



Keystroke logging in writing research
Observing writing processes with Inputlog

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ISSN 1470 – 9570

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Abstract

Not only has the use of computers as writing instruments had a profound effect on writing practice and attitudes towards writing, it has also created new possibilities for research on writing. In the field of cognitive writing research especially, keystroke logging programs have become very popular. In this paper we describe a logging program called Inputlog. Inputlog 4 consists of four modules: (1) a data collection module that registers digital writing processes on a very detailed level; (2) a data analysis module that offers basic and more advanced analyses (e.g. pause and revision analysis); (3) an integration module that allows data merging between data files from different sources; (4) a play module that enables researchers to review and visualize a writing session including revisions.

In this paper we describe the main functional characteristics of Inputlog 4 and further explain its functionality by presenting three case studies from different research projects: (1) writing processes of novice and professional writers, (2) writing processes in L1 and L2, and (3) writing processes and learning styles.

1. Introduction

In this day and age, researchers make frequent use of keystroke logging tools to describe online writing processes in detail in various research domains: children's writing, professional writing, L1 versus L2 writing (for a review, see Latif 2009; Sullivan & Lindgren 2006). Logging programs enable researchers to accurately register and reconstruct the writing processes of writers who compose texts on the computer (Leijten & Van Waes 2006; Lindgren 2005; Strömquist et al. 2006; Sullivan & Lindgren 2006). The basic concept of the different logging tools that have been developed is more or less comparable. First, the keystroke logging tools register all keystrokes and mouse movements. During the writing process these basic data are stored for later processing. Unlike other methods (e.g. think-aloud protocols) online data collection by keystroke logging tools is relatively non-obtrusive. Therefore, it ensures an ecologically valid research context. At a later stage, the logged data can be made available for further analysis, either within the program environment itself or as

exported data in statistical programs such as SPSS or SAS. Depending on the research question, researchers can choose to analyze different aspects of the writing process and the writing behavior by combining, for instance, temporal data (e.g. time stamps or pauses) with process data (keystrokes or mouse movements), or they can study different aspects of the writing process or writers' behavior by combining temporal data and writing process data for more fine grained analysis (Leijten 2007).

In this article we briefly describe Inputlog, a logging tool for writing process research developed for Windows environments. First, we present the most important characteristics of Inputlog 4.0. Then, to illustrate the program's functionality, we present three case studies from different research projects: (1) writing processes of children and professional writers, (2) writing processes in L1 and L2, and (3) writing processes and learning styles.

2. Inputlog 4.0

Inputlog¹ has been developed since 2003 at the University of Antwerp. The most distinguishing characteristics of Inputlog to date are its word processor independent functionality, the parsing technology, the standard XML structure of the output and the integration of speech recognition (Dragon Naturally Speaking, Nuance).

Inputlog allows researchers to record writing process data, generate various data files, integrate various types of data from other programs and playback the recorded session. In this paragraph we elaborate briefly on the program's main functions. A more detailed description can be found in the Inputlog manual.

2.1 Record a writing session

Inputlog enables researchers to record data of a writing session in Microsoft Word and other Windows based programs (e.g. Internet explorer, Mozilla, Powerpoint, etc.).

¹ Inputlog 4 has been developed by Luuk Van Waes and Mariëlle Leijten. We would like to thank all the programmers who contributed to the program. Inputlog is freely distributed for academic research purposes and can be downloaded from the website: www.inputlog.net. The minimal requirements needed to run the latest version of Inputlog are stated there (see FAQ section).

Inputlog logs every keystroke, every mouse movement and click, and - if available - speech input from Dragon Naturally Speaking. Furthermore, all the windows that the writers opens in different programs, are identified and logged. So, if a writer uses Google when writing a report, Inputlog logs the URL of the web page accessed together with a time. This enables researchers to take writers' search behavior into account (see Case study 3).

Besides these general options for observing the writing process, researchers can opt to use one of the five versions of Inputlog, which differ in the way data are logged.

The basic logging mode enables logging basic data in Microsoft Word or any other Windows application. However, data logged in the 'basic' mode cannot be analyzed in the revision module. Alternatively, researchers can use the Light, Minimal, Plus and Full versions that all log the writing process at a more detailed level, including more formatting characteristics of the text. In these versions, it is possible to conduct a revision analysis (cf. the Inputlog manual).

2.2 Generate data files for statistical, text, pause and mode analyses

In this part of the program, analysis files are generated on the basis of a source file that was recorded in a previous logging session. In other words, any Inputlog Data File (idf file) can be opened at any time to generate data output files for specific analyses. The output files are all XML-based files, which can be converted to Excel files or exported to SPSS for further analyses.

Output	Position	Doc length	Start Time	End Time	Pause Time	Pause Location	X	Y
document1.doc - Microsoft Word			0	0	0	7		
T	2	2	5500	5547	5500	5		
e	3	3	5860	5954	360	1		
s	4	4	6079	6172	219	1		
t	5	5	6485	6579	406	1		
SPACE	6	6	9813	9922	3328	2		
Movement			14297	16282	4484	7	174	893
Left Button			16313	16469	31	2	174	893
Internet Explorer			16313	16313	0	7		
www.google.com			16313	16313	0	7		
u			28907	28985	2063	7		
n			29141	29235	234	1		
i			29407	29469	266	1		
v			29704	29782	297	1		

Figure 1. Example of general file from Inputlog

Inputlog 4.0 offers five different data analyses:

- 1) **General file:** An XML file containing basic logging information of the writing session in which every line represents an input action (keyboard, mouse click or movement and – if present – speech, window information); for every input action the session information is stored together with an identification of the start and end time of the input (key in and key out), the pause time that followed it, and – for a mouse operation – the xy-value of the screen position (see Figure 1).
- 2) **Linear text:** A plain linear text in XML-format containing the complete linear production of the text (keyboard and speech) including mouse movements and pauses. The linear analysis is divided into two options: on the one hand researchers can generate a linear output in which the writing activities are divided into periods (fixed time durations of x seconds, free to choose) or intervals (fixed number of equal timeslots in which the writing process is to be divided) of their choice. In both options the threshold for the pause length can be adapted to meet the requirements of a particular study.
- 3) **Summary data:** An XML file containing basic statistical information of the writing session on a more aggregated level. Several process characteristics are shown, such as the number, mean and standard deviation of characters, words, sentences, and paragraphs produced, pause times (based on the threshold entered in the interface) and the use of the different writing modes.
- 4) **Pause analysis:** An XML file containing analyses of every non-scribal period. The threshold for the pauses can generally be set to 1, 2 or 5 seconds or to any user defined level larger than 1 millisecond. Pause data are generated on a more general level: number of pauses, mean and standard deviation of pause length, and on a more specific interval level in which the writing session is divided into 10 equal timeslots. Finally, pauses are summarized per word, sentence and paragraph location.
- 5) **Revision analysis:** An XML file containing a basic analysis of e.g. the number, the level and the kind of revision that has taken place during the writing session.

To define revisions we have developed an algorithm and a set of rules. The revision analysis first of all defines critical events in the writing process that can be linked to a revision and then evaluates these instances by comparing the operations in the isolated writing episode to the revision rules in the algorithm. Inputlog successively analyses the

beginning of the revision, the selection of the text to revise or the positioning of the cursor, the (possible) deletion of the text and the end of the revision. In the fragment (1) we describe two (technical) revision operations to change the last word of the sentence ‘Questions of science, science and progress’ into ‘evolution’.

(1) *Questions of science, science and [progress.]¹|₁ {evolution.}*

The first operation is a very basic one: the writer simply uses the backspace key at the point of utterance to delete the full stop and the word ‘progress’ and then types the new word ‘evolution’. This is a rather minimal operation, because the writer does not have to move or position the cursor in the text produced so far. However, the writer could also opt for another sequence to realize this substitution: for instance, he can move the mouse to the left, position the cursor by left-clicking the mouse, use the delete key to delete the word, change the text and move to the point of utterance by using arrow keys to the right. In the revision analysis these revisions will be identified identically because the representation represents the same basic text operation; the linear file shows the detailed revision actions.

At the moment the revision analysis of Inputlog calculates: number of revisions, type of revisions, level of revisions, number of words and characters involved in the revision operation, as well as the location of the revisions in relation to the point of utterance.

2.3 Integrate various types of data from other programs

Inputlog’s third tab is *Integrate*. This module allows researchers to merge different XML output files from other logging and observation programs. At present, Inputlog’s output can be integrated with Dragon Naturally Speaking 8.1 and EyeWrite. The integration results in a single XML-file or Excel-file that can be used for further analysis.

2.4 Playback the recorded session at different speeds.

The final tab of the Inputlog interface is the play function. A recorded writing session can be replayed using, the IDF file as a source file. In the basic version of Inputlog researchers can replay the logging file as it was recorded. However, it should be noted

that the screen settings should be exactly the same before and after logging. In the Light, Minimal, Plus and Full versions the text can be replayed in four main windows (1-4; see Figure 2) and a flexible toolbar (5):

1) Text process – top left window (1)

The writing session can be replayed at different speeds. It can be played back exactly as it was recorded (in real time). Since this might take too long the recording can also be replayed at the default speed, during which each interkey interval is limited to 150ms. Finally, users can also replay the session at a percentage of the real time speed or can set each pause to a fixed interval.

2) Revision data – top right window (2)

The revision data is represented in an Excel-like matrix, showing the main characteristics of each revision (revision number, revision type, recursiveness, start time revision, end time revision, nesting depth, pause time before revision, number of characters before revision, number of characters after revision). Besides these fixed variables, researchers can add new variables: e.g., type of error, linguistic category of error, grammatical error, etc. All variables – given and added – can be changed and saved. This creates great flexibility for researchers to analyze the data according to their research question.

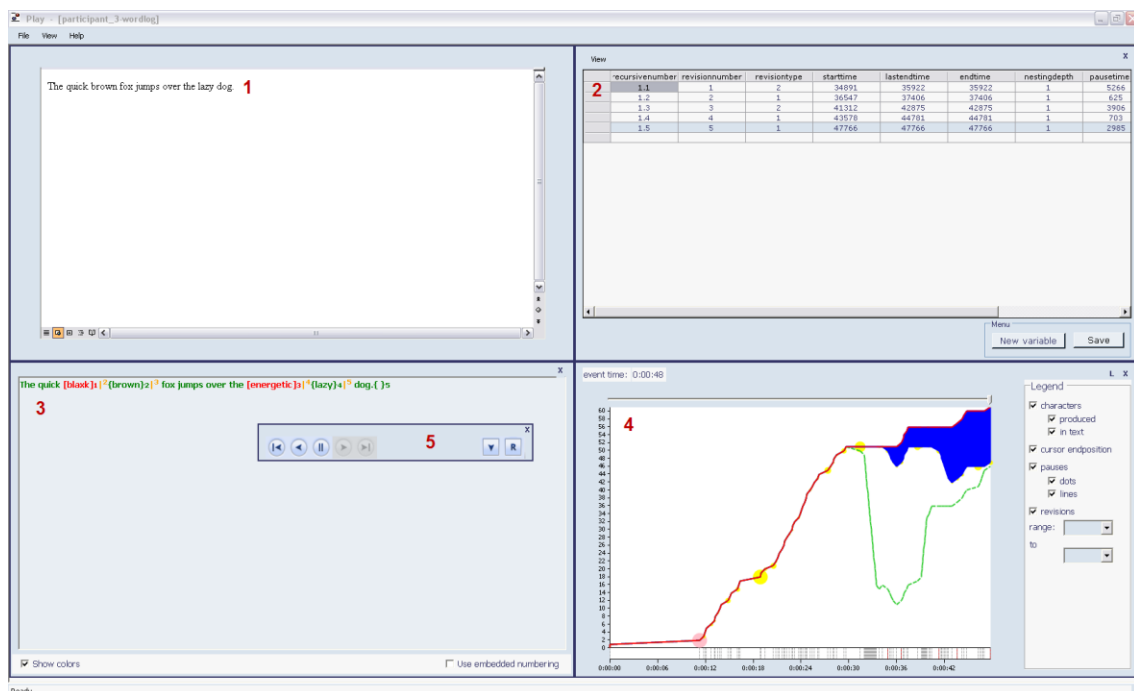


Figure 2. Example of replay full writing process and revisions.

3) **Linear representation** – *bottom left window (3)*

The linear representation of the text is based on the S-notation by Kollberg and Severinsson (Kollberg, 1998; Severinsson Eklundh & Kollberg, 1996). The S-notation has been developed together with Trace-It (Severinsson Eklundh & Kollberg, 1992) and has subsequently been used to describe revision in on-line writing processes (Lindgren & Sullivan, 2006; Severinsson Eklundh & Kollberg, 2003; Sullivan & Lindgren, 2006). An example of S-notation is presented in Fragment 1.

4) **Graphic representation** – *bottom right window (4)*

Finally, we have opted for a graphical representation of the writing process. The graphical representation is a visual representation of the number of characters that are produced and deleted at each moment during the writing process. The cursor position and the pauses longer than a predefined threshold value are also shown. The graphical representation is based on a combination of Perrin's progress analysis (Perrin 2003) and Lindgrens' interactive representation via a Geographical Information System (Lindgren, 2002, 2007).

The x-axis represents the time (in seconds) while the y-axis indicates the number of characters that are produced *cq.* realized effectively in the text produced so far. The top red line indicates total character production including deleted characters at each point in time (cursor end position); the bottom green line indicates the characters retained after deletions at each point in time. So, when the green line drops, a number of characters are deleted. The blue field shows the difference between the characters produced and the characters in the text. The dotted line on the x-axis shows all the points in time at which the writer pauses during text production and the large pauses are represented by yellow circles. The size of each yellow circle indicates the length of the pause.

The red lines on the x-axis represents the location of each revision.

Researchers can generate a graphical representation automatically, but it can also be generated manually based on the revision data. In the next section we describe a case study in which the graphic representation was generated manually to represent differences in the writing process of two writers, a novice and a professional writer.

3. Case studies

In this paragraph we briefly describe three different case studies in order to illustrate the different possibilities to use Inputlog – and keystroke logging in general – to observe and analyze writing processes in different settings. Our first case deals with developmental aspects of writing, comparing the online writing behaviour of a novice and a professional writer. In a second case we focus on the comparison of writing strategies in L1 and L2. In this study keystroke logging was combined with concurrent think-aloud protocols. A last case study describes the observation of writers with different learning styles performing a writing task in an online writing center called Calliope (www.calliope.be).

3.1 Writing processes of novice and professional writers²

As stated before, Inputlog enables researchers to produce a graphical representation of the writing process. We show the possibilities for research with this kind of graphs by presenting a case study from a project that explored the notion of writing development as a gradual process from knowledge telling, through a knowledge transforming phase into a knowledge crafting stage (Kellogg 2008). Awareness of the reader during writing is considered a crucial aspect of successful writing and maturation of the working memory plays an important role in the development of reader awareness. Against this background, various writers, representing different levels of expertise in writing, undertook the same writing tasks.

The study included writers that were assumed to represent different levels of writing experience: knowledge telling (10-year old), knowledge transforming (14-year old) and knowledge crafting (adult professional writer). In this article we show an example of a young girl, aged 10, and a professional writer, aged 34.

One of the writing tasks the writers performed was writing an *instructive text* about ‘How to plant a Bambi bamboo’. The writers were shown a video clip on how to plant and take care of bamboo, and were allowed to watch the video as many times as they wanted. The writing process data were collected using Inputlog 4.0. The process data

² The case study was taken from a study Mariëlle Leijten and Luuk Van Waes conducted together with Eva Lindgren, University of Umeå, Sweden.

illustrates how the text evolves on the screen over time. By analyzing the writing process data we gain more insight into choices the writers make to formulate their text more coherently for their implicit or explicit reader.

As mentioned above, the instructive text the writers had to write was based on a video. In this video we had manipulated some structural elements and the way in which the audience was addressed. This enabled us to analyze how writers with different levels of writing experience deal with these audience related issues.

Figures 3 and 4 show graphical representations of the way the two writers wrote their texts. The graphs show (1) the total text production as a cumulative number of characters produced at different intervals, (2) the actual length of the document at every interval which gradually increases and sometimes decreases when text is deleted, (3) the cursor position as an indication of the (non-)linearity of the process, and finally, (4) the distribution of pauses as dots which relate to the right y-axes. The combination of these pieces of information enables us to describe the specific characteristics of each writing process and relate them to the writer's audience awareness.

Figure 3 shows that Judith's writing process is clearly linear. Her writing process lasts for about 39 minutes and her text gradually grows throughout that period, with only few

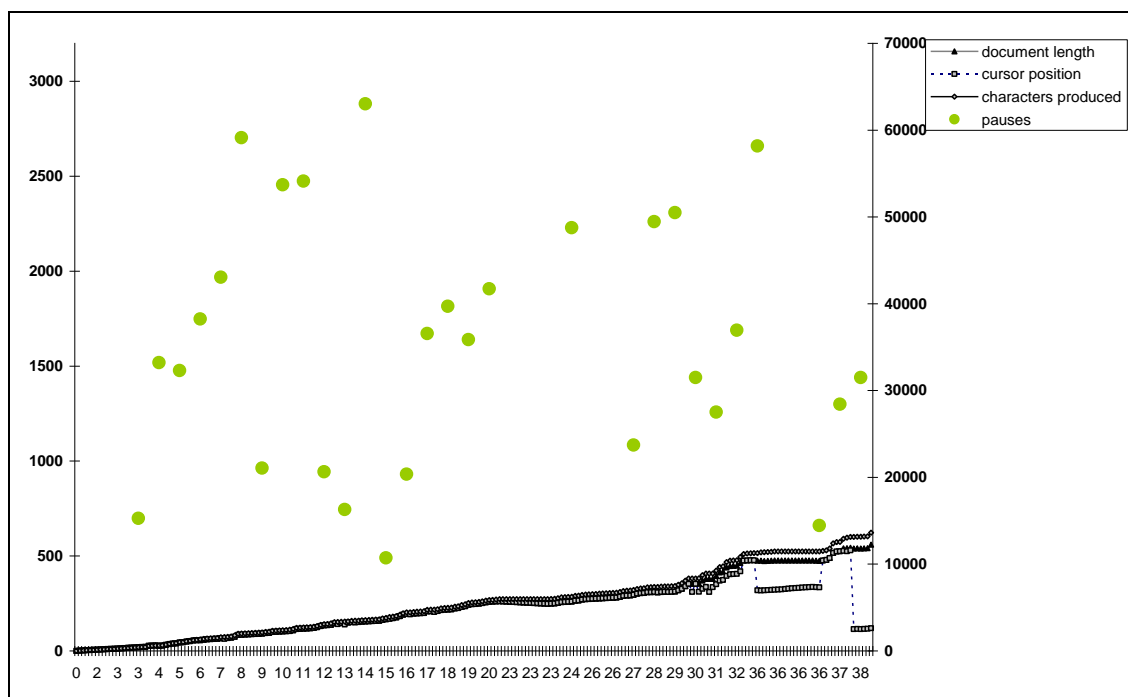


Figure 3: Graphical representation of Judith's writing process (instructional text).

revisions. During the first half hour Judith (10) only revises smaller typing errors. The distribution of the pauses (dots) indicates that she is struggling with the text. The pattern of the dots shows that she produces numerous pauses longer than five seconds during the entire writing session, probably reflecting a strong emphasis on internal text formulating and revision.

In sum, Judith's writing process is characterized by limited interaction between planning and translating, with minimal reviewing, which reflects a knowledge telling strategy, with only limited transformation as compared with the source text.

In Figure 4 Dieter's writing process is shown (professional writer). The first seven minutes of Dieter's writing process are characterized by a fluent and rather linear text production. Dieter starts by creating a skeleton structure and distributes the information presented in the video into these contents categories he himself calls 'structural devices'. He distinguishes two main – user centered - themes in the overall instruction: 1) how to plant a bamboo, and 2) how to care for a bamboo. When he has filled in his 'skeleton', he elaborates the different parts of the text, while relistening to the video in the background. But, as the graph in Figure 4 shows, not necessarily consecutively.

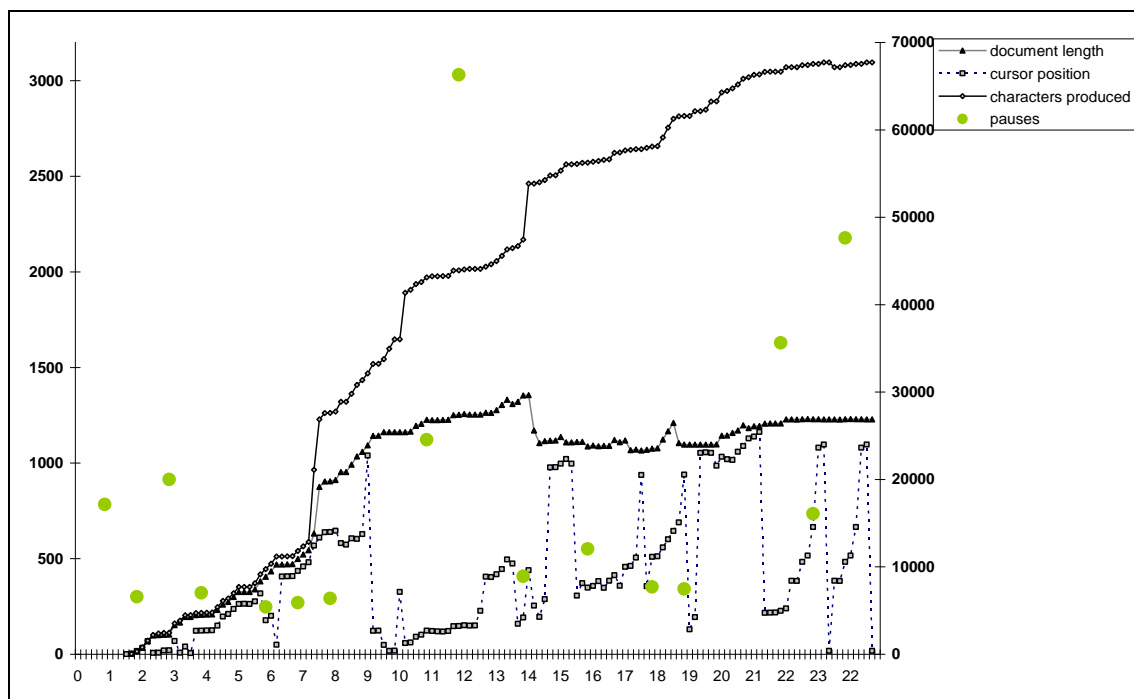


Figure 4: Graphical representation of Dieter's writing process (instructional text).

He is aware of the fact that revision of one part of the text can affect other parts of the text. After about nine minutes a first draft of the text is finished, and he then revises in

four different rounds (9-15; 15-20; 20-the end). Apparently, every round has its own focus, and the rounds gradually become shorter:

9-15	focus on the persuasiveness of the text
15-20	focus on instructive quality (e.g. numbering, parallel phrasing and separating speech acts)
20- the end	focus on stylistic perspective (readability and attractiveness).

In short, Dieter spends about two thirds of his time ‘sculpting’ the content towards the reader’s needs. He frequently produces two versions of a sentence next to each other before he decides which of them is most appropriate. This also explains why his final text only contains half of the words that he produced during the writing session.

The graphical representation of keystroke logging data provides a clear picture of the emerging text. In combination with retrospective interviews the writing processes can be described in great detail and differences between writers and their strategies become apparent (see also Lindgren, 2002).

3.2 Writing processes in L1 and L2

In the past, writing process research has often been carried out using the think-aloud method, first proposed in this field by Flower & Hayes (1980). However, although it proved very useful, the method is far from perfect. Therefore, in recent years thinking aloud has sometimes been combined with other methods such as keystroke logging. One such study, comparing online writing processes in L1 Dutch and L2 English was carried out by Van Weijen (2009a). In this study, think-aloud protocols were generated based on think-aloud and Inputlog data for the L1 and L2 writing processes of 20 student writers (4 protocols each in L1 and L2, N = 160). The analysis focused on a comparison of the orchestration of cognitive activities such as Planning, Generating Ideas and Formulating (cf. Van Weijen 2009a), to determine what the influence was of the language being written in (L1 or L2) on the orchestration of the writing process. Results indicate that, in general, writers varied their writing behaviour less between tasks when writing in L2 than in L1, possibly because an increase in cognitive load inhibits them from doing so (cf. Van Weijen 2009a).

The use of Inputlog (Leijten 2007; Leijten & Van Waes 2006) in Van Weijen’s (2009a) study, made it possible to analyse on-line writing processes in L1 and L2 in far greater

detail than was previously possible (cf. Sullivan & Lindgren 2006). The combination of thinking aloud and detailed keystroke logs enabled the production of richer and more accurate think-aloud protocols than was previously possible based on audio- or video-recordings alone. During the production of the think-aloud protocols, the think-aloud data were transcribed as conceptual activities, while the Inputlog data provided very accurate data on formulating (typing) and revision activities.

To illustrate the way in which the two types of data were combined, Table 1 contains a short example of think-aloud data, from an analysis by Van Weijen (2009a) on the function of thinking-aloud in L1 while writing in L2 (cf. Van Weijen et al. 2009). A number of writers in the study regularly thought aloud in their L1 while writing a text in their L2. Writer 6, for example, wrote a text in L2 on the use of mobile phones in public. Based on her think-aloud data alone, we determined that she used her L1 quite regularly, see for example the segment shown in Table 1. However, based on this input alone, it is nearly impossible to (a) distinguish between what the writer is merely saying, and what she is actually writing down, and (b) determine why she used her L1 at that specific moment during the writing process. Therefore, additional information on this writer's behaviour is needed before conclusions can be drawn.

Thinking aloud	Translation of L1 use
I think it's all about politeness towards other people to call in public (.) or not ehmm but I need another reference (.) ehmmm (...) statictics (.) statistics show (..) that (..) the supermarket is (..) oh no <u>dit is dit is</u> eh hh <u>dat was wel een mooie conclusie eigenlijk</u> ehmm statistics show that supermarkets are (..)	This is this is eh h that was quite a good conclusion actually ehmm

Table 1. Example of L1 use while thinking aloud in L2 (pauses indicated in brackets).

Subsequently, Figure 5, shows the Inputlog data from that same section of the writing process. The data in the table are from the linear file which is split into 5-second intervals (i.e. each row in the table represents 5 seconds of the writing process). This shows that the writer started a new paragraph in interval 342 by pressing the Enter key once. However, after the start of this new paragraph she uses the mouse to select the last sentence and then deletes it (interval 345). Then she uses the arrow keys to move the cursor up 7 lines, placing it above the paragraph she had just completed (interval 346), and presses the Enter key once to start a new paragraph above the previous one. Then

she begins to type the same sentence as before (interval 347). Again, based on the Inputlog data alone, it is impossible to say why she deleted the sentence and moved up a few rows to work on her text in the paragraph above the last one she had just produced (cf. Jakobsen 2005; Wengelin 2006).

337 (1680 - 1684,999 sec.)	I thin
338 (1685 - 1689,999 sec.)	k it's all about poliness
339 (1690 - 1694,999 sec.)	towards other people to cal
340 (1695 - 1699,999 sec.)	l in public or no
341 (1700 - 1704,999 sec.)	t.
342 (1705 - 1709,999 sec.)	[ENTER 1]
343 (1710 - 1714,999 sec.)	Statistics show
344 (1715 - 1719,999 sec.)	that the superm
345 (1720 - 1724,999 sec.)	arket is [MwC.900,703-575,636]
346 (1725 - 1729,999 sec.)	[Mselect] [MwC.209,651-206,647] [BS 1] [UP 1] [UP 1] [UP 1] [UP 1] [UP 1] [UP 1] [UP 1] [UP 1] [UP 1] [ENTER 1] [UP 1]
347 (1730 - 1734,999 sec.)	Statistics show that su
348 (1735 - 1739,999 sec.)	permarkets are

Figure 5. Example of a section of output from an Inputlog Linear File in 5 sec. intervals

However, when the two data sources were combined to form a think-aloud protocol, this provided a clear picture of what had taken place (see Figure 6). First of all, in segment 816, the writer concludes that she needs ‘another reference’, as the assignment requires her to incorporate information from at least two references into her text, and so far she has only used one. Then, she starts a new paragraph (segments 820 – 825), deletes that paragraph and starts a new paragraph above the previous one (segments 833 – 834). But why does she do this? Well, in segments 831 we find the answer, which she provides in L1 Dutch: ‘This is this is ehh that was quite a good conclusion actually’. In other words,

she decided that she liked the sentence produced in segments 812 to 814 so much that she wants to use it as a conclusion for her essay. Why she produces this specific comment in her L1 is uncertain, although it seems likely that she switched to her L1 because she was carrying out a rather complex, higher level revision. This interpretation is supported by multiple other examples of L1 use by the same writer and by other writers in the study (cf. Van Weijen 2009a; Van Weijen et. al. 2009).

Segment	Process	Thinking aloud	Typing/Revising	Pausing
812.	Formulating	I think it's all about politeness towards other people to call in public	I think it's all about poliness towards other people to call in publi	
813.	Pausing			(.)
814.	Formulating	or not	c or not.	
815.	Pausing			ehmm
816.	Self-instruction	but I need another reference		
817.	Pausing			(.) ehmmm (...)
818.	Generating	stastictics		
819.	Pausing			(.)
820.	Revision		[ENTER 1]	
821.	Formulating	statistics show	Statistics show	
822.	Pausing			(..)
823.	Generating	that		
824.	Pausing			(..)
825.	Formulating	the supermarket is	that the supermarket is	
826.	Pausing			(..)
827.	Selfinstruction	oh no dit is		
828.	Revising		[MwC.900,703-575,636] [Mselect] [MwC.209,651-206,647] [selects: Statistics show that the supermarket is] [deletes: Statistics show that the supermarket is BS 1]	
829.	Self-instruction	dit is		
830.	Pausing			ehhh
831.	Metacomment	dat was wel een mooie conclusie eigenlijk	7 x [UP 1] [ENTER 1] [UP 1]	
832.	Pausing			ehmm
833.	Revising	statistics show that supermarkets are	Statistics show that supermarkets are	
834.	Pausing			(..)

Figure 6. Section of a think-aloud protocol, containing input from the think-aloud method and Inputlog data

What we hope to have demonstrated with this example (Figure 7), is that the Inputlog data were necessary to determine what the writer was actually formulating and revising on the computer, while the think-aloud data clarified why she was carrying out the revision she carried out in segment 828. Furthermore, the think-aloud data indicated that she commented on the revision in her L1 instead of in her L2, which would otherwise not have come to light. In other words, the Inputlog data made it possible to ‘fill in the blanks’ in the think-aloud data in great detail, without which the analysis and comparison of writers’ L1 and L2 formulating and revising behaviour would have been impossible.

3.3 Writing processes and learning styles³

The last case study is taken from a research project in which we evaluated a module for writing bad news letters in Calliope, the on-line writing centre of the University of Antwerp (Jacobs et al. 2005). Calliope contains different modules related to business communication in three languages: Dutch, English and French. Each module consists of four inter-linked components: (1) a general introduction, (2) a theory section, (3) a set of exercises, and (4) a case (see also Opdenacker & Van Waes 2007; Opdenacker et al. 2007). Each of these components is linked to the other three, which gives users the opportunity to access them in the order they feel is appropriate. This structure was chosen in order to make the different modules accessible and user-friendly for users with different types of writing profiles (cf. Van Waes & Schellens 2003) or learning styles (cf. Opdenacker & Van Waes, 2007), such as those developed by Kolb (1984): the accommodator, the diverger, the assimilator and the converger (cf. also Opdenacker & Van Waes, 2007: 258-259).

Each of these types usually tackles a new task or deals with new information in a different way. For example, Accommodators prefer to learn-by-doing, and are thus likely to focus on the module’s case or exercises and are less likely to focus on the module’s theoretical information. Assimilators, on the other hand, prefer to focus on

³ The study was part of the QuADEM project (Van Weijen 2009b) that has been funded with support from the European Commission (229759-CP-1-2006-1-BE-MINERVA-M). QuADEM stands for Quality Assessment of Digital Educational Materials. It is a method which aims at facilitating and streamlining the development and review process of digital educational materials in the field of academic and professional writing.

theory and structure first, before putting this new knowledge into practice by carrying out the case. Divergers, generally prefer to look at a new task from several perspectives and gather plenty of information before carrying it out. Therefore, they are likely to spend a lot of time in Calliope gathering information before carrying out the writing task. Finally, Convergers, prefer to solve problems and make decisions by actively searching for a solution, which suggests that they may focus on the case initially, before examining the theory section of the module.

The study from which this case study was taken, was carried out to determine whether the *Bad news letter* module is suitable for students with different learning profiles, and whether students with different learning styles make use of its potential flexibility. Twenty students each completed the module and wrote a bad news letter. Their work processes were recorded with Inputlog 4.0 and with Statcounter^{TM4}. An effect of learning style was found, which suggests that writers with different learning styles tackle the module in different ways.

In this case study we present data from two students with different learning styles, an accommodator and a diverger, who completed the writing task, which was writing a bad news letter, in Dutch, by completing the module related to bad news letters in Calliope. The main aims of the module are to help students learn how to: analyze the context of the bad news that has to be conveyed, choose a suitable structure and strategy for the letter, and write a personal letter which is perfectly suited to the context and the reader's needs. The students have to go over the information in all the Calliope sections and complete the case within a four hour time limit. However, they are free to access the information in the different sections in any order. This is explicitly stated on the module's introduction page, as well as on the first page of the case that had to be completed.

As described above, Inputlog enables us not only to record keystrokes and mouse movements, but also registers which Windows environment is active: either program identification, document identification or URL; see output column in Figure 7). We used this functionality in this study to identify the pages the participants consulted in Calliope, and to count the number of switches they made between the different Calliope sections and the Word document in which they produced their text. We also examined

⁴ Statcounter is an invisible web tracker to develop web stats (www.statcounter.com).

when the different types of switches occurred during the writing process, and *how much time* each writer devoted to each section during the different phases of the writing process. This was done by dividing each writer's total time on task into three parts: beginning, middle, and end. For each part we calculated the percentage of time devoted to each section of the module and text production in Word. This enabled us to determine the characteristics of their writing process in detail, taking into account their interaction with the online learning environment.

Figure 7 (see next page) shows a fragment from the general logging file Inputlog generated for Writer 1. In the output column we see that the writer opens a page in the theory section of Calliope with the information about the *Structure* of a bad news letter. She reads this page for about 25 seconds (cf. StartTime) and then moves on to the page which contains information about the *Subdivisions* in such a letter. After having read this page for about 20 seconds she accesses the empty Word document to type the first word of the letter 'Betreft' [Subject]. However, she makes a typing error (transposition of two letters) which is corrected at the end of the word.

Before we present the case study, we briefly summarize the preliminary results of the study (20 participants). The overall results suggest that on average, Assimilators worked longer on the case than writers with the other three learning styles, generally viewed the highest proportion of pages in Calliope, and also switched most, on average, between Calliope and Word. The results also indicate that, in the beginning, Assimilators (69.67%) and Divergers (59.35%) appear to spend most of their time in the Theory section, while Convergents split their time between the Theory section (41.21%) and the Case (43.58%). We also found an interaction effect between time and learning styles for the Case section ($F(6, 45) = 2.78$; $p < .05$; $\eta^2 = .27$). Thus it appears to be the case that writers with different learning styles interact with Calliope in different ways to a certain extent during the writing process. In other words, the module's users appear to make use of its potential flexibility instead of solely interacting with the module in a more traditional linear way.

Output	Position	Doc length	StartTime	StartClock	EndTime	EndClock	Action Time	Pause Time
Calliope - Slechtnieuwsbrieven - Structuur - Microsoft IE			2157735	00:35:57	2157735	00:35:57	0	0
Movement			2157735	00:35:57	2167750	00:36:07	10015	0
Movement			2169281	00:36:09	2175406	00:36:15	6125	1531
Movement			2180094	00:36:20	2182719	00:36:22	2625	4688
Left Button			2182797	00:36:22	2182922	00:36:22	125	78
Calliope - Slechtnieuwsbrieven - Onderdelen - Microsoft IE			2182797	00:36:22	2182797	00:36:22	0	0
Movement			2182922	00:36:22	2184250	00:36:24	1328	0
Movement			2187813	00:36:27	2188125	00:36:28	312	3563
Movement			2200672	00:36:40	2201922	00:36:41	1250	12547
Left Button			2201985	00:36:41	2202094	00:36:42	109	63
document1.doc - Microsoft Word			2201985	00:36:41	2201985	00:36:41	0	0
Movement			2202110	00:36:42	2202531	00:36:42	421	16
B	2	2	2203500	00:36:43	2203781	00:36:43	281	969
t	3	3	2203797	00:36:43	2203797	00:36:43	0	297
e	4	4	2203797	00:36:43	2203891	00:36:43	94	0
r	5	5	2203875	00:36:43	2203969	00:36:43	94	78
f	6	6	2204031	00:36:44	2204125	00:36:44	94	156
e	7	7	2204094	00:36:44	2204188	00:36:44	94	63
t	8	8	2204219	00:36:44	2204297	00:36:44	78	125
BS	7	7	2204516	00:36:44	2204594	00:36:44	78	297
BS	6	6	2204672	00:36:44	2204750	00:36:44	78	156
BS	5	5	2204813	00:36:44	2204875	00:36:44	62	141
BS	4	4	2204938	00:36:44	2205016	00:36:45	78	125
BS	3	3	2205094	00:36:45	2205188	00:36:45	94	156
BS	2	2	2205297	00:36:45	2205344	00:36:45	47	203
e	3	3	2205781	00:36:45	2205860	00:36:45	79	484
t	4	4	2205844	00:36:45	2205922	00:36:45	78	63
r	5	5	2206000	00:36:46	2206110	00:36:46	110	156
e	6	6	2206078	00:36:46	2206172	00:36:46	94	78
f	7	7	2206156	00:36:46	2206266	00:36:46	110	78
t	8	8	2206328	00:36:46	2206422	00:36:46	94	172

Figure 7. Fragment from the Inputlog general file of Writer 1.

To illustrate these results in more detail and to clarify the methodological approach in this study, we now present some qualitative data of two writers involved in the study: Writer 1, a diverger, and Writer 12, an accommodator. An overview of the main process

characteristics for these two writers is presented in Table 2, while an overview of how they split their time between the different sections during the three phases of the writing process is presented in Table 3.

The results in Table 2 indicate that, in addition to their learning styles, the two writers differ on a number of other criteria, such as time on task and proportion of pages in Calliope that they viewed. Writer 1 took nearly two hours to complete her bad news letter. During that time she spent a higher percentage of time in Calliope than in Word and viewed about 85% of the pages in the Calliope module. While working in Calliope, she focused mainly on the Theory section, and far less on the Case. Writer 12, on the other hand, took only one hour and 16 minutes to complete her bad news letter. She spent most of her time in Word rather than in Calliope, and only looked at around 41% of its content. Furthermore, she devoted her time in Calliope almost exclusively to the Case section, and paid very little attention to the Theory section.

Criterion	Mean (sd) N = 20	PP 1	PP 12
Learning style (Kolb)	n.a.	Diverger	Accommodator
Time on task (minutes)	117.5 min (25.74)	114.95 min	76.79 min
Proportion of pages viewed (total pages in module = 42)	82% (13)	85.37%	41.46%
Number of switches between Calliope and Word	321 (110)	272	162
Proportion of time spent in Word	44.8% (8.1)	46.70%	59.40%
Proportion of time spent in Calliope (overall)	53.5% (8.4)	51.40%	39.90%
Theory	44.2% (10)	56.90%	18.50%
Exercises	11.9% (7.6)	4.20%	0.0%
Case	43.9% (13.1)	38.90%	81.50%
Word count final essay	311.45 (72.92)	347 words	364 words

Table 2. Overview of mean scores and ranges for several process characteristics

The results in Table 2 show that the differences between the two writers are most apparent in the beginning of the writing process. In the first phase of the writing process, Writer 1 spends most of her time in the Theory section (73%), and delays working in Word until the second phase of the writing process. By contrast, Writer 12 spends relatively little time in the Theory section (less than 20%), and only does so in the first phase of the writing process. She focuses far more on the Case and on working in Word, in all three phases of the writing process. Thus these two writers appear to

have taken opposing approaches to interacting with the Bad news letter module during the writing process.

The fact that Writer 12 spent so much of her time in the Case section might be related to her learning profile. She is an Accommodator, a learning type which is known to prefer learning through experience, which might be the reason why she hardly paid any attention to the Theory section, but started with the writing task fairly quickly. This is also confirmed by the fact that she started writing her letter roughly 15 minutes after the start of the task, while Writer 1, a Diverger, spent roughly 35 minutes examining the Theory section before starting her letter. An approach which is also in line with her preferred learning style, as Divergers prefer gathering a lot of relevant information, before carrying out a new task.

Section	Phase	Mean (sd)	PP 1	PP 12
Theory	Beginning	55.40% (17.37)	73 %	20%
	Middle	8.68% (6.15)	1%	0%
	End	7.76% (5.58)	15%	3%
Exercises	Beginning	15.95% (10.28)	6%	0%
	Middle	3.11% (7.07)	0%	0%
	End	0.57% (1.04)	0%	0%
Case	Beginning	22.67% (13.86)	19%	43%
	Middle	30.90% (13.29)	24%	25%
	End	16.56% (7.77)	18%	33%
Word	Beginning	5.97% (9.89)	2%	37%
	Middle	57.31% (15.11)	75%	75%
	End	75.11% (9.75)	68%	64%

Table 3. Proportion of time spent on each section during each phase

In the next stage of this on-going research project we will relate these observations to more product related issues, e.g. by also assessing the quality of the final products. Also, from a more pedagogical perspective, it can be interesting to find out whether forcing students to explore an interaction profile that conflicts with their supposed learning profile might lead to a more explicit awareness of their learning preference.

The detailed process information that Inputlog provides will certainly be very helpful in this research context.

4 Conclusion

In this article we wanted to show how keystroke logging is a valuable method for writing process research. Of course, researchers should take into account that keystroke logging provides a lot of data that need to be carefully analyzed (Spelman Miller & Sullivan, 2006). Therefore, it is important that researchers adapt the output files to provide the correct information to their research question. For instance, determining the adequate pause threshold level is an important issue in writing research and mainly depends on the kind of research question that is focused upon (Barbier & Jullien, 2009; Schilperoord, 2002). For instance, researchers that are interested in high level cognitive processes will often ignore pauses smaller than 2 seconds, while researchers that investigate (ir)regularities in interkey intervals (e.g. Nottbusch et al. 2005) will have a special interest in pauses that are smaller than 200 ms. However, it is certainly one of the main advantages of keystroke logging research that it gives the researcher the flexibility to filter and select data post hoc in line with his or her research objectives.

In our opinion the use of keystroke logging should however not be limited to research. It can also be of great value as a pedagogical tool, because it makes pupils and students aware of the process characteristics of writing (see also Sullivan & Lindgren, 2006). For example, the replay function in keystroke logging programs can be used to elicit certain writing strategies in order to make writers more aware of their own approach to a writing task. If possible this should be done in combination with introspective interviews as a basis for a discussion with peer writers. Having students explain certain revisions and other choices in their text production, will give them the opportunity to get acquainted with diverging problem solving strategies in writing. Also, giving students the opportunity to look at the way in which professional writers develop their ideas while writing and show them their technical and strategic expertise might be a very inspiring activity in a training or educational setting. It goes without saying that these kinds of pedagogical activities in the context of observational learning are very important to complement a more product oriented approach to writing (cf. Braaksma et al. 2004).

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Keywords: Inputlog, keystroke logging, on-line writing processes, pauses, pause analysis, revision analysis, thinking-aloud protocols, cognitive processes, learning styles.