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Organizing the Internet of Robotic Things: The Effect of Organization Structure on Users' Evaluation and Compliance toward IoRT Service Platform *

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***Abstract*— As robots and robotic things become to have more agency, IoRT which consists of robots and robotic things can be considered as a social organization. Accordingly, social organization structure of IoRT could affect users' behavior and perception of IoRT. In this study, in order to examine the effect of social organization structure on people's acceptance of IoRT, we conducted a 2 (social organization structure: flat vs. hierarchical) within-participants experiment (*N*=30). In the experiment, a participant was asked to take part in cooking task with the aid of a robot, a robotic measuring cup, and a robotic mixer. We executed a post-experimental survey and counted the duration of participants' following the instruction given by the platform. People gave higher scores of trustworthiness and purchase intention to the platform with flat organization structure than that with hierarchical one. On the contrary, participants were more compliant with the hierarchical IoRT service platform than a flat one. Implications for the theory and design of IoRT are discussed.**

I. Introduction

The number of intelligent things surrounding humans has been rising rapidly [1]. The Internet of things (IoT) is cooperative network of intelligent things that currently provide novel ways to provide services to the users. In addition, intelligent things are evolving into robotic things owing to the technology of advanced automation and actuation [2]. Moreover, novel robots are being developed and introduced into everyday life. This new situation for robots or robotic things demands a new approach for the design of the service platform that they constitute. The Internet of Robotic Things (IoRT) is introduced to this end. IoRT takes into account the networking of robotic things and robots, and make them constitute a service platform.

Within the IoRT service platform, users not only can collect information or place orders but also discuss and cooperate with constituents of the IoRT [3]. This is similar to the activity within social organizations such as bureaucracies and corporations. A social organization consists of multiple agents and coordinated interaction between them [4]. However, social organizations have generally been considered to consist only of human beings. Although various things are needed for the successful functioning of social organizations, those objects have not been included in the group of constituents of the social organization. Until recently, the adjective "social" has always been reserved for human beings or, at most, organic creatures including some species of animals or insects [5].

Thus, humans had not considered creating an organization with things or artifacts. However, currently, as objects can perceive, recognize, and make decisions, they can interact and cooperate with both other things and users. Hence, consideration regarding organizations of artificial agents is now opportune. It is time to regard robots and robotic things as social agents that can co-organize a social organization [6]. Thus, when designing the service platform of IoRT, the social organizational approach needs to be seriously considered. This paper is the first step toward further studies in this direction.

Sociologists have argued that two groups that consist of exactly the same members can be significantly different if they are organized differently. The design of the organization structure can affect the members of the organization, and the results of the organizational performance can differ accordingly [7, 8]. Among those organizational factors, what has been regarded as most important is the level of organizational hierarchy.

In this study, we examined one broad aspect and one specific aspect, which, respectively, are 1) the applicability of the result of social organization studies to IoRT service platform design in a broader context, and 2) the significance of the organization structure depending on whether it is hierarchical or flat.

To this end, we conducted an experiment that provided the participants with an experience of two different organization structure types of the IoRT. By controlling the direct interactions with robotic things at different levels, we made the participants interact with the two IoRT service platforms and perform the same task with each platform. The only difference was the level of organizational hierarchy in each case. The task assigned to the participants for the experiment was cooking— baking cookies. We experimentally examined six hypotheses and verified whether a certain feature of organization structure affected the performance of an organization that consisted of a robot and robotic things.

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II. RELATED WORKS

A. Characteristics of IoRT

IoRT is defined as "a concept where intelligent devices can monitor events, fuse sensor data from a variety of sources, use local and distributed intelligence to determine the best course of action, and then act to control or manipulate objects in the physical world, and in some cases while physically moving through that world" [9]. The major features of IoRT are as follows: 1) Agency [10] 2) Multiplicity (which will proceed to the social) [11] 3) Objectivity (task specificity).

As the predecessor of IoRT, IoT is already a predominant phenomenon. Primarily, an IoT system is comprised of multiple functional blocks to facilitate all sorts of utilities, including sensing and identifying. In this aspect, we can refer to these blocks, that is, intelligent objects as the constituents of IoT [2]. It implies that intelligent things have become members of the organization named IoT.

In IoRT, actuation and automation become more central parts of the system. IoRT is an infrastructure enabling advanced robotic services by interconnecting robotic things. This interconnection enables robotic things to use the benefits of wireless connections and cloud infrastructure, which reduces the operating duration and enhances robotic mobility [12]. Simoens et al. also viewed IoRT as the addition of objects with robotic and autonomous systems into IoT [3].

Then, the importance of, not just robotic things but, robot in IoRT has been explored. Vermesan et al. claimed that the participation of personal robots in IoTs would enhance the combination of six main factors of IoT: advanced sensing, actuating, control, planning, perception, and cognition [13]. In this sense, researchers such as Razafimandimby et al. [11] dealt with the efficient deployment of robots in an IoRT platform. An association of robots can accomplish tasks faster, more efficiently, and is more reliable than a single robot [14, 15, 16]. This is very similar to the core research question of social organization studies. However, the aforementioned studies are limited to the network linkage of multiple robots and exclude the effects of the social organization that consists of them. It lacks social organizational approach exploring the effects on performance of the way how they are organized.

B. Applicability of Social Organizational Approach

Seeing IoRT as social organization means that we think robotic things and robots in that IoRT constitute a social dimension. This kind of thinking has sociological basis. Prominent sociologists in contemporary sociology called Actor-Network Theorists argue that human-centered researchers have been overlooking the agency of things. Actor-Network Theory (ANT) researchers contend that all things, in reality, are nonhuman actors that have their own agency and associate with all other things.

The primary argumentation of Actor-Network Theorists is that "Objects Too Have Agency" [6]. "Objects" of ANT can be everything in the world, including, i.e., humans, animals, boats, fishing nets, scallops, and concrete shells for scallop farming [17]. Further, "agency" refers not just to movement or mobility but also to an objects' effect that ends in the interaction partner doing something obligatory. This presumption of agency of all "objects" discards the asymmetrical relationship between human and nonhuman beings and treats all of them as equal "Actors" in a network.

Nonhuman-centered social approach has also developed in the domain of product design. The framework of Product Ecology, coined by Forlizzi, was derived from social ecology theory. Forlizzi proposed an expansion of this theory, and explored how transforming an ordinary product into a robotic product would affect users' quality of life and the balance of product ecology by changing its status among the rest of products and human beings [18].

The two aforementioned sociological approaches tried to apply their study results into the domain of robotic things and robots. However, this has been limited to resolving ontological discriminations between human beings and artificial things. With robot participation and the introduction of actuation and sensing into things, constituents of IoRT become more like human beings, with consciousness, sense, and their own volition. These products have become agents in a more traditional sense. [10]. It is the agentialization of things and robots. They have more agency than ever before. Thus, An enhanced agency of the constituent things and robots in IoRT needs the approach of designing a social organization.

Due to this reason, service platform design approach is more likely to design an organization rather than Product Ecology or Actor-Network. While Actor-Network or Product Ecology is formed based on individually accumulated or coincidently combined relationships, social organization is designed by human intention. The same is true of service platform design. An IoRT service platform can be structured for a specific task, and the constituents of this IoRT should be deployed for that task [19].

C. Flatness/Hierarchy of Social Organizations

As aforementioned, a collective of robotic things and robots can also be categorized into social organizations. The most fundamental factor of social organization design is the hierarchy of an organization. Many social organization researchers have studied for a long time whether the level of a hierarchy of an organization affects the performance of that organization.

The adjective 'hierarchical' means that it ranks its constituents in order. Only a chosen someone receives the right to decision making. Moreover, there is also a reporting structure that constrains the free delivery of information. However, in large scale organizations and when routinized work is its objective, it is reported that hierarchical organizations show better performance [20]. Nevertheless, the hierarchy will negatively affect organization constituents who are doing something more creative or swift [21].

Traditionally, it was considered as true that hierarchical organizations have a high level of performance and efficiency in the achievement of objectives until the mid-20th century. However, after the generalization of intelligent labor with the rise of the 3rd industrial revolution, the question of horizontal or vertical, that is, flat or hierarchical organization has been rediscovered in terms of organizational efficiency and objective achievement. Today, many sociologists argue that there is no absolute truth as to which organization structure is more efficient. Rather, the performance and efficiency is contingent on the objective and task of each organization. Thus, organization design needs to be conducted thoroughly and sensitively by considering various factors such as the situation, environment, and change in the organization structure and its constituents [22, 23].

We tested hypotheses while the user was practicing a cooking task. Cooking is one of the most prominent tasks for IoRT in domestic environments and it requires a high number of task-specific products with complex and sensitive functions. This opens up a wide range of possibilities for using various organization structures for an IoRT service platform for cooking. It is said that if the task of a social organization is a creative thing, a relatively flat organization structure is better for the performance and efficiency of the organizational achievement. Following these arguments, we set the orientation of the hypotheses of our study.

D. Hypothesis

H1. Users will be more satisfied with the service from an IoRT service platform with a Flat Organization Structure (OS) than one with a Hierarchical OS.

The evaluation of the provided service is different from the perception or judgment of the provider itself, that is, the IoRT service platform. Reeves and Nass suggested that people tend to perceive a new media interface directly related to a specific domain as more professional. Thus, people think that a thing which is directly related to a specific domain is more intelligent, persuasive, and trustworthy [24]. We adopted this theory to describe our following hypotheses:

H2. Users will perceive that an IoRT service platform with Flat OS is more intelligent than one with a Hierarchical OS.

H3. Users will perceive that an IoRT service platform with Flat OS is more persuasive than one with a Hierarchical OS.

H4. Users will perceive that an IoRT service platform with Flat OS is more trustworthy than one with a Hierarchical OS.

As an overall evaluation of the IoRT and the service provided, we asked participants to indicate their willingness to buy this service platform.

H5. Users will show a higher willingness to purchase an IoRT service platform with a Flat OS than one with a Hierarchical OS.

Goetz et al. suggested that a personal service robot needs to elicit both acceptance and compliance from its users because a personal service robot is expected to induce users to perform certain tasks, such as exercise. They examined the correlation between compliance in behavior and perception from the survey. They counted the duration of a participant's following the instruction to measure the compliance of a participant to the personal service robot [25]. In this study, we expected that the organization structure would affect human behavior in the cooking task.

H6. Users will follow the instruction from the IoRT service platform with a Flat OS more strictly than one with a Hierarchical OS.

III. Method

A. Participants

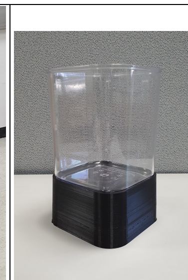
We recruited 30 participants via webmail. All participants were recruited, regardless of age and gender. $12 was given to each participant.

B. Materials

To test the hypotheses, we modeled two different organization structures with a simulation of an IoRT service platform. We started the service platform design with the decision of what things will constitute the platform. We selected three things because the number three has been considered as the starting point for social interactions. We designed and simulated three agents as below: 1) Robot, 2) Measuring Cup 3) Mixer.

We used the robot "Temi" developed by Robotemi [26] and two robotic cooking products, including a robotic measuring cup and a robotic mixer as an IoRT service platform. We developed a robotic measuring cup and mixer by modifying a plastic container and a normal mixer with speakers connected by Bluetooth communication. By the method of the Wizard of Oz, we simulated a measuring cup and mixer as intelligentialized things that can sense weight, the concentration of fluid, and identify the material in contact with it (See Table 1). All of these robot and robotic things provide participant with information via speech interface. Voice for speech interface was based on the text-to-speech open software "Oddcast" that provides several different voices[27]. We fitted each of the three agents with the most distinguishable voices so that participant can identify which agent he/she is interacting with at that moment only by hearing those voices.

TABLE I. SIMULATED ROBOT AND ROBOTIC THINGS FOR THE EXPERIMENT

Appearance			
Device	Robot	Measuring Cup	Mixer
Simulated function	• Know the recipe • Share the information collected by any robotic device in common		
	• Deliver the recipe	• Perceive the identity of the material in contact • Measure the weight of the material	• Perceive the status of material in contact • Percieve the concentration of fluid

C. Procedure

The IoRT service platform that consists of the robot, the robotic measuring cup, and the robotic mixer provided the cooking assistance for baking cookies. In order to exclude a fire or electrical accident, experiment subjects only participated in baking cookies up until the stage of completing the dough. Every participant had access to all materials needed for baking cookies for real. They had real flour, sugar, salt, and baking powder in amounts that exceeded the instructed amount. Butter and eggs were measured by the authors in advance and provided to the participant in the right quantity (See Fig. 1). The detailed process of this assistance service is described in Table 2.

After explaining the overall experimental process and the form of informed consent provided by IRB, we provided participants with information as a means for the manipulation of different conditions. The details are below:

> *The service platform consists of three intelligent devices—a robot, mixer, and measuring cup. The mixer and measuring cup have sensors so they can do things such as measuring weight and the concentration of a fluid, identifying the material in contact, and so on. The information collected by the mixer and measuring cup will be shared within the entire service platform. They also share the correct recipe for baking cookies.*
>
> *Sometimes you will be in situations in which you are asked to keep whisking the cooking material. Every device of service platform keeps perceiving the status of the material and knows until when exactly you should keep doing what you are doing. However, if you start believing that it is done or wonder how long you should keep doing this, please feel free to tell the robot about what you are thinking at once.*

During the experimental process, participant was asked by the service platform five times to keep whisking the cooking material until the robot gave the next instruction. Two times out of five, participant was asked to do the whisking task for 60 seconds, and one time out of five, we gave him/her the next instruction instantly so that he/she could comply to the process with no doubt. On the contrary, two other times, he/she was asked to keep whisking without exact information about the duration. According to the accurate recipe, the amount of the cooking material that we provided must be whisked more than 90 seconds.

However, as aforementioned, we intentionally allowed participants to ask or talk to the robot freely if he/she thinks that it is done. Although participants already knew that the service platform knows the right duration of the whisking required, some participants still resisted that fact and told the robot preemptively that they thought differently, that is, that it was finished. Using this phenomenon, the authors designed a measurement index of obedience to the service platform. Each participant showed a different compliance duration, from the start of whisking to the moment they stopped and asked the IoRT platform whether it is not over yet. The compliance duration was dependent on differences in organization structure as well as individual differences. We measured the exact length of the compliance duration to the level of seconds and used the result as a dependent variable for the statistical analysis.

TABLE II. EXPERIMENT SCENARIO

	Detail of each stage of the process	***Main agent in action of each organizational condition***	
		Hierarchical OS	***Flat OS***
1	Participant says to robot "Tell me how to make cookies"	Participant	
2	"This are the instructions for making cookies. Put the butter into the bowl and whisk it with the mixer for one minute."	Robot	
3	Participant whisks materials for one minute.	Participant	
4	"The preparation is completed."	Robot	Mixer
5	"Prepare 100 g of sugar with the measuring cup. Pour sugar into the measuring cup slowly. The measuring cup percieves the weight of sugar and will notify you when it reaches 100 g."	Robot	
6	Participant keeps pouring sugar into the measuring cup.	Participant	
7	"It is 100 g."	Robot	Measuring Cup
8	"Put the prepared sugar into the bowl, whisk the materials in the bowl with a mixer for one minute."	Robot	
9	Participant whisks it for one minute.	Participant	
10	"The preparation is completed."	Robot	Mixer
11	"Put an egg into a new container. Put 2 g of salt into the container and whisk it with the mixer."	Robot	
12	Participant whisks it for 5 seconds.	Participant	
13	"Stop the mixer and leave it as it is. The mixer will perceive the amount of salt."	Robot	
14	Pariticipant stops whisking and puts the mixer into the container.	Participant	
15	"The amount of salt is not enough. Add adnother quarter-teaspoon of salt."	Robot	Mixer
16	Participant adds another quarter-teaspoon of salt.	Participant	
17	"Put the mix of eggs and salt into the bowl. Whisk materials in the bowl with the mixer until they are well blended."	Robot	
18	Participant whisks materials in the bowl until either they say something to the robot implying they think that it is done or when 90 seconds have elapsed.	Participant	
19	"The preparation is completed."	Robot	Mixer
20	"There are two types of flour. Prepare 200 g of weak flour with the measuring cup. The measuring cup will inform you whether the flour you just measured is the proper sort for baking cookies. Pour flour into the measuring cup slowly, then it will notify you when it reaches 200 g."	Robot	
21	Participant starts pouring weak flour into the measuring cup.	Participant	
22	"It is weak flour."	Robot	Measuring Cup
23	Particiapnt keeps pouring weak flour.	Participant	
24	"It is 200 g."	Robot	Measuring Cup
25	"Put 3 g of baking powder into the measuring cup."	Robot	
26	Participant puts baking powder into the measuring cup.	Participant	
27	"Put the sifter over the bowl and pour materials in the measuring cup. Sift materials on the sifter until all things go through and into the bowl."	Robot	
28	Participant sifts materials through the sifter.	Participant	
29	"Whisk all materials in the bowl with a mixer until they become a mass."	Robot	
30	Participant whisks materials in the bowl until either they say something to the robot implying they think that it is done or when 90 seconds have elapsed.	Participant	

Figure 1. Pariticipant interacting with agents of IoRT service platform

D. Experimental Manipulation

We should simulate hierarchical organization with only three robotic agents, so we adopted the way of simulating hierarchy from experimental psychology. Frauendorfer et al. suggested that, in a small group such as twelve people, if someone is perceived as dominant in collective decision making, a hierarchy is emerging without multi-level organization[28]. Following this approach, we manipulated and simulated the experimental conditions, that is, the organization structure types by different levels of the robotic things' participation via utterance. When a participant performed the task with the Flat OS IoRT service platform, robotic things spoke for themselves directly about the information and what they have done – perceiving or sensing the materials or time. On the contrary, within the condition of a Hierarchical OS, the mixer and the measuring cup did the same thing; however, they did not report directly to the participant. Instead, the robot received the information as a result of perception from other robotic things and told it on behalf of them. Due to this bureaucratic structure that allowed for the information to be reported only by the higher agent, users of this service platform perceive this organization structure as hierarchical. Two different types of IoRT service platform delivered exactly the same instruction, as stated in Table 2.

E. Measures

After completing the task in cooperation with the IoRT service platform, participants were asked to answer a questionnaire. We constructed the following five questionnaire categories for evaluating the service platform: 1) service evaluation [29], 2) intelligence [30], 3) persuasiveness [31], 4) trustworthiness [31], and 5) willingness to purchase [32]. We used a seven-point Likert scale for the questionnaire, and the same version of the questionnaire was used for the two different conditions as well. The details of the questionnaire are in Table 3.

We measured participant's responses repeatedly. Participant had interacted with the IoRT service platform with one organization structure and then did it again with the other OS. To nullify the effect of the order of repeated experiments,

TABLE III. E. SURVEY QUESTIONNAIRE FOR EVALUATION OF IORT SERVICE PLATFORM

Measuring Category	***Item***	***Scale (7-point Likert scale)***	
Evaluation of the service[a]	How was the service provided by the service platform?	Very poor	Very good
	How satisfied were you with the service provided by the service platform?	Completely dissatisfied	Completely satisfied
	Would you use the service provided by the service platform again in the future?	Would avoid using the service	Would want to use the service very much
Intelligence[b]	Please rate your impression of the robot on these scales:	incompetent	competent
		ignorant	knowledge-able
		irresponsible	responsible
		unintelligent	intelligent
		foolish	sensible
Persuasive-ness[c]	The service platform's suggestion convinced me to choose the suggested way of cooking.	Not at all	Very much
	The service platform was like a good cooking assistant.		
	I would use the service platform's suggestion in the future.		
Trustworthi-ness[c]	The service platform was believable.		
	The service platform was trustworthy.		
	I trust the information that the service platform gave me.		
Willingness to purchase[d]	How much do you want to purchase the service platform?		
	Do you really want to purchase the service platform?		

a. [27] b. [28] c.[29] d.[30]

we randomized the order of the experimental process for each participant. Data analysis was conducted with the package *psych* in R [33] for Cronbach's alpha test between the questions, and the package *pingouin* in Python [34] for the statistical significance test of the responses of the participants.

IV. RESULTS

We conducted Cronbach's Alpha test to examine the reliability of the items within each evaluation category in the survey questionnaire. As shown in Table 4, all of the items exhibit a statistical consistency with each other and present strong reliability within each category. Then, we conducted a one-way repeated measured analysis of variance (ANOVA) on the within-comparison categorized by different OS conditions. This analysis was conducted for every five evaluation categories of the service platform and mean scores of the counted compliance time (See Table 5).

TABLE IV. CRONBACH'S ALPHA TEST RESULTS

Measuring Category	***Number of Items***	***Item-total alpha (standardized)[a]***
Service Evaluation	3	0.94 (0.94)
Intelligence	5	0.87 (0.87)
Persuasiveness	3	0.90 (0.90)
Trustworthy	3	0.97 (0.97)
Willingness to Purchase	2	0.94 (0.96)

a. 95% confidence boundaries

TABLE V. THE EFFECT OF ORGANIZATION STRUCTURE ON THE EVALUATION OF IORT SERVICE PLATFORM

Measuring Category	***Mean (Standard Deviation)***	
	Hierarchical OS	***Flat OS***
Service Evaluation	5.21 (1.36)	5.23 (1.49)
Intelligence	4.76 (1.06)	4.94 (1.31)
Persuasiveness	5.28 (1.33)	5.37 (1.43)
Trustworthiness	5.17 (1.39)+	5.39 (1.40)+
Willingness to Purchase	4.17 (1.61)*	4.50 (1.66)*
Compliance (seconds)	77.98 (12.81)**	71.03 (16.65)**

a. + p<.10 *p<.05 **p<.01 (One-Tailed)

There was no statistically significant difference between the mean scores from different OS conditions as determined by the one-way repeated measured ANOVA within the categories of service evaluation (F[1, 29] = 0.037, p = 0.4248), intelligence (F[1, 29] = 1.086, p = 0.1529) and persuasiveness (F[1, 29] = 0.119. p = 0.2718) measurements. Thus, hypotheses H1, H2, and H3 are not supported by the statistical analysis.

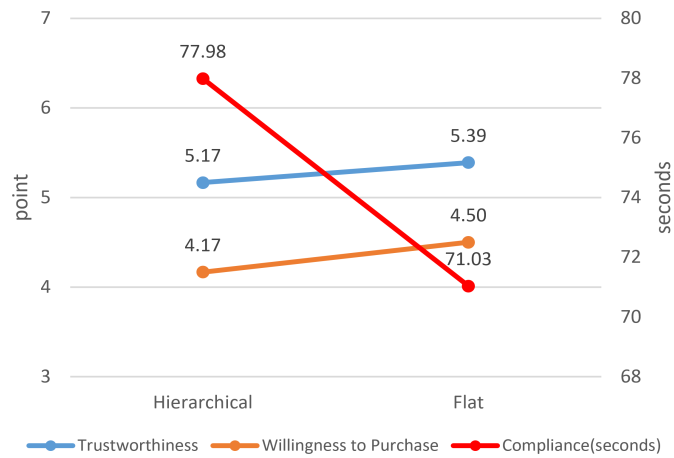
On the evaluation category of the willingness to purchase, there was a significant effect on the mean values of each OS condition (F[1, 29] = 5.631, p = 0.012). Post hoc comparison indicated that the mean score of the willingness to purchase the IoRT service platform with Flat OS (M = 4.50, SD = 1.66) was significantly higher than that with a Hierarchical OS (M = 4.17, SD = 1.60). This result suggests that participants prefer the IoRT service platform with a Flat OS to the Hierarchical OS when they need to purchase one of them. Hypothesis H5 is supported according to this result.

Although its statistical significance is relatively weak, the trustworthiness of the IoRT service platform showed a different tendency depending on the different organization structures (F[1, 29] = 2.071, p = 0.080). Participants thought that the IoRT service platform with a Flat OS was more trustworthy than the one with a Hierarchical OS. Post hoc comparison revealed that the mean score of trustworthiness toward the IoRT service platform with a Flat OS (M = 5.39, SD = 1.40) was higher than that of a Hierarchical OS (M = 5.17, SD = 1.39).

The comparison between mean scores of compliance seconds also showed a statistical significance (F[1, 29] = 7.298, p = 0.005). However, post hoc comparison revealed that the direction of our hypotheses H4 and H5 was opposite to the result. Compliance seconds were higher with the condition of the Hierarchical OS (M = 77.98, SD = 12.81) compared with that of the Flat OS (M = 71.03, SD = 16.65). Even though our original hypothesis is not supported, the result strongly suggests that participants have a stronger tendency of compliance in the interaction with the IoRT service platform with a Hierarchical OS than with a Flat OS.

Taken together, these results suggest a counter-intuitive aspect of the IoRT service platform evaluation. According to our statistical analysis, participants wanted and trusted the IoRT service platform with a Flat OS more than that of a Hierarchical OS. Nevertheless, when participants received

Figure 2. Intersection between the evaluation based on survey and compliance behavior



instruction from two different IoRT service platforms, they followed the instruction from the Hierarchical OS more strictly than that from the Flat OS (See Fig. 2).

V. DISCUSSION

Our study result supports that the difference in organization structure affects both the IoRT service platform evaluation and the users' behavior towards the platform.

A. *Interaction with Multiple Agents was Preferred and Trusted over Centered One*

The current development orientation of IoRT service platforms mostly focuses on direct interaction with a single agent, such as an intelligent device like a smart speaker or a robot that takes the role of a hub in the IoRT platform. In this study, we found that IoRT service platforms with a Flat OS that are associated with multiple robotic products would be more accepted by users than the current development orientation of IoRT, which is towards Hierarchical OS.

Furthermore, it was also revealed by our study that latent users of IoRT may prefer Flat OS platform in which users directly interact with multiple agents to Hierarchical OS platform, especially when they need to buy the platform. Moreover, an IoRT service platform that was organized in the flat mode resulted in gaining the latent user's trust more than one in the hierarchical mode. With the dissemination of IoRT, people will use and interact with it to do more complex and sensitive tasks in more private spaces such as homes. In this respect, a service platform design to enhance credibility is crucial. IoRT service platform developers could adopt a Flat OS to increase the credibility of a platform.

B. *Hierarchical Organization Structure Draws Actual Compliance More*

On the contrary, the IoRT Service Platform with a Hierarchical OS failed to draw more willingness for purchase and trustworthiness toward itself. However, our study result revealed that the platform with Hierarchical OS was more effective in making latent users comply with the instructions provided by itself. Similar to bureaucratic organizations that are the most representative for hierarchical ones, the platform with a Hierarchical OS is more successful at controlling the constituents according to its internal operation. This aspect of the platform with Hierarchical OS may be a considerable advantage, especially when it is applied to tasks related to the domain of health or security.

Notably, there was a dissonance between the evaluation based on the survey questionnaire and the compliance behavior during the experiment. It means that the actual performance that leads users to a more successful result can be independent of the opinion of the users toward the service platform. Our study result supports that IoRT service platform designed in the principle of Flat OS may be more satisfactory and successful in the market because latent users 'think' of the platform with a Flat OS more positively. However, if the results of the cooperation with the IoRT service platform accumulate, the disadvantages in gaining a compliant behavior of the user might affect the overall evaluation toward the platform itself in the long run. Thus, when designing an IoRT service platform, both survey and behavior analysis are needed.

C. Specific Task Distinction and Organizational Effect

Because of limitations in our experimental conditions, the compliance behavior measurement was only possible for the specific task of whisking. We conducted our experiment and measurement based on the presumption that cooking is overall a creative process and might fit a Flat OS better. However, the specific task of keeping whisking does not require creativity. We did not conduct other measurements of the duration of compliance behavior except for the whisking task, and it can hardly be rationalized that the IoRT service platform with a Hierarchical OS has the effect of enhancing compliance for all sorts of cooking behaviors in general. The dissonant result between the survey and the compliance duration may be due to this distinction between specific tasks according to the criterion of creativity. Further studies have to be conducted to verify this interpretation.

D. Limitation: More Studies Beyond a Single Task Needed

Similar to human social organizations, the consumer adoption of an IoRT depends on how the social organization structure of the IoRT matches with the task or the objective of the service platform. It is true that latent users preferred and trusted the IoRT service platform with a Flat OS more than those with a Hierarchical OS; however, this is only valid with the condition that the task is cooking. Studies on human social organizations have reported that suitable organization structures can vary depending on which objective or main task is imposed on the organization. If the main task of the service platform changes, there is a considerable possibility that the evaluation of the two OSs will be reversed. As aforementioned, if specific tasks need the platform's capability to draw a user's compliance, this hypothesis must be examined in further studies that will adopt the experimental structure of comparison between different tasks. In addition, as socioloigsts investigate the influence of organization structure through long periods of observation, the effect of organization structure of IoRT service platform needs to be further explored through long-term study.

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REFERENCES

[1] F. Dahlqvist, M. Patel, A. Rajko, and J.Shulman, "Growing opportunities in the Internet of Things," *McKinsey Insights*, July 2019. [Online]. Available: www.mckinsey.com/industries/private-equity-and-principal-investors//our-insights/growing-opportunities-in-the-internet-of-things

[2] A. Puliafito, A. Cucinotta, A. L. Minnolo, and A. Zaia, "Making the internet of things a reality: The wherex solution." in *The Internet of Things, D.* Giusto, A. Iera, G. Morabito, and L. Atzori, Eds. New York, NY: Springer, 2010, pp. 99-108.

[3] P. Simoens, M. Dragone, and A. Saffiotti, "The internet of robotic things: A review of concept, added value and applications," *International Journal of Advanced Robotic Systems*, vol. 15, no. 1, pp. 1-11, 2018.

[4] C. H. Cooley, *Social Organization.* New Jersey: Transaction Publishers, 1983.

[5] A. Degelsegger and A. Kesselring, "Do non-humans make a difference? The actor-network-theory and the social innovation paradigm." in *Challenge Social Innovation*, H.-W. Franz, J. Hochgerner, and J. Howaldt, Eds. Heidelberg, Germany: Springer, 2012, pp. 57-72.

[6] B. Latour, *Reassembling the Social: An Introduction to Actor-network-theory.* London: Oxford University Press, 2007.

[7] W. R. Scott and G. F. Davis, *Organizations and Organizing: Rational, Natural and Open Systems Perspectives*. Abingdon, Oxon: Routledge, 2015.

[8] D. R. Dalton, W. D. Todor, M. J. Spendolini, G. J. Fielding, and L. W. Porter, "Organization structure and performance: A critical review," *Academy of Management Review*, vol. 5, no. 1, pp. 49-64, 1980.

[9] D. Kara and S. Carlaw, "The internet of robotic things," *ABI Research*, 2014. [Online]. Available: www.abiresearch.com/market-research/product/1019712-the-Internet-of-robotic-things/.

[10] N. Cila, I. Smit, E. Giaccardi, and B. Kröse, "Products as agents: Metaphors for designing the products of the IoT age," *in Proc. of the 2017 CHI Conference on Human Factors in Computing Systems,* Denver, CO, May 2017, pp. 448-459.

[11] C. Razafimandimby, V. Loscri, and A. M. Vegni, "A neural network and IoT based scheme for performance assessment in internet of robotic things," *in Proc. of the 1st IEEE International Conference on Internet-of-Things Design and Implementation (IoTDI)*, Berlin, Germany, April 2016, pp. 241-246.

[12] P.P. Ray, "Internet of robotic things: Concept, technologies, and challenges," *IEEE Access*, vol. 4, pp. 9489-9500. 2016.

[13] O. Vermesan, A. Bröring, E. Tragos, M. Serrano, D. Bacciu, S. Chessa, and P. Simoens, *Internet of Robotic Things: Converging Sensing/actuating, Hypoconnectivity, Artificial Intelligence and IoT Platforms*. Gistrup: River Publisher, 2017.

[14] T. Arai, E. Pagello, and L. E. Parker, "Advances in multi-robot systems," *IEEE Transactions on Robotics and Automation*, vol. 18, no. 5, pp. 655-661, 2002.

[15] Y. U. Cao, A. S. Fukunaga, and A. Kahng, "Cooperative mobile robotics: Antecedents and directions," *Autonomous Robots*, vol. 4, no. 1, pp. 7-27, 1997

[16] M. A. Hsieh, A. Cowley, V. Kumar, and C. J. Taylor, "Maintaining network connectivity and performance in robot teams," *Journal of Field Robotics*, vol., 25, no. 1-2, pp. 111-131, 2008.

[17] M. Callon, "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Brieuc Bay," *The Sociological Review*, vol. 32, no. 1, pp. 196-233, 1984.

[18] J. Forlizzi, “The product ecology: Understanding social product use and supporting design culture,” *International Journal of Design*, vol. 2, no. 1, pp. 11-20, 2008.

[19] P. F. Donnelly, *Organizational Forming in (a) Modern Times: Path Dependence, Actor-network Theory and Ireland's Industrial Development Authority.* Amherst, MA: University of Massachusetts. 2007.

[20] M. Weber, “Bureaucracy”. In *Working in America*. A. S. Wharton, Ed. Abingdon, Oxon: Routledge, 2015.

[21] J. P. Olsen, “The ups and downs of bureaucratic organization”, *Annual Review of Political Science*, vol. 11, pp. 13-37. 2008.

[22] S. W. Geiger, W. J. Ritchie, and D. Marlin, “Strategy/structure fit and firm performance,” *Organization Development Journal*, vol. 24, no. 2, pp. 10-22. 2006.

[23] J. L. Wildman, A. L. Thayer, M. A. Rosen, E. Salas, J. E. Mathieu, and S. R. Rayne, “Task types and team-level attributes: Synthesis of team classification literature,” *Human Resource Development Review*, vol. 11, no. 1, pp. 97-129, 2012.

[24] B. Reeves and C. I. Nass, *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places*. New York: Cambridge University Press, 1996.

[25] J. Goetz, S. Kiesler, and A. Powers, “Matching robot appearance and behavior to tasks to improve human-robot cooperation,*” in Proc. of the 12th IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN)*, Vancouver, Canada, November 2003, pp. 55-60.

[26] Temi, Robotemi, [Online] Available: www.robotemi.com

[27] Oddcast,text-to-speech [Online] Available: https://ttsdemo.com/

[28] D. Frauendorfer, M. Schmid-Mast, D. Sanchez-Cortes, and D. Gatica-Perez, “Emergent power hierarchies and group performance ,” *International Journal of Psychology,* vol. 50, no. 5, pp. 392-396, 2015.

[29] M. K. Lee, S. Kiesler, J. Forlizzi, S. Srinivasa, and P. Rybski, “Gracefully mitigating breakdowns in robotic services,” in *Proc. of the 5th Annual ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, Osaka, Japan, March 2010, pp. 203-210.

[30] C. Bartneck, D. Kulić, E. Croft, and S. Zoghbi, “Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots,” *International Journal of Social Robotics*, vol. 1, no. 1, pp. 71-81, 2009.

[31] S. Andrist, E. Spannan, and B. Mutlu, “Rhetorical robots: Making robots more effective speakers using linguistic cues of expertise,” in *Proc. of the 8th Annual ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, Tokyo, Japan, March 2013, pp. 341-348.

[32] M. Zhao, S. Hoeffler, and D. W. Dhal, “Mental simulation and product evaluation: The affective and cognitive dimensions of process versus outcome simulation,” *Journal of Marketing Research*, vol. 48, no. 5, pp. 827-839, 2011.

[33] W. Revelle. “psych: Procedures for Psychological, Psychometric, and Personality Research.”, Evanston, Illinois: Northwestern University, R package version 1.9.12, 2019. [Online]. Available: CRAN.R-project.org/package=psych.

[34] R. Vallat, “Pingouin: statistics in Python,” *Journal of Open Source Software*, vol. 3, no. 31, 1026, 2018 [Online]. Available: doi.org/10.21105/joss.01026