which the operation system has gradually become uncontrollable. In Experiment 1, we examined the correlation between operators' ability to discriminate the variance of operation-response noise and their performance in the stop-operation decision-making task. In Experiment 2, we trained a group of operators in the variance discrimination task and investigated the training effect on performance in the stop-operation decision-making task. We demonstrated that the higher the operator's ability to discriminate variance, the earlier they decide to stop system operation. However, the ability to discriminate variance did not influence other indices of this decision-making process. These results indicate that sensitive perception of operation-response noise causes the earlier stop operation, but it is not sufficient to lead to optimal decision-making in this regard.

Chapter 6 describes the conclusion of this thesis. Furthermore, it is discussed the importance and limitations of this study and potential future research in the study of variance perception.