Word Processing Software: The Rise of MS Word

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Abstract In the mid-1980s, more than 300 different versions of word processing software existed (Bergin, 2006a, b), but within a decade, Microsoft Word emerged from the pack and became the standard writing tool. MS Word convinced the public to exchange their typewriters for microcomputers with writing software. It gave writing an (inter)face to become familiar with. A new era of literacy had begun and started to shape writing, thinking, design, and communication in its own way. First, we provide an overview of the developments that made MS Word successful and describe in broad terms the core issues of word processing before we look at the functionalities that MS Word offers. Next, we reflect on the importance of research on word processors and show that it has dwindled since the initial wave of studies. Research ceased since the 2000s, even though new technological opportunities to study word processors arrived, such as key logging and screen recording. The report ends at the time when the internet had developed sufficiently to change literacy once more and when word processing had to adapt to the tasks, technologies, and demands of writing for the web or in the web.

Keywords Word processors · Microsoft Word · Inscription · Writing research

1 Overview

This chapter covers the stage in the history of word processing that Bergin (2006a) called the "consolidation phase" (see also Heilmann, "The Beginnings of Word Processing: A Historical Account"). It began with the implementation of Microsoft Word in MAC OS in 1986 and three years later in Microsoft Windows. Both offered

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comfortable window-like operating systems and were tailored to affordable PCs such as the one IBM launched in 1981 (Haigh & Ceruzzi, 2021) or, at the same time, Apple with its II, SE, or Macintosh. The consolidation phase ended around 2006 when Google Docs was launched and a new chapter in word processing as a platform-based technology started (see Rapp et al., "Beyond MS Word: Alternatives and Developments", and Castelló et al., "Synchronous and Asynchronous Collaborative Writing").

Even though word processing for PCs was not a technical or conceptual revolution, as Heilmann ("The Beginnings of Word Processing: A Historical Account") noted, it was a media revolution—at least when its impact on literacy development and writing cultures is considered. The revolutionary act was the rapid and almost complete adoption of word processing as the dominant means of writing in education, sciences, business, and more. Word processing, along with desktop publishing software, marked the end of the age of the letterpress and heralded a new era of literacy (Baron, 2009; Bolter, 1989; Haas, 1989, 1996; Harris, 1985; Heim, 1987; Mahlow & Dale, 2014, Porter, 2002; Reinking et al., 1998).

In this chapter, we look at MS Word as the dominant software in the 1990s and 2000s that, for a long time, has set the agenda for digital writing. Its significance could be compared to that of Henry Ford's "Tin Lizzy" in the 1910s, which is said to have put America on wheels. Similarly, MS Word, along with the Mac and Windows operating systems, put America on screen and made it go digital. The rest of the world followed suit when MS Word internationalized writing by first adapting itself to different languages and then also to other script systems.

After 40 years of development, it is increasingly difficult to characterize or describe MS Word as it covers more changes, additions, and technical adaptations than can be listed or described here. One attempt can be found on Wikipedia at https://en.wikipedia.org/wiki/History_of_Microsoft_Word. In this chapter, in contrast, we restrict ourselves to the downloaded, offline version of MS Word and leave browser-based versions for the following chapter, even if for some questions we had to extend the focus to a longer period of time. Alternatives to MS Word will be covered in Rapp et al. ("Beyond MS Word: Alternatives and Developments").

This contribution also brings up the question of how much we need to know about word processing and exactly what kind of research writing science can and should deliver about it. The technical development of word processors has been addressed in various publications (for example, Baron, 2009; Bergin, 2006a, 2006b; Haigh & Ceruzzi, 2021; Heilmann, 2012), but we know much less about what word processors actually do and how writers use them. Word processors are the white elephant in the living room of the writing sciences. They have continuously changed and integrated many functions without anyone in our disciplines keeping track of it and commenting on its transformations. Today, MS Word and similar processors are virtual hubs for writing technology and keep expanding their functional portfolios in many directions.

For the writing sciences, the word processor is the critical technological element determining what writing is and how literacy develops, particularly in academic domains. Even if "digital writing" is a broader term encompassing many kinds of software for various mobile devices and internet applications (McKee & DeVoss, 2007), the word processor still forms the core element from which all digital writing evolved. We refer to MS Word as the prototype of word processing in spite of the many existing alternatives (see Rapp et al., "Beyond MS Word: Alternatives and Developments"). In this chapter, we will look at word processors from three different angles: (i) from the technological principles of word processing and their meaning for the nature of writing, (ii) from the perspective of technological functionalities and their meaning for the practice of writing, and (iii) from the viewpoint of research and the various attempts to understand digital writing technology.

2 Core Idea of the Technology

2.1 Inscription

In all its versions, writing technology consists of fixing letters, words or symbols on a writing surface, be it a temple wall, papyrus roll, or sheet of paper, with some form of paint or ink (Ong, 1982). This procedure is generally referred to as "inscription" (Bazerman, 2018; Kruse & Rapp, 2023). For alphabetical writing systems, this may be seen as a notation procedure for sounds which allows to reproduce oral language. Lindgren et al. (2019, p. 347) define: "The point of inscription is always the location where the writer is currently producing or deleting text."

If a script was to endure, it had to be fixed permanently; otherwise, like with slates, blackboards, or wax pads, it could be erased and would lose its permanence. Durability and changeability were exclusive attributes of all pre-digital writing technologies. Digital writing did not alter the fact that inscription is a notation procedure for sounds in letters, but it did change the way to make script permanent by storing letters as digital codes which can be flexibly arranged and rearranged on screen as a two-dimensional document. This altered the relation of durability to changeability of script allowing for an easy inscription, deletion, relocation, and recombination of letters and words.

To insert letters, computer designers relied on keyboards similar to those used with teleprinters and type writers. Keys were connected to letters or other symbols which, in turn, had been assigned digital signatures by the ASCII code (American Standard Code for Information Interchange) developed in the early 1960 and revised several times. The original code provided a number and a digital signature to 128 letters and symbols, making them processible by a machine in a standardized way (see: https://en.wikipedia.org/wiki/ASCII). Later standardizations, known as "Unicode," overcame the limitations of its 7-bit design (allowing for up to 128 characters) by extending it to 16 bits and later 32 bits. This made it possible to encode more than 65,000 signs, among them 21,000 Chinese symbols. With the latest 32-bit version, more than four million positions are available, each of which can be defined by a particular symbol (Lobin, 2014). What is essential for writing is that these codes connect the keyboard to a universe of signs ready to be accessed and used in writing.

Any restriction to the Latin alphabet of the early ASCII code was overcome, and all major script systems are now available for word processing.

2.2 Linearization and Formulation

Unlike a picture, where content can be presented simultaneously, language enforces linearity where only one sound can be produced at a time and only one word can be placed in a line of words—never two or more (Kruse & Rapp, 2023). Notably, this is a matter of language, not technology. Writing technology has to model the sequentiality of language and support it. A text can be read in one direction only, and there is a dependency between what is said later from what has been said earlier. Additionally, transitions from one topic to the next must be managed—a task that de Beaugrande (1984) called the creation of a "moving focus." Such a moving focus can be described at the level of idea development (which linguists call "coherence") and at the level of the linguistic connectors and transitional phrases (called "cohesion"). Word processors must support the creation of language and support writers in transforming whatever they want to say into a coherent line of words that others can decode. For this, the string of words must follow a defined order, usually governed by grammar.

Lindgren et al. (2019) distinguish the point of inscription from the "leading edge" of text production as "the point in writing where new meaning is being created." While inscription can be devoted to marginal corrections or revisions, writing at the leading edge relates to the creation of meaning. The activity involved in creating text (oral or written) is traditionally called "formulation" (Kruse & Rapp, 2023; Levelt, 2013; Wrobel, 1997). In writing, formulation is a way of thinking that happens in interaction with the writing tool along the leading edge. Different from speakers, writers can see what they think on the writing surface and can modify, extend, delete, and restructure their thoughts as desired. Formulation is not simply the translation of cognitively generated content into language but the creation and modification of content using a writing tool (Wrobel, 1997, 2002). Word processors, today, support formulation processes through functionalities such as grammar, style and spell checkers, synonym finders, sentence completion apps, and more. They are currently at the edge of creating content, conducting literature searches, proposing formulations, and translating. As Lobin (2014, p. 95) suggested, formulation has become a hybrid activity in which the word processor acts as a co-author.

2.3 Formatting

Writing has always been a graphic venture; not only did the letters need to be designed, but so did the pages that framed the writing. It has always been tied to a two-dimensional way of displaying script, and so has reading as the eye follows the text (see Heilmann, "The Beginnings of Word Processing: A Historical Account"). However, word processor technology reduces text to a one-dimensional line of digital code. Hence, one of the tasks facing developers of word processors was to invent ways of making the stored line of code visible. The formatting instructions are also part of these lines of code, as are all graphic elements and the commands they follow. Two inventions were necessary to provide MS Word with user-friendly ways to make code visible: The first were graphic user interfaces (GUIs) which were programs such as Mac OS or MS Windows, transforming code into a graphic content to be displayed on a screen. The second was the "WYSIWYG" principle, which ensures that the image on the screen matches the image on paper when the line of code is printed out. The WYSIWYG principle mimics the former writing technologies by making the graphic appearance of a text as fixed as inscriptions on paper once were.

2.4 Revision

The relation of fixity and changeability of written text determines the options for revision. In digital writing, text revision has been greatly simplified, where the "delete" button and the "cut" function stand for an unlimited replaceability of any inscribed sign. Even if technically insertion and deletion are basic elements of text production, the boundary between inscription and revision has been blurred by them to such a degree that it is questionable whether this distinction is still meaningful. They are both practiced at the same time and have become inseparable in text production.

Opportunities for revision exist not only at the level of inscription but also at the macro-level of structure and outline. The outline function allows users to shift text blocks or recycle text that has been temporarily removed. Outlines may be adjusted, and hierarchical orders can be altered or adapted easily.

2.5 Networking and Interaction Among Writers

Writers relate to other writers in several ways. Traditionally, quoting other authors was the primary means of interaction and community building among researchers (Hyland, 2000). Also, co-authoring publications was a common way of connecting researchers. Since digital code can be read by all computers with similar operating systems and editor functions, writing in a digital context means not only that the users can interact with their computers, but that computers can communicate with other computers and, in turn, their users. Word processors successively support and enable networking between authors, leading to several forms of collaborative writing. In addition, texts are interconnected in new ways by hyperlinks and web-based publications. Even though intertextuality has always been a principle of academic texts, hyperlinks have simplified these connections and offered new opportunities for intertextuality (see Castelló et al., "Synchronous and Asynchronous Collaborative Writing").

3 Functional Specifications

The following compilation of functionalities contained in MS Word makes no attempt to be complete, nor does it say anything new to readers familiar with word processors. Instead, we seek to demonstrate what difficulties arise when verbalizing what writers can do more or less intuitively with MS Word. MS Word is a universal writing tool designed to suit all purposes of text production in all contexts and domains, and we focus here on what is essential for the writing sciences rather than what is technically possible. Furthermore, we make no distinction between when the respective functionalities were added to MS Word or how they have evolved over time.

3.1 Entering, Editing, and Revising Text

Entering and modifying character strings: The core function of word processors is to produce chains of characters and words. Characters (and other symbols such as numbers, connective signs "&", "+", and punctuation marks) are entered into the system and then graphically displayed on the screen. Each keystroke generates (or better, selects) a letter (for upper cases or special symbols, two or more keys must be pressed simultaneously, as with a traditional typewriter).

Characters, symbols, and signs: An almost unlimited number of signs and script systems are available. Character sizes can vary, and dozens of fonts can be selected. In addition, a wide palette of colours can be used for fonts, graphics, and backgrounds.

Cut, copy, paste, shift, and delete: These are the basic commands that writers have at their disposal to insert, modify, remove, or dislocate letters or words. Letters and words can be marked and then deleted, copied, cut out, and shifted to another part of the text. Also, text from other sources can be imported or vice versa, and existing text can be exported to another document.

Emphasizing, highlighting, and marking: Several modes of highlighting are available, such as bold, underlining, italic, and crossed out. Other textual effects such as shadowed, mirrored, or shining characters can be chosen.

Search and replace: The search and replace function is both a tool for navigation and revision when words need to be exchanged, deleted, or altered.

3.2 Handling and Formatting Documents

Creating files: As letters are not fixed on paper, it was necessary to create "files" as containers for digital code that a computer could transform into visible text. Files were not stored within the word processing program but in the operating system, which also provides the file register and directory. Today's cloud solutions have expanded the memory capacity of computers almost infinitely.

Save, retrieve, and import text files: Any text produced in the computer's working memory can and must be saved as a document if it is to be retrievable. For this purpose, the operating system enables the creation of directories in which a file name can identify the document. Files can be opened and edited at any time. Electronic storage takes a fraction of the space it would take in an analogue environment, with writing and storage taking place on the same device.

Organizing file structures and personal libraries: Even though file structures are not a part of word processors but of the operating system, the creation of consistent file structures is an important part of the digital writing, learning, and working environment.

Document design: MS Word is not only a text creation program but also a layout program, which can assume many functions of formatting text—and there is a wide range to choose from. Automatic word wrapping was one of the first tasks word processors had to solve to arrive at a consistent layout. The typing area can be determined by specifying line spacing, indents, margin sizes, headers and footers, page numbers, etc. The text can be arranged either right-aligned, left-aligned, centred, or arranged in block space. Line spacing and indentations can be generated automatically.

Styles: To make formatting choices in designing a document easier, the function "styles" has been included from which a large number of integrated designs can be selected. A visually represented "styles gallery" of pre-designed formatting choices can be used or different styles can be customized by the user and then included in the gallery.

3.3 Text and Idea Organization

Enumerations, lists, sequences: MS Word offers many ways to organize the linear arrangement of texts that on paper were difficult to implement, such as bullet points, numbered lists including indentation and modified line spacing and tables. Furthermore, genre-specific text templates are available, e.g., for applications, letters, CVs, certificates, reports, invitations, and so on, which, in addition to a sample structure, also offer a plausible layout for the respective task.

Non-linguistic text elements: MS Word provides writers with many graphic elements and symbols that can be placed into the document or used to create visualizations, such as SmartArt in MS Word and PowerPoint. Videos or audio files can also be included in the text and hyperlinks can be inserted. The sole connection between the writing system and printed paper is thus removed in favour of multimedia technology.

3.4 Language and Formulation Support

Language interface: Several language preferences can be chosen at the Windows level. One is the language of the User Interface determining the language of all commands and instructions. A second is the choice of the authoring language which refers to the language that is used for writing and connects to the proofreading services. Over hundred languages and dialects are available for this.

Grammar, spelling, hyphenation, and punctuation: Grammar and spelling services inform the writer by a wave-like underscoring about errors in a defined part of the text. Alternative formulations may be displayed by mouse click. Grammar checkers rely less on grammatical rules but on lists of common linguistic errors. Punctuation, spelling, and hyphenation support is usually included in the grammar checkers. Automatic checking of spelling is done by comparing the input with lists of correctly spelled words and their morphologies. Hyphenation is similarly done with lists of words where the division points are marked and applied when the text approaches the margin.

Support at the word level: Synonyms can be displayed with a mouse click when a word is, and a thesaurus provides directories of common words and expressions.

Sentence completion: Autocompletion and word prediction are mainly used in mobile phones and small or restricted input devices but are now increasingly found in word processors as optional features. They operate based on word frequencies or collocation lists but can also be adapted to individual linguistic preferences.

3.5 Internal and External References

Automatically created tables: Lists of figures or tables can be generated and numbered; page numbers are adjusted automatically.

Footnotes and endnotes: Both can be selected with a mouse click and graphically inserted precisely at the bottom of the page or the end of the text.

Tables of content: Marked chapter headings can be assembled to a table of content with several graphical options for its design.

Hyperlinks: Both, within a document and across documents (provided it owns an URL address) hyperlinks can be arranged.

3.6 Reviewing Features

Tracking changes: Changes can be tracked and marked so that different text versions remain visible.

C*omment function:* The comment function can insert suggestions for improvement and corrections by others remain visible; these can be accepted or rejected individually. Comments can be inserted, answered, accepted, or rejected.

Version control: Different document versions can be compared, and deviations will be highlighted. In earlier versions of MS Word, this could be done when a text was exchanged by e-mail; in online versions, Share Point is used to compare the texts (see Rapp et al., "Beyond MS Word: Alternatives and Developments").

Understanding word processing as a technology needs to refer to the many kinds of actions users can perform. Writing processes are mediated by these technological functions and by the actions they allow or request. Even if many of these activities may concern lower-order processes, enough of them interact with the conceptual, structural, and rhetorical issues of writing or with the social contexts in which it occurs that it seems legitimate to speak of the work processor as a co-author (Lobin, 2014).

4 Research on MS Word and Word Processors

4.1 Technological Research: General Considerations

MS Word and similar word processors determine to a large extent what writing means and how it is done. Accordingly, this should motivate research that includes the technological aspects of word processors. But MS Word is, as we have shown, a complex tool with hundreds of specifications, which makes it a somewhat daunting research prospect. Indeed, there seems to be considerable uneasiness about technological research in writing and how such research should be done.

Although there is a great demand for this research, there are only a few specified methods that would particularly suit a study of word processors. Some basic and obvious questions are: (i) What do writers do in MS Word? (ii) Which functions do they use and which don't they use? (iii) How do they organize the interaction of text input and revision? (iv) What kind of language support are they using? (v) How do writers shuttle between word processors and other tools for translation, literature searches, note taking, feedback, collaboration, etc.? and (vi) How do writers choose their preferred word processors, and what do they think of them?

Such research questions aim to study the quality of word processors as a writing medium that enables writing and sets the limits. It would, at the same time, include the writers as actors relying on and responding to the medium. When the mediating force changes, the writing changes too, has been expressed by Haas (1989). But how can research react to a constant change? The comparability and generalizability of studies referring to technologies at different developmental stadiums must be questioned (Honebein & Reigeluth, 2021). Along with the generalizability, the integration of knowledge in the writing sciences is also in question.

4.2 Comparative Research and Intervention Studies

Historically, the first reaction to the new writing technology was to test it against the traditional one to see whether it led to better papers, made writing more enjoyable, and enriched writing processes in terms, for instance, of more planning or revision. Several reviews of this early research (Bangert-Drowns, 1993; Goldberg et al., 2003; Hawisher, 1986, 1988; Hawisher et al., 1996; Moran, 2003; Selfe, 1999; Susser, 1998) looked at studies comparing the new technology with previous ones. Most of them came from the K-12 context and sought answers to whether schools should switch from handwriting to computers (Bangert-Drowns, 1993). Expressed in terms of impact factors, the results of the meta-analyses were mixed. The impact factors, for instance, of computer writing on the text quality reported from the individual studies ranged from −0.75 to +1.75 (Bangert-Drowns, 1993), which gave a slight edge to positive impact even if reports on negative effects appeared repeatedly. Similarly, Goldberg et al. (2003) found in their meta-analysis that computer writing led to longer and slightly better texts. All in all, a small advantage of word processing over conventional writing can be derived from the comparative literature. From their meta-meta-analysis of writing studies, Graham, Harris & Chambers (2016) even made a substantial recommendation for "evidence-based practice" out of the "use of word processing as a stylus for writing" for students in grades 1 to 12.

Among the studies comparing the digital writing of college students with previous writing technologies, the work of Haas (1989) is instructive, including its programmatic title: "How the writing medium shapes the writing process." Haas restricted her study to the effects of word processor use on planning and compared three conditions of writing: One with paper and pencil, another using a computer only, and finally, a hybrid of the two. All test subjects were equally familiar with the word processor used—Carnegie Mellons's EZ word processor from the user interface "Andrew" which the university had developed in cooperation with IBM. Evaluating think-aloud protocols, her study was able to distinguish between several kinds of planning activities at several stages of the writing process. Protocols were transcribed and then analysed for statements referring to planning activities.

The results of Haas' studies showed a significant difference between the handwriting and the computer condition, but not between any of these two or the hybrid condition. When using word processors, writers planned significantly less before beginning to write, and did significantly less conceptual planning but more local or sequential planning. This effect was the same for experienced and novice writers. This tendency towards less conceptual planning surprised the author, and she speculated about the possible adverse effects of word processing. However, she did not (and certainly could not) consider back then that word processors would develop powerful tools for conceptual and structural planning such as outline functions or other text organizers to make up for the tendency of a shallower way of planning. The study also brings up the question whether planning in digital writing still is the same as in handwriting. Can we assume that Hayes and Flower's (1980) cognitive process theory, on which she relied, still applies to digital writing?

4.3 Widening the Focus to Include Developments and Contexts

During the 2000s, comparative research and intervention studies ceased. Writers now had up to 20 years of experience with computer-based writing, which had changed their attitudes, social practices, writing habits, and more. Qualitative studies, including the writers' personalities and biographies, seemed a more promising way to react to the new technology (Selfe & Hawisher, 2002). One consequence was the choice of single or small case studies to document the individual gain from digital writing (for example, Selfe & Hawisher, 2002).

Hartley (2007) proposed to focus on the *changes* in writing rather than on the writing itself. Treating writing as a fluid activity might bring back the generalizability of the results and account for one of the most salient aspects of today's technologies—its rapid development. In a small-case study, Hartley compared the texts which authors had written over a period of thirty years and showed that despite of considerable changes in working modes, some personal preferences and styles of the professional writers remained stable over time and different technologies.

Additionally, teaching contexts had also changed. Writing courses would move into the computer lab, laptops appeared in the classrooms, LAN and WLAN allowed for networked writing and learning management systems enabled an exchange of papers with more ease than before (see, for instance, Selfe & Hilligoss, 1994). Accordingly, the focus of research started to shift. Digital literacy became a new focus providing access to cultural change in writing and connecting it better with reading. Later in the 2000s, the internet made writing global, and word processors lost ground to browsers, which were the entrance gate to large social networks, new professional environments, sales platforms, digital library services, and search tools (see, for instance, Hawisher & Selfe, 2000).

It became clear that word processors were framed socially, economically, politically, and environmentally and had become part of a more extensive scenery that expanded the boundaries of digital writing. Consequently, evaluative research chose a broader focus for studying the effects of digital writing technologies. Purcell et al. (2013), for instance, surveyed more than 2,400 teachers about their evaluation of digital writing, from which 96% agreed that digital technologies "allow students to share their work with a wider and more varied audience"; 79% agreed that these tools "encourage greater collaboration among students" and 78% agreed that they "encourage student creativity and personal expression." As for disadvantages, 68% noted that digital tools made students more likely "to take shortcuts and not put effort into their writing"; 46% said that "these tools make students more likely to write too fast and be careless," and 40% said that they made students "more likely to use poor spelling and grammar" (although another 38% said they made students less likely to do this). The study of Purcell et al. (2013) suggested that research approaches should not only look at the interior complexity and sophistication of word processors but also at the complex digital and social environments they are part of.

Current research on digital writing similarly has expanded its focus to a broader view on technology, including “technology-based writing instruction” (Limpo et al., 2020; Little et al., 2018), “digital support for academic writing” (Strobl et al., 2019), Writing and digital media (Van Waes et al., 2006), “Digital tools in academic writing” (Schcolnik, 2018), or simply “digital writing” (DeVoss et al., 2010). Word processing has become part of a larger complex of communicative, enabling and educational technologies where it is difficult to single out its influences on writing and the writers.

4.4 Keystroke Logging Studies

New lines of research emerged when technologies for the registration and recording of digital writing processes became available—one was keystroke logging (or “key-logging” in short), and the other was screen capture or screen recording. Both provide insights into what happens during writing, although in different ways.

Eklundh (1994) developed a registry for keylogging activities, which recorded every input by the keyboard and the mouse along with a time stamp in milliseconds. Key logging is perhaps the most direct way of studying writing processes as it records all the commands given to the computer via the keyboard (and mouse) in a separate table. These tables can be processed and evaluated by statistical tools in various ways. Research summaries have been provided by the edited collections of Sullivan and Lindgren (2006) and Lindgren and Sullivan (2019). A profound account of keylogging technology is given by Wengelin & Johansson (“Investigating Writing Processes with Keystroke Logging”).

Keylogging led to various tools for writing research, such as “progression analysis” (Perrin, 2003, 2019), ScriptLog (Strömqvist et al., 2006) or “InputLog” (Leijten & Van Waes, 2013; Van Waes & Leijten, 2006). Keylogging research focused mainly on text progress (fluency), pauses, and revision activities as these variables are what the data reveal most easily. However, it can be connected to many other aspects of writing, provided respective data recording or evaluation measures are included (Wengelin et al., 2019).

Although keylogging produces valuable data to study writing processes, it has some restrictions. Logging data can register mouse clicks but does not cover the functionalities that the mouse addresses, such as changes in format, the opening of tables, creating footnotes, graphical insertions, use of outline generator, or literature management. Since none of these can be represented by keylogging recordings, logging studies were comparatively unsuccessful in assessing the technology of word processors and their various functionalities unless combined with other technologies such as screen recording (for example, Knospe et al., 2019), self-report measures, or eye tracking (Wengelin et al., 2019). Keylogging studies make it possible to assess the following variables:

- *Linearity*: Eklundh (1994), one of the pioneers of keylogging technology, used this technology initially to study the linearity of writing. She referred to any deviation of the generation of text from the final order in which the words appear as "non-linear writing." Even though she recognized non-linear writing as part of the recursivity of text production, she hypothesized that digital writing leads to new ways of non-linear writing. She built on studies by Lutz (1987) and van Waes (1992), who had observed that revision in digital writing was somewhat local in nature, while in her small group research ($n = 5$; four writing tasks), three of the participants were linear writers but changed their style to a more non-linear way of revising with more recursive changes.

- *Pauses*: The idea of studying pauses as an access point to thinking activities during writing has a long tradition (for example, Matsuhashi, 1981; Pianko, 1979). Flower and Hayes (1981) called them "pregnant pauses" to indicate that they are not simply time wasted but used to prepare the next part of the text or revise something already written. In cognitive models of writing, this is called "planning." Wengelin (2006) described a pause as any interruption that takes longer than the time needed to find the next letter. Accordingly, pauses can be classified along their lengths, their frequency, their consequences (resulting in a revision or new text), or their position in the micro context of text production ("within word," "between words," or "between letter and punctuation mark").
- *Revision*: The study of text revision is the most common use of keylogging research, as Eklundh (1994) demonstrated in a study on linearity. In this context, revision means to alter, delete, or replace any letter or word in a text. Revisions can be classified with respect to the time relative to the primary inscription (immediate, delayed, retrospective) or with respect to size (minor or major revisions).
- *Fluency*: Words in speaking and writing do not flow at a constant rate but rather as chunks of words which Chenoweth and Hayes (2001) called "bursts." The bursts of experienced writers are longer than those of inexperienced ones, and those of L1 writers are longer than those of L2 writers. Van Waes and Leijten (2015) showed that by adopting a process perspective fluency should preferably be approached as a multi-faceted concept. They identified four dimensions to describe fluency: (i) production (e.g., characters per minute), (ii) process variance (e.g., the standard deviation in character production during the process), (iii) revision (e.g., product/process ratio), and (iv) pause behaviour (Leijten et al., 2019, p. 72). Fluency can either be captured as a product-related measure (how many words result from writing in a particular time unit) or as a process-related measure (how many words are written down and eventually deleted again) in a specific unit of time.

Keylogging research opens the door to the study of writing processes as they happen in word processors and provides valuable indicators for relevant process parameters of writing, such as linearity, pauses, revision, planning, and fluency, which seem to apply to all forms of writing. If we see inscription as the defining element of writing, then keylogging provides access to the most salient aspect of writing. From there, inferences on the formulation processes and cognitive activities of the writers can be drawn.

4.5 Screen Recording and Screen Capture Technology

Screen recording or screen capture technology is a method that records what can be seen on the screen of the computer used. It runs in the background of the operating system and can record data from word processors or browsers (Geisler & Slattery, 2007; Seror, 2013). The data provided covers everything visible on the screen, such as inscription activities, the use of word processor support functionalities, all windows opened during observed session, all contacts to internal files, web-based sources, and use of tools other than the word processor. Screen recording is a technology applied most often in settings conducting usability research, along with eye-tracking and think-aloud or stimulated-recall assessments (for example, Menges et al., 2018). The primary difference between screen recording and keylogging is that the former does not automatically provide a database but must be evaluated manually by examining the recordings and applying additional analytic methods. The advantage of screen recording is the larger scope of relevant user data beyond the keystrokes, including shuttling between different texts, tools, websites, and services.

Screen recording research offers a powerful way to study what writers do with or in their word processors. Bailey and Withers (2018) used screen-capture methodology with 20 university students writing a summary and evaluated the screencasts in respect of the functions of MS Word they used. They found that the synonym finder was the most frequently used tool (23%), followed by spell checkers, grammar checkers, and external resources. Frequent use, however, did not necessarily mean improved writing. In 62% of cases where the synonym finder was used, the writers changed their text, but 29% of the chosen synonyms were unsuitable. Good technology can also result in a worse outcome; unfortunately, only eight of the 20 participants in the study were L1 English speakers, so conclusive generalizations about synonym finder use by either L1 or L2 students were not possible. Still, this research shows what can be done with screed recording.

A similar, small case study was conducted by Hort (2020) to examine how student writers manage their workflow in essay writing. As a result, she pleaded for more investigation into word processing, especially by studies considering the type of "navigation" through a text that can be seen in screen capture recordings.

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