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Uncovering Users' Decisions through Serious Game Playing with A Formal Description Method

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Abstract

The purpose of this study is to verify that virtual cases involving players' changes in awareness during the gaming process can be described with the Managerial Decision-making Description Model (MDDM). Previous studies proposed a method to measure and evaluate players' cognition and judgment during gaming. Based on this, we developed a game system with a function to detect players' changes in awareness. Your Life to Come Game (YLCG), which we originally developed, runs on this system. We checked whether it was possible to formally describe virtual cases in which players experienced changes in awareness during the game and found that the formal description language of the MDDM had this capability.

Keywords: simulation and gaming, serious games, business simulations, formal description method, MDDM, decision making, game performance, virtual case.

1. INTRODUCTION

The purpose of this study is to show that it is possible to formally describe virtual cases involving a player's change in awareness in gaming. We defined a virtual case as a situation that consists of players' cognition and decision-making in a game experience, as opposed to a business case that consists of decision-making in real business. A change in awareness is defined as a change in the priority of a player's play objectives. Play objectives are what players aim to achieve in gaming.

Gaming is a traditional method that originated in military training exercises [1][2]. In recent years, gaming for the business sector has received a lot of attention [3]. In this type of gaming, players compete as individuals or a team to achieve a predetermined goal, following the facilitator's instructions and prescribed rules [3]. In this independent experience, players learn by themselves.

Protocol analysis [4][5][6] has generally been used to measure and evaluate players' cognition and judgment during game playing (e.g., [7], [8], and [9]) . This procedure involves collecting, transcribing, and analyzing voice data emitted by players during the gaming process. Since protocol analysis requires time to compile, analyze, and evaluate the data, it may not be suitable for applications in which game facilitators use the results of the analysis in the middle of a course of education or training with gaming.

The "performance sheet" (PS) [9] developed by Koshiyama et al. is suitable to overcome the problems of these traditional methods. Koshiyama et al. introduced the PS to an existing business simulation game. During the game, each player records his or her own perceptions and judgments on a PS. The information recorded by the player in the PS is the recognition of the target state, state variables and control variables. Then, the researchers compared the histories of players' cognitions and judgments recorded in the PSs with those revealed by protocol analysis. The results showed that the PS could be a good alternative to protocol analysis. Specifically, they found that it is possible to know the history in players' cognitions and judgments and detect changes in them, and to compare them between players.

In this study, we developed a game system with a function to record players' decisions and play goal priorities during the gaming process, based on the works of Koshiyama et al.. We also developed a serious game called Your Life to Come Game (YLCG) that runs on the game system. The game system runs in the PC environment. In addition, we extracted a virtual case in which a player had a change in awareness, as seen from the play logs collected in the serious game experiment. We then attempted to describe the virtual case using the Managerial Decision-making Description Model (MDDM) [10][11]. The results confirmed that MDDM adequately described the player's change in awareness.

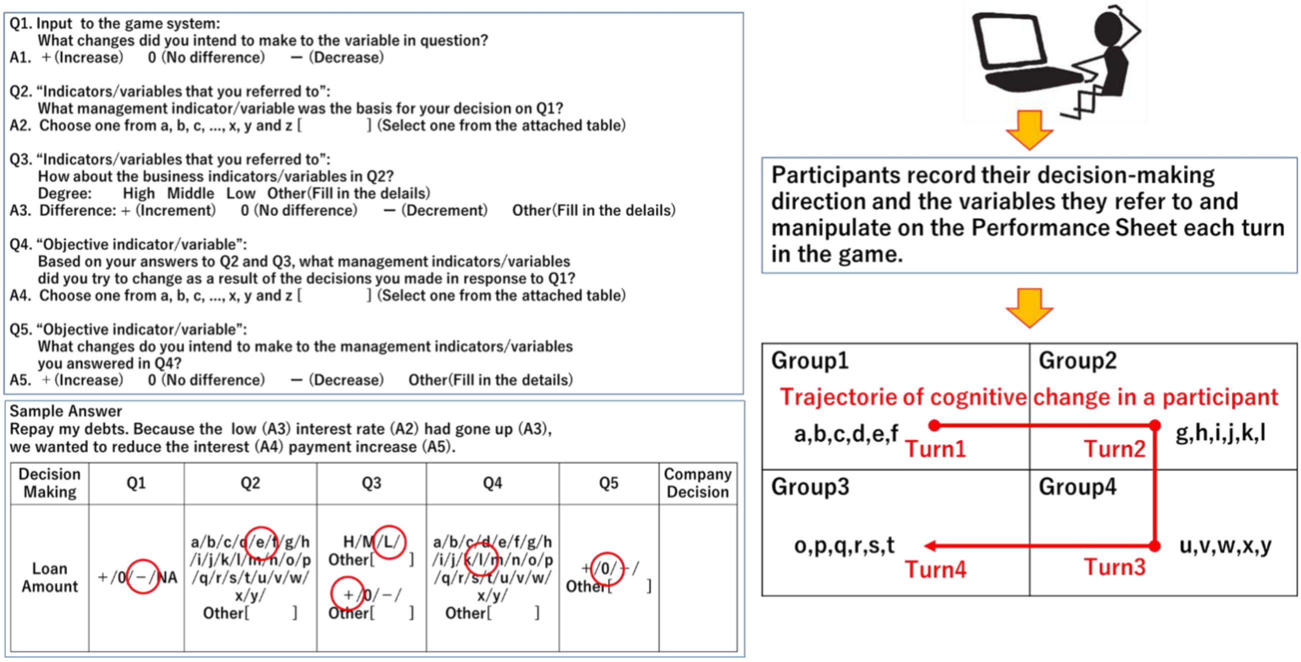

Fig.1 An Overview of Visualization of Cognition and Judgment in Business Games.
The player records his or her perceptions and decisions on the PS each turn. Each of the variables in the game referenced by the player belongs to one group. If the groups are connected by arrows to each other in the order in which variables are referred to, it is easy to visually understand how their cognition changes over time.The figure was described with reference to [9].

The formal description of the virtual cases generated from the game playlog has the advantages described below. Nakano et al. developed a business game based on real business cases, and showed that virtual cases similar to real business cases can be generated by gaming [12]. Kikuchi et al. showed that real business cases and hypothetical cases generated by Agent-Based Model (ABM) can be formally described and compared, respectively [13]. Based on the work of Nakano et al. and Kikuchi et al. it is not only easier to visually understand virtual cases if we can formally describe virtual cases generated from gaming playlogs, but also to compare virtual cases generated by real cases and ABMs with virtual cases generated from gaming playlogs. A simple understanding and comparison of cases generated by various means could support game facilitators working in gaming and debriefings.

The structure of this paper is as the follows. Section 2 describes previous methods of measuring player's cognition and judgment in the gaming process and MDDM, a formal and comparable model for representing agents' decisions in business cases. Section 3 describes the experimental method of this study. Section 4 describes the results of the experiments. Here, a decision-diagram created using MDDM is presented, which is a virtual case containing player's change in awareness generated from gaming playlogs. In addition, a text describing the participant's perceptions of his own cognition and decision-making, which were obtained from the interviews with the participant conducted after the gaming, is also presented. In Section 5, we analyze the results of the experiments. Section 6 summarizes this study.

2. RELATED WORK

2.1 Methods for Measuring Players' Cognition and Judgment in the Gaming Process

Many researchers used protocol analysis [4][5][6] to measure and evaluate players' cognition during the gaming process (e.g. [7], [8], and [9]). However, there is a problem in that it is difficult to provide players (learners) with instruction based on the results of protocol analysis in educational activities or trainings because the protocol analysis takes time and may not be completed before the end of gaming.

To overcome this challenge, Koshiyama et al. introduced PS into Simulation and Gaming, which has a function to record players' cognition during gaming and visualize it as the game progresses [9]. Koshiyama et al.'s approach using PS to visualize cognition, shown in Fig. 1, is to

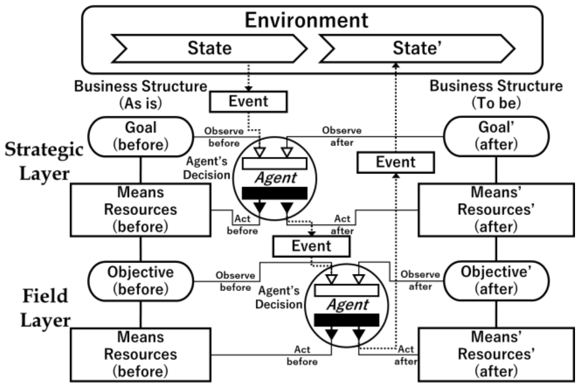

Fig.2 An example of case described by MDDM.

The MDDM represents the managerial decision-making as a decision diagram with the three components, the Environment (top), the business structure (right and left side) and the agent's decision (four terminal elements between the Business Structures)

consider the game as a player's control problem and record how the player perceives the target state, state variables, observed variables, and control variables (i.e., the concept of the problem) at any given time. Koshiyama et al. showed that PS-based method enables experimenters to understand players' cognitions and judgments, detect changes in them, and compare them between players by contrasting the results of the PS-based analysis with the results of protocol analysis. The PS-based analysis method can also be used to visualize changes in players' cognition and decision-making over time so that experimenters can visually understand them.

2.2 Managerial Decision-Making Description Model (MDDM)

Kunigami et al. proposed the MDDM as a formal and comparable model for representing agents' decisions in business cases to respond to changes in the business structure of an organization [10][11]. This model consists of three elements: the Business Structure Component, Environment Component, and Agent's Decision Element. By placing these elements in a frame and linking them together according to their relationships, we describe the decision-making associated with changes in the organization's business structure as a "decision diagram."

Here, the Business Structure Component consists of symbols of "objectives" and "means" in each layer of the organization (Strategic Layer, Middle Layer, Field Layer, etc.). The Environment Structure Component consists of state symbols and their changes over time, both inside and outside the organization. It also places "event" symbols generated from changes in state. The decision-making element of the agent is represented by a device with four terminals. The top two terminals connect the objects that the agent observes. The bottom two terminals are connected to the target on which the agent acts.

The model can be described by the following four features:

(a) The multi-layered structure of the organizational business, and its transition.
(b) The focus (or bounded scope) of the agent's observations and actions.
(c) The agent's position corresponding to each layer in the business structure.
(d) The chronological order and the causality of the agents' decisions.

It has been pointed out that MDDM has the potential to represent the simulation logs of the actual business case and the agent model in a certain common format. In Fig. 2, the MDDM represents management's decision-making as a decision diagram with three elements: the Environment Component (top), the Business Structure Component (left and right), and the Agent's Decision Element (the four end elements between the Business Structure Components).

3. METHODS

In this section, we describe our experimental method. Section 3.1 provides an overview of the serious game YLCG. Next, Section 3.2 introduces the execution and development environment of the game system. Section 3.3 provides information on the experiment participants, and Section 3.4 describes the experiment procedure.

3.1 Your Life to Come Game (YLCG)

This section describes the details of YLCG, a turn-based serious game. In the game, a player takes on the role of a Japanese businessperson and experiences a virtual life in an environment provided by the game system. YLCG requires the player to use player-specific resources (i.e., time, money, and abilities) for various purposes on each turn. The quantity of resources used by the player is assigned by the game system to the MATH model described below. As a result, the player's resource and status information change.

3.1.1 MATH model

YLCG incorporates the MATH model (See Fig. 3) so that the game system makes players experience the consumption and acquisition/loss of resources during their virtual life. For this study, we adopted a simplified MATH model that excluded the health component. The individual equations corresponding to the simplified

MATH model are listed in (1)–(12); the variables of the MATH model are summarized in Table 1.

$$\begin{bmatrix} M_{(t+1)} \\ A_{(t+1)} \end{bmatrix} = \begin{bmatrix} M_{(t)} + \Delta M_{(t)} \\ A_{(t)} + \Delta A_{(t)} \end{bmatrix} \quad \#\#(1)$$

Table 1. The parameters used in the MATH model.

Parameters	Description	Parameters	Description
t_{Ework}	Time spent for work	ε_{Invest}	Normalized random number
t_{Learn}	Time spent on developing skills for the job	ε_{Trust}	Normalized random number
t_{Invest}	Time spent on investments	μ_{Invest}	Average return on investment
m_{Invest}	Funds to be spent on investment	μ_{Trust}	Average return on investment trust
m_{Trust}	Funds to be spent on investment trust	σ_{Invest}	Standard deviation of return on investment
m_{Learn}	Cost of developing job skills	σ_{Trust}	Standard deviation of return on investment trust
c_{Ework}	Effectiveness of growth in work capacity per time spent on the job	Δt	Time available in one turn
c_{Learn}	Effectiveness per time spent on capacity developing skills for the job	ΔA_{Invest}	Amount of change in the ability to invest per turn
c_{Invest}	Effectiveness per time spent on capacity building of investment	ΔA_{Ework}	Amount of change in work capacity per turn
W_{Ework}	Pay per hour spent on the job	Δm_{Invest}	Funds recouped from one turn of investment.
A_{Invest}	Investment ability	Δm_{Ework}	Wages earned from one turn of work.
A_{Ework}	Work ability	Δm_{Trust}	Funds recouped from one turn of investment trust.

Table 2. Detailed Description of Events.

Once an Environment Event (EE) is triggered, it automatically modifies the equations and parameters that make up the MATH model, or changes the status information of the player. Additionally, once Ordinary Event (OE) and Extraordinary Event (ExOE)) is triggered by a player, the game system modifies MATH model parameters and equations, or changes the player's status information.

Event	Type	Occurrence condition	Details
Job Hunting	OE	This event occurs every turn.	Players can choose from the following occupations: university students, freelancers, investors, and company employees.
Marriage Hunting	ExOE	Player's attribute is set to unmarried	Players have a 20% chance of getting married. When the player's attribute becomes a married player, the maximum amount of time resources that can be used in one turn is reduced from 100% to 90%.
Financial Chance	ExOE	This event has a 20 % chance of occurring.	When you perform this event, there is a 5% chance to increase your savings by 5 times and a 95% chance to increase your savings by 1/5.
Childbirth	EE	If the player is married, this event has a 1/3 chance of occurring.	When a birth event occurs, the number of children is automatically increased by one in the player's attributes.
Financial Crisis	EE	This event has a 10% chance of occurring.	In the event of a financial crisis, the return on investments is automatically increased by 0.05 times and the return on mutual funds is increased by 0.25 times.

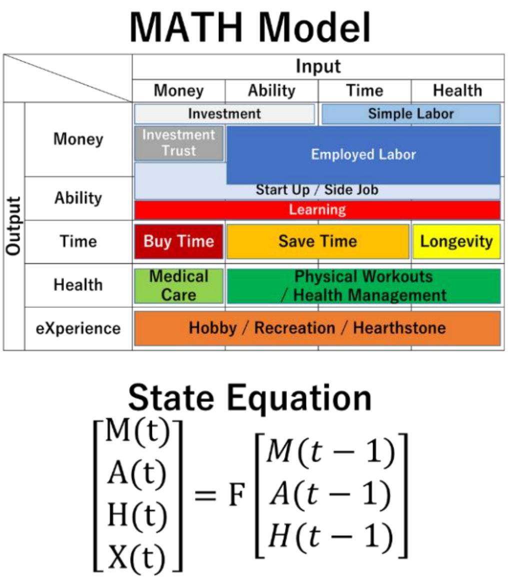

Fig.3 MATH model.

The MATH model represents the phenomenon that a player uses his or her resources (money, ability, time, and health) for various purposes in each turn, and gains (or loses) new resources as a result.

$$A_{(t)} = \begin{bmatrix} A_{Ework(t)} \\ A_{Invest(t)} \end{bmatrix} \quad (2)$$

$$t_{Ework\,(t)} + t_{Invest(t)} + t_{Learn\,(t)} \le \Delta t \quad \#(3)$$

$$m_{Learn\,(t)} m_{Invest\,(t)} + m_{Trust\,(t)} + m_{Learn\,(t)} \le M_{(t)} \quad \#(4)$$

$$\Delta A_{Ework\,(t)} = \left(c_{Ework} \times t_{Ework\,(t)} + c_{Learn} \times \sqrt{m_{Learn\,(t)}} \times t_{Learn\,(t)} \right) \times A_{Ework\,(t)} \quad (5)$$

$$\Delta A_{Invest\,(t)} = c_{Invest} \times \sqrt{t_{Invest\,(t)}} \times A_{Invest\,(t)} \quad \#(6)$$

$$\Delta M_{(t)} = \Delta m_{Ework\,(t)} + \Delta m_{Ework\,(t)} + \Delta m_{Invest\,(t)} + \Delta m_{Trust\,(t)} - m_{Invest\,(t)} - m_{Trust\,(t)} - m_{\,Learn\,(t)} \quad (7)$$

$$\Delta m_{Ework\,(t)} = W_{Ework} \times \left(1 + \frac{A_{Ework\,(t)} - A_{Ework\,(0)}}{A_{Ework\,(0)}} \right) \times t_{Ework\,(t)} \quad (8)$$

$$\Delta m_{Invest\,(t)} = \varepsilon\left(\mu_{Invest}, \sigma_{Invest\,(t)}\right) \times m_{Invest\,(t)} \quad \#(9)$$

$$\Delta m_{Trust(t)} = \varepsilon\left(\mu_{Trust}, \sigma_{Trust(t)}\right) \times m_{Trust\,(t)} \quad \#(10)$$

$$\sigma_{Invest\,(t)} = \sigma_{Invest\,(0)} \times \left(1 + \frac{A_{Invest\,(t)} - A_{Invest\,(0)}}{A_{Invest\,(0)}} \right) \quad \#(11)$$

$$\sigma_{Trust\,(t)} = \sigma_{Trust\,(0)} \quad \#(12)$$

3.1.2 The Steps to Play YLCG

First, when it is the player's turn, an environmental event (EE) occurs stochastically. When an EE occurs, the MATH model calculations are corrected for each type of EE. Next, players must consider the correspondence between ordinary events (OE) and extraordinary events (ExOE). An OE and ExOE is an event that a player is allowed to process once per turn, unconditionally. An ExOE is generated by the game system when the player meets certain conditions. The game system allows a player to process ExOE only once per turn (see Table 2 for details on each event). Third, a player is ordered to use his or her resources. Fourth, after the player completes the resource allocation task, the game system presents him or her with multiple play objectives and instructs the player to prioritize them. Finally, the player's state is updated according to the MATH model built into the game system, and the turn transitions.

3.1.3 Players' Decision-making about Using Resources

When playing YLCG, players must allocate their unique resources (i.e., time and money) to a total of six items. The items are Money and Time for Stock Investments, Time for Mutual Funds, Time for Work, and Money and Time for Learning. Each turn, the player allocates an amount to be spent on each item from his or her own savings and then allocates time to each item within a range of 0% to 100%.

3.1.4 Prioritizing Play Objectives

At the end of each turn, the game system presents the player with some pre-prepared play objectives and asks him or her to prioritize them. Table 3 shows the options of the play objectives registered in the game system. If the player decides that none of the play objectives presented by the system are appropriate, he or she may add new, original ones. If a change in the order of the play objectives is observed, it is assumed that the player has had a change in awareness. Figure 4 shows a screenshot of the player deciding the priority of the play objectives.

Table 3. Options of play objectives.

No.	Options of play objectives
A	Securing a stable source of income.
B	Acquiring knowledge and skills that are useful on the job.
C	Earning a high income.

3.1.5 Visualizing Players' Process

Each player can see the history of the values of savings, investment capacity, and work capacity on a line chart.

3.1.6 Parameters of YLCG

The values of the parameters used within the YLCG are listed in Table 4.

3.2 Game System

YLCG can be played on a PC running Windows 10. The game system was developed using Unity 2019.4.6f1. The programming language used in the system development with Unity is C#. Unity was selected because it is expected that players will be able to play serious games on non-

Fig. 4 Examples of the game screen of YLCG (Left: Standard screen, Right: The screen in prioritizing play objectives.). The left column shows the player's various status information (from top to bottom: amount of money saved, investment ability, working ability, occupation, marital status, number of children). On the left side of the screen, events that occur at each turn (from the top, job hunting, marriage hunting, childbirth, profit-telling, and financial crisis) are lined up. At the bottom center of the screen, there are six forms for players to input their decisions (money and time). The player enters numbers into the form using the keyboard.

Table 4. Constants used in the MATH model.
The player is given a parameter set that corresponds to the task he has chosen. Different jobs have different values of the parameters related to the reward of the job.

Job	c_{Ework}	c_{Learn}	c_{Invest}	c_{WEwork}	μ_{Invest}	μ_{Trust}	σ_{Invest}	σ_{Trust}
University Students	0.4	0.28	2.5E-6	1	1.3	1.04	1.3	0.104
Employee	0.7	0.28	2.5E-6	1	1.3	1.04	1.3	0.104
Investor	0.4	0.28	2.5E-6	1	1.3	1.04	1.3	0.104
Part-time jobber	0.4	0.28	2.5E-6	1	1.3	1.04	1.3	0.104

Table 5. History of the participant's decisions and priority of play objectives. (“#” indicates that the value of the distributed resources and the priority of the play objectives has changed from the previous turn.).

Turn No.	Decisions						Priority of play objectives		
	t_{Invest}	t_{Learn}	t_{Ework}	m_{Invest}	m_{Trust}	m_{Ework}	No. 1	No. 2	No. 3
1	0	0	0	0	0	0	A	B	C
2	0	30	10	0	0	1	A	B	C
3	5	30	20	0	2	1	A	B	C
4	10	10	70	0	3	3	A	B	C
5	10	10	70	0	4	3	A	B	C
6	10	10	70	0	2	1	A	B	C
7	10	10	70	0	2	0	A	B	C
8	10	5	70	0	2	0	A	B	C
9	15	5	70	0	$3^{\#}$	0	$B^{\#}$	$A^{\#}$	C
10	15	5	70	0	$4^{\#}$	0	B	$C^{\#}$	$A^{\#}$

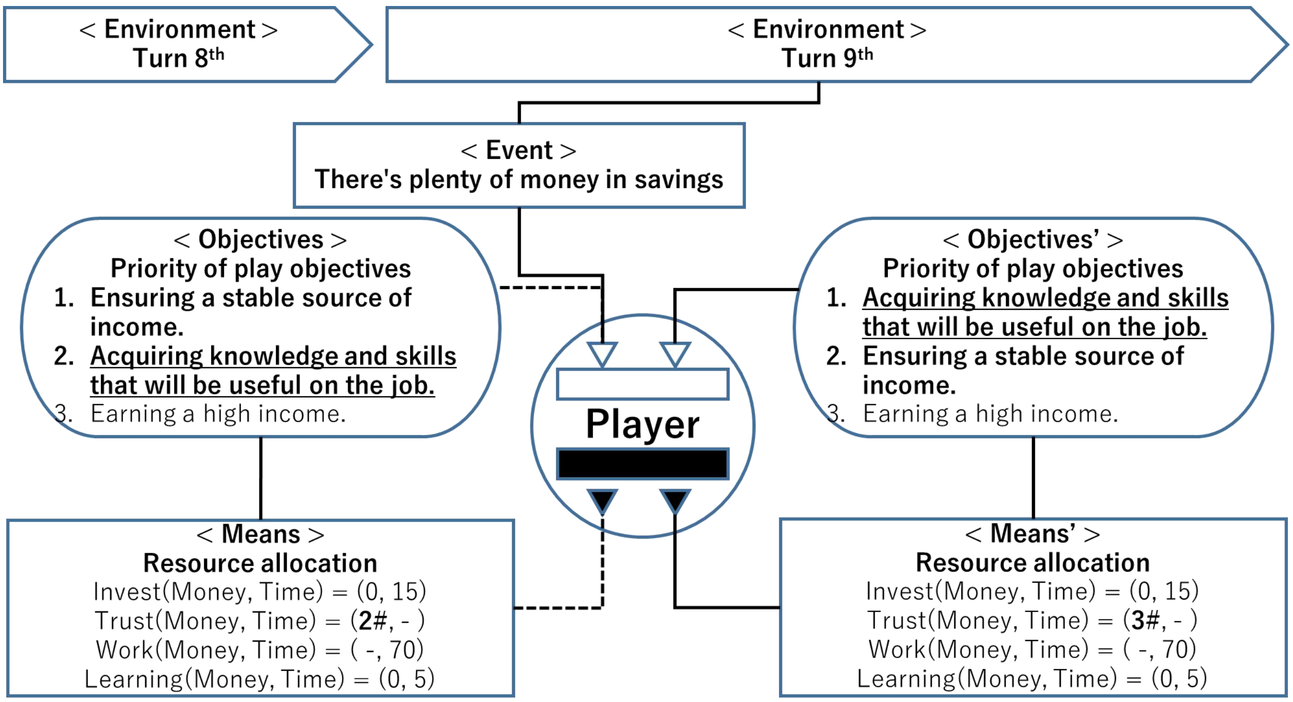

Fig. 5 The above figure was transcribed in the decision diagram from the YLCG playlog and interviews.
Prioritized play goals are described in the "objective" symbol and the results of resource allocation are described in the "means" symbol. From the debriefing interviews, the motivation for the change in decision-making is described in the "event" symbol.

The Question from the Experimenter to the Participant>

From turn 8 to 9, the "Acquiring knowledge and skills that will be useful on the job" moved to the number one priority. In our last interview, you said that in turn 9 you thought, "Now that I have some extra money in savings, I'm going to try some things. Honestly, if the importance of the play goal of "Acquiring knowledge and skills that will be useful on the job" becomes more important, I think we would invest time and money in learning and increasing our capabilities, but You did not ... Why is that?

The Answer from the Participant to the Experimenter>

I thought it was important to learn within the game. But I wasn't sure what benefit I would get from investing my time and money in learning in this game. I was hesitant to invest in learning because while I was playing the game, I didn't realize that there was a way to check what benefit I would get from investing in learning. Additionally, In general, I believe that learning computers is different from learning investments. In the former case, the more you study, the more results you get, but even if you spend a lot of time and money on your investment and study diligently, you won't necessarily succeed. If I thought it was useless to do it in the real world, I didn't want to do it in a game either.

Fig.6 The participant was interviewed on the next day of the experiment, and the answers are summarized by the experimenter as shown above.

Windows operating systems (such as Linux and Mac OS X) in the future.

3.3 Participants

The participant were one Japanese businesspersons.

3.4 Procedure

First, the participants were given an explanation of how to operate the game system and play YLCG. They were briefed on the player status information, the various types of events and how to handle them, the various resources and resource distribution, and how to prioritize play goals and play objectives. Then, the game was played for 10 turns per player. At the end, we asked each participant to explain why his or her changes in awareness occurred.

4. RESULTS

As the example virtual case, a participant's decisions and play goal priorities for each turn are listed in Table 5. The play logs shows that the order of priority of play objects, which did not change through Turn 8, changed on Turn 9. We considered this phenomenon as a change in awareness and created a decision-making diagram in the MDDM (see Fig. 5). The "objectives" symbol was described based on the priorities of the play objectives, and the "means" symbol was described based on the content of the resource allocation. The "event" symbol was based on the results of the interviews with the participants during the post-game debriefing.

On Turn 9, the player changed Play Objective B (Acquiring knowledge and skills that will be useful on the job) from second to first priority. In contrast, the content of the player's decisions regarding resource allocation changed only slightly in terms of the amount of investment trust. The participant was interviewed a second time in order to analyze and clarify the relationship between his change in awareness and judgment as described above (see Fig. 6.

The second interview revealed the following. The participant recognized that there was potential for some benefit in playing YLCG by developing his capacity to invest in learning. However, in playing the game, he did not discover the significance of using his resources for investment learning. Additionally, the participant recognized that taking a lot of time to learn about investing does not make sense in the real world. Therefore, the participant's attitudes about investment in the real world influenced his decisions about resource allocation in the game.

5. DISCUSSION

The first interviews with the player revealed that on Turn 9, he changed his perception of the amount of money he could afford to save. This corresponds to the content of the "event" symbol in the decision diagram. Then, the update of the player's recognition triggered a change in the priority of the play objectives. This corresponds to a change in the content of the "objective" symbol. A change in the content of the "means" symbol would reflect the player's perception that he was now able to do what he could have not done before because he had more money to save.

On the other hand, the second interview with the participant revealed that his change in awareness of the increasing importance of learning was not necessarily reflected in his decision-making during gaming. It seems to have been difficult for the players to understand the structure of the MATH model for developing his capability within the limited play time. In addition, the players' real-life experiences and common sense influenced their decisions for resource allocation. A similar phenomenon was reported by Nakano et al. in their study. Nakano et al. point out that the presence or absence of business experience related with business simulation can make a difference in the gaming experience [12]. This indicates that prior knowledge and beliefs about the problems represented in the game may affect players' perceptions and decisions during gaming.

As discussed, the experimental results showed that it may be possible to formally describe virtual cases in which a player changes his or her awareness during gaming with the MDDM. This suggests that using the MDDM to create a decision diagram of individual players' cognitions and judgments during the gaming process may help the players themselves, experimenters, and other observers to visually and easily understand the players' actions and the intentions behind them. This possibility will need to be tested in the future.

The scope of application of the MDDM would be not limited to a game played by a single player. We also consider that this work can be applied to games in which multiple players participate in repeated interactions. These gaming simulations are designed to allow players to refer to each other's decisions and mid-game performance (e.g., [14], [15], and [16]). In such a situation where players observe each other, one player may experiences insights and changes in his or her cognition and judgment because he or she observes other players' actions and results. A decision diagram described with the MDDM may be useful to understand virtual cases involving cognitive and judgmental changes that occur as a result of player-to-player interactions such as the above. To do this, we need to find evidence that the MDDM's "event" symbol is associated with changes in the decisions of other players.

6. CONCLUSION

In this study, we developed an original serious game, YLCG. Furthermore, we implemented a function in the game system to record the history of players' decisions and play objectives during the gaming process. Next, in the game experiment, we extracted data on the players' changes in awareness and created decision diagrams using the MDDM. As a result, we showed that it was possible to describe a case in which a player's change in awareness with the formal description language, the MDDM.

In the future, we will verify whether our system and the MDDM can formally describe virtual cases that include players' cognition and decisions detected using PS. Additionally, we focused on gaming in which a single player participated in the game in this study; however, in the future we plan to show that the use of MDDM can be effective in gaming in which multiple players participate.

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