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Framework for Building a Thinking Processes Analysis Support System: A Case Study of Belief Conflict Thinking Processes

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Abstract: While the metacognitive skills are the essence of human existence, it is difficult to train thinking skills because they essentially involve cognitive activities and implicit behaviors. This study proposes a framework as a methodology to approach the implicit and chaotic metacognitive processes. The developed framework provides a guidance to develop a system that interprets the users' thinking processes. As a case study, we develop an application based on the framework to capture the users' gazing behaviors and actions to modify externalized thoughts in the thinking processes about belief conflict. In addition, we propose an analysis support system for the thinking processes that allows analysts to develop a set of interpretation rules to grasp a part of the users' metacognitive monitoring and control processes. The study findings indicate the efficiency of the proposed gaze-thinking framework. This is shown through the provided examples of the set interpretation rules and the results of interpreted thinking processes.

Keywords: Metacognitive thinking processes, gaze behaviors, interpretation of thinking processes, thinking of dissolution of belief conflicts

1. Introduction

Metacognition or "thinking about thinking" is the process that corresponds to higher order thinking which involves active control over the cognitive processes. Such metacognitive skills play critical role in successful learning (Livingston, 1997). The ability to clearly express the inherent thoughts in a logical manner has received increasing attention as an essential skill in our social life (Griffin et al., 2012). However, it is challenging to train these thinking skills because they essentially involve cognitive activities and implicit behaviors that are unobservable by others. On the other hand, the proper teaching materials/methodologies for cultivating such skills have not been established yet.

Thinking aloud is a well-known form of an implicit metacognitive thinking process that requires participants to think aloud while solving a problem or performing a task (Jaspers et al, 2004). This method is traditionally applied mainly in psychological and educational research on analyzing cognitive processes. However, some of its limitations have been recognized by researchers in the field; for example, only the information that is actively processed in the working memory can be verbalized (Jääskeläinen, 2010). Additionally, the high cognitive load hinders verbalization by exhausting the available cognitive resources (Miyazaki & Miyazaki, 2004). The thinking-aloud task would also be challenging for the participants with poor self-reflection skills, as it tends to interrupt their natural thinking processes. Stimulated recall is another research method that uses video and audio recordings while the participant is performing a task. The recorded mediums are later reviewed and used as a prompt to get the participants reflections (Fox-Turnbull, 2009). However, this method involves asynchronous work that requires the participants (thinkers) to perform introspective work after they complete their tasks and they might add extra reasons/opinions afterwards.

In order to tackle these problems, many studies that utilize eye-tracking data (gaze data) have been conducted based on psychological perspectives. e.g., verbalization processes (Guan et al., 2006) and normal vs. mindless reading (Reichle et al., 2010). Furthermore, several studies in the research field of intelligent tutoring systems have focused on the gaze features as means to support learning. In general, they apply supervised machine learning techniques to analyze and predict not only the participants' learning level (Bondareva et al., 2013) but also their internal affective states such as boredom vs. curiosity (Jaques et al., 2014), and occurrences of confusion (Lallé et al., 2016). However, to the best of our knowledge, there is no established methodology to capture "metacognitive thinking processes" based on the gaze behavior using the eye-movement.

In order to create the common understanding and steadily accumulate the findings of the invisible, shapeless, and complex structure of the thinking processes, the researchers essentially need to reach common ground on "how to capture what types of thinking processes from what kind of gaze behaviors (eye-movement patterns)". Certainly, it is impossible to use gaze behavior to capture all metacognitive thinking processes in our daily life. This research addresses the difficult but crucial challenge and proposes one of the powerful methodologies to test the hypothesis that a part of the meta-level thinking processes could be captured from the "gaze behaviors" and actions to modify externalized thoughts ("thinking control actions"). The study is based on the assumption that an application allows a user to externalize his or her base-level thinking into a designed interface component.

In this study, we propose a novel framework to develop a system that interprets users' thinking processes according to their gaze behaviors and thinking control actions. Based on the framework, we introduce a thinking processes analysis support system called thinking processes analyzer which focuses on the thinking processes in dissolution of belief conflicts as a case study. In addition, we demonstrate the interpretation results of data gathered in the context of the knowledge building method workshop for nurses. In Section 2 we discuss the gaze-thinking interpretation framework, and then in Section 3, we explain the details of interpretation rules. Based on the framework, we introduce an implementation example of a thinking processes analyzer in Section 4, and discuss the interpretation results of thinking processes in Section 5.

2. Gaze-Thinking Interpretation Framework

Figure 1 shows a framework for capturing thinking processes from gaze behaviors and thinking control actions originally proposed by Hayashi et al. (2016a). It is known that the thinking processes cannot be observed from the external world. The thinking processes include base-level thinking (Fig. 1(i)) and meta-level thinking (Fig. 1(ii)), where the meta-level thinking monitors (metacognitive monitoring) and controls (metacognitive control) the base-level thinking processes (Nelson, 1990; Hacker et al., 2009). The internal self-conversation about the dissolution of belief conflicts (see Section 4.1) involves thinking about *fact*, *conflict*, *hypothesis*, *decision*, *result*, etc., each of which is related to belief conflict that corresponds to base-level thinking activities; for example, "Eri was bullied because she changed her attitude when she interacted with boys" (*fact*), and "I was bullied because I got along well with Eri" (*result*). Meta-level thinking targets the base-level thinking; for instance, "comparing certain fact with the reason" and "proving a hypothesis," are components of metacognitive monitoring while, "modifying the conflict" is an aspect of metacognitive control.

Gaze behaviors are observable activities (Fig. 1(iii)) that can be captured by eye-tracker devices. In reading, the eye moves continuously along a target, running through short rapid movements (saccades) and short stops (fixations) (Barlow, 1952). Meanwhile we need to carefully note the duration times of fixations, we can track gaze behavior such as "gazing at certain object at #t1" and "changing gaze target object at #t3" based on the series of saccades and targets of fixations.

Within this context, we introduce the concept of representation objects, which allow thinkers to externalize their output of base-level thinking activity (representation objects for externalization (Fig. 1(iv)). The objects include areas, text-boxes, buttons, and select-boxes, at the software application level. These objects are observable; hence, we can capture the processes of eye movements and thinking control actions to the base-level thinking representation objects.

In this research, we focus on the isomorphism between the cycle of metacognitive monitoring and control in meta- and base-level thinking in one's head on one side and the cycle of gaze behaviors and thinking control actions to the representation objects on the other side. Hence, if an application allows a user to externalize his or her output of base-level thinking activity onto the appropriate representation objects (Fig. 1(v)), gaze behaviors and thinking control actions toward the objects indicate a portion of his or her meta-level thinking. As the externalized base-level thought is a portion of base-level thinking

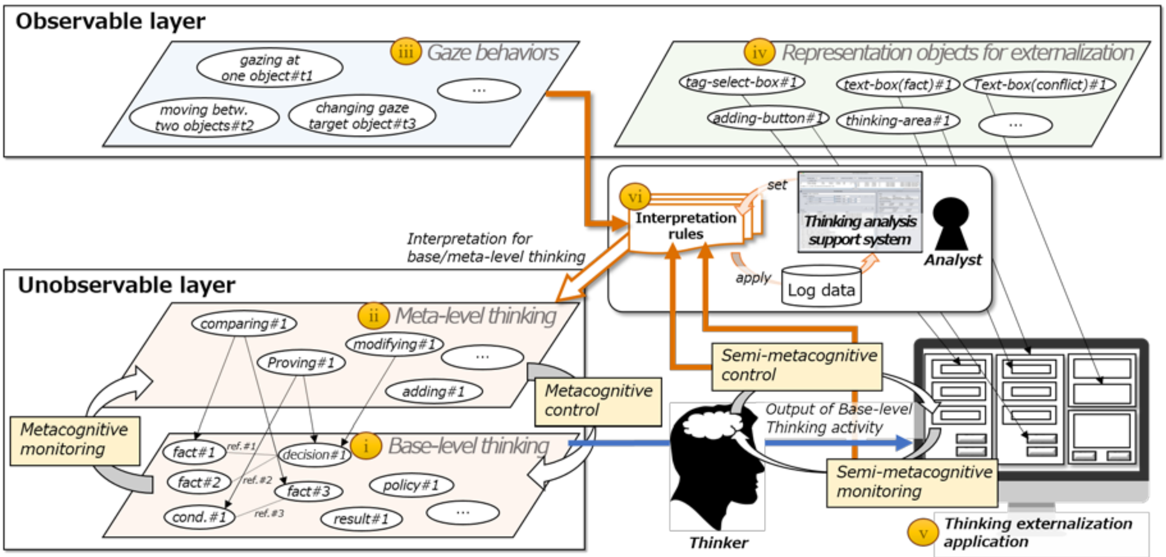

Figure 1. Gaze-thinking Interpretation Framework.

and may be added to or modified through the externalization of internal self-conversation processes, we regard the latter cycle as *semi-metacognitive monitoring and control*.

In meta-level thinking processes, the monitoring and control of base-level thinking differ depending on the thinking task. For example, when one thinks of the case externalized by another (e.g., correction strategies), he/she needs to recognize, understand, and modify the other's case. In order to deal with the aspect on the semi-metacognitive level, we introduce "interpretation rules" (Fig. 1(vi)) that express the possible base-/meta-level thinking by gaze behaviors and/or thinking control actions according to the thinking strategies. However, as several meanings can be interpreted from some gaze behaviors representing not only meta-level but also base-level thinking, we consider that the interpretation rules do not determine a unique interpretation for each gaze behavior and thinking control actions.

The interpretation rules in the proposed framework are set by analysts using a thinking processes analysis support system. Thus, we assume a portion of the thinking processes in the metacognitive monitoring and control can be captured by developing a thinking externalizing application with an interface that consists of representation objects each of which is indexed by the base-level thinking of the target task, and by setting interpretation rules for the captured gazing behaviors and thinking control actions of thinkers.

3. Representation Format of Interpretation Rules

Interpretation rules play an important role in the gaze-thinking interpretation framework discussed in the previous section, as they tend to highlight the aspects of the implicit metacognitive thinking processes. The explicitly defined interpretation rules allowed the analysts to understand, share, and compare the interpretation results on a common ground. In this section, we explain the representation format of the interpretation rules. Figure 2 shows a schematic that illustrates the application of interpretation rules to raw data, which includes both the thinker's gazing behavioral data to representation objects and thinking control action data measured by a thinking externalization application. This process is roughly divided into the following two steps:

Preprocessing step: This process unites the measured raw data with noise rejection. First, very short time gazing data are eliminated based on the defined fixation time. Then, similar raw data are checked to determine whether the adjoining data can be unified as gazing behaviors and thinking control actions or not based on the defined time interval.

Thinking-task-structure-dependent step: This step applies the interpretation rules to each data interval unified in the previous step. In order to deduce the metacognitive-level thinking processes and obtain various interpretations, we employ forward-processing interpretation rules. In this study, we define two

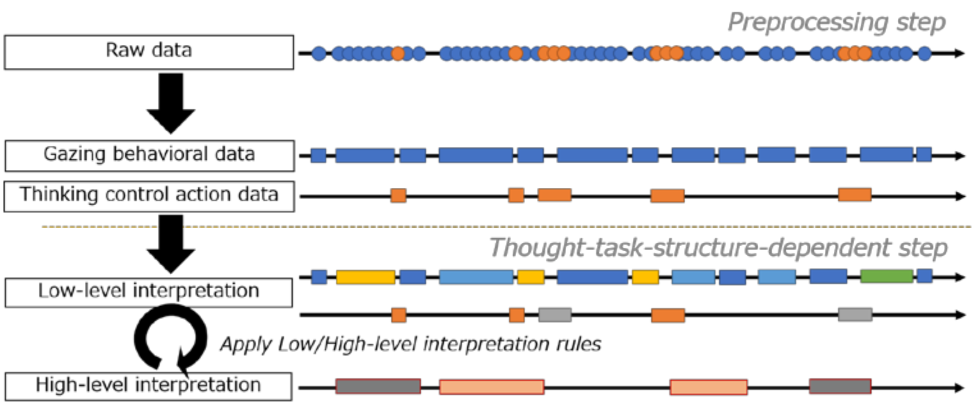

Figure 2. Schematic of Interpretation Rule Application.

types of interpretation rules: *low-level interpretation rules,* which provide primitive interpretations, and *high-level interpretation rules,* which infer the metacognitive-thinking/control based on the low-level interpretations.

3.1 Low-level Interpretation Rules

In order to provide primitive interpretation *PI_L* of the measured row data, the low-level interpretation rule lr_x is represented by the following expression 1:

$$lr_x(Act(tro_i), PI\_L) \qquad (1)$$

where *Act* (tro_i) represents gazing behaviors and thinking control actions processed in the preprocessing step and this function provides certain low-level interpretation of the corresponding interval data. Each of the actions take a certain thinking representation object tro_i as an argument. *GazeAt* (tro_i) is prepared for gazing behaviors, and *Keypress* (tro_i), *Delete* (tro_i), *Press* (tro_i), etc. are used as the elements of thinking control actions.

3.2 High-level Interpretation Rules

The high-level interpretation rules raise the low-level interpretations to the metacognitive monitoring/control levels. A high-level interpretation rule is represented by the following expression 2:

$$hr_x(Cond, HI\_L) \qquad (2)$$

where hr_x represents the function that detects the matching intervals of the condition *Cond*, and gives a high-level interpretation *HI_L* of the intervals. *Cond* consists of one or more sets of conditional function(s). Table 1 summarizes the conditional functions and their explanations that are used to set *Cond* based on the possible relations between two intervals (Allen, 1983) to be utilized for time series analysis. As shown in Table 1, arguments L_1 and L_2 represent the results of data intervals deduced by the low-/high-level interpretation rules. *All* (L_1) represents all data of L_1. *BEFORE* (L_1, L_2, t) indicates the interval between the starting time of L_1 and finishing time of L_2 if the interval of L_1 is before that of L_2 within t ms. *OVERLAPS* (L_1, L_2) detects the overlapped intervals between L_1 and L_2, and *DURING* (L_1, L_2) extracts the intervals L_1 if L_2 is also observed simultaneously.

Note that the appropriateness of the detected interpretations depends on the analysts, since the thinking itself cannot be observed from the external world. Hence, we cannot obtain the genuinely correct answers of one's base-/meta-level thinking processes. Within this context, the analysts can explicitly set their interpretation rules that express what sort of metacognitive activities can be captured by the types of gazing behaviors

Table 1: Conditional Functions for Time Series Analysis.

Function	Interpretation
ALL (L_1)	*all* L_1
BEFORE (L_1, L_2, t)	L_1 *takes place before* L_2 *within* t *ms.*
OVERLAPS (L_1, L_2)	L_1 *overlaps with* L_2
DURING (L_1, L_2)	L_1 *during* L_2

toward the kind of base-level thinking representation objects and thinking control actions. Accurate examples of applying low-level and high-level interpretation rules are described in Section 5.

4. Example of a Thinking Processes Analysis Support System

In this section, we explain the analysis support system developed based on the gaze-thinking interpretation framework. First, in Section 4.1, we clarify the target thinking processes and summarize the thinking training environment developed by Chen et al. (2011) that forms the basis of our system. In Section 4.2, we introduce an application that can capture the sequence of the user's gazing behavioral data to representation objects and thinking control actions during his/her meta-level thinking processes. Then, in Section 4.3, we introduce an analysis support system of thinking processes which allows analysts to set their interpretation rules as discussed in Section 3 and confirm the results of metacognitive monitoring/control levels' thinking processes through the visualized timeline window.

4.1 Target Thinking Processes

Ito (2009) reviewed the effect of the thought verbalization as a learning strategy and proposed a model on verbalization to meet the learning goals. The model describes the sequence of three phases: *description* (cyclic state of verbalizing one's thought based on personal experiences), *cognitive-conflict* (state of facing the conflict through the verbalization of one's thought and interaction with others), and *knowledge-building* (cyclic state to resolve the conflict states). Throughout these phases, if the learners actively and logically think about the problem they face, their thinking processes become clear and they tend to develop more sophisticated thinking skills.

Based on the verbalization model, Chen et al. (2011) proposed a thinking training environment called Sizhi to improve the learners' thinking about thinking skills. Sizhi targets the thinking processes about belief conflict, which is defined as a fundamental confrontation caused by the situations individuals face when their beliefs are questioned (Kyougoku, 2011; Kyougoku et al., 2015). The interface is designed to logically verbalize one's own thinking and that of others by reflecting on one's own thinking process in a logical manner, in order to find meaningful conflicts.

Sizhi has been continuously used in previous research to conduct educational programs for first-year bachelor students many of whom are beginners to meta-thinking (Seta et al., 2013), in addition to hospital nurses who suffer from belief conflict in the medical field (Kanou et al., 2013). The nursing education program, not only involved nurses externalize their own belief conflict, but also offered skill training (by an expert on meta-thinking) who corrects and reviews the outcome of the cases externalized by nurses. The reported results revealed that the Sizhi can effectively cultivate the metacognitive skills of the learners.

On the other hand, as the quality of the externalized/corrected thought (i.e. collective statements and their logic) varies depending on the learners/correctors, the thinking processes leading to externalization of thought is still implicit. If we could grasp a part of one's implicit thinking processes in metacognitive monitoring and control level, we would further advance the learning analytics of certain thinking tasks, e.g., the difference between the thinking externalization/correction processes of learners/correctors and whether they are deeply finding meaningful conflicts or not. In addition, if the processes can be modeled in human-understandable levels, intellectual support can be provided to foster the thinking about thinking skills.

4.2 Eye-Sizhi

Based on the proposed framework, we have proposed an Eye-Sizhi application, as a case study to capture the user's gaze behaviors and thinking control actions toward representation objects of base-level thinking (Hayashi et al., 2016b). Figure 3 represents the interface of the Eye-Sizhi, which follows the design principle of Sizhi. The application is used as instructional equipment that is premised to be utilized in the context of thinking training. The interface consists of four thinking areas: '*A's-thinking*' that denotes one's own thinking, '*B's-thinking*' denotes opponent's thinking, '*conflict*' denotes the difference between A's- and B's-thinking, and '*knowledge-building*' denotes dissolving the belief conflict.

In the application, the user can add/delete their statements using the statement edit buttons and input the statement text into the textbox by specifically selecting the pre-defined Sizhi-tags such as *fact*, *hypothesize*, *decision*, *assumption*, and *policy* to logically verbalize his or her output of base-level thinking activity. The user can also associate other statements as 'references' to express the basis for adding the statement. In order to help the learner gain deep insight into the belief conflicts in the conflict areas, the user is allowed to select only one policy statement from each of the statements externalized in the A's- and B's-thinking areas, and express the belief conflict in the conflict textbox.

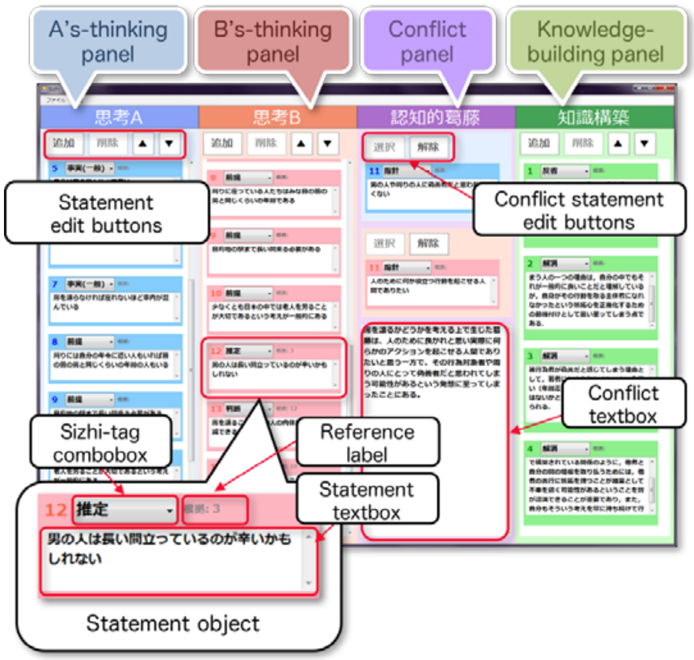

Figure 3. Interface of Eye-Sizhi.

In order to capture the users' gazing target data, Eye-Sizhi is implemented using a screen-based eye-tracker, which distinguishes and records the thinking area in the interface at which a user is looking by setting the area of interest (AOI) regions of the representation objects. The application recognizes the four thinking areas (*A's-thinking*, *B's-thinking*, *conflict*, and *knowledge-building*), each statement area itself and the included components (Sizhi-tag combo-box, reference label, and textbox), the conflict textbox area, and the edit buttons. The application records the user's activity on millisecond time scale, which includes the user's gaze events and thinking control actions (i.e. keyboard and mouse click events).

4.3 Thinking Processes Analyzer

We developed a system called thinking processes analyzer which accepts the Eye-Sizhi records as an input file and allows the analysts to set their low-/high-level interpretation rules. Figure 4 illustrates the interface of the analyzer. The interface mainly consists of the following three areas and the timeline visualization window for the results of set interpretations.

(1) Low-level interpretation processing area: In this area, the analysts can set three types of time intervals on the millisecond time scale: (i) the duration times of fixations, (ii) time interval for unifying the similar adjoining data as gazing behaviors and externalization actions (gazing at same thinking/statement areas, typing out actions), (iii) time interval for the instantly recorded actions such as clicking buttons in order to be assessed and visualized in the visualization window. After the settings have been established, the analyzer reads the raw data of imputing the Eye-Sizhi log file and extracts each gazing behavioral and thinking control action data. In addition, it annotates the preset low-level interpretation rules (e.g., "*Understanding_Thinking.all*" to the intervals of gazing at each thinking area, "*Modifying_Statements.all*" to the intervals of typing out actions in statements, etc. in case of correction strategy). These processes correspond to the processing of row data into low-level data interpretation, as shown in in Fig. 2.

The results of the low-level interpretation rules are displayed in the visualization window where each of the interpreted intervals is allocated in a timeline style. The timelines can be accessed by dragging the operation, and the analysts can check the detail contents of each interval by hovering a mouse cursor over the interval. The lower right part of Fig. 4 illustrates the situation between section *1: 00* to *2: 00* during the session (about 42 minutes) that can be viewed by zooming in and hovering the mouse cursor over a certain gazing interval of a thinking statement. In this case, the statement information (ID: *36*, Sizhi-tag: *結果* (*result*), basis: statement whose ID is *35*) and the gazing time interval are shown on the tooltip.

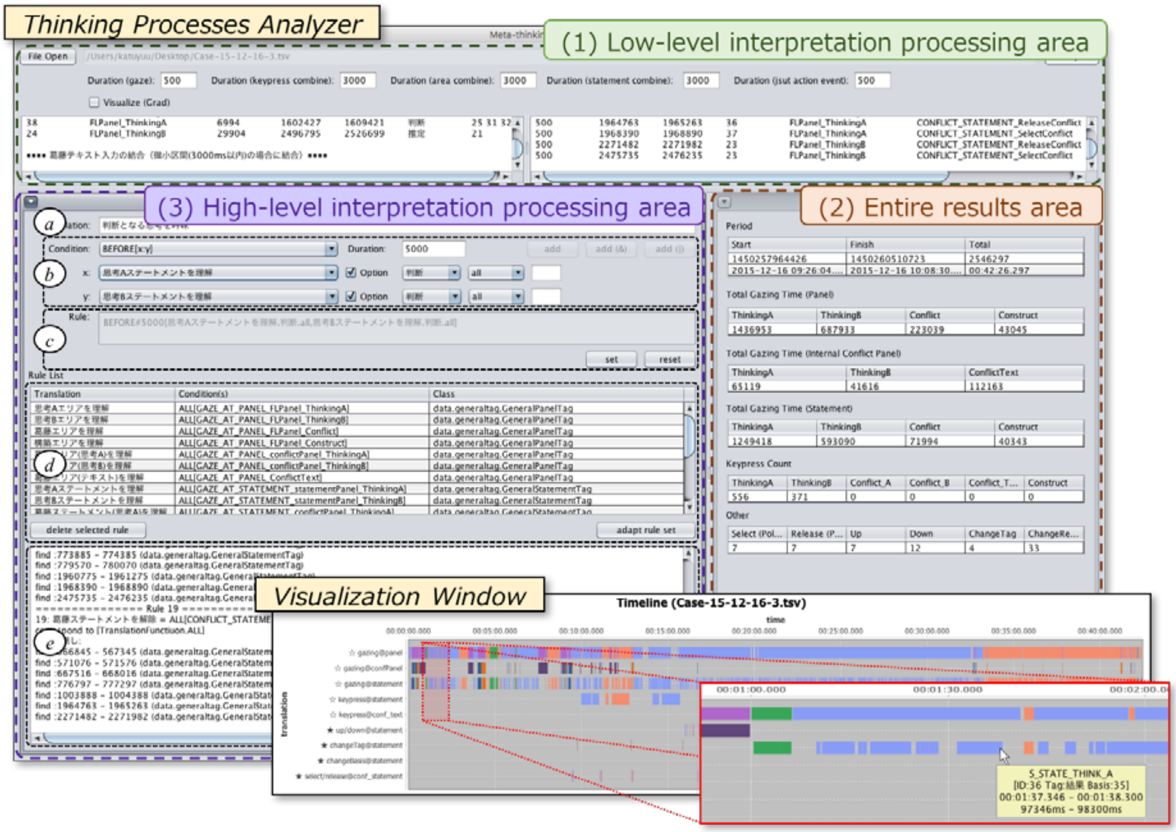

Figure 4. Interface of Thinking Processes Analyzer.

(2) Entire results area: This area displays the generalized results of the Sizhi input record file in which the analysts can confirm the total time of how a learner/corrector gazes at each thinking panel/statement; how many times he/she inputs the text, adds/deletes statements, changes Sizhi-tags; etc., throughout the session.

(3) High-level interpretation processing area: This area allows the analysts to set their high-level interpretation rules to the results of Process (1), and analyze the results of set rules obtained from the timeline window. This process corresponds to the cycle of applying high-level interpretation rules shown in Fig. 2.

A high-level interpretation tag-name for the new rule is set in the textbox area in Fig. 4(*a*). Functions of the condition part and the argument(s), which corresponds to the result of low-level interpretation rules, can be selected from the combo-boxes in Fig. 4(*b*). In order to provide detailed specifications of the base-level thinking of statements, the analysts can set a particular type of Sizhi-tag in case the argument class is a statement. If necessary, they also specify the type of Sizhi-tag of the basis statements and statement ID as optional settings for Sizhi. The area shown in Fig. 4(*c*) allows the analysts to check and add the set interpretation rules. The added interpretation rules are listed in the rule list table (Fig. 4(*d*)), which includes the low-level interpretation rules obtained in Process (1). The tag-name of each interpretation rule appears in combo-box items, as shown in Fig. 4(*b*). After setting a series of high-level interpretation rules, the corresponding intervals of the rules are extracted in the area shown in Fig. 4(*e*) that can be visualized in the timeline visualization window (Fig. 6) apart from the window obtained in Process (1).

As explained above, the raw data about belief conflicts are manipulated by the developed thinking processes analyzer using Processes (1) to (3). This allows the analysts to develop their interpretation rules regarding the raw data measured during the thinking processes. They can visually capture the results through the visualization window and add further high-level interpretation rules in order to grasp a part of the learners/correctors metacognitive monitoring and control processes.

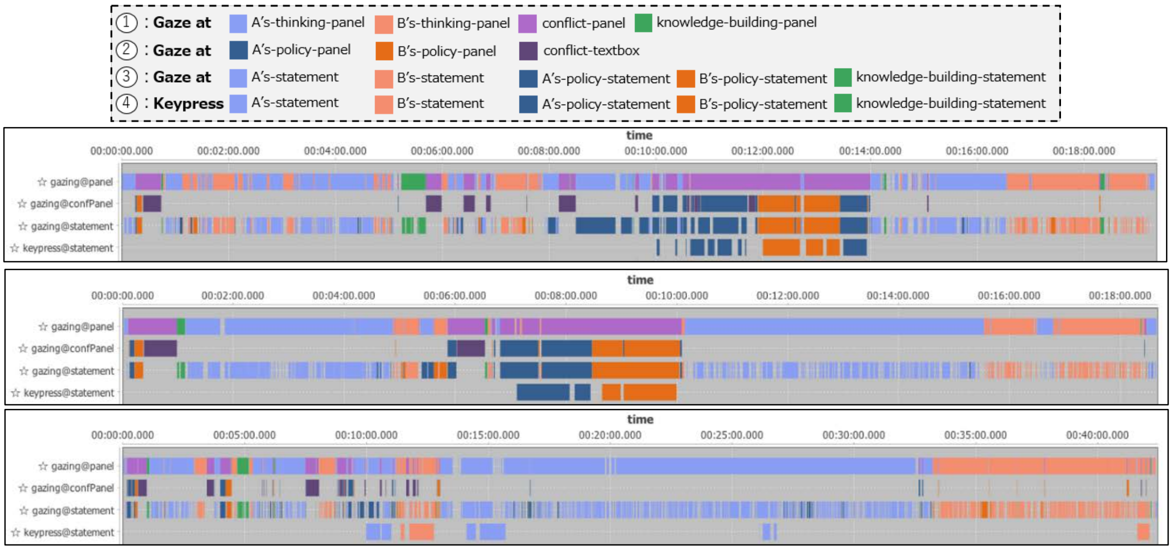

Figure 5. Examples of Applied Low-level Interpretation Rules.

5. Example of Interpreted Thinking Processes

5.1 Data Collection

In order to examine the efficiency of the proposed gaze-thinking framework in interpreting the metacognitive thinking processes, we collected the correction processes data using Eye-Sizhi described in Section 4.2. In the correction situation, the correctors are expected start with understanding the externalized thought and they mainly focus on the metacognitive activities under the objective of the correction. Thus, we expect a part of the metacognitive monitoring and control processes is reflected in gaze behaviors and thinking control actions that take the form of typing out actions as semi-metacognitive monitoring and control.

The knowledge building method workshop for nurses (Kanou et al., 2013) is selected as a case study. Two correctors, who have some previous experience correcting hospital nurses' cases, were asked to correct the cases of the nurses about their experiences of belief conflict in the medical field using Eye-Sizhi. Eye-Sizhi is continuously used in the knowledge building workshop since 2015. Currently, 26 correction processes datasets exist performed by two correctors for 14 nurses' cases. The correction task was continued until the correctors were fully satisfied. The guiding principle of the correction was to check whether the externalized A's- and B's-thinking are logically correct and reveal meaningful belief conflicts.

5.2 Results and Discussion

Figure 5 illustrates some examples of visualization windows showing the applied low-level interpretation rules to recorded correction processes of three cases. The applied interpretation rules are listed in Table 2. The timeline shows the intervals of ①: gazing at types of thinking panels (lr_1), ②: gazing at the contents in conflict area (lr_2: areas of policy statement of A's-/B's-thinking and conflict textbox), ③: gazing at statements (lr_3), ④: typing out statement actions (lr_4), as shown in Fig. 5. The visualized results of ① and ② indicate that the sequences of gazing are not always chaotic; instead, they have a certain time duration to understand and correct the nurses' externalized thought. This explains how to interpret the succession of correctors' monitoring and control

Table 2: Examples of Low-level Interpretation Rules.

Low-level Interpretation
lr_1 (GazeAt(Thinking_area[all]), "Understanding_Thinking.all")
lr_2 (GazeAt(Conflict_area[all]), "Understanding_Conflict.all")
lr_3 (GazeAt(Statements[all]), "Understanding_Statements.all")
lr_4 (Keypress(Statements[all]), "Modifying_Statements.all")

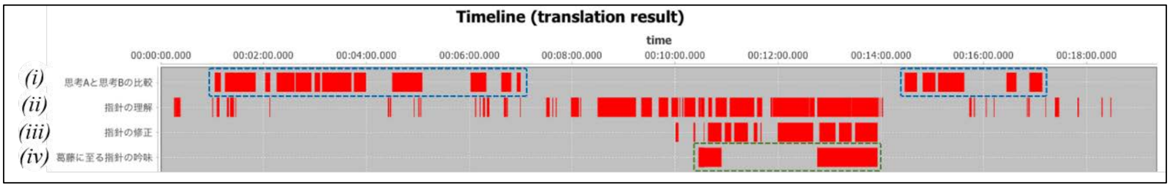

Figure 6. Examples of Applied High-level Interpretation Rules.

processes. In addition, we also found these three cases started by focusing on understanding the contents in conflict area (purple colored intervals).

Figure 6 shows examples of adapting high-level interpretation rules. In this case, a set of rules listed in Table 3 is applied to Case 1 shown in Fig. 5. Figure 6(i) is the timeline that corresponds to the intervals in which the corrector was comparing A's-thinking with B's-thinking by using high-level interpretation rule hr_1, whose condition includes low-level interpretation rule lr_1. Based on this timeline, we can grasp the corrector's metacognitive monitoring processes of comparing one's thinking with that of another in the first half and last of the session (the blue dotted-line area in Fig. 6(i)). The timelines visualized in Fig. 6(ii) and (iii) are derived from high-level interpretation rules hr_2 and hr_3. These rules aim to clarify the corrector's understanding processes intervals (hr_2) and modify the actions (hr_3) related to the policy statements that form the root of belief conflict. The results of these rules set the high-level interpretation rule hr_4 to capture the intervals of metacognitive thinking processes. These intervals involve corrector deliberation about the policy statement correction, as the policy statement intervals are understood before the statements are modified (the green dotted-line area in Fig. 6(iv)).

Table 3: Examples of High-level Interpretation Rules.

High-level Interpretation
hr₁ ((BEFORE (lr₁.ThinkingA, lr₁.ThinkingB, 5000) OR BEFORE (lr₁.ThinkingB, lr₁.ThinkingA, 5000)), "Comparing_ThinkingA_and_ThinkingB")
hr₂ (ALL (lr₃.policy), "Understanding_Statements.policy.all")
hr₃ (ALL (lr₄.policy), "Modifying_Policy.all")
hr₄ (BEFORE (hr₂, hr₃, 5000), "Deliberating_Correction_of_Policy_Statements")

The above discussion demonstrates the results of applying high-level interpretation rules to uncover a portion of the thinking processes on the metacognitive thinking level in the context of the thinking task about belief conflict. However, it is difficult to determine whether the result of interpretations is truly correct. Hence, in order to steadily approach the intangible human thinking processes, we believe it is necessary to share the knowledge about what forms of meta-level thinking processes are to be captured by what types of gaze behaviors toward what kind of base-level thinking representation objects on the basis of our proposed framework.

6. Conclusion

In this study, we proposed a gaze-thinking interpretation framework as a promising methodology to capture a part of the learners' metacognitive thinking processes. The fundamental idea of the framework is based on the isomorphism between the cycle of metacognitive monitoring and control in the thinking processes in one's head and the cycle of gaze behaviors and thinking control actions to the base-level thinking representation objects.

As a practical application of the framework, we developed a thinking processes analyzer that allows analysts to analyze the belief conflict thinking processes by setting low-/high-level interpretation rules. To examine the efficiency of the proposed gaze-thinking framework, we demonstrated the results of applying interpretation rules using limited study sample. The future research will provide a more detailed analysis of the data collected from the knowledge building method workshop for nurses to clarify the difference between the thinking correction processes adopted by correctors based on the developed analyzer.

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