Lund University, Dept. of Linguistics and Phonetics
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# Reading during writing: Four different groups of writers

Roger Johansson, Victoria Johansson, Åsa Wengelin and Kenneth Holmqvist

This paper presents the methodology behind a larger project aiming at uncovering several cognitive aspects of the complex interplay between reading and writing in text compositions. Overall results of how much writers actually read their own emerging texts are presented and discussed for two genres (expository and picture description). By using participants of different ages (adult university students and 15-year-olds) and skills (with and without reading and writing difficulties) the results have been considered both from a developmental and a skill-oriented perspective. The methodology that has been used is a combination of keystroke logging and eye tracking, which offers unique possibilities to study both what and when someone is typing as well as what she was looking at. In addition, patterns based on eye movement data were used to identify reading activity. The results suggest that reading during writing is performed to a higher extent if you are a skilled and developed reader/writer, and decreases if you are less skilled and developed. Finally, we propose that the genre of the text composition affect how much the emerging text is read.

## Introduction

The process of reading your own text during an emerging text composition is as understudied as it is important. Most cognitive models of writing (e.g. Hayes & Flower 1980) include components of planning, translation and revision, but also assume reading to be an important factor in the writing process. Despite this, reading has been more or less ignored by most empirical investigations of writing. In cases where reading has been taken into account at all, it has focused on the reading of other sources than the emerging text. Reading before revision or before continuing to write has hardly been addressed at all. One important reason is the lack of good research tools for analyzing these phenomena until now. Present-day technology opens up new possibilities, however. Alamargot and Chesnet's *Eye and Pen* system (Chesnet & Alamargot 2006) permits detailed analysis of eye movements during handwritten composition. Some early findings using this system are summarized in Alamargot et al. 2006. But to our knowledge, no other published research has described writers' eye movements within their own emerging text compositions.

In earlier studies we have used the keystroke logging software *ScriptLog* (e.g. Strömqvist & Malmsten 1998, Strömqvist & Karlsson 2001, Wengelin 2002) to study the emerging text. Like most keystroke logging programs *ScriptLog* produces data on temporal and editing patterns during text production. This offers the possibility to study both what happens (e.g. which keystrokes were pressed and the duration of a pause) and when it happens. Keystroke logging has proven to be a useful tool in several studies that typically focus on either planning or revision processes (e.g. Matsuhashi 1981, Chanquoy, Foulin & Fayol 1996, Severinson Eklundh & Kollberg 1996, Wengelin 2002, Alves et al. 2007). However, in some respects the methodology is limited. For example, it cannot tell us what the writer does during a pause in the text production. Is she reading through her text so far, planning her next sentence or simply looking out the window thinking of something else? In order to get closer to the answers of these questions, our research group has developed a research environment where keystroke logging is combined with eye movement technology (cf. Andersson et al. 2006).

Many areas of reading have been studied using eye-tracking technology, for example different types of reading material (e.g. Rayner & Pollatsek 1989), reading development (e.g. Buswell 1922), speed-reading (e.g. Just & Carpenter 1987), poor readers (e.g. Olson, Kliegl & Davidson 1983) and reading strategies (e.g. Hyönä, Lorch & Kaakinen 2002). Although eye tracking has been used to study reading in so many aspects, to our knowledge virtually no studies have been made of people reading their own emerging texts during typing.

In fact, the overall relation between reading and writing has been very little explored so far. Beyond the knowledge of how children acquire the skills of reading and writing (e.g. Frith 1985), and that most people with reading difficulties also have writing difficulties, and vice versa (e.g. Høien & Lundberg 1999), very little is known.

In our project, we made the assumption that the standard definitions of reading (e.g. Rayner 1998) can be applied to the reading of an emerging text. This assumption is far from obvious since reading of an emerging text is a very complex activity. For example, video observations of the reading activities in writing tasks (described below) showed that reading one's own emerging text is not performed in a straightforward way from the beginning



to the end. Instead, the writer/reader frequently moves backwards and jumps back and forth in the text. It is unclear which cognitive processes are at work during these irregular reading patterns, and whether they are at all comparable to regular reading activities. Nevertheless, since no definitions of reading during writing exist, we have chosen to start with those that are established in reading research (e.g. Rayner 1998).

Further, only regular forward reading has been considered as reading in this paper. However, one of the future aims of this project will be to define the possible differences between reading activity of static texts written by someone else and the reading activity during one's own emerging text.

Text production is a complex activity that requires the management of several processes in working memory (e.g. Alamargot & Chanquoy 2001). The demands of a given process is highly dependent on how automatized it is. In text production on a computer, *low-level* processes like lexical access (McCutchen et al. 1994) and typing (Alves et al. 2007) can be automatized with practise. Conceptual processes, like planning and revision involve decisions about content selection and organization, and require constant attentional control. These *high-level* processes are very difficult to automatize and are therefore considered the most demanding ones (Kellogg 1996).

Cognitive demands during text writing also vary depending on the type of text. In the current study we collected texts in two genres: a picture description and an expository text. While the writer is aided by the picture in her text composition in the picture description task, the expository discourse poses more cognitive efforts; the lack of innate temporal structure in the expository text makes it more difficult to decide on its beginning and end, as well as on the order of the arguments (cf. Longacre 1983, Goutsos 1996).

*Aim of the study*

The current paper presents the methodology of combining keystroke logging with eye tracking, with the purpose to study reading during writing, as well as overall results on how much one actually reads one's own emerging text. By using both university students with and without reading- and writing difficulties (RW-difficulties), and 15-year-olds with and without RW-difficulties as participants, the reading activity was explored both from a developmental and a skill-oriented perspective.

## Method

*Participants*

In total, 79 persons participated in the experiment: 28 university students with no reading and writing (RW) difficulties, 29 15-year-olds with no RW-difficulties, 9 university students with RW-difficulties, and 13 15-year-olds with RW-difficulties. The distribution was balanced for gender, although there is a slight bias towards more male representation in the two groups of weak writers.

*Data*

Synchronized eye movement and *ScriptLog* data exist for:

(1) an expository task, where the participants wrote an expository paper discussing problems in a school setting;
(2) a picture description task, where the participants wrote a description of a picture;
(3) a reading task, where the participants read a text written by someone else.

The two writing tasks (1) and (2) were balanced for order. In addition, literacy questionnaires exist for all participants. For the university students with no RW-difficulties we also have retrospective commentaries about one of their texts.

*Equipment and stimuli*

The two text composition tasks were performed on a PC computer with the keystroke logging software *ScriptLog*, which records all events on the keyboard, the screen position of these events and their temporal distribution. Synchronized with the *ScriptLog* recording, a *SMI iView X* (HED + HT 50 Hz) eye tracking (ET) equipment was used. The ET recording equipment was mounted on a bike helmet and uses a *Polhemus* magnetic head-tracker, which gives the participants freedom to move both body and head during the experiment. During the recording we used two computers, connected to each other. One computer recorded the *ScriptLog* activity, and the other the ET activity. See Figure 1 for a schematic outline of the experimental setting.

This methodology gives rise to renouncing some precision in measuring. However, the ability to move head and body is crucial when the participants are involved in an experimental setting of this complexity. It would be almost impossible for the writer to be comfortable in a situation where she has to



hold the head still, while typing at the same time as the visual attention shifts between keyboard, monitor and picture. The participants wore the ET equipment during all three tasks. The ET equipment outputs the eye movement data and an MPEG movie showing the participant's view during the experiment with an overlayed circle, illustrating the eye movements.

To facilitate later analysis of the visual focus during various parts of the writing session, we wanted to avoid (too much) scrolling on the screen. Therefore, we used a 19" screen and allowed for a full screen usage. For the writing task, we chose single spacing, to use the screen more effectively, and a large font (17 points), which made it possible to state with high accuracy, almost to the word, what a person was looking at. In the reading task, we also used 17 points, but 1,5 spacing and a more narrow text space, to facilitate the reading. For all tasks the font Times New Roman was used.

In the picture description task we used a picture (500mm × 700mm) that showed a detailed picture from a children's book (Nordqvist 1990). It was presented a bit behind the screen of the computer (see Figure 2).

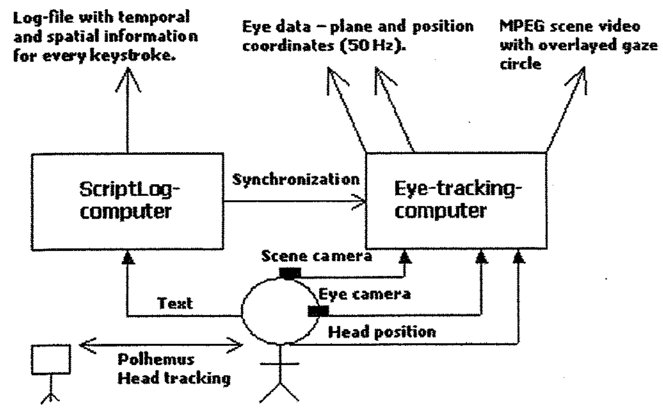


**Figure 1.** The experimental setting with synchronized *ScritptLog* and ET data.

**Figure 2.** The picture used in the picture description task (Nordqvist 1990). Reproduced with permission of Sven Nordqvist.

*Procedure: data collection*

The group of university students was recruited from students who had at least 4 terms of studies behind them. In order to avoid influences from earlier language studies, the participants were all recruited from outside the faculties of humanities. After the permission of the parents, the 15-year-olds were recruited from schools in the areas surrounding Lund.

All participants were chosen after a careful screening process, consisting of a word decoding test *DJUR* (Herrström 1998) and a spelling test (Johansson 1992), both standardised for Swedish. All participants knew that the screening was a way of deciding whether or not they fit the profile for the full experiment. The initial inclusion criterion for the groups with RW-difficulties was results with stanine 3 or lower for both word decoding and spelling. For the group of 15-year-olds this criterion turned out to be a functional criterion. However, in order to find enough university students with RW-difficulties we had to include participants who had stanine 4 in one of the tests. Interestingly, all these participants had stanine 1 in the other test, indicating that they were either very poor word decoders or very poor spellers, despite their better results in the other test. The inclusion criterion for the groups without RW-difficulties was at least stanine 5 in both tests.

The screening tests were corrected promptly, and the persons with a profile that met the inclusion criteria stated above were usually contacted on the telephone within days from the screening.



All participants identified as having reading and writing difficulties were contacted by a speech therapist with special training, who made sure that they received further professional help with their difficulties (if no such help was provided already).

In total, more than 300 persons were screened for participation. 99 persons were qualified to take part in the data collection, and complete high-quality recordings are available from 79 of them. Despite the relaxation of our original inclusion criteria our groups with RW-difficulties are very small. There are at least two explanations for this. First, it is always very difficult to recruit participants with RW-difficulties for experiments that include a lot of reading and writing. Such tasks are very tiresome for them and they tend to avoid 'unnecessary' reading and writing. Thus, we can presume that some of them declined participation already in the initial screening process. Second, concerning the university students, few students with RW-difficulties continue to university studies.

*Procedure: experiment*

The participants came to the eye-tracking laboratory at Lund University, were welcomed by the experimental leader and were informed that they were to write two texts (although more detailed instructions would follow immediately before the writing tasks), and read one text on the computer, have a short coffee break, and then take part in an interview. They were also informed that during the writing and the reading we would record their eye, and that we would be happy to answer any questions, but would only give more detailed information on the project afterwards.

To balance for order, half of the participants started with the expository task, and then performed the picture description task, and the other half did the other way around. Between the tasks, the ET equipment was removed, and the participant was allowed to stretch her legs.

In the expository task the participants watched a short film (Berman & Verhoeven 2002), showing various problems from a school day, such as cheating, stealing, and bullying. The participants were then asked to write an essay on a computer where they discussed possible reasons and solutions to the problems in the film. They were told to write for 30 minutes and were informed when 5 minutes remained[1]. However, no participant who needed more time to finish his or her text was ever prevented from doing so. In the

[1]The elicitation of the expository task followed the lines of the Spencer project (cf. Berman & Verhoeven 2002).

picture description task the participants were shown a picture, which they were asked to look at and describe in writing on a computer. They were told to write for 30 minutes and were informed when 5 minutes remained. Again we did not prevent anyone who needed more time from finishing his or her text.

After the two writing tasks the participants were asked to read a text on a computer screen. The text was an expository text produced in an earlier, pilot experiment, which discussed the same topics as in the expository task. Hereafter the participants had a break with fruit refreshments.

After this, the university students with no RW-difficulties performed a retrospective of the last text they wrote, i.e., half of the group made a retrospective of their expository texts, half of them of the picture description. The participant and the experiment leader sat together in front of a computer watching the MPEG-movie with the overlaid circle indicating the gaze. The participants were told that they would now watch a recording of their just finished writing session, and that the experiment leader would like to be guided through the writing session by the participant in ways of what she thought about and what choices she made during the writing session. The retrospectives were audio-recorded with dat-tapes.

Finally, all participants took part in a literacy questionnaire. The questionnaire asked questions about their reading and writing habits outside studying or work. We asked about newspaper reading (in paper and on the internet), about the numbers of books they had at home, what their favourite books were, and whether or not they sometimes read aloud to somebody. Further, we took the opportunity to check which language(s) the participants used an ordinary day. We also aimed at finding the socio-economic status by asking about the parents' education and profession.

Additionally, the questionnaire included a few control questions on whether the participants recognized the picture used for the description task, and – in that case – whether they were familiar with the story behind the picture (i.e. to exclude that possible narratives elicited from the picture was the result of the participant already knowing the story). Some other control questions checked whether the participants had perceived the content of the text used for the reading task (i.e. to exclude the possibility that the participant had just skimmed through the text, without understanding it). The answers to the questionnaire were audio-recorded with analogue tapes.



*Data analysis*

Data analyses on reading activity during writing can be performed if we know when a writer pauses, looks at the monitor and reads her own emerging text. To analyze writing data synchronized with eye data the software *TimeLine* was developed (Andersson et al 2006). *TimeLine* combines *ScriptLog* and ET data, and outputs a graphical representation of the temporal distribution of what the writers look at during the writing process, as well as of the keyboard usage. *TimeLine* further presents the possibility to perform analyses of several unique planes. In this study we had defined the planes *keyboard*, *monitor*, *picture* and *elsewhere*. Alongside with an overview of when a writer looked at a certain plane, *TimeLine* also summarizes what the writer looks at while performing different types of keystroke events (e.g. lower case letters, numerical keys, backspaces, cursor keys, etc).

However, to know when reading actually takes place, the eye movements on the monitor have to be recorded and evaluated. For this purpose, we have used a reading filter that can be trained to automatically detect reading activity based on fixation-saccade sequences with a hidden Markov model (Kollmorgen & Holmqvist, to appear).

A graphical *TimeLine* sheet of the eye data and writing activity, with regular forward reading activity included, is shown in Figure 3.

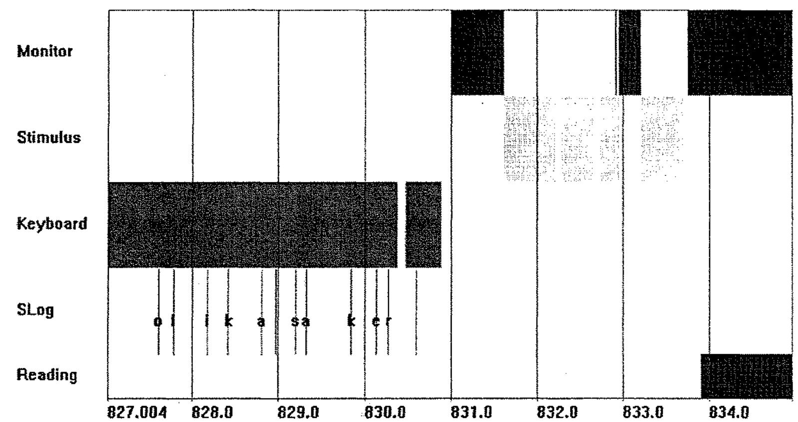


**Figure 3.** Graphical example of a *TimeLine* sheet. It shows if and when (time in seconds at the bottom) the participant looks at the monitor, the keyboard or the Stimulus (the picture). The Slog tier shows the keystroke events of the text production, and Reading represents the reading activity of the emerging text.

## Results

In this paper we present our first analyses of the overall reading activity in the text compositions.

To study the overall reading activity, ANOVAs were conducted with the proportion of regular forward reading due to the overall task time as a dependent variable for all the four groups in both the expository and the picture description task. Additionally, a paired *t*-test for the reading proportion between the two tasks was conducted to test if there were any differences in reading activity between the two text genres.The proportion of regular forward reading in relation to all the task time was analyzed as a dependent variable between the four groups both in the expository task and in the picture description task.

The average results indicated that in the expository task the university students without RW-difficulties spent most time reading their own text, then followed by the 15-year-olds without RW-difficulties, the university students with RW-difficulties, and finally the 15-year-olds with RW-difficulties spent the least time reading their own text (see Figure 4 and Table 1).

No significant main effect was found for either age or skill in this task (although very close, $p = 0.062$). However, as already mentioned, the groups with RW-differences are rather small, which most likely did affect the outcome. Therefore, separate group comparisons were also analyzed showing a significant difference between the 15-year-olds with RW-difficulties and the university students without RW-differences, $F(1,38) = 4.843$, $p = 0.034$, as well as with the 15-year-olds without RW-differences, $F(1,39) = 4.656$, $p = 0.037$. No significant differences were found between the other groups.

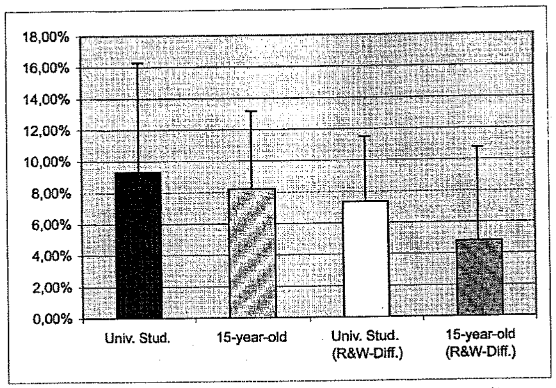


**Figure 4.** Average proportion of reading in the expository task



**Table 1.** Average proportion (in per cent) of reading for all four groups of writers in both writing tasks. The means and standard deviations (within brackets) are given.

| RW / AGE | *No RW-difficulties* | *RW-difficulties* |
|---|---|---|
| *15-year-olds* | Expository: 8.18 (4.96)<br>Pict. Descr: 4.80 (3.35) | Expository: 4.77 (4.09)<br>Pict. Descr: 2.97 (1.95) |
| *University students* | Expository: 9.33 (6.98)<br>Pict. Descr: 6.02 (4.64) | Expository: 7.22 (5.89)<br>Pict. Descr: 5.45 (5.58) |

The average results in the picture description task showed that the university students without RW-difficulties spent most time reading their own text, followed by the university students with RW-difficulties and the 15-year-olds without RW-difficulties. Finally the 15-year-olds with RW-difficulties spent least time reading their own text (see Figure 5 and Table 1).

As in the expository task, no significant main effect was found for either age or skill. The group comparisons, however, revealed a significant difference between the 15-year-olds with RW-difficulties and the university students without RW-difficulties, $F(1,39) = 4,648$, $p = 0.037$. No significant differences were found between the other groups.

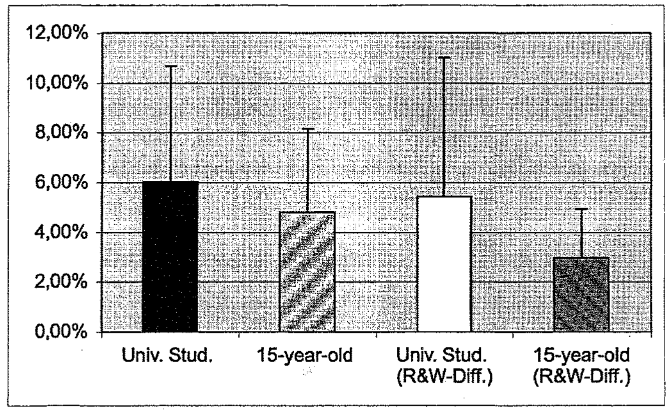


**Figure 5.** Average proportion of reading in the picture description task

A paired *t*-test between the expository task and the picture description task revealed a significant difference ($p < 0.001$) in how much of the total time that was used on reading for the groups without RW-differences (see Table 2). For the groups with RW-difficulties no significant difference was found.

## Discussion

In this paper we investigated how much writers of four different groups read their own emerging texts in two different text genres.

The results indicate that the university students read their own emerging text to a higher extent, and that the reading proportion decreased with both development (age) and skill. However, this difference was only significant between the 15-year-olds with RW-difficulties and the groups without RW-difficulties in the expository task, and between the 15-year-olds with RW-difficulties and the university students without RW-difficulties in the picture description task. A comparison between the two text genres further revealed that for the groups without RW-difficulties the expository text elicited a higher proportion of reading.

The groups with RW-difficulties contain much fewer participants; this is especially true for the university students with RW-difficulties (only 9 participants). The individual variation within this group is also very high. Very little is known about the writing of adults with RW-difficulties at the university level. Our results could be interpreted as if students with RW-difficulties at this level have developed very different heterogeneous strategies to cope with their difficulties.

The problem with on the one hand one small and heterogeneous groups and on the other that the reading proportion did not differ significantly between most of the groups makes the results somewhat weak. However, the most important finding is that the university students without RW-difficulties read their own emerging texts about twice as much as the 15-year-olds with RW-difficulties in both text genres. As the university students were considered to be much more skilled and developed text composers, this result strongly suggests that the reading of one's own ongoing text composition is closely related to high-level cognitive processes, such as planning and revisions of content, organization and structure. An unskilled and less developed text composer would then on the other hand mostly read in relation to lower level processes, like checking for spelling and grammatical errors.



These results gain further support by the fact that the groups without RW-difficulties differed significantly in reading proportion between the two text genres, while the groups with RW-difficulties did not. The proportion of reading was higher in the expository text than in the picture description. An expository text is likely to require more content planning and content revision than a mere descriptive text and would thus also require more reading of one's own text. Observations of the MPEG-movies of the groups without RW-difficulties also confirmed that the picture descriptions were written in a much more linear fashion than the expository texts, which involved much more revisions back and forth in the emerging text.

It could, of course, be argued that this difference is an effect of the fact that the participants have one more thing (i.e., the picture) to look at and consider in the picture description task. While this is probably true to some extent we find it unlikely that this alone explains why the reading proportion is lower in this task. This conclusion is also supported by the result that the reading proportion did not differ between the text genres for the groups with RW-difficulties. If the main part of these groups' reading activity were related to lower level processes (like spelling and grammar) the complexity of the text genre would not affect the reading proportion. The higher demand posed by constructing the expository discourse would thus not elicit more reading for these groups.

### *Advantages and limitations of the data*

Major collections of experimental on-line writing are today rare, and collections of on-line writing by persons with RW-difficulties are even harder to find. Thus, in this respect our data fills an important gap. However, more importantly, the greatest advantage with our data is presumably the combination of data from eye-tracking and keystroke logging, which enhances the possibility of creating a high quality database of synchronized writing and eye movement recordings. This database is – to our knowledge – unique in the world, and provides excellent opportunities to study the writing process as well as the interplay between reading and writing. Furthermore, by using groups with university students and 15-year-olds with and without RW-differences the data can be studied both from a developmental and a skill perspective.

By choosing an ET equipment that allows the writer to move head and body, and a keystroke logging program that is very similar to a regular text editor, the ecological validity of the data is also very high (at least compared to most experimental settings). Moreover, the semi-natural nature of our data – i.e. 'free' (task oriented) text production – provides excellent possibilities of forming hypotheses about writing, which could be tested experimentally in a more controlled setting.

But there are also several limitations with the data. First, as already mentioned, we do not yet know if the established reading definitions can be applied to the reading of one's own emerging text in a relevant way. Second, the explorative and data-driven nature of our data provides not only possibilities but also restrictions. The data is better for generating research questions and hypotheses than for drawing reliable conclusions. Third, the groups with RW-difficulties – especially the group of university students – are rather small and heterogeneous. It is therefore, in many respects, hazardous to generalise the results from these groups.

Fourth, today we lack an analysis tool that automatically outputs exactly those words that the participants focus on for a particular moment. This makes detailed qualitative analyses very difficult and time consuming.

Fifth, are the results from reading one's own emerging text a consequence of its being an *emerging* text, or being one's *own* text? Although it is probable that they are due to the emerging character of the text, we cannot be certain, since we lack data on people reading their own static texts.

Finally, from the data we have also seen that there is an individual variation of typing skill in all groups.

*Future research*

In future analyses we will investigate in detail eye movement characteristics in the reading activity as well as the features of the text production. The reading activity will for example be analyzed with regard to different types of patterns, fixation durations, saccade amplitudes and regressions, and the text production will be analyzed for typing speed, pauses, different categories of keystrokes (e.g. lower case letters, cursor keys, backspaces, etc), text deletions, discourse and quality. These analyses can then, for example, be used to study how the reading activity differs between the reading task and the text composition tasks, how different typing skills affect text production and reading, and detailed characteristics of how development and skill affect the interplay between reading and writing.

In future experiments we will let the participants reread their own texts at a later occasion to find out if the reading result is a consequence of the text being an emerging text, or one's own text.



We will also let the participants take a working memory span test, because some of the results might depend on the individual working memory capacity.

To cope with the individual typing skill, we will in addition measure the participants typing speed before the writing tasks.

Finally, for comparative reasons, we will also include a reading comprehension test.

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