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Proposal of the Model of the Influence of Judgement of Agency on Sense of Fulfillment with Assistive Method

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Abstract: According to the self-determination theory, we considered the disappearance of autonomy of product operation result in the decrease in sense of fulfillment of product use. The purpose of this study was to develop a mathematical model that explained the effect of sense of agency (SoA) on sense of fulfillment. For this purpose, we integrated the idea of judgment of agency (JoA), flow theory, and attribution theory. We formulated the effect of the locus of causality on skill and challenge using attribution theory. Self-determination theory explains the relationship between increased sense of fulfillment and autonomy needs that are fulfilled. The model explains the relationship in self-determination theory where sense of fulfillment increases when judgement of agency is internal. We conducted an experiment using a game task with different types of assistance to verify the hypothesis. Flow score was used as an indicator of sense of fulfillment between two assistance methods in which judgement of agency was changed according to ease of recognition of assistance. We assumed that the hard-to-recognize assistance made judgement of agency internal. As a result of the experiment on three subjects, the flow scores were high with the hard-to-recognize assistance. Therefore, the experimental result supported the hypothesis.

Keywords: *sense of agency, flow theory, attribution theory, intrinsic motivation, self-determination theory*

1. INTRODUCTION

In recent years, various products have been digitized and made autonomous, thereby realizing high performance. Meanwhile, the operation unintended by the user occurs. It is a problem for users to feel that they don't control or determine product operation [1]. Studies on sense of agency have been made against such problems [1],[2]. The sense of agency (SoA) is the sense that "I am the one who is causing or generating an action" [3]. Self-determination theory [4], which is one of the intrinsic motivation theories, argues that autonomy is necessary for intrinsic motivation and that human-beings feel a sense of fulfillment with intrinsic motivation. We considered the disappearance of autonomy of product operation result in the decrease in sense of fulfillment at the time of product use. It is necessary to understand the mechanism of influence of SoA on sense of fulfillment in order to utilize the findings of SoA. However, there are not many studies published on the mechanism, and the mathematical model in the design has not been developed.

Based on the above situation, we have been studying the occurrence of SoA of product operation [2]. On the other hand, we focused on the effect of SoA in product operation. We predicted that SoA of product operation would affect both intrinsic motivation and sense of fulfillment. We focused on the effect of the assistance method in product operations as a factor of SoA.

The purpose of this paper was to propose a mathematical model of the effect of sense of agency (SoA) on sense of fulfillment. For this purpose, we conducted research as follows: 1) We developed a model using SoA, flow theory, and attribution theory, then 2) mathematically formulated the model, 3) conducted a simulation of the effect of SoA on sense of fulfillment using the mathematical model, and 4) verified a hypothesis derived from the mathematical model with an experiment using a game task in which assistance method was manipulated as a factor of SoA.

2. MODELING

2.1. Qualitative Model

Figure 1 showed the outline of the proposed model. We created the model by integrating SoA, attribution theory, and flow theory. The assistance changed the skill and the challenge. The skill increased and the challenge decreased. Based on the two-step account of agency, SoA is distinguished between feeling of agency and judgment of agency. Based on attribution theory, the locus of causality affected the amount of change in both the skill and the challenge. We considered the locus of causality as JoA. Based on flow theory, both the skill and the challenge affected sense of fulfillment. Based on the model, sense of fulfillment changed according to SoA.

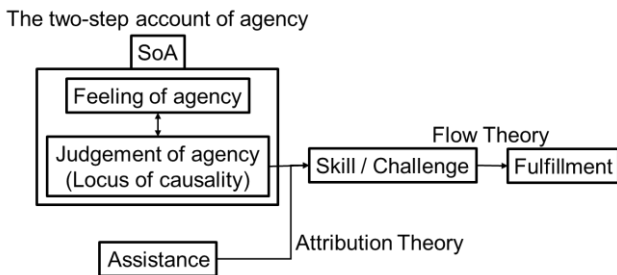


Figure 1: Overview of proposed model.

2.2. Transitions to Flow State via Assistance

Figure 2 shows an overview of transitions to flow state via two types of assistance. The origin (the α state) in Figure 2 represents the state where both the skill and the challenge were perceived as balanced at the average level. The average state was the expectation of the skill and the challenge for oneself.

In the flow state, the skill and the challenge were balanced and the task was achievable. The challenge was perceived to be greater with the unachievable task than in the average state. The β state in Figure 2 represents the state perceived with the unachievable task. The two γ states shown in Figure 2 are examples of transitions from the β state by two assistances. In the γ_1 state, the distance from the α state was small; in the γ_2 state, it was large. In the transition from the β state to the two γ states, the perceived skill increased and the perceived challenge decreased. The γ_1 state represents a state where assistance strongly influenced the decrease of the perceived challenge, and the γ_2 state represents a state where assistance strongly influenced the increase of the perceived skill. We compared these two types of assistance. The distance between the α state and the γ states was larger between γ_2 than γ_1 , resulting in a stronger flow state. As sense of fulfillment is experienced in the flow state, sense of fulfillment was higher in the γ_2 state than in the γ_1 state.

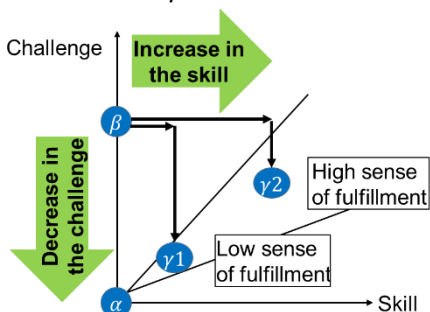


Figure 2: Transition to flow state via two types of assistance.

2.3. Classification of Assistance via Attribution Theory

Using attribution theory, we investigated the factors that classified whether or not the perceived skill increased or

the perceived challenge decreased. The locus of causality classified the cause of achievement with assistance as the increase in the perceived skill or the decrease in the perceived challenge.

When the locus of causality is internal, it is judged by the result of the self-caused action. We considered the locus of causality a judgment based on posterior reasoning. SoA is distinguished from FoA based on sensory feedback and from JoA based on posterior reasoning. We treated the locus of causality as JoA.

Based on the above information, we hypothesized the following: assistance increases the perception of skill and sense of fulfillment is higher when the locus of causality is internal rather than external.

2.4. Mathematical Model

2.4.1. The perception of the skill and the challenge

Prior to executing a task, humans have expectations of their own skill level and the challenge of the task (the average state). We considered that these expectations could be represented by a normal distribution with expected value and variance, and called prior distribution. We considered that the likelihood of actual skill and actual challenge could be represented by normal distribution with expected value and variance, and called likelihood function. From Bayesian inference [9], posterior distribution could be calculated from prior distribution and likelihood function. The expected value of the posterior distribution represents the perceived value. We represented the perception of skill and challenge with S and C , respectively. Since the average state was the origin, the expected value of the prior distribution was 0. Thus, equations (1) and (2) represent the perception of the skill and the challenge.

$$S = \frac{N_s \delta_s}{v_s + N_s} \quad (1)$$

$$C = \frac{N_c \delta_c}{v_c + N_c} \quad (2)$$

Where, δ is the prediction error that is the difference between the expected value of prior distribution and the expected value of the likelihood function, v is the variance of the prior distribution (uncertainty), and N is the variance of the likelihood function (noise).subscripts s and c represent the skill and the challenge, respectively.

We defined the strength of psychological state H as the distance from the origin (the average state). Equation (3) represents H . In the flow state, we assumed that H corresponded to the degree of sense of fulfillment.

$$H = (S^2 + C^2)^{\frac{1}{2}} \quad (3)$$

2.4.2. State transitions in the Skill-Challenge space via assistance

We formalized the prediction error of each state shown in Figure 2. The α state was the average state. The actual challenge in the β state was sufficiently higher than the α state, and the actual skill was the same as in the α state. Assistance increased the skill and decreased the challenge. In the γ states, assistance changed the prediction error of the skill and the challenge. The total amount of prediction error that changed due to assistance is x ; x was greater than $\delta_c(\beta)$ because the task became achievable in the γ state. The x consists of x_s (the change in prediction error of the skill) and x_c (the change in prediction error of the challenge). We assumed that the total change amount of prediction error was constant when the amount of assistance was constant. Equations (4) and (5) represent the prediction error of the γ states. Where β represented the β state and the γ represents the γ states.

$$\delta_s(\gamma) = \delta_s(\beta) + x_s \quad (4)$$

$$\delta_c(\gamma) = \delta_c(\beta) - x_c \quad (5)$$

2.4.3. Attribution theory

We treated the locus of causality as JoA. We defined JoA as a continuous quantity JoA of 0 to 1 with 1 when the location of the cause was completely in the self and 0 when it was completely in the other. In other words, the larger JoA is, the stronger the judgment that oneself caused the action and result. JoA classified the increase in the perceived skill and the decrease in the perceived challenge. The x_s was larger when JoA was larger. Also, x_c was larger when JoA was smaller. We represented this relation as a first order relation with equation (6) and (7).

$$x_s = x \cdot JoA \quad (6)$$

$$x_c = x \cdot (1 - JoA) \quad (7)$$

2.4.4. A function model of sense of fulfillment

From the above equations, (9) - (10) represent sense of fulfillment with the transition to the flow state via assistance. $A_{1\sim3}$ is a variable for simplifying the expression.

$$H = (A_1 \cdot JoA^2 + A_2 \cdot JoA + A_3)^{\frac{1}{2}} \quad (8)$$

$$A_1 = x^2 \left(\left(\frac{N_s}{v_s + N_s} \right)^2 + \left(\frac{N_c}{v_c + N_c} \right)^2 \right) \quad (9)$$

$$A_2 = 2x \left(\frac{N_c}{v_c + N_c} \right)^2 (\delta_c(\beta) - x) \quad (10)$$

$$A_3 = \left(\frac{N_c}{v_c + N_c} \right)^2 (\delta_c(\beta) - x)^2 \quad (11)$$

2.4.5. Simulation using the mathematical model

Regarding equations (16) - (19), when x , N_s , v_s , N_c , v_c , and $\delta_c(\beta)$ is constant, $A_{1\sim3}$ is also constant and is more than zero. H monotonically increased with respect to JoA . We hypothesized that sense of fulfillment would be high when the JoA was internal.

3. EXPERIMENT

3.1. Method

We verified the hypothesis obtained from the mathematical model. The hypothesis was that the sense of fulfillment was high when the JoA was internal. To verify this hypothesis, we proposed a new experimental paradigm. The method was to evaluate the flow score between two conditions in which JoA was changed by changing the ease of recognition of assistance. The flow score is the indicator of the strength of the flow state. We used the flow score as the indicator of sense of fulfillment in the flow state. We used a shooting game with the above-mentioned two types of assistance as an operation task in the experiment. Three right-handed, healthy male volunteers between 23 and 24 years old with normal or corrected-to-normal vision and hearing participated in this study.

3.2. Results

Figure 3 shows the comparison of flow scores for each subject. From Figure 3, flow scores are higher with the hard-to-recognize assistance than with easy-to-recognize assistance. In addition, t test with sample number 3 showed significant difference at significance level 0.05.

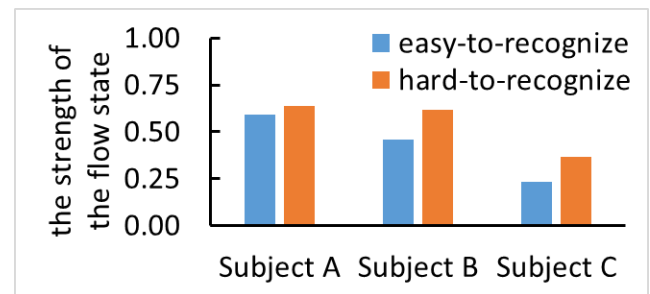


Figure 3: The flow scores for each subject.

4. DISCUSSION

The model proposed in this paper explained how SoA affected sense of fulfillment. According to equations (16) - (19), JoA , x , N_s , v_s , N_c , v_c , and $\delta_c(\beta)$ change the strength of psychological state H . That is, sense of

fulfillment in the flow state are changed by JoA, the expectation of the skill and the challenge, the actual skill and challenge, and the amount of assistance. H monotonically increases with respect to JoA when x , N_s , v_s , N_c , v_c , and $\delta_c(\beta)$ are constant. That is, sense of fulfillment in the flow state increases when JoA is internal.

We discussed the validity of the model by verification of our hypothesis that sense of fulfillment increased when JoA was internal.

By using SoA, flow theory, and attribution theory, the proposed model mathematically explained the relationship discussed in self-determination theory [4]. Self-determination theory explains the relationship between autonomy and sense of fulfillment. Autonomy is necessary for intrinsic motivation, and fulfilling the need for autonomy provides humans with a sense of fulfillment and intrinsic motivation. We thought that JoA was autonomy of action; the self-determination theory supported our hypothesis.

We conducted the experiment to verify our hypothesis. As a result of the experiments with three subjects, flow scores were higher with hard-to-recognize assistance than with easy-to-recognize assistance. These experimental results supported our hypothesis.

5. CONCLUSION

In this paper, we proposed a mathematical model that explains how SoA affects sense of fulfillment when an unachievable task becomes achievable via assistance. We developed the mathematical model using SoA, flow theory, and attribution theory. Figure 1 and equations (16) - (19) represented the proposed model.

By proposing the model, we detailed and mathematically explained the effect that SoA of product operation affected sense of fulfillment. Based on the model, JoA, the expectation of the skill and the challenge, the actual skill and challenge, and the amount of assistance changed the psychological state, which transitioned via assistance and sense of fulfillment in the flow state

We confirmed the validity of the mathematical model in the following list, although the number of subjects used in the experiment was not sufficiently large enough to verify the hypothesis.

- 1) The model explained the relationship between autonomy and sense of fulfillment as explained in self-determination theory as the relationship between a higher sense of fulfillment and internal JoA.
- 2) We verified our hypothesis that sense of fulfillment was high when JoA was internal. The experimental results supported our hypothesis obtained from the model.

Experimental verification of the mathematical model makes it possible to use the model to simulate the psychological state and sense of fulfillment. According to the simulation using the model, sense of fulfillment can be designed according to the purpose of the product at the product design stage.

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REFERENCES

- [1] Berberian, B., Sarrazin, J. C., Le Blaye, P., and Haggard, P. "Automation technology and sense of control: a window on human agency." *PLoS One* 7.3 (2012): e34075.
- [2] Manabe, M., Yanagisawa, H., and Ueda, K. "Effects of the sensory modality and the expectation consistency of the operational feedback on the sense of agency" *Proc. 20th Annual Meeting of JSKE*, 2018. (in Japanese)
- [3] Gallagher, S. "Philosophical conceptions of the self: implications for cognitive science." *Trends in cognitive sciences* 4.1 (2000): 14-21.
- [4] Deci, E. L., and Vansteenkiste, M. "Self-determination theory and basic need satisfaction: understanding human development in positive psychology." *Ricerche di psicologia* 27 (2004): 17-34.
- [5] Frith, C. D., Blakemore, S. J., and Wolpert, D. M. "Abnormalities in the awareness and control of action." *Philosophical Transactions: Biological Sciences* 355.1404 (2000): 1771-1788.
- [6] Synofzik, M., Vosgerau, G., and Newen, A. "Beyond the comparator model: a multifactorial two-step account of agency." *Consciousness and Cognition* 17.1 (2008): 219-239.
- [7] Nakamura, J., and Csikszentmihalyi, M. "The concept of flow." *Flow and the foundations of positive psychology*. Springer, Dordrecht, 2014. 239-263.
- [8] Weiner, B. "A theory of motivation for some classroom experiences." *Journal of Educational Psychology* 71.1 (1979): 3.
- [9] Yanagisawa, H., Kawamata, O., and Ueda, K. "Modeling emotions associated with novelty at variable uncertainty levels: a bayesian approach" *Frontiers in Computational Neuroscience* 13.2 (2019).