Towards investigating the validity of measurement of self-regulated learning based on trace data

Supplementary Materials

Appendix 1. Theoretical framework and think aloud coding scheme

Main Category 1: Metacognition			
Activities that involve regulation of cognitive activities in the learning process.			
Subcategories	**Code**	**Definition**	**Think aloud examples**
Orientation	MC.O	Orientation on the learning-related activities; on prior knowledge; on the task and feeling about the task. Reading of general instruction and rubric.	*"Four things are important in the assignment"*
Planning	MC.P	Planning of the learning process by arranging activities and determining strategies. Proceeding to the next topic.	*"I will explain these topics in my essay"*
Evaluation	MC.E	Evaluation of the learning process; checking of content-wise correctness of learning activities. Saying that one owns work is correct.	*"I doubt whether Artificial Intelligence will have such an impact"*
Monitoring	MC.M	Monitoring and checking the learning process; checking of progress according to instruction or plan.	*"This information does not appear to be relevant"*
Main Category 2: Low_Cognition			
Lower level activities concerning information and processing aspects of the task.			
Subcategories	**Code**	**Definition**	**Think aloud examples**
First-reading	LC.F	Reading information from the texts and superficial describing of pictorial representations.	*"Artificial Intelligence is the ability of …" or read out loud the content in figures "Zone of proximal development is when tasks achievable with help"*
Re-reading	LC.R	Rereading of information in the text or figures.	*"Artificial Intelligence is the ability of … (re-read out aloud again)"*
Main Category 3: High_Cognition			
Higher level activities that elaborate and organise information in the learning task.			
Subcategories	**Code**	**Definition**	**Think aloud examples**
Elaboration/ Organisation	HC.E/O	Elaborate by connecting content-related comments and concepts; reasoning and association. Organising of content by creating an overview; write down information point by point; summarizing; adding information generated by oneself; and editing information by rephrasing or integrating information with prior knowledge.	*"This means that both Artificial Intelligence and humans can learn…" "To summarise, … are important for future education"*

Main Category 4: Other			
Other activities that mainly detectable in think aloud data.			
Subcategories	**Code**	**Definition**	**Think aloud examples**
Motivation	MOT	Activities that indicate positive or negative appraisal of the task, the learner itself, or the situation.	*"I do not like writing essays."*
Procedural	PRO	Activities that concern the procedure of learning and the use of the learning environment.	*"Should I start the task now?"*

Appendix 2. The action library and the labelling process

Action Labels	Action Descriptions
GENERAL_INSTRUCTION	Learners read or re-read general instructions and learning goals
RUBRIC	Learners read or re-read the rubric for essay writing
RELEVANT_READING	Learners read and learn learning content for the first time
RELEVANT_RE-READING	Learners re-read and review for learning content which they have read before
IRRELEVANT_READING	Learners read the pages which are not relevant to the learning goal or writing task
IRRELEVANT_RE-READING	Learners re-read the pages which are not relevant to the Learning goal or writing task
NAVIGATION	Learners navigate through pages or scroll at catalog zone
WRITE_ESSAY	Learners write, edit or stay in the essay zone
COPY_PASTE	Learners copy and paste some content from reading materials into the essay or notes
NOTE_EDITING	Learners create, delete, edit or label the notes
NOTE_READING	Learners click to open and read or re-read the notes
HIGHLIGHT_EDITING	Learners create, delete or edit the highlights
HIGHLIGHT_READING	Learners click to open and read or re-read the highlights
HIGHLIGHT_LABELLING	Learners create tags for highlights
TIMER	Learners click to check timer during learning
SEARCH_CONTENT	Learners use search tool on the left to search learning contents
SEARCH_HIGHLIGHT_NOTE	Learners use search tool on the right to search notes or highlights
PLANNER	Learners click to open planner tool, and create or edit their plans
OTHER	Learners pause the learning session or other unlabelled data
OFF_TASK	Learners do not have any action for relatively long time (5 minutes in this study)

Detailed Labelling Process:

GENERAL_INSTRUCTION

Logging

The first row of the file should be labelled as general instruction, because that is the default landing page.

Page visits to the general instruction are logged as “nav_instruct_G” and sometimes there is an additional line that precedes this one: “Navigate to: instruction”.

Duration

Only the row with the click to navigate is labelled.

Action

1. Label the first row of the log as GENERAL_INSTRUCTION.
2. Label logs “nav_instruct_G” and “Navigate to: instruction” as GENERAL_INSTRUCTION.

RUBRIC

Logging

Page visits to the rubric are logged as “nav_instruct_R” and sometimes there is an additional line that precedes this one: “Navigate to: rubric”.

Duration

Only the row with the click to navigate is labelled.

Action

1. Label logs “nav_instruct_R” and “Navigate to: rubric” as RUBRIC.

RELEVANT_READING

Logging

Page visits to a content page are logged as “nav_” followed by “content” when clicking in the menu, by “note” when clicking on a note, by “highlight” when clicking on a highlight, or by “search” when clicking on a search result. The final part of the log indicates the page that was navigated to, such as “1.1”. There is one exception, which is “nav_search_cancel_1.1” and this should not be labelled.

Duration

Only the row with the click to navigate is labelled. As no end is defined, reading ends when a new action occurs. There are multiple instances where the label automatically returns to reading of the page that was open, see for example HIGHLIGHT_CREATING.

Action

1. Label all page visits of more than 6 seconds as RELEVANT_READING.
2. Label scrolling the content as reading (either RELEVANT_READING or one of the other reading actions, including navigation, and instruction pages).

IRRELEVANT_READING

Logging

Pages: 1.2, 1.4, 2.3, 3.2, and 3.5, have content that is not necessarily relevant for the assignment. These are logged just as all page visits.

Duration

Only the row with the click to navigate is labelled.

Action

1. Label all RELEVANT_READING (page visits of more than 6 seconds) as IRRELEVANT_READING when it was to page 1.2, 1.4, 2.3, 3.2, or 3.5.

RELEVANT_RE-READING

Logging

See RELEVANT_READING.

Duration

Only the row with the click to navigate is labelled.

Action

1. Label all page visits to relevant pages of more than 6 seconds to pages that were already opened at least once for 6 seconds as RELEVANT_RE-READING.

IRRELEVANT_READING

Logging

See IRRELEVANT_READING.

Duration

Only the row with the click to navigate is labelled.

Action

1. Label all page visits to irrelevant pages of more than 6 seconds to pages that were already opened at least once for 6 seconds as IRRELEVANT_RE-READING.

NAVIGATION

Logging

See reading. Short page visits are recorded as NAVIGATION. Note that instruction pages are a special case; these are not labelled as READING or NAVIGATION.
In addition, interactions with the menu are logged as “menu_1”, which means that there was a click on topic 1 on the menu to view all subpages.

Duration

See reading.

Action

1. Label all page visits of less than 6 seconds as NAVIGATION.
2. Label all interactions with the menu as NAVIGATION.

WRITE_ESSAY

Logging

A click in the essay is logged as “type_location2”, but not always.
Clicks that have coordinates in the essay are logged as “screen X: 1681, Y coords: 109”.
Scrolling in the essay results in the log “scroll_essay_141”, where 141 indicates the amount of scrolling in pixels.
Changing the essay size results in a log “essay_size_1”, where 1 is small, 2 is medium, and 3 is large.

Duration

The start is when there is a click or scroll inside the essay and it ends when there is a click or scroll outside the essay or when a new action occurs.

Action

1. Label all “type_location2” as ESSAY.
2. Label all clicks “screen X: 1681, Y coords: 109” as ESSAY when the click was inside the essay. To do so, the essay size and coordinates of the click are taken into account.
3. Label all scrolling in the essay as ESSAY.
4. Auto-return the label to reading of the page that was open when there was a switch from essay to outside the essay as indicated by a click outside the essay.

COPY_PASTE

Logging

Copying is logged as “copy_copied text” and pasting as “paste_copied text”.

Duration

Start is copying and end is pasting.

Action

1. Label copy until paste as COPY_PASTE when something was pasted. Do not label it when nothing was pasted.

TIMER

Logging

A click on the timer is logged as “nav_timer”.

Duration

The start is when there is a click on the timer and it ends when a new action occurs or it ends after 4 seconds when the new action occurs after 4 seconds. In addition, when clicks on the timer or close to each other in time: 4 seconds, but other actions are in between, these other actions are merged with the timer clicks.

Action

1. Label all “nav_timer” as TIMER.
2. Label all rows in between when clicks on the timer were within 4 seconds as TIMER. This overrides previous labels and should therefore be done in the final labelling step.
3. Auto-return the label to reading of the page that was open 1) if the action after TIMER occurred after 4 seconds, then insert a row that return the label, and 2) if the action after TIMER was not labelled yet and if the action occurred within 4 seconds after clicking on the timer, then return the label of the action after TIMER to reading of the page that was open.

PLANNER

Logging

A click on the planner is logged as "tools_tab_P".

Duration

The start is when there is a click on the planner and it ends when a new action occurs.

Action

1. Label all “tools_tab_P” as PLANNER.

SEARCH_CONTENT

Logging

A click in the search box is logged as "type_location1”.
When the search was performed, there were three logs: “search1_1452.909_created”, “Search number 1, for text: toetsen”, and “Search number 1, number results found: 1”.
When search was cancelled it was logged as “nav_search_cancel_1” and there was another log associated with this click “screen X: 137, Y coords: 1052”.
Scrolling in search results is logged as “scroll_search_60”.
Clicking on a search result is logged as “nav_search_content_1.1” and there was another log associated with this click “screen X: 137, Y coords: 1052”.

Duration

The start is when there is a click in the search box and there are four possible ends: 1) when the search was cancelled, 2) when there was a click on the search result, 3) the search ends, because there was no search results, and 4) the click in the search box is also the end, as there was no search conducted.

Action

1. Label all “type_location1” as SEARCH.
    a. As a consequence, clicking in the search box without searching (ending 4) results in only this row being labelled as SEARCH.
2. Label all rows until “nav_search_cancel_1” as SEARCH.
    a. Automatically return the label for the additional log associated with this click to reading of the page that was open.
3. Label all rows until “nav_search_content_1.1” as search.
    a. Automatically return the label for the additional log associated with this click to reading of the page that was open.
4. Label all rows until “Search number 1, number results found: 0” as SEARCH.
    a. The label is not automatically returned. The time until the next action is maximally 3.156 seconds, see searchend.csv, so this SEARCH label is not too long.

5. Merge search when there were searches within 4 seconds from each other, but this does not happen.

HIGHLIGHT_EDITING (including: creating, editing and deleting)

HIGHLIGHT_EDITING _CREATING

Logging

There is a click to save the highlight, which causes 5 logs: “highlights_1” to “screen X: 1649, Y coords: 316”.
Before saving, a tag can be selected, which causes two logs: “screen X: 1681, Y coords: 109” and “screen X: 1681, Y coords: 109”. A tag does not have to be selected. The time difference between the two rows associated with selecting a tag is 0-10 milliseconds.
In addition, a tag could be self-generated, which is logged as “type_location3”. A self-generated tag does not have to be created.
Before saving, and optionally selecting a tag, there always is a click to select “create highlight”, which is logged as a simple click: “screen X: 440, Y coords: 117”.
Before clicking “create highlight”, text was selected to be highlighted. When selecting was done the mouse button was released, which often is logged as a simple click: “screen X: 440, Y coords: 117”, but it is not always logged.

Duration

Highlight creating takes place from clicking “create highlight” to saving the highlight. Directly after saving, the label returns to reading of the page that was open. Do start with the click on “create highlight”, because that is when thinking what about the highlighted text or what to do with the highlighted text likely starts.

Action

1. Label the first and last row to save the highlight as HIGHLIGHT_CREATING [done].
2. If there was a self-generated tag, label all rows from start of typing this label to the end of highlight saving as HIGHLIGHT_LABELLING, also see below [done].
    a. If the time between the start of typing and saving the highlight is too long, do not label the rows in between [not needed]. This is not needed, because the time is not too large, see the file called labelz.csv.
3. If saving the highlight or typing a self-generated tag is preceded by the selection of a tag, then extent the range of HIGHLIGHT_CREATING to start from the selection of a tag, regardless of how many tags were selected for the current highlight [done]. Extent means that all rows from selecting a tag to saving a highlight are labelled as HIGHLIGHT_CREATING.
    a. Exception: if the time between selecting a tag and saving a note or starting to type a label is too long (20 seconds or more), then label it as two separate occurrences of HIGHLIGHT_CREATING [done]. The cap was set to 20 seconds based on the data:, see tagselecters.csv. Shorter durations revealed ongoing highlight creation, while longer durations revealed that the participant forgot to click on “save highlight”.
    b. To make sure the click was on a tag, which is in the side panel with tool, coordinates of the click were limited to this area: X > 1590 and Y < 333 [done]. X minimum of 1590 was based on minimum x to select a tag (first column of tags in side panel). Y maximum of 333 was based on maximum y

to select a tag (lowest row of tags if two menus are open: note and highlight creation).
    c. To further make sure the clicks was on a tag, the time difference between the two rows was taken into account, this should be less than 0.2 second.
4. Label the last row of highlight saving as HIGHLIGHT_CREATING.
5. Label the click on “create highlight” until the other processes of highlight creating (see actions 1-4) as HIGHLIGHT_CREATING.
6. Automatically return the label for the last of these rows with log “screen” to reading of the page that was open [done].
    a. Addition: if the time to the next log was more than 4 seconds, then a line was inserted to return the label to reading of the page that was open [done]. Note that this not happen at the end of saving a highlight, but it happens when tag selection was more than 20 seconds before the other processes of highlight creating.
7. Due to actions 2 and 3, labels of rows in between self-generating a tag or selecting a tag and saving the highlight are labelled as HIGHLIGHT_CREATING, this can override labels in between, such as HIGHLIGHT_NOTE_SEARCHING. Therefore, these actions take place after labelling HIGHLIGHT_NOTE_SEARCHING.

HIGHLIGHT_EDITING _EDITING

Logging

There is a click to save the edited highlight, which causes 4 logs: “highlight2_342.704_edited”, “highlight2_tag1_0,1,0,1”, “highlight2_tag2_0,1,0,0,1”, and “screen X: 1649, Y coords: 316”.
Before saving, the highlight was opened, causing 3 logs: “highlight_2_O”, “nav_highlight_2.1”, and “screen X: 1679, Y coords: 205”.
In between, editing takes place, which for highlights can only be deselecting or selecting tags. Note that editing does not have to take place. A highlight could be saved (again) without editing anything. Selecting or deselecting a tag causes two logs: “screen X: 1681, Y coords: 109” and “screen X: 1681, Y coords: 109”. A tag does not have to be selected. The time difference between the two rows associated with selecting a tag is 0-10 milliseconds.
When selecting a tag, the tag could also be self-generated, which is logged as “type_location3”. A self-generated tag does not have to be created.

Duration

Highlight editing takes place from opening the highlight to saving the highlight again. Directly after saving, the label returns to reading of the page that was open. Do start with opening of the highlight, because that is when thinking what about how to edit the highlight likely starts.

Action

1. Label the first and last row to save the highlight as HIGHLIGHT_ EDITING [done].
2. If there was a self-generated tag, label all rows from start of typing this label to the end of saving the highlight again as HIGHLIGHT_LABELLING [done].
    a. If the time between the start of typing and saving the highlight again is too long, do not label the rows in between. This is not needed, because this does not happen, check via labelz.csv
3. If saving the highlight or typing a self-generated tag is preceded by the selection of a tag, then extent the range of HIGHLIGHT_EDITING to start from the selection of a tag, regardless of how many tags were selected for the current highlight [done].

Extent means that all rows from selecting a tag to saving a highlight again are labelled as HIGHLIGHT_EDITING.

   a. Exception: if the time between selecting a tag and saving a note or starting to type a label is too long (20 seconds or more), then label it as two separate occurrences of HIGHLIGHT_ EDITING [done], but this does not happen, see tagselecters.csv. The cap was set to 20 seconds based on the data:, see tagselecters.csv.
   a. To make sure the click was on a tag, which is in the side panel with tool, coordinates of the click were limited to this area: X > 1590 and Y < 333 [done]. X minimum of 1590 was based on minimum x to select a tag (first column of tags in side panel). Y maximum of 333 was based on maximum y to select a tag (lowest row of tags if two menus are open: note and highlight creation).
   b. To further make sure the clicks was on a tag, the time difference between the two rows was taken into account, this should be less than 0.2 second.

4. If opening the highlight occurred before editing the highlight, label it as HIGHLIGHT_EDITING as well [done].
   a. The time between opening and saving the edited highlight is small (< 20 seconds) and all reveal spending time on editing the note, see highedit_open.csv.
5. Label the last row of highlight saving as HIGHLIGHT_EDITING.
6. Automatically return the label for the last of these rows with log "screen" to reading of the page that was open [done].
7. Due to actions 2, 3 and 4, labels of rows in between self-generating a tag or selecting a tag and saving the highlight are labelled as HIGHLIGHT_EDITING, this can override labels in between, such as HIGHLIGHT_NOTE_SEARCHING. Therefore, these actions take place after labelling HIGHLIGHT_NOTE_SEARCHING.

HIGHLIGHT_EDITING _DELETING

Logging

There is a click to delete a highlight, which causes two logs: "highlight10_331.597_deleted", and there is a row with the same time or a few milliseconds more that recorded the click: "screen X: 1649, Y coords: 316".

Duration

Highlight deleting takes place from opening the highlight until it is deleted.

Action

1. Label deleting the highlight as HIGHLIGHT_DELETING [done].
2. Automatically return the label in the last of these rows to reading of the page that was open [done].
3. Label opening the highlight until deleting it as HIGHLIGHT_DELETING [done].
   a. Therefore, labelling HIGHLIGHT_DELETING should take place after HIGHLIGHT_READING.

HIGHLIGHT_LABELLING

This is a special case of highlight creating. In this case, a self-generated tag was selected and saved with the highlight, see HIGHLIGHT_CREATING. When there was a self-generated tag, label it as HIGHLIGHT_LABELLING.

HIGHLIGHT_READING

Logging

There is a click to open the highlight menu, which causes at least one log: "highlight_menu_O", and a number of additional logs, depending on the amount of highlights: "size_highlight_selection_1_53", "nr_tag1_highlight_1_0", and "nr_tag2_highlight_1_1" per highlight. Plus after this there is a row with the same time that recorded the click: "screen X: 1649, Y coords: 316".
There is a click to close the highlight menu, which causes two logs: "highlight_menu_C", and there is a row with the same time that recorded the click: "screen X: 1649, Y coords: 316".
There can be a click to open a highlight itself, which causes three logs: "highlight_4_O", "nav_highlight_2.1", and "screen X: 1649, Y coords: 316". Note that the second log is a navigation that is also recorded as such (the label is reading of the page that is open). In this case when the navigation is short (logged as NAVIGATION), one can assume that clicking the highlight was done to read its tags. When the page visit is long, one can assume that the reading of the page occurred, or when there were other actions, they were not related to reading of the highlight.
There can be a click to close a highlight itself, which causes three logs: "highlight_4_C", "nav_highlight_2.1", and "screen X: 1649, Y coords: 316". Note that the second log is a navigation that is also recorded as such (the label is reading of the page that is open).

Duration

Highlight reading takes place from 1) opening the menu until a different action occurs or the menu is closed, and 2) opening a highlight until a different action occurs or the highlight is closed.

Action

1. Label opening the highlight menu as HIGHLIGHT_READING [done].
    a. Make sure to label all rows associated with opening the menu [done].
2. Automatically return the label after the last of these rows to reading of the page that was open, unless there already was a label [done].
    a. Addition: insert a row when the time difference was more than 21 seconds, see highlighttime.csv.
3. Label closing the menu as reading of the page that was open [done].
4. Label closing the highlight as reading of the page that was navigated to by clicking on the highlight to close it [done].
5. Label opening a highlight as HIGHLIGHT_READING, when the navigation associated with opening the highlight was short (label of the navigation is NAVIGATION) [done].
6. Label opening a highlight as reading of the page that was opened by the navigation associated with opening the highlight when the page visit was long (label of the navigation is (IR)RELEVANT_(RE-)READING, or RUBRIC/GENERAL_INSTRUCTION) [done].

NOTE _EDITING (including: creating, editing and deleting)

NOTE_EDITING_CREATING

Logging

There is a click to save the note, which causes 7 logs: “notes_1” to “screen X: 1649, Y coords: 316”.
Before saving, there is a click to type either the note title: “type_location4” or the note content: “type_location5”. These clicks cause two logs: “type_location5” and “screen X: 1659, Y coords: 263”. The time difference between these rows is 0-150 milliseconds. If a participant forgets to type either one, there is an error message before saving: "Missing title or note information".
Before saving, a tag can be selected, which causes two logs: “screen X: 1681, Y coords: 109” and “screen X: 1681, Y coords: 109”. The time difference between these rows is 0-10 milliseconds. A tag does not have to be selected.
In addition, a tag could be self-generated, which is logged as “type_location3”. A self-generated tag does not have to be created.
Before typing, and optionally selecting a tag, there is a click to select “create note”, which is logged as a simple click: “screen X: 440, Y coords: 117”. When selecting was done the mouse button was released, which often is logged as a simple click: “screen X: 440, Y coords: 117”, but it is not always logged.

Duration

From self-generating a tag, from selecting a tag, or from starting to type a note title or note content to saving the note. Directly after saving, the label returns to reading of the page that was open. Exclude clicking on “create note”, because this is preparation for the note and probably does not include the actual thinking. This thinking likely occurs when self-generating content (content-related information, or plans on what to do with the information, etc.).

Action

1. Label the rows to save the note as NOTE_CREATING [done]. Only the first row of the save is labelled in this step.
2. Label the rows to type a note title or note content as NOTE_CREATING [done].
    a. Check the time and labels between this row and note saving [done].
        i. Some long (over 90 seconds), but they were working on the note (there might be one exception, but eye-tracking would be needed to reveal the switching between reading and note creating)
    b. Label these in-between rows as NOTE_CREATING [done].
3. If there was a self-generated tag, label all rows from start of typing this label to the end of note saving as NOTE _CREATING [done].
    a. If the time between the start of typing and saving the note is too large, do not label the rows in between [not needed]. This is not needed, because the time is not too large, see the file called labelz.csv.
4. If self-generating a tag or typing note title or content was preceded by the selection of a tag, then extent the range of NOTE_CREATING to start from the selection of a tag, regardless of how many tags were selected for the current note [done]. Extent means that all rows from selecting a tag to saving a note are labelled as NOTE_CREATING.
    a. In contract to highlights, there is no exception based on the duration, because two instances with long duration revealed continuous working on the note.
    b. To make sure the click was on a tag, which is in the side panel with tool, coordinates of the click were limited to this area: X > 1590 and Y < 333

[done]. X minimum of 1590 was based on minimum x to select a tag (first column of tags in side panel). Y maximum of 333 was based on maximum y to select a tag (lowest row of tags if two menus are open: note and highlight creation).

   c. To further make sure the clicks was on a tag, the time difference between the two rows was taken into account, this should be less than 0.2 second.

5. Label the last row of note saving as NOTE_CREATING.
6. Automatically return the label for the last of these rows with log "screen" to reading of the page that was open [done]
   a. Addition: do check if there is not too much time between NOTE_CREATING and the next action in the case tag selection was a separate session of NOTE_CREATING. This does not happen, see notetime.csv.
7. Due to actions 3 and 4, labels of rows in between self-generating a tag or selecting a tag and saving the note are labelled as NOTE_CREATING, this can override labels in between, such as HIGHLIGHT_NOTE_SEARCHING. Therefore, these actions take place after labelling HIGHLIGHT_NOTE_SEARCHING.

NOTE_EDITING _EDITING

Logging

There is a click to save the edited note, which causes 6 logs: "note3_998.392_edited", "note3_title_turing test", "note3_content_de turing test ontworpen om een definitie van intelligentie te kunnen geven", "note3_tag1_1,0,0,1", " note3_tag2_0,0,0,0,0", and "screen X: 1649, Y coords: 316".
Before saving, the note was opened, causing 3 logs: "note_3_O", "nav_note_1.2", and "screen X: 1679, Y coords: 205".
In between, editing takes place, which for notes can be (de)selecting tags, and typing note title or content. Note that editing does not have to take place. A note could be saved (again) without editing anything.
Selecting or deselecting a tag causes two logs: "screen X: 1681, Y coords: 109" and "screen X: 1681, Y coords: 109". A tag does not have to be selected. The time difference between the two rows associated with selecting a tag is 0-10 milliseconds.
When selecting a tag, the tag could also be self-generated, which is logged as "type_location3". A self-generated tag does not have to be created.
Typing a title is logged as "type_location4" and typing note content as "type_location5".

Duration

Note editing takes place from opening the note to saving the note again. Directly after saving, the label returns to reading of the page that was open. Do start with opening of the note, because that is when thinking what about how to edit the note likely starts.

Action

1. Label the first and last row to save the note as NOTE_ EDITING [done].
2. If there was a self-generated tag, label all rows from start of typing this label to the end of saving the highlight again as NOTE_EDITING [done].
   a. If the time between the start of typing and saving the highlight again is too long, do not label the rows in between. This is not needed, because this does not happen, check via labelz.csv
3. If saving the note or typing a self-generated tag is preceded by the selection of a tag, then extent the range of NOTE_EDITING to start from the selection of a tag, regardless of how many tags were selected for the current note [done]. Extent means

that all rows from selecting a tag to saving a note again are labelled as NOTE_EDITING.
    a. In contract to highlights, there is no exception based on the duration, because two instances with long duration revealed continuous working on the note.
    b. To make sure the click was on a tag, which is in the side panel with tool, coordinates of the click were limited to this area: X > 1590 and Y < 333 [done]. X minimum of 1590 was based on minimum x to select a tag (first column of tags in side panel). Y maximum of 333 was based on maximum y to select a tag (lowest row of tags if two menus are open: note and highlight creation).
    c. To further make sure the clicks was on a tag, the time difference between the two rows was taken into account, this should be less than 0.2 second.
4. If opening the note occurred before editing the note, label it as NOTE_EDITING as well [done].
    a. The time between opening and saving the edited note is small (< 22seconds) and all reveal spending time on editing the note, see noteedit_open.csv.
5. Label the last row of note saving as NOTE_EDITING.
6. Automatically return the label for the last of these rows with log "screen" to reading of the page that was open [done].
    a. Addition: do check if there is not too much time between NOTE_CREATING and the next action in the case tag selection was a separate session of NOTE_CREATING. This does not happen, see notetime.csv.
7. Due to actions 2, 3 and 4, labels of rows in between self-generating a tag or selecting a tag and saving the note are labelled as NOTE_EDITING, this can override labels in between, such as HIGHLIGHT_NOTE_SEARCHING. Therefore, these actions take place after labelling HIGHLIGHT_NOTE_SEARCHING.

NOTE_EDITING _DELETING

Logging

There is a click to delete a note, which causes two logs: "note10_331.597_deleted", and there is a row with the same time or a few milliseconds more that recorded the click: "screen X: 1649, Y coords: 316".

Duration

Note deleting takes place from opening the note until it is deleted.

Action

1. Label deleting the note as NOTE_DELETING [done].
2. Automatically return the label after the last of these rows to reading of the page that was open, unless there already was a label [done].
3. Label opening the note until deleting it as NOTE_DELETING [done].
    a. Therefore, labelling NOTE_DELETING overrides labels and should take place after labelling NOTE_READING.

NOTE_READING

Logging

There is a click to open the note menu, which causes at least one log: "note_menu_O", and a number of additional logs, depending on the amount of notes: "size_note_selection_1_53",

“nr_tag1_note_1_0”, and “nr_tag2_note_1_1” per note. Plus after this there is a row with the same time that recorded the click: “screen X: 1649, Y coords: 316”.
There is a click to close the note menu, which causes two logs: “note_menu_C”, and there is a row with the same time that recorded the click: “screen X: 1649, Y coords: 316”.
There can be a click to open a note itself, which causes three logs: “note_4_O”, “nav_note_2.1”, and “screen X: 1649, Y coords: 316”. Note that the second log is a navigation that is also recorded as such (the label is reading of the page that is open). In this case when the navigation is short (logged as NAVIGATION), one can assume that clicking the note was done to read its tags. When the page visit is long, one can assume that the reading of the page occurred, or when there were other actions, they were not related to reading of the note.
There can be a click to close a note itself, which causes three logs: “note_4_C”, “nav_note_2.1”, and “screen X: 1649, Y coords: 316”. Note that the second log is a navigation that is also recorded as such (the label is reading of the page that is open).

Duration

Note reading takes place from 1) opening the menu until a different action occurs or the menu is closed, and 2) opening a note until a different action occurs or the note is closed.

Action

1. Label opening the note menu as NOTE_READING [done].
    a. Make sure to label all rows associated with opening the menu [done].
2. Automatically return the label after the last of these rows to reading of the page that was open, unless there already was a label [done].
    a. Addition: insert a row when the time difference was more than 21 seconds, but this does not happen, see notetime.csv.
3. Label closing the menu as reading of the page that was open [done].
4. Label closing the note as reading of the page that was navigated to by clicking on the note to close it [done].
5. Label opening a note as NOTE_READING, when the navigation associated with opening the note was short (label of the navigation is NAVIGATION) [done].
6. Label opening a note as reading of the page that was opened by the navigation associated with opening the note when the page visit was long (label of the navigation is (IR)RELEVANT_(RE-)READING, or RUBRIC/GENERAL_INSTRUCTION) [done].

HIGHLIGHT_NOTE_SEARCHING

Logging

To search in notes and highlight, two fields can be used: type_location7 and type_location6. After clicking in the field, a click is recorded: “screen X: 1582, Y coords: 106”. The time difference between these rows is 0-850 ms.
Finally, there is a registration of what was searched, for tags: “Input search highlight/notes tag:” and for text: “Input search highlight/notes text: uitingsvormen”. This is logged just before a new action occurs. This is where the search ends.
Then, one can click to open the note or highlight menu (“note_menu_O”) and click on a note or highlight that was found via the search “highlight_8_O”.

Duration

From activating either search field until the search results.

Action

1. Label the logs with type_location6 and type_location7 as HIGHLIGHT_NOTE_SEARCHING
2. Label the logs of the search “Input search highlight/notes tag:” and “Input search highlight/notes text:” as HIGHLIGHT_NOTE_SEARCHING
3. Label all rows in between as HIGHLIGHT_NOTE_SEARCHING
4. Exception: when “Input search highlight/notes tag:” or “Input search highlight/notes text:” occurred after more than 25 seconds, do not label them or the rows in between. There were two instances of a search of approximately 20 seconds that were a continuous search, and there was one with more than 25 seconds, who did not intend to search.

Appendix 3. The theory-driven process library and the detection process

Metacognition	No.	SRL processes
Orientation (MC.O)	1	GENERAL_INSTRUCTION/RUBRIC* -> NAVIGATION -> RELEVANT_READING*
	2	GENERAL_INSTRUCTION/RUBRIC -> GENERAL_INSTRUCTION/RUBRIC
	3	GENERAL_INSTRUCTION/RUBRIC <-> HIGHLIGHT_EDITING/NAVIGATION
	4	GENERAL_INSTRUCTION*/RUBRIC*
Planning (MC.P)	5	PLANNER -> NAVIGATION -> RELEVANT_READING
	6	GENERAL_INSTRUCTION/RUBRIC <-> PLANNER (during first 15mins)
	7	PLANNER (during first 15mins)
	8	SEARCH_CONTENT*
Evaluation (MC.E)	9	IRRELEVANT_(RE-)READING* -> GENERAL_INSTRUCTION -> RELEVANT_(RE-)READING*
Monitoring (MC.M)	10	GENERAL_INSTRUCTION* -> WRITE_ESSAY -> WRITE_ESSAY*
	11	NAVIGATION <-> NOTE_READING
	12	GENERAL_INSTRUCTION <-> PLANNER (after the first 15mins)
	13	WRITE_ESSAY <-> PLANNER
	14	TIMER*
	15	PLANNER* (after the first 15mins)
Low_Cognition	**No.**	**SRL processes**
First-reading (LC.F)	16	(IR)RELEVANT_READING* -> HIGHLIGHT_EDITING/NOTE_EDITING -> (IR)RELEVANT_READING*
	17	(IR)RELEVANT_READING* -> NAVIGATION -> (IR)RELEVANT_READING*
	18	RELEVANT_READING* -> IRRELEVANT_READING -> IRRELEVANT_READING*
	19	(IR)RELEVANT_READING* <-> HIGHLIGHT_EDITING/NOTE_EDITING/ HIGHLIGHT_READING/NOTE_READING
	20	(IR)RELEVANT_READING* <-> (IR)RELEVANT_READING*
	21	IRRELEVANT_READING*
Re-reading (LC.R)	22	RELEVANT_RE-READING*
	23	IRRELEVANT_RE-READING*
High_Cognition	**No.**	**SRL processes**
Elaboration/ Organisation (HC.E/O)	24	(IR)RELEVANT_RE-READING* -> WRITE_ESSAY -> WRITE_ESSAY*
	25	RUBRIC* -> WRITE_ESSAY -> WRITE_ESSAY*
	26	WRITE_ESSAY -> WRITE_ESSAY*
	27	WRITE_ESSAY <-> HIGHLIGHT_READING/NOTE_READING
	28	GENERAL_INSTRUCTION/RUBRIC <-> WRITE_ESSAY
	29	NAVIGATION <-> RELEVANT_RE-READING/WRITE_ESSAY
	30	HIGHLIGHT_LABELLING*
	31	NOTE_EDITING*
	32	HIGHLIGHT_READING/NOTE_READING*

Note: "->" means a transition from action A to action B; "<->" means a transition from action A to action B or the other way around; "()" means optional; "*" means one or more consecutive instances of the same action; "/" means either action A or action B.

Detailed Detection Process:

1-We first merged same consecutive actions, following this rule:

All continuous rows of: TIMER, PLANNER, NAVIGATION, SEARCH_CONTENT, HIGHLIGHT_EDITING, HIGHLIGHT_READING, HIGHLIGHT_LABELLING, NOTE_EDITING, NOTE_READING and SEARCH_HIGHLIGHT_NOTE actions were merged into one row;

For example : timer timer timer timer → timer

The rest continuous rows other actions were merged into three rows, in which, we kept the first and the last row and merged all rows in between;

For example:Relevant_reading;Relevant_reading;.....;Relevant_reading;Relevant_reading
→ Relevant_reading; Relevant_reading ;Relevant_reading

2-Then, we first detected all three-step processes based on the process library

We consider that three-step processes were in highest priority;

3-Then, we detected all two-step pattern based on the process library

We consider that two-step processes were in medium priority;

4-Then, we detected all one-step pattern based on the process library

We consider that one-step processes were in lowest priority;

5- If one action does not belong to any processes in the process library, then this row will be labelled as No_Process;

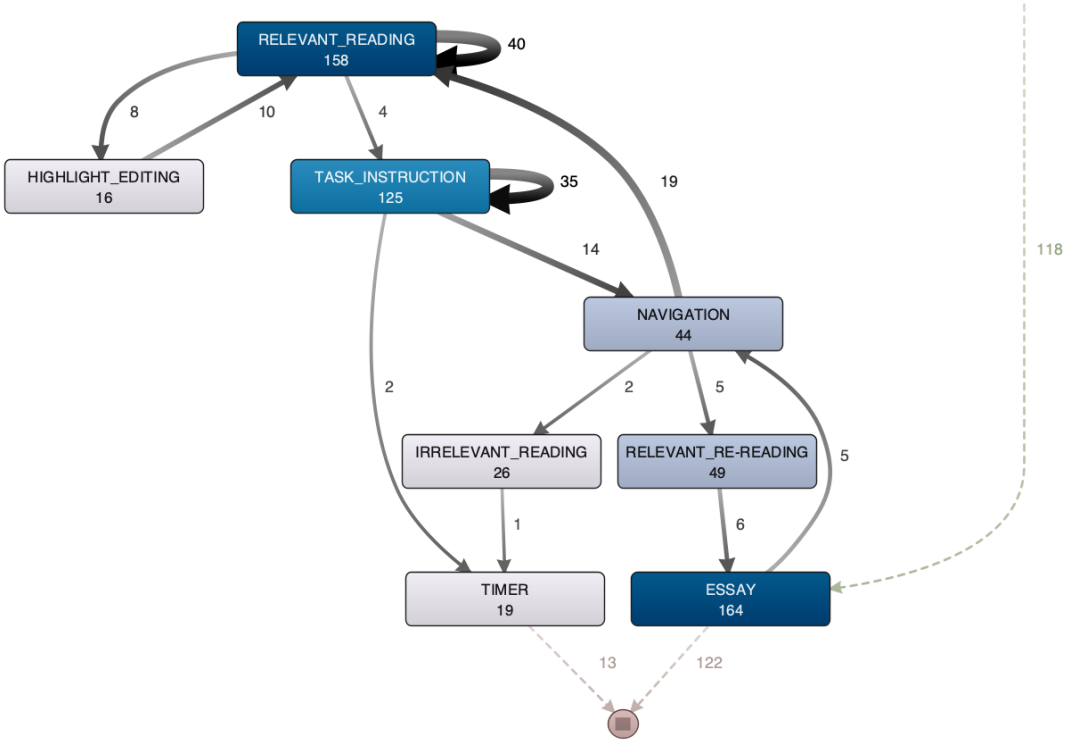
Appendix 4. The improved process library

Metacognition	No.	SRL processes
Orientation (MC.O)	1	GENERAL_INSTRUCTION*/RUBRIC* -> NAVIGATION -> RELEVANT_READING
	2	GENERAL_INSTRUCTION/RUBRIC -> GENERAL_INSTRUCTION/RUBRIC
	3	GENERAL_INSTRUCTION/RUBRIC <-> HIGHLIGHT_EDITING/NOTE_EDITING/ NAVIGATION
	4	GENERAL_INSTRUCTION*/RUBRIC*
Planning (MC.P)	5	PLANNER -> NAVIGATION -> RELEVANT_READING
	6	GENERAL_INSTRUCTION/RUBRIC <-> PLANNER* (during first 15mins)
	7	PLANNER* (during first 15mins)
	8	SEARCH_CONTENT*
Evaluation (MC.E)	9	IRRELEVANT_(RE-)READING -> (NAVIGATION) -> GENERAL_INSTRUCTION*/ RUBRIC* -> (NAVIGATION) -> RELEVANT_(RE-)READING
Monitoring (MC.M)	10	NAVIGATION <-> NOTE_READING
	11	GENERAL_INSTRUCTION/RUBRIC <-> PLANNER* (after the first 15mins)
	12	WRITE_ESSAY <-> PLANNER*
	13	TIMER*
	14	PLANNER* (after the first 15mins)
	15	SEARCH_HIGHLIGHT_NOTE*
	16	HIGHLIGHT_READING/NOTE_READING*
Low_Cognition	**No.**	**SRL processes**
First-reading (LC.F)	17	(IR)RELEVANT_READING -> HIGHLIGHT_EDITING/NOTE_EDITING -> (IR)RELEVANT_READING
	18	(IR)RELEVANT_READING -> NAVIGATION -> (IR)RELEVANT_READING
	19	RELEVANT_READING -> IRRELEVANT_READING -> IRRELEVANT_READING
	20	(IR)RELEVANT_READING <-> HIGHLIGHT_EDITING/NOTE_EDITING/ HIGHLIGHT_READING/NOTE_READING
	21	(IR)RELEVANT_READING <-> (IR)RELEVANT_READING
	22	IRRELEVANT_READING*
	23	RELEVANT_READING*
Re-reading (LC.R)	24	RELEVANT_RE-READING*
	25	IRRELEVANT_RE-READING*
High_Cognition	**No.**	**SRL processes**
Elaboration/ Organisation (HC.E/O)	26	(IR)RELEVANT_RE-READING -> (NAVIGATION) -> WRITE_ESSAY
	27	GENERAL_INSTRUCTION*/RUBRIC* -> (NAVIGATION) -> WRITE_ESSAY
	28	WRITE_ESSAY -> WRITE_ESSAY
	29	WRITE_ESSAY <-> HIGHLIGHT_READING/NOTE_READING
	30	HIGHLIGHT_LABELLING*
	31	NOTE_EDITING*

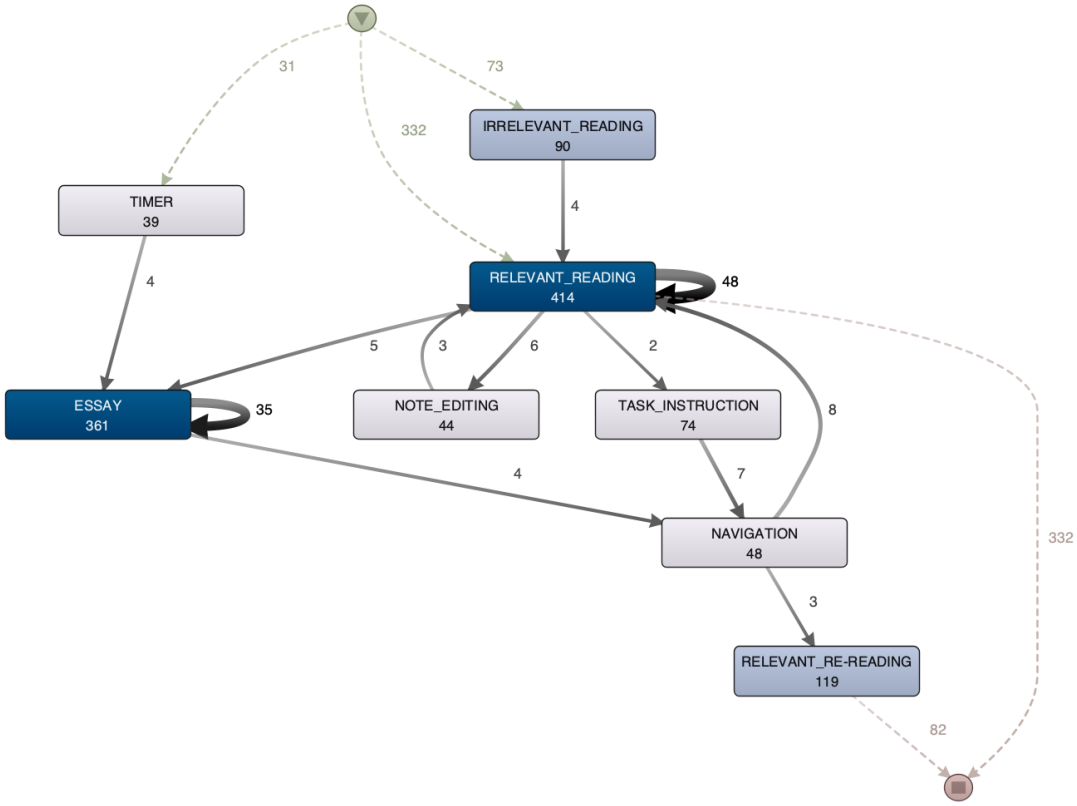
Note: "->" means a transition from action A to action B; "<->" means a transition from action A to action B or the other way around; "()" means optional; "*" means one or more consecutive instances of the same action; "/" means either action A or action B.

Appendix 5. The process map for all session-groups based on think aloud code

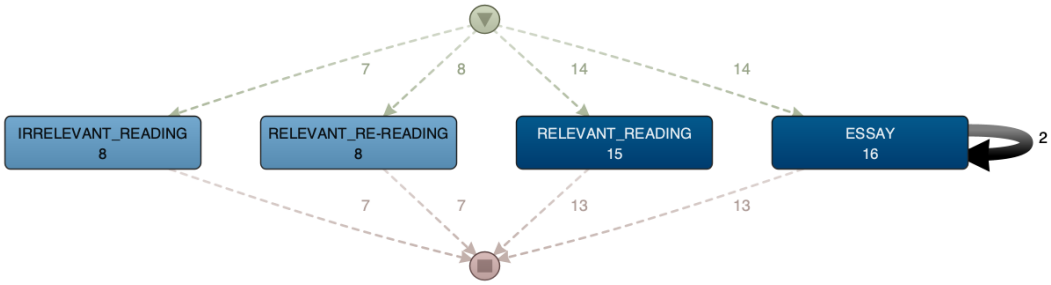
Process map of actions for MC.O-based session-group



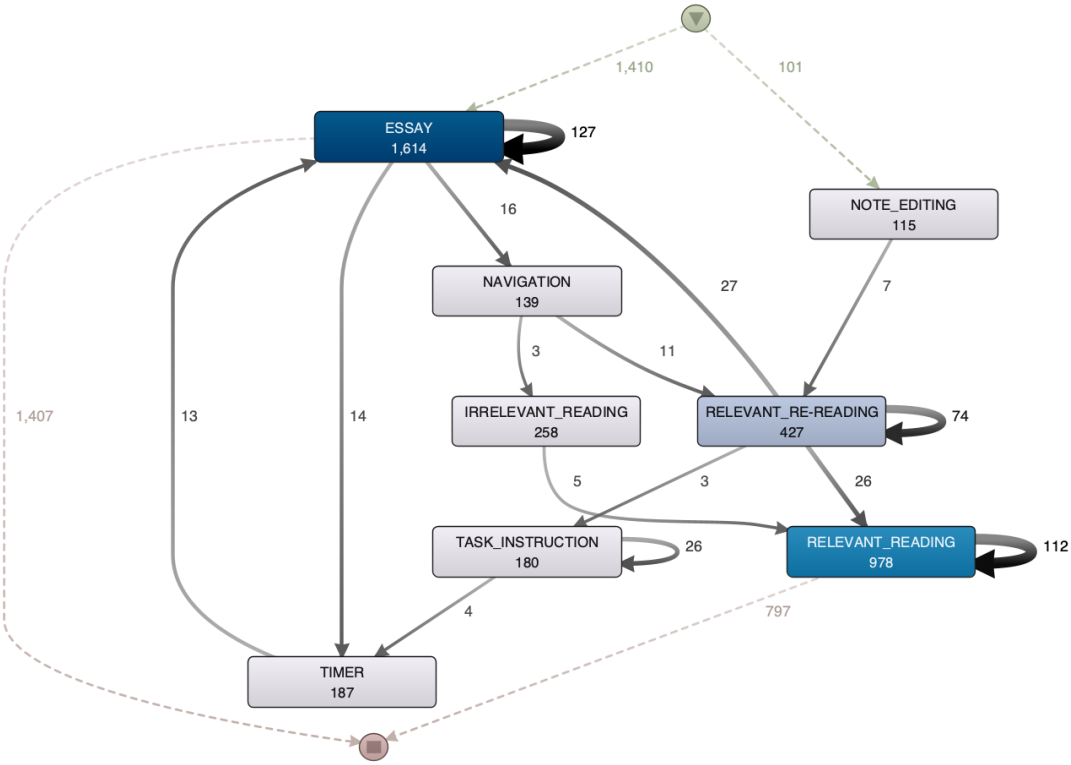
Process map of actions for MC.P-based session-group



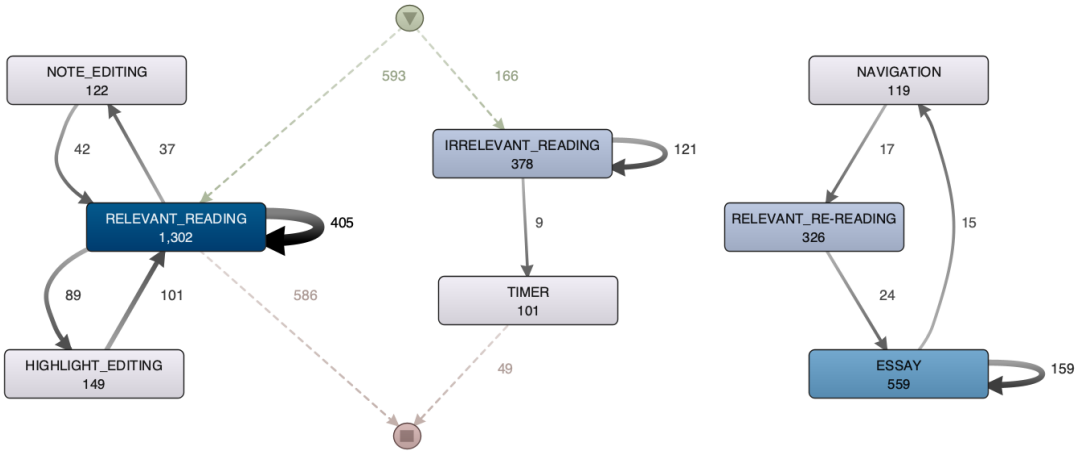
Process map of actions for MC.E-based session-group



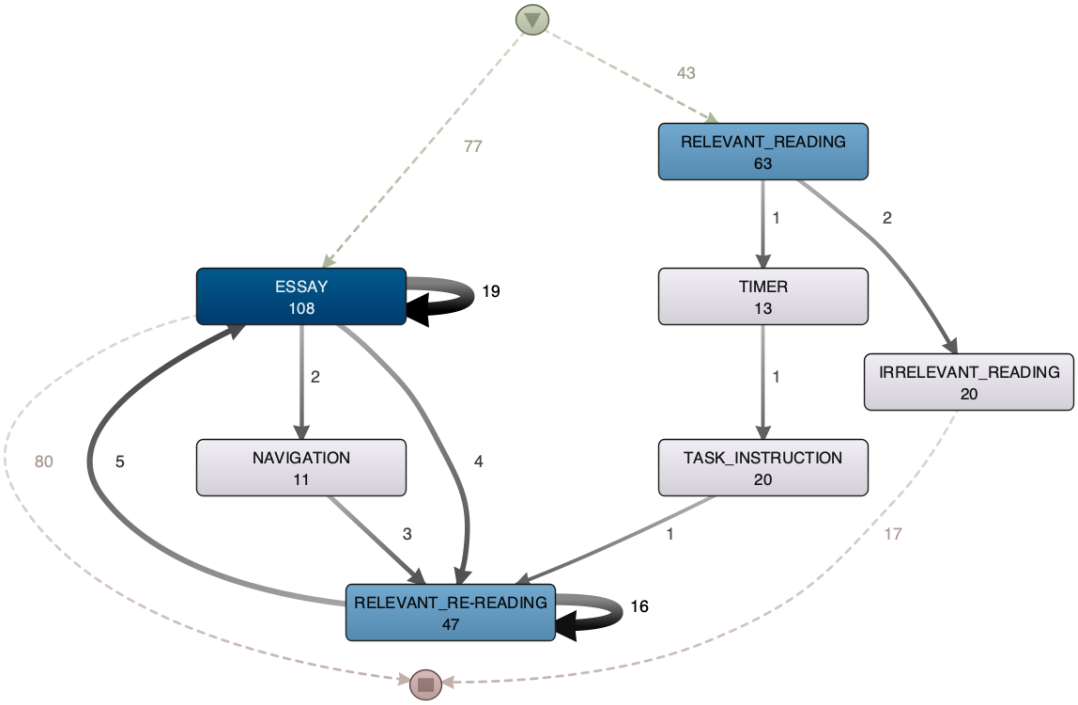
Process map of actions for MC.M-based session-group



Process map of actions for LC.F-based session-group



Process map of actions for LC.R-based session-group



Process map of actions for HC.E/O-based session-group