WRITING AND REVISING
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Didactic and Methodological Implications of Keystroke Logging

Eva Lindgren
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PREFACE

The seed that eventually grew into this thesis started to germinate many years ago when I was working as a teacher of music and English at Artediskolan in Norrland. I was puzzled by the fact that my pupils developed their music skills more than their English language skills. At first I explained the difference by motivation; Music as a subject appealed more to the pupils than English. I soon came to realise, though, that the explanation was more complex than that.

Traditionally, in Swedish schools music is taught from the basis of every individual and the next piece a pupil is to learn is slightly more advanced than the previous one. Most teachers of music would also agree that one of the best ways to develop one’s music skills is to play together with those who are just slightly above your own level. I applied these ideas to my music classes, but my English teaching was different. There every pupil used the same material, got the same homework and I expected everyone to answer the same questions. I started to use a more individual-based approach in the English classroom together with more social interaction, which had positive effects on my pupils’ language skills and motivation.

Later I met Py Kollberg and Kirk Sullivan, who directed my didactic interests towards keystroke logging and writing. Kirk then became my supervisor and he has guided me through this project, supported my ideas, critically examined my work and become a very good friend. Kirk has been a most excellent supervisor and he has always made time to read and discuss various issues – over a cup of coffee.

I am grateful to everyone at the Department of Modern Languages who believed in my ideas and gave me the opportunity to explore the intriguing topic ‘writing and revising’. The atmosphere at the Department reflects the generosity of the people who are working there and so many of you have willingly given me of your time to read and comment my work. I thank Pat Poussa, my second supervisor, for careful reading and useful comments, and I am grateful to Ingela and Anders for providing constructive input of how to improve this thesis. Everyone in Paviljongen has made the lunch breaks an event to look forward to and has given me support and cheerful comments when I best needed them.

I have enjoyed the uncountable coffee breaks with my ‘old’ colleagues at the Department of Philosophy and Linguistics with time for laughs as well as serious discussions. I also thank Jan van Doorn for most helpful comments on Kappan.

Writing this thesis has not been a nine-to-five job. At times it has been demanding for people around me, when the computer has constantly been on the kitchen table. My wonderful family has put up with me throughout and never complained. Thank you Urban for your unconditional love and support of every possible aspect of me, my work and our family, and Fanny and Klara for your joyfulness, laughs, hugs and kisses, and for taking my mind off work. My parents, my brother and my mother-in-law, all my good friends and neighbours in Sörbøle, the soup group and all my other friends have always been there, even when I drifted away into writing.

Finally, I thank the writers who patiently wrote all the texts for me and their teachers and schools for supporting the project. I hope the results of this thesis will provide both teachers and learners with concrete ideas that they can apply to their own writing and language classrooms.

LIST OF PAPERS


VII. Lindgren, E. (submitted). Promoting individualisation and reflection in EFL Writing
1. INTRODUCTION

In research on first (L1) and second (L2) language writing processes, computer key-
stroke logging can be used as an objective data-collection method (see Severinson
Eklundh & Kollberg, 1996a; Strömqvist & Malmsten, 1998; Leijten & Van Waes,
2004). Keystroke logging records writing sessions and stores accurate and detailed
information about time and occurrence of every keystroke in a log file; it registers
traces of cognitive activity during on-line writing. Planning and revision of writing
can be reflected as pauses, changes and movements in the text. In order to gain more
information about writers’ motivation from these traces, additional data collection
methods can be used. Keystroke-logging programs include a replay function, which
allows retrospective analysis of or reflection on text evolution. This thesis argues
and demonstrates that watching a text unfold can provide useful insights into writing
development and that it can be used didactically to assist writers in developing their
writing and language skills.

2. BACKGROUND

English is a core subject of the Swedish compulsory school curriculum (LPO-94,
2001). In most schools English is taught from school year one with the primary aim
of “developing an all-round communicative ability” (Syllabuses for the compulsory
school, 2001: 11) in spoken and written English. The syllabus emphasizes that every
school should strive to ensure that all pupils develop their oral skills as well as “their
ability to express themselves with variety and confidence in writing in order to re-
late, describe and explain, as well as give reasons for their views” (p.11). This en-
tails knowledge of how to account for both situation and audience in linguistically
coherent English texts. In order to meet with these goals, pupils need to be provided
with learning methods that assist their development of writing as well as of language
skills.

Indeed, experiences from school have led many people to view writing a cha-
lenging task. Texts should be of good quality, with substantial content, clear struc-
ture, appropriate style and linguistically correct language. Even if writers, when
asked, report that they know all this they cannot always employ their knowledge
sufficiently on task. The cognitive demands of writing can obstruct knowledge re-
trieval and may, for example, result in writers’ not noticing inconsistencies in their
texts in need of revision.

While a text is being produced, writers continuously have to plan, translate (for-
mulate and transcribe text), read and revise in order to create a text that meets with
their goals and intentions (e.g. Flower & Hayes, 1981; Hayes, 1996; Alamargot &
Chanquoy, 2001). During writing, these activities not only interact more or less si-
multaneously but they also trigger one another (Riljaarsdam, Couzijn & Van den
Bergh, 2004). For example, after reading parts of the already written text, inconsis-
tencies can be noticed which result in revision. Reading can also trigger discovery of
new ideas or relationships in the text and result in revision (Hayes, 2004) The revi-
sion may in turn result in a need to plan the following section, in order to fit it in
with the revised text and the planning may in turn result in more revision.
Cognitive processing during writing thus forms a recursive pattern in which the different activities, planning, formulation, transcription, reading and revising interact. These activities can leave traces in the writing process as pauses, revisions and movements.

Taken together, the numerous, detailed and complex traces form a web of interacting events, constructed and constrained by one specific writer under certain specific conditions. The pattern of cognitive processes created during writing may, thus, differ both between writers and within writers, depending on factors such as writing task (Severinson Eklund, 1994), writing medium (Haas, 1996; Van Waes & Schellens, 2003), writing experience (Bereiter & Scardamalia, 1987) and writing language (Silva, 1993; Thorson, 2000; Spelman Miller, 2002). Studies of L1 and L2 writing, for example, have shown that writers tend to revise more frequently (Silva, 1993; Thorson, 2000) and that they tend to employ a form focus on linguistic demands in their L2 (e.g. Broekkamp & Van den Bergh, 1996; New, 1999; Chenoweth & Hayes, 2001).

Overall, writers seem to use similar writing patterns in terms of planning and revising in L1 and L2 (Roca de Larios, Murphy & Marin, 2002). However, when writers start formulating their ideas into linguistically correct L2 text differences between writing languages become apparent. While formulation in the L1 tends to be automatized, items of the L2 that have not yet been automatized have to be actively retrieved from L2 lexicon and grammar (Zimmermann, 2000). As a result, L2 writing fluency can be affected by constant interruptions of the transcription process when writers revise spelling or consider grammatical structures; writers risk losing the thread of the argument (Chenoweth & Hayes, 2001; Ransdell, Arecco & Levy, 2001). In their critical examination of second language writing processes, Roca de Larios et al. (2002) emphasize the need for more studies on the relationship between planning, formulation and revision processes in L2 writing. On the one hand, L2 planning can be restricted by lack of L2 knowledge; writers are likely to avoid plans and ideas they cannot express in their L2 (Roca de Larios et al., 2002). On the other hand, L2 formulation can be affected by planning if writers choose to express their plans, although they lack L2 knowledge. An effect of the latter example can be more extensive revision during formulation, before (Witte, 1987) or after text has been written down.

The complexity of writing not only creates a complex web of interacting cognitive activities, it puts pressure on the writer, the creator of the web. During writing, writers plan content and form, consider audience and style, re-read and revise. If writers are inexperienced and/or are writing in a foreign language, the complexity of the task increases; resulting from lack of automatisation, writers can be implicitly forced to focus their attention and cognitive resources towards some specific aspects of their writing (e.g. McCutchen, 1996, 2000; Graham, Berninger, Abbot, Abbot & Whitaker, 1997; Graham & Harris, 2000). Other aspects would thereby be left unattended to and the quality of the final text could suffer. A raised awareness of which and how processes interact during writing in L1 and L2 could assist writers in reducing cognitive load during writing and, hence, promote writing development.
2.1 Writing development

One major difficulty writers have to struggle with during writing is to distribute their limited cognitive resources between the various constraints of writing (McCutchen, 1996, 2000). Language, topic, content, goals, style and genre are only a few of the items writers need to consider during writing in order to complete a good text (Hayes, 1996; Chenoweth & Hayes, 2001). A strong focus on, for example, FL linguistic demands during writing occupy a large amount of a writer’s working memory resources. As a result, less cognitive capacity is available for higher level processing of, for example, content, audience and style (e.g. Whalen & Ménard, 1995; Schoonen et al., 2003).

Thus, in order to produce as good a text as possible writers need sufficient cognitive capacity during writing to be able to retrieve and juggle both knowledge and writing skills. In a study of young writers, Chanquoy (2001) studied the effect an extra writing opportunity had on revision of content in L1. The results showed that writers revised content more during the second writing session and Chanquoy explains this as a result of reduced cognitive load. During the second writing session, writers could focus their attention towards content issues, as they did not have to produce, plan and transcribe at the same time. This enabled writers to access knowledge about content and incorporate it into their texts.

Successful writing demands both skills and knowledge about writing and a capacity to access them when required. It is possible 1) that writers have sufficient skills and knowledge and can access them, 2) that writers have the knowledge and skills but cannot access them, and 3) that writers do not have sufficient skills or knowledge, yet can access the knowledge they have. For example, up to a certain age, of 12 to 14 years, writers tend to use a knowledge-telling writing strategy; they plan and write their texts in a ‘listwise’ manner and revise mostly form features (Bereiter & Scardamalia, 1987). As long as writers are not yet aware of other writing strategies, such as knowledge transformation, they would not be able to use them either in L1 or in L2.

Thus, in order to develop their writing and language skills, writers need to be provided with a learning environment where the cognitive load affords space enough to notice potential areas of improvement (cf. ‘noticing’ in Schmidt, 1990). If writing and reflection are split into two different sessions writers could focus their attention on reflection and learning without the constraints of writing at the same time.

One learning method that builds on this idea is observational learning (e.g. Braaksma, Van den Bergh, Rijlaarsdam & Couzijn, 2001; Braaksma, Rijlaarsdam & Van den Bergh, 2002; Couzijn & Rijlaarsdam, 2004). Braaksma et al. (2002) used observational learning in argumentative writing. In their study participants, ‘observers’, watched other writers, ‘models’, composing. While watching, the observers noticed, commented and reflected on the model writer’s actions during writing. The observer was provided with on-line writing process input, from which various items could be noticed depending on the focus and level of the learner and the focus and level of the model. Observational learning has been used with positive results in L1 writing studies. It is, however, likely that the method would be equally useful in a more cognitively demanding L2 writing environment.
In order to develop L1 as well as L2 writing, writers need not only to become aware of different writing strategies and linguistic structures, they should also become aware of their own strategy and language usage. Whalen and Ménard (1995), in their study of multiple-level discourse processing in L1 and L2, suggested that in order for writers to develop their L2 writing, their individual cognitive ‘makeup’ has to be taken into consideration. Different writers possess different competences, determined by their “cognitive style, writing experience and personality” (p. 413). The authors emphasised the importance of respecting each learner’s developmental level, the learner’s zone of proximal development (Vygotsky, 1978; cf. ‘readiness’ in L2 acquisition in Pienemann, 1998), when selecting input and instructional method.

One way of targeting the input towards individual learners is to use the learner’s own output, spoken or written, as input (e.g. Swain, 1995, 2000; Rijlaarsdam & Couzijn, 2000). A previously recorded conversation or writing session is replayed as input for the learner. Without having to produce language at the same time, learners can focus their attention on their own production, which enables noticing of L2 or writing features that were unclear during production. These could be indicated in the output as, for example, revisions or pauses.

Once a feature has been noticed “we can analyze it and compare it to what we have noticed on other occasions” (Schmidt, 1990: 132). It becomes available for reflection and discussion. The discussion, i.e. collaboration and social interaction, further strengthens the learning process (Vygotsky, 1978; Fortune & Thorp, 2001) and has been investigated in several L2 learning studies (e.g. Swain & Lapkin, 2001; Kuiken & Vedder, 2002; Malmqvist, forthcoming). It will be demonstrated in this thesis that observation of and reflection on one’s own L1 and EFL writing processes using keystroke logging can reduce cognitive load and provide suitable input of the foreign language as well as of writing per se.

3. KEYSTROKE LOGGING

Over the past two decades keystroke logging has become increasingly used as a research tool to capture and analyse the richness in detail of writing processes and several keystroke logging programs have been developed (e.g. Cederlund & Severinson Eklundh, n.d.; Ransdell, 1990; Van Waes, 1992; Severinson Eklundh & Kollberg, 1996a; Levy, 1994; Strömqvist & Malmsten, 1998; Leijten & Van Waes, 2004).

To writers, most keystroke logging programs appear as word processors that enable writers to work with their texts as they normally would on a computer. At the same time, but invisible to the writers, the programs register the exact occurrence of all keystrokes and all inactivity between them, i.e. all pauses, deletions, insertions and movements during writing. The data is stored in a log file, which can generate automatic analysis of pause length frequency, syntactic location of pauses, insertion and deletions and various time statistics, among other things. Most keystroke logging programs include a replay facility, in which a text can be replayed exactly as it was inscribed (e.g. JEdit in Cederlund & Severinson Eklundh, n.d.; Scriptlog in Strömqvist & Malmsten, 1998 and Inputlog in Leijten & Van Waes, 2004).
The digitalised data in the log files can be used in complementary digital analysis environments, such as Excel for analysis and preparation of log file data (Leijten & Van Waes, 2004), Geographical Information Systems (GIS) for visualisation and analysis of spatial and temporal data (Lindgren & Sullivan, 2002; Lindgren, Sullivan, Lindgren & Spelman Miller, forthcoming), and Trace-it, for detailed revision analysis (Severinson Eklundh & Kollberg, 1996b, 2001; Kollberg, 1998). In order to gain information about the content of a revision or the effect it has on the text, manual analysis is necessary.

To date, keystroke logging has been used both in writing and in translation research. In writing research the method has been used to study, for example, discourse structuring (Severinson Eklundh & Kollberg, 2003), genre effect (e.g. Severinson Eklundh, 1994), writing profiles (e.g. Van Waes & Schellens, 2003), L1 and L2 writing (e.g. Spelman Miller, 2002; Stevenson, Schoonen & de Glopper, submitted; Thorson, 2000; Sullivan, Kollberg & Pålson, 1998), writing development (e.g. Johansson, 2000), dyslexia (e.g. Wengelin, 2002), prefabs in EFL writing (Wiktorson, 2000), and awareness of language and writing (e.g. Sullivan & Lindgren, 2002). In research on translation, keystroke logging has been used as a tool to analyse translation strategies (e.g. Jensen, 1999; Lykke Jakobsen, 1999; Hansen, 2003), the effect of think-aloud protocols on translation strategies (Lykke Jakobsen, 2003), and cognitive processes in translation (Englund Dimitrova, forthcoming).

Provided subjects are familiar with the computer as a writing medium, keystroke logging offers a natural writing environment in which writers can feel comfortable and work undisturbed with their texts. Hence, this method is non-intrusive and non-reactive, and the data obtained in the log files captures exact details of writer’s interaction with the computer. However, keystroke logging cannot give any direct insight into writers’ thought processes.

3.1 Interpreting keystroke logging data

Keystroke logging captures and presents traces of cognitive processes involved in writing in an exact and detailed manner. In a keystroke log, pauses are often indicated in tenth of seconds within brackets, <4.2> and revisions are indicated either as deletions or insertions of text. However, the analysis and interpretation of these traces, represented as pauses and revisions in keystroke log files, is not as clear-cut as they first seem.

A revision, for example, can be undertaken in several ways and is not restricted to already written, i.e. externalised, text. Revision of form as well as of concepts can be revised internally, i.e. in the head of the writer, before any text has been externalised (cf. ‘pre-text revision’ in Witte, 1987). Internal revisions are not visible in a keystroke log file as changes of text, but can appear as pauses. Other revisions are made to partly written words or sentences in the course of writing, when writers decide to reformulate form or concepts they have just transcribed. These revisions are externally undertaken; in a keystroke log file they are represented as deletion at the point of inscription with or without a pause.
Furthermore, revisions can be related to each other in ‘revision episodes’ (Kollberg, 1998; Severinson Eklund & Kollberg, 2003). For example, one revision can trigger revision of another item at another location in the text or revisions can be embedded in a larger revision.

These examples raise important questions about the interpretation of keystroke logging data as representation of cognitive processing. Traces, i.e. pauses, deletions, insertions and movements, can reflect cognitive activities, but their internal structure, interaction and functions are complex and cannot be directly interpreted from the log files. Without additional information, conclusive distinctions between cognitive activities and traces in the log file cannot, currently, be made. However, additional data-collection methods can assist in the interpretation and understanding of traces in log files as representations of cognitive processing.

3.2 Keystroke logging and additional data collection methods

Other data-collection methods than keystroke logging have been used to study the cognitive aspects of the on-line writing process. Examples of such methods are concurrent, think-aloud, protocols (e.g. Flower & Hayes, 1981; Scardamalia & Bereiter, 1983; Breetvelt, Van den Bergh & Rijlaarsdam, 1994), retrospective protocols (e.g. Greene & Higgins, 1994; Di Pardo, 1994), and video recordings (e.g. Matsushashi, 1982).

In recent studies, keystroke logging has been combined with verbal protocols to provide complementary data about cognitive processes reflected in the log files. Think-aloud protocols have been used together with keystroke logging in research on L1 and L2 writing (Stevenson et al., submitted), journalistic writing (Sleurs, Jacobs & Van Waes, 2003) and in research on translation processes (e.g. Jensen, 1999). The validity of concurrent protocols has been criticised for being incomplete, i.e. only revealing items of focal attention and leaving out automated knowledge that is stored in long-term memory (Sleurs et al., 2003), and for being reactive, i.e. the method might actually interfere with the process it is intended to illustrate (Russo, Johnson & Stevens, 1989; Jansen, Van Waes & Van den Bergh, 1996). Despite this, they can, together with the log files, give valuable insights into on-line cognitive processing of writing as well as into interpretation of different revision types.

Stimulated recall (Gass & Mackey, 2002) has been used together with keystroke logging to study cognitive processing involved in translation (Hansen, 1999) and writing at the workplace (Perrin, 2001). Directly following a writing session, the replay function in the keystroke-logging program is used to encourage writers to recall and verbalise their thought processes during writing. The method is non-intrusive and leaves subjects undisturbed during production. Although criticism exists of the reliability of retrospective methods (e.g. Levy, Marek & Lea, 1996), stimulated recall prompted by keystroke logging accounts for three conditions that are considered important for accurate retrospective recall: 1) it follows directly upon the writing session (Greene & Higgins, 1994), 2) it recreates the original writing session by replaying the text (Levy et al., 1996), and 3) it includes carefully chosen prompts when necessary (Greene & Higgins, 1994; Gass & Mackey, 2002).
Sleurs et al. (2003) used triangulation of keystroke logging, concurrent and retrospective protocols in a case study of journalistic writing. As a part of a larger study, one writer’s writing process was examined with a particular focus on preformulations in press-release discourse. Sleurs et al. (2003) concluded that the triangulation of methods provided researchers with a deeper understanding of cognitive processing during writing. Keystroke logging gave an accurate picture of the writing session, the concurrent protocol provided information about the writers’ thought processes during writing that could not be obtained by means of the final text or the log file, and the retrospection which was prompted by the on-line registration gave insights into events that were not verbalised during writing because they were “automated (long-term memory), too obvious to be mentioned or too complicated to reflect upon while working” (Sleurs et al., 2003: 210, note 3).

By combining keystroke logging with additional data-collection methods, new understandings of keystroke data can be gained. However, as additional methods add more information to the vast amount of data in the log files, the complexity of interpretation increases.

3.3 Keystroke logging as a learning tool

Researchers using, or developing keystroke logging software programs, have pointed at the potential advantages of using keystroke logging as an awareness-raising learning tool (e.g. Kollberg, 1998; Ransdell, 1990; Livbjerg & Mees, 1999; Kollberg & Severinson Eklundh, 2001). The replay function and the log files can be used as tools to reflect on writing processes and may “provide insight for the composition instructors and students” (Ransdell, 1990:143). Sullivan et al. (1998) used keystroke logging to study the composition processes of young EFL writers and suggest that the methodology can assist L2 teachers by providing information about students’ “areas of insecurity and security” (p. 22). Thereby teaching could be better targeted towards individual students. However, from the point of view of learners, of foreign languages or of writing, it has remained unclear if, how and to what extent keystroke logging and reflection can enhance awareness of and development in writing and language.

4. AIMS

This thesis investigates how the understanding of keystroke logging data can be developed methodologically and investigates didactically if, how and to what extent keystroke logging can enhance awareness and understanding of cognitive processing during writing.

The aim of Part One (Papers I–III) is to develop new visual presentations of log data and a taxonomy for categorizing revision in on-line writing to enhance the interpretation of computer keystroke logged data.

The aim of Part Two (Papers IV–VII) is to develop and evaluate a didactic approach to in Swedish (L1) and English as a foreign language (EFL) writing using keystroke logging.
The keystroke logging software JEdit has been used throughout this thesis to record writing sessions, provide writing time statistics and to replay writing sessions (Cederlundh & Severinson Eklundh, n.d; Severinson Eklundh & Kollberg, 1996a). JEdit is described in detail in Paper I. The log files from JEdit can be exported to a MID format (Move, Insert, Delete), which opens in the revision analysis program Trace-it (Severinson Eklundh & Kollberg, 1996b; Kollberg, 1998). Trace-it divides the screen into two main windows. In one window all insertions and deletions made during writing can be replayed step-by-step backwards and forwards. The other window presents the entire text in S-notation. S-notation is a notational system that indicates the position where the writer stopped to revise, i.e. delete or insert text and the position where the revision took place. Trace-it further includes statistical information about, for example, revision level, revision order and number of deleted and inserted characters. See Paper I for a description of the MID format and Paper IV for a screen configuration and description of Trace-it. Trace-it has been used in this thesis to replay writing sessions for reflection, for automatic analysis, and in conjunction with JEdit for manual revision analysis of how the revisions affect the text produced thus far.

Stimulated recall was used for two purposes in this thesis: 1) to gain complementary information to that in the keystroke log files about writers’ cognitive activities during writing (Paper III) and 2) to investigate whether the replay of writers’ own keystroke logs can assist in raising writers awareness of writing and language (Papers IV–VII). Immediately after writing, the replay facility in Trace-it (Paper IV) or JEdit (Papers V–VII) was used as a prompt for recall of the writing process. During the recall session writers were induced to talk freely about their thoughts and actions as their text appeared on the screen. A peer and a researcher (the author, who is also a qualified EFL teacher) were present during the replay session. The replay could be stopped if the writer, the peer or the researcher needed time to talk about a specific writing or language event. The role of the peer was to observe and ask questions if anything that appeared on the screen was unclear. The role of the researcher was both to prompt talk when necessary and to provide the students with appropriate focus on form if they requested it (Swain, 1998). Only open prompts were used, such as ‘What are you doing now?’, referring to a pause, cursor movement or revision in the text or ‘Can you talk about that revision?’. If the writers could not recall the item at once, no further questions were asked. In order for recalled items to be considered accurate in the present study, the writer must have recalled them spontaneously or after the researcher’s prompts.

Finally, graphics and Geographical Information Systems (GIS) have been used for visualisation and data mining of writing data collected with JEdit, stimulated recall and manual analysis of revisions and pauses (Papers I–II). A script transforms MID file information into coordinates for each typed character, pause, insertion and deletion. The coordinates are time of occurrence and position, defined by number of typed characters. All the information about pauses, insertions and deletions collected with keystroke logging and additional methods is stored in a database file. From the
database the researcher chooses which information to present, and creates different layers of information that can be displayed simultaneously on the screen. The database further enables data mining of well-known relationships as well as not yet known patterns in the data.

6. PART ONE: ENHANCING AWARENESS OF KEYSTROKE LOGGED DATA AS TRACES OF COGNITIVE ACTIVITY

The primary purpose of Part One is to develop methods for analysis and interpretation of keystroke logging data. The papers in Part One have both didactic and research implications.

The interpretation of keystroke-logged data as representations of cognitive activities has been developed on a holistic as well as on more specific levels. The use of visualisation of the writing process and GIS provide a holistic view of the various traces of the writing process and are presented in Papers I and II. Information from the logs about time and location of actions are coupled with additional information from stimulated recall and manual analysis of pauses and revisions. When presented on the screen, the different information layers afford a visual overview of how the writing session developed and the various actions the writer undertook during text creation. On a more detailed level, the data mining function in GIS provides search facilities for particular occurrences within the writing process and information on the screen is point-and-clickable for access to details in the database.

In Paper III, the understanding of cognitive processing as traces in keystroke logging data is developed through a revision taxonomy for analysis of on-line revision. The taxonomy divides revisions according to their position in the text and whether they affect the text written thus far on a ‘form’ or a ‘conceptual’ level (cf. ‘surface’ and ‘text-base changes’ in Faigley and Witte, 1981). Studies of on-line writing have shown that several revisions occur at the end of the on-going text, at the point of inscription (Matsuhashi, 1987), before a full context has been externalised. In paper III the concept of the ‘pre-contextual’ revision is introduced as revision at the point of inscription. Other revisions, ‘contextual’, occur within a previously written context. In order to establish the effects of pre-contextual revision, i.e. whether they affect the text on both form and conceptual levels, complementary data-collection is needed. Stimulated recall data is used to determine the effect of pre-contextual revisions. In order to further understand cognitive processing at the point of inscription, the paper includes a study in which the effect of writing language (L1 or EFL) and text type (descriptive or argumentative) on pre-contextual revision is examined.

6.1 Summary of Paper I: The LS Graph: a methodology for visualizing writing revision

This paper illustrated the complexity of writing process data analysis and presented a way of graphically representing and summarizing the quantitative data collected with keystroke logging. Automatic data from the keystroke log of when and where
revisions and pauses occurred was coupled with manual analysis of revisions and the results were incorporated into a graphic representation, the LS graph. In the graph, the axes represented time (x-axis) and number of typed character (y-axis), which creates a common frame, in which events can be plotted objectively.

One of the key features of the graph is layering of information of various types. One layer can, for example contain revision information directly generated from the keystroke log file. Another layer can present data coded from a researcher’s manual analysis of the logged data, a retrospective report collected by replaying the writing session in stimulated recall (DiPardo, 1994; Perrin, 2001), or a think-aloud protocol collected simultaneously with the log file.

The example graphs in the paper illustrated how the method can be used in both writing research and writing didactics to locate patterns and compare writing of different genres and between different drafting strategies. The LS graph provides visual information about variation in cognitive processing during writing both within and between writers. It can be used to illustrate, for example, differences in the way a single writer sets about solving different tasks, the differences in the problem-solving approaches taken by two or more writers to a single task, it shows how the way in which writers work to reach their composition goals in their L2 resembles or differs from that taken in their L1, and it illustrates the changes that occur over time as a language learner’s written linguistic competence increases.

Figure 1. A GIS visualisation of an EFL descriptive writing session.
6.2 Summary of Paper II: GIS for writing: applying geographic information systems techniques to data-mine writing’s cognitive processes

Here the method presented in Paper I, the LS graph, was expanded. The paper demonstrated how spatial and temporal information about cognitive activities involved in writing can become available for visualisation as well as for data mining, through the use of Geographical Information Systems (GIS). Data mining is a technique in which large quantities of data can be analysed and explored automatically in order to find meaningful patterns (Berry & Linoff, 1997). Information of various types, collected automatically from keystroke logs as well as from manual analyses of, for example, pauses and revisions, stimulated recall records or think-aloud protocols is stored in a database. The GIS software is then used to create information layers from the information stored in the database. The various layers can be plotted individually or together, allowing visual analysis of data relevant to the researcher. Advanced search functions further facilitate analysis of the interaction of cognitive processes during writing, represented as pause and revision data in the database file. It is, for example, possible to search for a particular revision type, which is preceded by a pause of a particular length or type and followed by another revision. Thus, GIS can be used to explore data, locate patterns, plot them and allow the researcher to point and click to view the underlying data.

In the paper, the method was demonstrated through a step-by-step analysis of one writer’s descriptive EFL text. Automatically retrieved data of time, number of typed characters, pauses and revisions is layered together with manual analysis of a stimulated recall session, manual revision (cf. Paper III) and pause analysis (Spelman Miller, 2002).

Figure 1 illustrates the writing process of an EFL writer’s descriptive text. A search was conducted for conceptual revisions that occurred at the point of inscription in conjunction with a pause of a particular category. One such revision, indicated by the arrow, occurred in the data. The inserted window shows the data stored in the database file about that particular revision, which is generated automatically from the keystroke log as well as from stimulated recall and manual pause and revision analysis. The paper concluded that GIS can assist writing researchers in the understanding of when, where and how various cognitive activities occur and interact during writing. Depending on the data stored in the database, the GIS technique permits analysis of individual writers, differences between writers or of the writing processes in general.

6.3 Summary of Paper III: Analysing on-line revision

This paper presented a theoretical background to revision analysis in general and on-line revision in particular. It discussed the difficulty of analysing revision at the point of inscription and developed a taxonomy for analysis of on-line revision. The paper included an empirical study that assisted in the development of the taxonomy and in the understanding of revision at the point of inscription. In the study, stimulated recall data was coupled with keystroke logging to provide additional information about the function of revisions.
The starting point for the taxonomy was Faigley and Witte’s (1981) notion of ‘surface’ and ‘text-based’ changes as revision of form or concepts. Their taxonomy was developed through analyses of drafts written on paper with different coloured pens, which permitted analysis of the revisions undertaken during a writing session. The methodology did not, however, account for revision undertaken in real time, as the text unfolded. In order to apply Faigley and Witte’s taxonomy to an on-line environment, the proposed taxonomy was divided into two main categories according to the location of the revisions in the text (see Figure 2).

According to the taxonomy, revision occurs within previously written text, ‘Contextual revision’, or at the point of inscription (Matsuhashi, 1987). The point of inscription is the point in the writing where ideas become instantiated as externalised text (cf. ‘the point of instantiation’ in Halliday & Matthiessen, 2004). This revision type was defined as ‘Pre-contextual revision’ and is theoretically framed within Van Gelderen and Oostdam’s model of revision (2004). In order to determine the effect of pre-contextual revision on the text, stimulated recall data was used in conjunction with keystroke logging data. Results showed that pre-contextual revisions affected the text written thus far both on a formal and on a conceptual level.

The category ‘contextual revision’ is divided into two sub-categories: Form and Conceptual. The first category, Form, include revisions that do not affect the content of the text. Form revisions are further defined as ‘conventional’, if the grammar of the language requires the revision, or ‘optional’ if it does not and ‘correct’, ‘erroneous’ or ‘neutral’ according to whether the revision corrects or creates a mistake or does neither (Allal, 2000; Chanquoy, 2001). Conceptual revisions affect the content of the text and include Text-based revision and Balance revision, i.e. style and audience orientation.

![Figure 2. Overview of the revision taxonomy.](image-url)
Research on revision has shown that writers employ different revision strategies depending on, for example, genre and language (e.g. Severinson Eklundh, 1994; Silva, 1993). The empirical study in Paper III investigated the effect of genre and language on pre-contextual revision.

The study included nine 13-year-old native Swedish writers, who wrote descriptive and argumentative texts in L1 and EFL. The results indicated a writing language effect on pre-contextual revision. The writers undertook more pre-contextual revision of both Form and Concepts in the EFL texts than the L1 texts.

In order to account for the different ways of conducting revision, revision episodes (Kollberg, 1998; Severinson Eklundh & Kollberg, 2003) were described and exemplified, and the notion of ‘revision units’, as units of pause/s and revision/s at the point of inscription, was introduced and related to on-line pause analysis and ‘framing devices’ (Spelman Miller, 2002; Spelman Miller, Lindgren & Sullivan, 2004).

7. PART TWO: ENHANCING WRITERS’ AWARENESS OF L1 AND EFL WRITING

In Part One it was demonstrated that keystroke logging, together with additional methods and tools, can assist writing researchers and instructors to develop their understanding of how writers create L1 and EFL texts. In Part Two, the emphasis shifts towards individual writers; Part Two investigates how keystroke logging can enhance writers’ awareness and understanding of L1 and EFL writing and help them to develop their own writing and language skills.

In Papers IV-VII, keystroke logging is used as a didactic tool for writing in L1 and EFL in two exploratory classroom projects. The first project is reported in a case study of four adults who wrote and reflected on EFL texts (Paper IV). The second and larger project included ten 13-year-old participants who wrote and reflected on L1 Swedish and EFL texts. Various aspects of this project are reported in Papers V-VII.

In the second project, a teaching and learning method, Peer-based intervention (PBI) was developed and tested. Writing sessions were recorded using keystroke logging. A stimulated recall session, in which writers replayed the texts and discussed their developments with a peer, followed directly after writing. A teacher was present to provide feedback when requested by the students. Writers then revised their texts on a second writing opportunity. The uptake of PBI was measured by text quality, revision types, and revision frequency. Areas of uptake were further illustrated through comparisons of discussions after the first writing session and revisions undertaken during the second writing sessions. The impact of PBI on text quality and revision in L1 and EFL was assessed through a qualitative case study (Paper V) and through quantitative analysis and statistics (Papers VI and VII).
7.1 Summary of Paper IV: Self-assessment in autonomous computer-aided L2 writing

This paper presented the results of a case study that aimed to investigate the promotion of self-assessment and reflection of writing and language in the adult L2 English classroom. Four adult learners first used a keystroke-logging program to record a writing session in which they wrote descriptive texts in L2. Later, a revision analysis program Trace-it (Severinson Eklundh & Kollberg, 1996b; Kollberg, 1998) was used to replay the entire text production, revision by revision in retrospective stimulated recall sessions. During the replay sessions, the writers reflected on and discussed their texts’ progressions and revisions undertaken during writing.

Results showed that after using the method, all writers experienced useful, although different, insights into their own writing behaviours. One writer focussed the discussion of her text around the content, as several of her revisions were on a content level. Another writer discussed writing strategies, as the replay session made salient her own strategies, which were to revise one paragraph extensively before moving onto the next. She commented that this might not be the best way to go about writing, as too extensive revision at one location could be the reason why she often lost the thread of the argument while writing. During the replay session one writer, who had revised spelling extensively, realised that her strong focus on spelling during writing had drawn her attention away from other aspects of writing.

The paper further included quantitative and qualitative data of pauses and revisions. Pauses were analysed according to frequency and syntactic position in the text: word-internal, between words, between sentences, between paragraphs and according to duration in seconds: 2.00–4.99, 5.00–9.99, 10.00–19.99 and 20.00+. Revisions were analysed according to their effect on the text, and divided into typographical revision, surface revision and text-based revision (see Paper III). These results strengthened the picture from the stimulated recall sessions: that the four writers approached their writing tasks differently. Their diverse foci during writing were reflected in the pause and revision data. The writer with spelling difficulties, for example, paused more extensively than the other writers, particularly within words.

The paper concluded that the method was successful in promoting self-assessment in an L2 environment by raising students’ awareness of their writing strategies as well as of aspects of their L2.

7.2 Summary of Paper V: Stimulated recall as a trigger for increasing noticing and language awareness in the L2 writing classroom: A case study of two young female writers

Building on the experiences from the case study presented in Paper III, the method was expanded into a larger project and applied to younger writers. Ten 13-year-old writers wrote and reflected on L1 and EFL texts. The stimulated recall sessions were prompted by JEdit instead of Trace-it, which made it possible for the writers to reflect on time information and pauses as well as revisions.
In Paper V a case study of two female writers from the project was reported. The study aimed to investigate whether the use of keystroke logging and writing as tools for reflective pair-work could assist in raising learners’ EFL awareness.

The girls wrote two EFL descriptive texts each using JEdit, Text 1 and Text 2. Each text was written in two drafts, ‘Writing day’ and ‘Text-revision day’. After each of the drafts of Text 2 the writing sessions were followed by peer-based stimulated recall sessions, in which the logs were replayed and discussed by the writer and the peer. The logs were thus used as prompts for noticing L2 items (e.g. Schmidt, 1990; Doughty & Williams, 1998; Sharwood Smith, 2000) that the learners would be ready to acquire (cf. ‘readiness’ in Pienemann, 1998). A teacher was present to provide feedback and necessary Focus on Form.

Two independent judges, both experienced EFL teachers, marked the final texts for content, grammar, vocabulary and style. Their judgements were based on the guidelines for the national tests in English for school year nine (for example guidelines see National Tests of Foreign Languages, 2005). All revisions made during the first and the second writing sessions were analysed according to whether they affected the text on a ‘form’ or a ‘conceptual’ level (see Paper III). Particular attention was paid to items that were noticed and discussed on the ‘Writing day’ that resulted in revision on ‘Text-revision day’.

The results showed that, although text quality was not affected, the stimulated recall sessions were awareness raising and also induced the two writers to revise more.

7.3 Paper VI: The uptake of Peer-based intervention in the writing classroom

This paper described a quantitative study of the L1 Swedish writing from the project described in Paper V. The aim of this paper was to examine whether the intervention method PBI could improve young writers’ text quality and enhance awareness of revision in L1 descriptive and argumentative writing.

The ten participants wrote four texts each, two descriptive and two argumentative. As in the case study in Paper V, each text was written on two occasions with or without PBI. A pre-test was used in order to ascertain the writers’ L1 levels. Text quality was judged by two independent judges, who marked the texts for content and language. Their assessments were based on the assessment guidelines for the National school tests in Swedish for school year nine (Kvalitet i elevtext, 2002). All revisions undertaken during writing were analysed according to their effect on the text (see Paper III). Text quality and revisions were further analysed statistically, using Analysis of variance (ANOVA), for effect of PBI, text type, writing day and writer ability.

The results indicated that PBI assisted the writers in improving their texts, but that the effect was clearer for the low-ability writers. After PBI they improved their texts in both the descriptive and argumentative text types, while the high-ability writers only improved their argumentative texts. The low-ability writers also made more revisions of Balance involving style and audience orientation after PBI in both the descriptive and the argumentative texts after PBI. Furthermore, around 30 per-
7.4 Paper VII: Promoting individualisation and reflection in EFL writing

The last paper in the thesis is framed within the need for language teaching and learning methods that account for the emphasis on individualisation and reflection that pervade the Swedish curriculum for the compulsory school.

The paper extended the results from Paper VI by replicating the method and statistical analysis with EFL data from the same project. A descriptive analysis of three writers with different EFL abilities was included to complement the statistical analysis. The aim of the paper was to describe the impact of PBI on EFL learners’ awareness of language and writing features.

The results confirmed the findings in Paper V and VI that PBI can be a useful method to enhance writers’ awareness of language and writing. PBI affected the writers’ revision behaviour in EFL but did not affect their EFL text quality.

The number of revisions of Balance, i.e. audience and style, increased after PBI and this effect varied across EFL ability and text type. High EFL ability writers revised more audience and style in the argumentative text type after PBI while PBI did not seem to affect their revision of Balance in the descriptive texts. The writers with lower EFL abilities revised Balance more in the descriptive texts after PBI. The results further indicated that both high and low EFL ability writers revised more spelling and grammar after PBI and that PBI induced high EFL ability writers to revise content more in their descriptive texts. The descriptive analysis indicated that the effectiveness of PBI not only depended on text type and ability but also on writers’ personalities and attitudes. The role of the teacher in PBI could be developed to better account for various needs different writers’ exhibit.

8. DISCUSSION AND IMPLICATIONS

In this thesis the use of keystroke logging to enhance researchers’ understanding of cognitive processing during writing and to enhance writers’ awareness of cognitive processing and language during writing have been investigated. The main findings are summarised, discussed, and developed in the sub-sections below.

8.1 Studying interacting cognitive activities

A keystroke log file from a thirty-minute writing session can include hundreds of pauses and revisions of different categories. The pauses, deletions, insertions and movements reflect a writer’s cognitive activities during writing and are constrained by, for example, task and writing medium (e.g. Van Waes & Schellens, 2003). Revi-
Revision episodes, for example, can show different patterns depending on task (Severinson Eklundh & Kollberg, 2003) and different pause types are used differently depending on writing language (Spelman Miller, 2002). Furthermore, pauses, deletions and insertions can interact to represent revision activity (Paper III).

Automatic analysis of log files can include time of occurrence, location and length of pauses, insertions or deletions. Results from additional data collection methods, such as concurrent protocols and stimulated recall, as well as from manual analysis, can add further information. Taken together, automatic, manual and additional data become difficult to overview and interpret. If all the data is stored in a database additional tools, such as graphic representations (Paper I) and GIS (Paper II), can be used to visualise, analyse and search for the different aspects of writing processes which have been captured by different analysis methods.

Visual analysis in GIS helps researchers to achieve an overview of one or more writing processes. For example, in the graphic representation, writing fluency during different stages of the writing process can be indicated by the angle of the ‘text length’ curve: the steeper the curve the faster the production of text. Intense cognitive processing can be represented as clusters of pauses and revisions, where writers have elaborated with the text, or by a flat ‘text length’ curve and long pauses where writers have stopped transcription, perhaps to plan or re-read text. Additional information from writers, or manual analysis, would give more details.

One of the useful facilities in GIS is the search function. All the data in the database can be searched and the results are presented in the visualisation on the screen. The areas, lines and dots on the screen are point-and-clickable for rapid access to the information stored about the item in the database. If revisions have been tagged and stored in the database it is, for example, possible to search for pre-contextual revisions that are preceded by a pause longer than five seconds.

Large amounts of data from different writers and different writing sessions can be included in the database and hence become available for data mining. Future studies of writing could use data mining techniques to confirm or contradict well-known patterns of cognitive activities. Individual writers’ different writing patterns could be examined as well as differences between writers. Furthermore, the large amount of data and the data mining functions provide the possibility for researchers to discover unknown patterns in one or more writing sessions. This possibility could be useful in identifying patterns in keystroke logs as representing particular cognitive processing during writing.

8.2 A window on cognitive processing during formulation in L1 and EFL writing

Recursiveness in writing is clearly illustrated by graphic representations in GIS. The ‘text length’ curve shows exactly where the writer is working with every character and whether the writer is working within previously written text or at the point of inscription. Revision undertaken at the point of inscription can be represented as pauses, as pre-contextual revision or as a combination of the two and is illustrated in GIS as revision and/or pause dots on the ‘text length’ line. Pre-contextual revisions function as modifiers of both form and of concepts and are undertaken at a position
in writing when writers are formulating text to be transcribed. Thus, in the course of writing, writers revise spelling and grammar, as well as plans and ideas, with or without pausing.

Pre-contextual revision as a means to shape the text at the point of inscription concurs with Galbraith’s (1999) notion of different writer types: high and low self-monitors. High self-monitors plan extensively before transcription, while low self-monitors plan in the course of writing. These writer types could be reflected in different pre-contextual revision patterns; low self-monitors producing more pre-contextual revisions than high-self monitors, who would more likely pause at the point of inscription. However, there does not seem to be a clear-cut border between these writer categories. Kieft, Rijlaarsdam and Van den Bergh (submitted) found that writers could employ strategies typical from both writer types. Further studies are required to determine whether and how writer type affects pre-contextual revision.

Pre-contextual revision seems to be sensitive to writing language, which indicates that different cognitive processing occurs at the point of inscription depending on whether the writer is writing in a first or a foreign language. Thus, usage and function of pre-contextual revision are language dependent; writers revised more Form and Concepts at the point of inscription in EFL than in L1 (Paper III).

These results partly confirm other L1 and L2 revision studies. The writers in this study revised more in EFL (Silva, 1993; Thorson, 2000) and they revised more on a linguistic level (Broekkamp & Van den Bergh, 1996). Contrary to the study by New (1999), however, the results of the present study did not show that the stronger focus on form, i.e. linguistic demands, in EFL writing prevented the writers from also revising at a conceptual level.

However, there is a possibility that writers’ usage of pre-contextual revision as modifiers of form and concepts differ from revision in general. In the studies above (Silva, 1993; Broekkamp & Van den Bergh, 1996; Thorson, 2000; New, 1999) revision was not restricted to pre-contextual revision but included all revision types. In order to better understand pre-contextual revision and to compare revisions in this thesis with other revision studies of L1 and L2 writing, the same keystroke logging data as that used in Papers I, III, VI and VII was reanalysed.

The study of pre-contextual revision presented in Paper III was complemented with an analysis of the contextual revisions in the same log files. Form and Conceptual revisions in four text types were analysed: Descriptive L1, Descriptive EFL, Argumentative L1 and Argumentative EFL. After analysis the effect of some revisions remained unclear. A total of 811 revisions from thirty-six texts written by nine 13-year-olds are included in the analysis. Typographical revisions and revisions where the writer is playing around with the computer are not included in the analysis. The number of revisions have been normalised by the total number of typed characters in each text.

The texts have been divided according to writing language, L1 or EFL, and text type, descriptive or argumentative. Table 1 shows the descriptive statistics, mean frequency of revisions per 100 typed characters, and standard deviations of the main revision categories ‘form’, ‘concept’ and ‘unclear’ in the four conditions.
Table 1. Frequency of revisions per 100 typed characters according to writing language and text type. Mean and Standard Deviation (in brackets).

<table>
<thead>
<tr>
<th>Text type</th>
<th>Form M (Std)</th>
<th>Conceptual M (Std)</th>
<th>Unclear M (Std)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptive L1 (N=9)</td>
<td>0.81 (0.56)</td>
<td>0.39 (0.22)</td>
<td>0.05 (0.07)</td>
</tr>
<tr>
<td>Descriptive EFL (N=9)</td>
<td>1.63 (0.93)</td>
<td>0.40 (0.32)</td>
<td>0.04 (0.06)</td>
</tr>
<tr>
<td>Argumentative L1 (N=9)</td>
<td>0.89 (0.69)</td>
<td>0.18 (0.13)</td>
<td>0.02 (0.03)</td>
</tr>
<tr>
<td>Argumentative EFL (N=9)</td>
<td>1.50 (1.21)</td>
<td>0.65 (0.48)</td>
<td>0.03 (0.05)</td>
</tr>
</tbody>
</table>

The data was analysed in three separate Repeated measures ANOVAs: one for Form revision, one for Conceptual revision and one for Unclear revisions. Apart from the different dependent variables, the designs were identical. The within subject variables were Text type, with two levels (descriptive and argumentative) and Language, with two levels (L1 and EFL). Significance levels (p-values) and effect sizes ($\eta^2$) are reported in the following discussion.

The results are similar to those presented in Paper III and show that, during writing, the writers revised both Form and Concepts more in EFL than when using L1 ($F_{form} (12.95); p < 0.01; \eta^2_p = 0.56$) and ($F_{Conc} (10.33); p < 0.05; \eta^2_p = 0.62$)). This agrees with results from other revision studies that revision is more frequent in L2 (Silva, 1993; Thorson, 2000). An interacted effect between Language and Text type was found for Conceptual revisions ($F_{Conc} (10.66); p < 0.05; \eta^2_p = 0.57$). In EFL, writers revised more concepts in the argumentative than in the descriptive text type. In L1, writers revised concepts more in the descriptive text type. There was no significant effect of Text Type on Form revisions. No significant effects were found in the Unclear revision design.

These results add more details to, for example, Broekkamp and Van den Bergh’s (1996) and New’s (1999), results, from which they concluded that writers employ a stronger focus on linguistic demands in L2 than in L1. In the present study, the writers revised more forms in EFL, but this did not prevent them from revising on a conceptual level. On the contrary, depending on text type, EFL seemed to trigger conceptual revision.

The fact that the writers revised concepts more in EFL argumentative texts than in descriptive texts can be tentatively explained by the fact that extra-linguistic features such as audience and style become more salient when writers have to address different audiences in EFL. The argumentative text type was a letter intended for an unknown reader, such as the municipality, which required a more formal style. The descriptive texts were addressed to a pen friend of their own age. When writing to someone their own age, writers are more familiar with and culturally aware of which style to employ as well as how to express that style linguistically. Most of the writers in this study are frequent users of the Internet and use EFL to chat with peers
around the world. However, in the argumentative texts, writers might have lacked the sufficient extra-linguistic knowledge of which style to use for the unfamiliar and formal reader. When writers try different options, the insecurity can be reflected as conceptual revision. The final texts, in both L1 and EFL, showed that the writers were aware of and had accounted for the different audiences.

The result that conceptual revision is more frequent in L1 descriptive texts than in L1 argumentative texts is surprising. One explanation is that in L1, the writers were more familiar with the argumentative than descriptive text types and could easily access the knowledge necessary for the task. However, considering their age, 13 years old, this seems unlikely.

Another explanation for the difference could be that in the argumentative texts, writers used more advanced vocabulary and more syntactically complex structures, which could have resulted in a stronger focus on spelling, grammar and vocabulary at the expense of conceptual issues. This is, however, not confirmed in the statistical analysis by more Form revisions in the argumentative L1 texts. It is possible, though, that writers compensated the complexity in the argumentative text with more time on task, producing longer or more frequent pauses than in the descriptive texts. In a study of revision, Piolat, Roussey, Olive and Amada (2004) found that writers needed more time to undertake higher level processing. By using more time writers could draw on their knowledge of writing as well as of linguistic and extra-linguistic knowledge without loosing focus on goals and plans.

The results indicate that revision in general and pre-contextual revision in particular reflect writers’ different cognitive processing during writing, triggered by text type and writing language. The next section will discuss how writers’ cognitive processing during writing triggers noticing during replay of the text.

8.3 Noticing form and concepts

Each writing session described in the previous section was followed by a stimulated recall session (see Papers V-VII) in which the texts were replayed as stimulus for discussion. In order to study which items writers noticed and recalled in the replay sessions the data from the previous section was further analysed.

<table>
<thead>
<tr>
<th>Text type</th>
<th>Form M (Std)</th>
<th>Conceptual M (Std)</th>
<th>Unclear M (Std)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptive L1 (N=9)</td>
<td>0.56 (0.55)</td>
<td>0.30 (0.24)</td>
<td>0.05 (0.07)</td>
</tr>
<tr>
<td>Descriptive EFL (N=9)</td>
<td>0.97 (0.76)</td>
<td>0.32 (0.32)</td>
<td>0.04 (0.06)</td>
</tr>
<tr>
<td>Argumentative L1 (N=9)</td>
<td>0.37 (0.31)</td>
<td>0.18 (0.18)</td>
<td>0.02 (0.03)</td>
</tr>
<tr>
<td>Argumentative EFL (N=9)</td>
<td>0.40 (0.25)</td>
<td>0.42 (0.28)</td>
<td>0.03 (0.05)</td>
</tr>
</tbody>
</table>
All revisions in the four texts that were recalled in the stimulated recall sessions were tagged according to whether the writers conducted the revision with the purpose of adjusting form or concept. The purpose behind some revisions remained unclear after the stimulated recall session. The total number of discussed revisions in the four sessions is 348. Table 2 shows the average number of discussed revision per 100 replayed characters in the stimulated recall sessions, divided into the categories ‘form’, ‘conceptual’ and ‘unclear’, according to the writers’ comments.

The data was analysed using repeated measures ANOVAs for the different dependent variables Form, Conceptual and Unclear revisions. The within subject variables were identical in the designs: Text type, with two levels (descriptive and argumentative) and Language, with two levels (L1 and EFL). Significance levels (p-values) and effect sizes (ηp²) are reported in the following discussion.

No significant effects were found in the Unclear revision design. In the Form design, the writers recalled more revisions during replay of the EFL texts than during replay of the L1 texts (F(3.81); p < 0.10; ηp² = 0.32) and the descriptive texts promoted writers to recall more form revisions than the argumentative texts (F(4.26); p < 0.10; ηp² = 0.35). The effect sizes indicate that Text type and Language had similar effects on writers’ recall of Form revisions during the replay sessions and that they account for more than 30 percent each of the variance in number of recalled Form revisions.

In the Conceptual revision design, the results show an effect of Language (F(4.06); p < 0.10; ηp² = 0.34). This effect varies across levels of Text Type (F(7.11); p < 0.05; ηp² = 0.47). In L1, writers’ recalled more conceptual revisions in the descriptive text type. In EFL, on the contrary, more conceptual revisions were recalled in the argumentative texts.

If these results are compared with writers’ revisions patterns during writing (see Table 1 in section 8.2), it seems as if writers’ recall of form and conceptual revision during replay corresponds well with what they revised during writing. During writing, writers revised more form in the EFL texts than the L1 texts, a pattern that was reflected in the stimulated recall sessions. The EFL argumentative texts include more conceptual revisions than the EFL descriptive texts and the L1 descriptive texts included more conceptual revisions than the L1 argumentative texts. These patterns were also reflected in the stimulated recall sessions.

However, in the case of the effect of Text type on recall of Form revisions, a similar relationship with revision during writing could not be found; writers recalled more Form revision during replay of the descriptive texts although these texts did not include significantly more form revisions than the argumentative texts.

In a study of ‘noticing’ in L2 acquisition, Schmidt (1990) argued that ‘task demands’ impacts upon noticing. In the present study ‘task demands’, defined as text type and writing language, affected the level of noticing and recall in the stimulated recall sessions.

The findings of the study presented here need to be replicated in larger studies in order to ascertain the effect of stimulated recall on noticing. Furthermore, these analyses focused on revision during writing and recall of revision in stimulated re-
call sessions. However, during writing, writers processed form and concepts during pauses as well as through revision. In the replay session writers recalled pauses and talked about what they used the pauses for. A complementary study of pauses, similar to the analysis in Paper IV, would provide a more complete picture of writers’ cognitive processing and noticing during writing as well as during stimulated recall.

The case study in Paper IV revealed how writers employed individual foci during writing. The writers’ individual characteristics triggered different cognitive processes that were reflected in their log files as different patterns of pauses and revisions, and noticed by the writers in the replay sessions. One writer, who struggled with the content of the text during writing, produced many pauses. From the log file and the stimulated recall data, this could be interpreted as reflecting cognitive processing of information retrieval from long-term memory. Another writer paused extensively within words, which in her case reflected her spelling problems. During writing she had to interrupt the transcription process in order to retrieve linguistic information. A third writer repeatedly got stuck in her own ideas. This cognitive processing was reflected in the log file as revision episodes within the same paragraph.

This section has illustrated how keystroke logging and stimulated recall can give writers’ insights into their own processing during writing and enhance noticing of forms and concepts. In the next section, the effect of keystroke logging and stimulated recall on awareness and learning will be discussed.

8.4 Awareness of cognitive processing to enhance learning

Peer-based intervention was introduced in this thesis as a possible method for enhancing awareness of cognitive processing during writing through keystroke logging and stimulated recall. PBI focuses on individual learning in a social context (Vygotsky, 1978) and emphasises the importance of a learning environment in which input on the ‘right level’ is coupled with space for reflection, discussion and feedback.

The two case-studies in Paper IV and Paper V illustrated how replay of keystroke logs gave writers insights into their own writing as well as new input from a peer’s writing process. The writers’ individual ‘makeups’ (see Whalen & Ménard, 1995) triggered noticing of different features of which they had not previously been aware. The adult writers in Paper IV brought different issues, cultural, computational or linguistic to the discussion determined by their personal experiences and thus they brought different ways of undertaking the writing task. Furthermore, as observers of a peer’s text evolution on the same topic, the writers in Papers V–VII noticed features that could later be incorporated into their own texts. Thus, replaying the logs provided input by making salient and ‘noticeable’ parts of their own as well as a peer’s writing processes.

In Paper VI and Paper VII the positive results from the case-studies were confirmed in statistical analysis. PBI was tested for its effect on writers’ revision and text quality and whether writer ability impacted on the level of uptake. The results confirmed the findings from the case-studies that the writers’ cognitive ‘makeup’, in
this case linguistic ability, was an important factor in determining the uptake of PBI in both L1 and EFL.

In L1, the writers who scored low on the pre-test improved most in text quality after PBI. They also revised more concepts after PBI, in particular audience orientation. This result is important, considering the fact that during replay, writers recalled and made salient more form than conceptual revisions in their own text (see section 8.3). Thus, writers could have been expected to incorporate more form rather than more conceptual issues into a revised version of their texts. A possible explanation is that the form issues that were recalled had been solved by revision during writing, while the writers had not to the same extent been able to reach a suitable solution of conceptual issues during writing. Further, in PBI writers are provided with input from two replay sessions of the same writing task, their own and a peer’s, and ideas from observing a peer’s writing process can provide useful input for revision.

In EFL, PBI increased writers’ revision of style and audience in particular, but did not affect text quality. In EFL, text type and EFL ability affected the uptake of PBI. High EFL ability writers revised more audience and style after PBI of the argumentative texts while low EFL ability writers revised more after PBI of the descriptive texts.

According to the analysis of the first versions of the PBI texts reported in section 8.2, the argumentative EFL condition induced writers to revise both Form and Concepts more than the other conditions. In the replay sessions of the argumentative EFL texts, reported in section 8.3, writers recalled more conceptual issues than during replay of the descriptive EFL texts. This stronger focus on concepts was, however, not reflected in low-EFL ability writers revised texts (Paper VII). One explanation is that, although a second writing opportunity would release cognitive space for writers to focus on conceptual issues, the EFL might still have been too demanding on working memory to afford space for processing all the conceptual issues that had been discussed.

A suggestion for future studies of PBI is to include other individual characteristics than linguistic ability, such as learner style, personality and background as these factors may also affect the uptake of PBI.

This thesis has shown that PBI has a positive effect on writers’ text quality and awareness of language and writing. The effect differs between writers and is affected by both writing language and text type. Future studies need to disentangle the interacting parts of PBI to better establish their individual effect on the outcome. Studies could, for example, focus on reflection of one’s own vs. a peer’s text process, social interaction vs. replay without discussion and input on the ‘right’ level vs. input from another level.

9. CONCLUSIONS

During writing, complex processing occurs which leaves traces as pauses, revisions and movements. Keystroke logging provides a basis for various analyses of on-line writing processing. The data is, however, difficult to interpret with respect to which and how cognitive processes are represented. Different patterns of pauses, deletions,
insertions and movements represent different cognitive processing, which can vary according to their position in the log file. In order to enhance the understanding of cognitive activity through keystroke logging, the methodology of how to interpret keystroke log files needs to be further developed. By combining keystroke logging with other data collection methods, such as verbal protocols and stimulated recall, complementary information can be obtained about the complex traces in the log files.

In this thesis, keystroke logging, stimulated recall and visualisation have been used as instruments to develop the interpretation of keystroke log files and thus the understanding of cognitive processing during L1 and EFL writing. Stimulated recall provides information about writers’ motives for pausing and revising, and proved useful in revision analysis.

This thesis has demonstrated that keystroke logging and stimulated recall can be used to target and define deletions at the point of inscription, i.e. pre-contextual revisions, as revisions of forms and concepts. Pre-contextual revision indicates a position in the writing where the writer is transforming mental representations into text, i.e. formulating text, and represents a position in the writing process that is particularly sensitive to writing language, according to Roca de Larios et al. (2002).

Studies in this thesis showed that pre-contextual revision was sensitive to writing language. The writers revised more form and concepts at the point of inscription in EFL than in L1, which indicates that the writers processed more form issues during transcription in EFL than in L1. Thus, one particular trace of cognitive activity in the log files, deletions at the point of inscription, has been defined as an important location for cognitive processing during writing. Future studies need to analyse the relationship between pausing and pre-contextual revision and relate this relationship to form and conceptual revision.

This thesis has illustrated how visualisation and data mining based on keystroke logged data can assist in interpreting keystroke log files and enhance the understanding of the cognitive processing of writing. Complex relations of, for example, pauses of a particular length at particular discourse boundaries that occur in conjunction with conceptual pre-contextual revision can be data-mined and visualised. These locations in unfolding discourse can be important indicators of the role of revision in planning. Further research including visualisation and data mining of large amounts of tagged log files could form the basis for an in-depth study of the relationship between planning, transcription and revision in L1 and L2 writing.

Furthermore, a learning method, Peer-based intervention (PBI), has been introduced and examined. Important aspects of PBI are individualised input, cognitive capacity and social interaction. PBI includes writers’ observations of how they undertook a writing task as well as observation of how a peer solved the same task. In stimulated recall sessions based on keystroke logging, writers’ own texts, i.e. output, are used as input, and form the basis for recall and reflection of form as well as conceptual aspects of their writing and language. The results of the studies included in this thesis indicate that PBI can enhance writers’ awareness of language as well as writing features in both L1 and EFL. However, the effect varies both across and within learners. Aspects such as ability, text type and writing language affect the uptake of PBI.
Thus, uptake of PBI as well as writing processes per se is determined by factors such as writing task and writing language. However, these two factors are in turn determined by writers, their knowledge of the task and the language, and influenced by writers’ attitudes towards the task and the writing language. The same writing task could be perceived differently by different writers depending on their individual cognitive ‘makeup’ (Whalen & Ménard, 1995). PBI allows writers to compose and reflect in a highly individualised manner, leaving to the writer and the peer to decide topics for discussion. The method is not restricted to the writing classroom, but is likely to be effective in other learning environments in which reflection forms a central part.

Recently, PBI was used in a pilot study in translation studies at the university level (Deutschmann, Lindgren, Steinvall & Sullivan, 2005). The study included two PBI sessions, one following upon an individual translation session and one following upon a collaborative translation session, and a retrospective questionnaire. The students involved were positive towards using the method and experienced positive effects of PBI on their awareness of both translation strategies and EFL.

In the PBI studies presented here, the teacher interfered as little as possible during the replay sessions. The role of the teacher in PBI is important to consider, in particular in relation to results that indicated that the replay sessions induced writers to focus on a form level rather than on a conceptual level in some of the writing conditions. If these results are confirmed in future studies the conclusion might be drawn that teachers should interfere more during PBI to direct students’ attention towards conceptual issues. The level and type of teacher intervention would, however, have to be considered in relation to the participants and the purpose of the intervention.

This thesis has shown that together with keystroke logging PBI, GIS and pre-contextual revision enhance awareness of writing and language. Visualisation or replay of the writing process not only assist researchers and educators in understanding writing processes, but can also assist writers in developing their own writing skills.

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