Nanogenesis: Keystrokes, Movements, and Technological Affordances in Digital Literary Writing Processes

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Abstract

The advent of home computers in the 1980s and the subsequent use of these devices by literary authors to write their novels and stories introduced numerous challenges to the study of the literary writing process (genetic criticism). The digital writing environment obscures the writing actions by default, complicating analysis. Despite these challenges, the digital environment also offers new opportunities for genetic criticism. This paper discusses the use of keystroke logging software as a solution to the difficulties posed by digital writing and as a means of acquiring new insights into the creation of texts and the creative process. It emphasizes how the temporal dimension of writing, captured through keystroke logging data, facilitates a novel type of 'nanogenetic' research. Through various examples from Jens Meijen's writing of his story "Constellaties", this paper defines nanogenesis and reflects on how this tracing of the author's movement can facilitate research into the technological affordances, the relation between reading and text production, and the writing dynamics regarding narratological aspects of the text.

Keywords: keystroke logging, genetic criticism, nanogenesis, creative writing, word processing, human-computer interaction

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"That bloody cursor blinking at me on the word processor screen is awful. I mean, it's blink, blink, blink—well, screw this bastard, it's telling me to get on!" exclaims the author Tom Sharp (Hammond 1984, 213; quoted in Chandler 1995, 31). In the same way, the Dutch poet Pieter Boskma experiences the cursor as extremely pressing and demanding of speed: "Het beeldscherm zuigt te veel. Die knipperende cursor zegt voortdurend: 'Kom maar, kom maar, kom maar'" ["The screen drains too much. That blinking cursor is constantly saying, 'Come on, come on, come on.'"] (Boskma in Hasselt and Sistermans 2021, 31). Since the advent of home computers in the 1980s, the demanding blinking cursor has replaced the infamous blank page to describe one of the difficulties of writing: finding the 'right' words to communicate what is on our minds. This change in writing tools, from writing with a pen on paper to using a personal computer, has affected not only the author's experiences of the writing process—with blinking cursors interfering with the thought process—but also the material traces available for researching the literary writing process, such as within genetic criticism.

Imagine looking over a writer's shoulder as they type on a personal computer, and you will notice that the word processor's Graphical User Interface (GUI) neatly displays any additions to the running text and renders deleted text invisible. Clean, formatted text in standard fonts has replaced the former traces of the writing process—this is the born-digital reality that genetic criticism must confront. The field must learn to work with born-digital works of literature. With 'born-digital', in this case, I particularly refer to literary works written on a computer (at least using a word processor) but that do not necessarily grow old exclusively in digital form.[1] As O'Kane Mara notes, few studies have considered "how to perform textual and genetic scholarship on *texts*

[1] My use of the term 'born-digital' therefore departs from definitions that emphasise the digital medium as a publishing environment rather than a production environment alone, such as the one used by Hammond: "A born-digital work [...] remains digital at every step of its production, transmission, and consumption: it is one that is composed, edited, and laid out on a digital device; that reaches its readership via the digital medium; and that is designed from the outset to be read and experienced on a screen, not a page" (Hammond 2016, 133).

created in a digital space but intended for and materially re-created as print books" (Mara 2013, 344, emphasis in original). In this paper, I specifically address how genetic criticism can be applied to born-digital literary works that are intended for publication (also) in print but that were created within a digital environment.

While genetic criticism applied to those born-digital literary works is still in its infancy, several studies have been conducted on the digital genesis of texts, revealing a variety of born-digital traces and techniques for studying them (Buschenhenke 2025; Pulkkinen 2023; Ries 2018; 2017; Kirschenbaum and Reside 2013; Kirschenbaum 2012; Crombez and Cassiers 2015; Vásári 2019; Vauthier 2016; Fenoglio 2009). Irène Fenoglio (2009) studied printouts of digital files, and Bénédicte Vauthier (2016) studied the digital files saved by the Spanish writer Robert Juan-Cantavella during the writing of his novel *El Dorado* (2008). How digital forensic methods and tools can be applied to recover deleted text files and reveal genetic layers hidden by the conventional GUI of word processors is demonstrated by the work of Matthew Kirschenbaum (2008), Thorsten Ries (2017; 2018), Veijo Pulkkinen (2023) and the 'Derrida Hexadecimal'-project led by Aurèle Crasson (Crasson 2023). These digital forensic methods show promising results for the genetic study of literary works that have already been written, mostly on, but not limited to, legacy devices.

A more 'proactive' approach was taken by the project 'Track Changes: Textual Scholarship and the Challenge of Digital Literary Writing', which investigated how keystroke logging can be used to document and analyse digital literary writing processes by collaborating with Dutch and Flemish literary writers.[2] Within this project, Floor Buschenhenke (2025) examined the keystroke-logged writing processes primarily within the framework of cognitive writing process research, while my research (2023) adopted the perspective of genetic criticism. This paper extends one of my main findings about the possibilities that keystroke logging offers for genetic criticism applied to born-digital works of literature, namely that it allows for the study of the nanogenesis (Bekius 2021; 2023). Writing on a word processor offers the possibility of moving the cursor at any time to produce text in any place without making an ink-stained mess, thus allowing great flexibility in writing. A nanogenetic perspective highlights this temporal and spatial dimension of writing and provides a way of analysing the affordances of the word processor and how this has interpretive value for the internal workings of the text.

[2] The project *Track Changes: Textual Scholarship and the Challenge of Digital Literary Writing* (2018-2024) was a collaboration between Huygens Institute (Royal Netherlands Academy of Arts and Sciences, Amsterdam) and the University of Antwerp (Antwerp Centre for Digital Humanities and Literary Criticism) funded by the Dutch Research Council (NWO).

The Context of the Keystroke

The word processor has become a central tool in digital writing, and its features—especially when compared to 'traditional' pen-and-paper methods—require some attention, particularly within the context of genetic criticism. In the early days of word processing, much of the fascination centred around the screen—the luminous, glowing "glass square" (Kirschenbaum 2016, 44). According to Kirschenbaum, this "aesthetics of luminescence" shaped how authors thought and talked about their experiences with word processing (45). Authors were referring to working and writing "with light", a process that allowed for greater speed, freedom and flexibility (45). Yet, as Kirschenbaum emphasizes, the most transformative aspect of word processing is 'suspended inscription'. This term, coined by Chandler (1992), means that

> the stored record of a text is separate from whatever the medium or surface on which it is ultimately printed or inscribed in more palpable form. When one writes with a pen, creating and composing a text is coterminous with the work of inscribing it; and it is the same with typewriting, the press of a key initiating a simple act of mechanical leverage that sends the type bar hurtling toward the page, its kinetic energy thus impressing the inky fabric of the ribbon it encounters in its path onto the paper behind it in the embossed shake of a letterform […] But word processing is different […] we can see that word processing's suspension of inscription is in fact a suspension both temporal and locative in nature. In other words, there is a gap or delay between the act of writing the text and rendering it in its documentary form; moreover, the record of the text and its documentary instantiation occupy physically distinct media and surfaces. (Kirschenbaum 2016, 47)

The convenience of this suspended inscription has also been highlighted by Bolter, who points out that word processors make it easy to copy, compare, and revise text "with the touch of a few buttons" (1991, 5), therefore streamlining the process. For some writers, the speed of typing helps them keep pace with their thoughts (Chandler 1995, 129), while the ease of revision reduces anxiety by making mistakes easily correctable (Mara 2013, 346). From its inception, word processing has been linked to "the quest for flawless efficiency and effectively flawless results" (Kirschenbaum 2016, 34). The technology promises the creation of a "perfect document" (34). However, this pursuit of perfection comes at the cost of the material traces of the writing process, "as though the document did not have a history, but rather emerged, fully formed in its first and final iteration,

from the mind of the author" (36). This characteristic of suspended inscription presents a significant challenge to genetic criticism. Fortunately, this challenge can be addressed using keystroke logging software.

In the Track Changes project, we used the keystroke logger Inputlog to log literary writing processes. This tool logs the writing operations in Microsoft Word, a word processing environment that the author is already familiar with (Leijten and Van Waes 2013). Each time an author activates Inputlog to start a new writing session, the Word document in which the author is working is saved in the background in a folder containing the date and number of the writing session. The Word document is saved again when the author ends the writing session by deactivating Inputlog. This results in a specific version of the text for each session (a 'session version'), showing the gradual evolution of the text. Inputlog does more than just save Word documents, however, as it records every keystroke and mouse movement with a timestamp whenever the program is running (Leijten and Van Waes 2013). The timestamp makes it possible to reconstruct the order in which the text was typed, how long it took the author to write a particular word or sentence, and the pauses during text production.

In the General Analysis, the most fine-grained level of output offered by Inputlog, every row represents one log event, such as a keystroke or a mouse movement, in combination with the position in the text and a timestamp. This output is not particularly suitable for genetic criticism, where the priority is to be able to study revisions and text production in the context of the text that has already been written—the text produced so far. For this reason, I have encoded the textual information from the keystroke logging data in the session versions and created visualisations that allow one to see all the changes made within a writing session simultaneously and to replay the writing session (Bekius 2021). These visualisations are available on Nanogenesis Digital (Bekius 2024). It currently includes the writing processes of Dutch authors Jente Posthuma and Roos van Rijswijk and the Flemish authors Gie Bogaert, Jens Meijen, David Troch, and Ellen Van Pelt.

These visualisations offer a way to bypass the 'perfect document' and provide the opportunity to retrace its 'hidden' history and the 'messy' text while still enabling an analysis of how the function of the suspended inscription facilitated the writing of the text. There are, of course, also several shortcomings with keystroke logging, including errors and gaps in the logging, internal aspects of the writing process that cannot be logged, and over-interpretation. Reading, for example, is not always traceable through keystroke logging data, as the text displayed on the screen at any given time leaves no trace. Scrolling with the mouse is captured, but again without knowing the position in the text. The use of the arrow keys and cursor movements provide the most information, but the exact text that was consulted is still difficult to reconstruct in most cases. This

applies both to reading text in a word processor and to reading text in other applications or on the Internet.

Combining eye tracking with keystroke logging, as is used in cognitive writing process research to analyse reading during writing (e.g., de Smet, Leijten and Van Waes, 2018), would reveal what the author was looking at while writing by capturing their eye movements. Yet, even then, matching gaze data and text data can pose methodological and technical challenges—for instance when the text requires scrolling—and would require the use of advanced tools such as the Tobii TX300 eye tracker (Wengelin et al, 2019; de Smet, Leijten & Van Waes, 2018). And even when keystroke logging is combined with eye tracking, questions about *why* writers look at something remain unknown. This would require additional data from, for example, think-aloud protocols, or the formulation of very specific hypotheses tested in highly controlled experiments (Wengelin et al., 2019, 35).

In the Track Changes project, we therefore chose not to use eye tracking, as we wanted the authors to write in a familiar environment with minimal interference.[3] As keystroke logging itself already introduces the possibility that the author is aware of being 'logged', an even more experimental setting involving eye tracking or even interfering with think aloud protocols raises further questions about the naturalness of the logged process.[4]

Despite these 'shortcomings' of keystroke logging, the resulting data still offers plenty possibilities to enhance a text genetic analysis of a born-digital work. To illustrate this, I will analyse the writing process of Jens Meijen's story "Constellaties".

Jens Meijen – "Constellaties"

Jens Meijen (1996–) is a writer, doctoral researcher, AI consultant and journalist. He debuted with the poetry collection *Xenomorf* (2019)—granted the C. Buddingh' poetry prize for best Dutch debut—followed by a novel, *De lichtjaren* (2021) and a second volume of poetry, *Sunset Industries*

[3] The goal of the Track Changes project was grounded within literary studies, scholarly editing, and genetic criticism, focusing on questions such as how existing methods and theories of textual scholarship and genetic criticism can still be applied to analyse digital literary writing processes. This therefore differs, for example, from the neuroscientific experiment with the Dutch author Arnon Grunberg. For this experiment, Grunberg wrote his new novel while wearing sensors to track brainwaves, heartrate and bodily processes reflecting arousal and emotion (galvanic skin response). This proof-of-principle study aimed to investigate links between brain activity and different emotions during writing and whether the brain activity can be linked with what he writes or how he writes (Van der Werf and Van Erp, 2014). The detailed genesis of the text was, to my knowledge, not investigated.

[4] One possible compromise would be to make a screen recording. Although this would be less accurate than eye tracking, it would still provide a more thorough representation of the author's interaction with the digital environment than using keystroke logging alone.

(2023). Meijen logged the writing process of his story "Constellaties" for the Track Changes project. The story was also the product of Meijen's writer's residency in Paris, organised by the Flemish-Dutch cultural organisation deBuren. The story was published on deBuren's website as well as in the literary journal *DW B* (Meijen 2020), where it appeared in the theme issue 'Altijd was die muur daar' ['Always there was that wall']. The 'wall' is indeed a prominent element in the story. For a better understanding of the genesis of the text, I will provide a summary based on the last logged version.

As a magical-realistic and metafictional detective story, "Constellaties" describes an unnamed first-person narrator's quest in Paris to solve the mystery of his uncle's disappearance. The story begins with the narrator recalling the night a message appeared on his wall telling him to go outside, where he would receive a letter from his uncle, Alain. The uncle writes that he has been murdered and that it is the narrator's job to catch the killers. He must go to a certain address in Paris and ask about the wall. Once arrived at the location in Paris, he meets Alain's former neighbour Marcel, who has high praise for Alain and his theory that 'everything is a word'—as soon as you think of a word, it also exists. Marcel explains: "Die kasseien die je ziet, dat is pure fantasie, de muren hier een hallucinatie, allemaal symbolen" ["Those cobblestones you see, that is pure fantasy, the walls here a hallucination, all symbols"]. This theory is also reflected in the story's metafictional elements.

Unsure of how to proceed, the narrator decides that interrogating suspects is the most logical option. Some water from the ice bucket at Marcel's feet points the way but then disappears through a sewer cover. The narrator approaches the sewer and hears voices telling him to follow the graffiti. He looks up, and graffiti appears on the wall, instructing him to 'not forget about the wall' and to 'find the wall'. Now, the narrator understands that the words are roads trying to lead him somewhere, but he can still decide not to read any further, to stop the progression—which he does for a while, describing the setting. He then continues the story and has an absurd conversation with an insurance company employee who is locked in the company's building. After a brief interruption by a memory of visiting a fortune teller—who told him that he would come to a realisation which, if he did not know his limits, would also lead to his downfall—the narrator finds himself on a market, indicated by the word 'MARKT' chalked on the street. There, he talks to a market vendor selling colourful eggs and to one selling only Bob Dylan records. In his second encounter with the egg vendor, he tells him some memories of his uncle and that he has to solve his disappearance to get the inheritance. The vendor tells him he is not the first; someone told him the same thing a week before. With the help of words appearing on a kebab skewer that refer to the wall and the kebab vendor pointing the way, the narrator finally reaches the wall. A shadow

falls over the wall, "de schim van een ding dat niet bestaat, of iets dat buiten deze stad bestaat, een reusachtige hand, een oog, een leeslampje, een ochtend- of avondzon, zijdelings, bijna verblindend, het licht van een computer, een hand, meerdere handen, gepauwgroefde vingers die hun sporen achterlaten op deze wereld, vetvlekken, speeksel" ["the shadow of a thing that doesn't exist, or something that exists outside this city, a giant hand, an eye, a reading light, a morning or evening sun, sideways, almost blinding, the light of a computer, a hand, several hands, pawed fingers that leave their marks on this world, grease stains, saliva"]. The wall marks the point between two realities, the border between him and the spectators (the reader). At the very end of the story, while he tries to unravel the knot in the rope that has been put in place to keep people away from the real wall, he realises that the rope is only a symbol—the literal representation of the denouement—that everything is an illusion, that the denouement of the quest is just the idea of a denouement. In the metafictional story, words appear all over the city and guide the narrator's path. With the keystroke logging data it is, in addition, possible to reconstruct how Meijen's own written words guide him through the text production.

From Macrogenesis and Microgenesis to Nanogenesis

The genesis of a text can be studied from a microgenetic and macrogenetic perspective. Microgenesis is the analysis of a restricted part of the text: "the total compositional development of a short textual fragment" (De Biasi 1996, 27). According to Van Hulle, it includes all intra-textual processes: "the processing of a particular exogenetic source text; the revision history of one specific textual instance across endogenetic and/or epigenetic versions; the 'réécritures' or revisions within one single version" (Van Hulle 2016, 50). In turn, macrogenesis analyses "large-scale phenomena" (De Biasi 1996, 27). It thus embodies "the genesis of the work in its entirety across multiple versions" (Van Hulle 2016, 50). When analysing keystroke logging data to draw text genetic hypotheses, both macrogenetic and microgenetic perspectives can be applied. However, I would argue that these perspectives are not sufficient to maximise the potential of keystroke logging data for such analysis. This specific type of text genetic data, therefore, requires a new text genetic perspective that emphasises the temporal dimension of writing on a fine-grained scale and addresses non-linearity in writing and the sequentiality of text production and revision. This is what I term the nanogenesis. A macrogenetic and microgenetic analysis of Meijen's writing process will illustrate why keystroke logging data necessitate a new text genetic concept.

The keystroke logging data and the session versions offer useful macrogenetic information for a general overview of how the writing process proceeded. Meijen wrote "Constellaties" in six

writing sessions in August 2020, and the logged writing process had a duration of 8 hours, 45 minutes and 50 seconds. The first three sessions occurred on August 4th and the fourth on August 5th. Meijen sent this version to his editor at deBuren. On 18 and 19 August, he revised the story based on the comments from the editor, resulting in the final logged version. The text was revised once again before publication in *DW B* and on the deBuren website, where Meijen introduced some major cuts, such as the memory of visiting the fortune teller and the encounter with the vendor selling only Bob Dylan records.

From a macrogenetic perspective, the sessions can be linked to the pre-compositional phase, the compositional phase, and the pre-publication phase (De Biasi 1996). The first session mainly involved the pre-compositional phase, as Meijen included the notes he took while staying in Paris. The second, third, and fourth sessions represent the compositional phase, in which Meijen structured the story and textualised these notes, and in the fourth session, he made final edits to reach the first version. During these sessions, the notes and the text produced so far were part of the same Word document. The fifth and the sixth belong to the pre-publication phase, as these sessions entailed making the final revisions. I refer to Buschenhenke (2025) for a more elaborate macrogenetic portrait of Meijen's writing process.

The keystroke logging data also ensure a continuation on a microgenetic level. An important aspect is that the keystroke logging data allow for analysing digital immediate revisions again. In handwritten traces, immediate revisions can be recognised through strike-through words, with the replacement word immediately following on the same line. In digital writing processes, immediate revisions are often irretrievable. Even when the writer uses the Track Changes function, immediate revisions are not visualised. When the writing process is logged with a keystroke logger, these immediate revisions can be observed again. Take, for instance, the composition process of the following phrase, in which text in pink represents immediate revisions:

> dat ik op de trein ~~wat~~[1380] [1381]zat en ~~icamnd~~[1382] [1383]iemand me vroeg of ~~ik~~ [1390]~~mijn koffer boven~~[1384][1385]~~een kff~~[1386][1391][1387]~~offer zilde~~[1388][1392][1389]~~wilde helpen tillen;~~[1393][1394]ik een wafeltje van de catering ~~zilde~~[1395][1396]~~wilde~~[1397][1398]wilde delen
>
> [that I ~~wat~~[1380] [1381]sat on the train and ~~socomone~~[1382] [1383]someone asked me if ~~I~~ [1390]~~my suitcase above~~[1384][1385]~~a sute~~[1386][1391][1387]~~itecase zanted~~[1388][1392][1389]~~wanted to help carry;~~[1393][1394]I ~~zanted~~[1395][1396]~~wanted~~[1397][1398]wanted to share a waffle from the catering]

This example contains a few typos (text in brown) and three of these are also caused by the writing tool—the differences between QWERTY and AZERTY keyboards. If we disregard these tool-specific revisions for a moment, we can imagine the other revisions being made on paper. For example, the following microgenetic analysis could apply to both an analogue and a digital writing process. Meijen is in the middle of writing a sentence describing an encounter the narrator has on the train. Someone approaches him and asks if he would be willing to put his suitcase on top, which Meijen then immediately changes into if he can help carry a suitcase. This is a rather mundane situation—as Meijen seems to think—because he replaces the question about helping with the suitcase with the question about sharing a waffle. This small change immediately makes the sentence less ordinary and more in line with the narrator's unusual encounters in the story. In general, it is a common revision to introduce a semantic effect to increase the specificity or originality of descriptions. In this example, the traditional concept of microgenesis can easily be transferred to the digital medium and the keystroke logging data.

It becomes rather difficult to do the same for the following text genetic narrative. About halfway through the writing session, Meijen is writing the dialogue between the narrator and the market vendor who only sells Bob Dylan records. In the conversation, the narrator asks the vendor if he knows anything about Alain Fournier: "Wat weet je van Alain Fournier?" ["What do you know about Alain Fournier?"] (n1132-n1134).[5] Writing is then interrupted for three seconds, after which Meijen begins scrolling through the document.[6] At the end of his notes section and above the proper beginning of the story, he stops and pauses again for almost three seconds. There, Meijen adds and removes some whitespace (keying ENTER). He moves his cursor to the left and adds whitespace again. Then he writes that the narrator has to interrogate suspects: "Ik moet verdachten ondervragen. Dat is de enige logische stap" ["I have to interrogate suspects. That is the only logical step"] (n1135-n1138). A pause over 11 seconds follows. Then he relocates the cursor again and starts writing in front of these new sentences: the narrator was surprised to receive a letter, especially since nowadays, no one sends letters anymore, so it must be something important. The uncle's letter—which explains why the narrator is wandering through Paris—did not appear in the story before, but will be added in other locations in the text during this session and eventually also be the opening of the story.

It would be impossible to write such a description of a handwritten writing process. The exact moment of Meijen's movement through the document, from the end of the document to the

[5] The numbers (n1132-n1134) refer to the number of the writing action in the visualisation on Nanogenesis Digital.
[6] Pauses are not accounted for on Nanogenesis Digital, but this information can be found in the General Analysis of Inputlog.

end of the notes section and the incipit of the story, and the pause time between these events would not be deductible from a handwritten document. The traditional concept of microgenesis does, therefore, not account for pauses and movements during sentence production. This movement and exact sequentiality is the new dimension that is added to the 'traces' of the writing process by keystroke logging and what denotes the nanogenesis.

The keystroke logging data namely also allow for new, nanogenetic questions. For the first example, what does it implicate that the decision to delete "ik een koffer wilde helpen tillen" was preceded by only one brief interruption of just over one second? And that "een wafeltje van de catering" was written after a pause of one and a half seconds? From a cognitive point of view, this nanogenetic information seems to indicate that these revisions did not seem to require much cognitive load. However, it does also show that Meijen needed to write a more common question first to then 'discover' the more creative expression, exemplifying what Galbraith (2009) terms the knowledge-constituting process in writing. It is by experiencing this knowledge-constituting process that writers find out what to write next through writing itself.

For the second example, the nanogenetic information points out that writing the dialogue with the market vendor—and specifically the point where the narrator starts to ask interrogating questions about Alain—triggered the need to introduce the quest for information about Alain's death earlier in the story. First, this led to the addition of sentences that state that the narrator needs to interrogate people, which in turn led to the inclusion of the uncle's letter in the opening of the story.

It becomes clear that the fine-grained data of keystroke logging require a new text genetic concept to complement the already existing terms macrogenesis and microgenesis because the keystroke logging data allow us to focus on the sequentiality of the text production and revision. It focuses on small—perhaps even the smallest—visible aspects of the writing process that we have not been able to perceive before.

This is not to say that the data provide objective insights into what the author was doing at any given moment—were they reading, thinking, or letting their mind wander? Nor does it provide insight into their intentions. The reason behind a revision, the trigger of the revision, cannot be known from keystroke logging data alone and remains subject to interpretation. However, Lindgren and Sullivan state that a pre-contextual revision, for example, can indicate that "some form of decision process is occurring that relates to how the composition is to proceed" (2006, 166). Since genetic criticism's aim is to construct "a series of hypotheses on the operation of writing" (Grésillon 1997, 106), it also encompasses interpretations of such decision-making processes that informed the revision.

For decades, textual scholars and geneticists have been drawing hypotheses about the reason behind revisions based on the material traces of a writing process, with John Bryant even defining revision as "the visible sign of altered intentions" (2002, 12). However, since the critical debate around the 'intentional fallacy', a term introduced by Wimsatt and Beardsley (1949), literary critics started to avoid using the term 'intention'. Yet, Van Hulle (2022) states that the notion of intention cannot be avoided in scholarly editing and that genetic dossiers make us aware of the mutability of the authors' intentions. Therefore, textual scholars defined the term intention more clearly.

Peter Shillingsburg, for example, distinguished between two concepts of intention: the "intention to mean" and "the intention to do" (1996, 33). The author may have an intention *to mean* something, which precedes its verbal formulation and the intention *to do*, the material act of inscription; yet in writing or reflection, new meanings may emerge, prompting renewed cycles of intending to mean and intending to do. According to Shillingsburg, the "intention to do" is more directly deducible from the written signs, and the task of the scholarly editor is to be accurate about the "process of doing and discovering new things to do" (35). The proposed nanogenetic analysis of the keystroke logging data can therefore focus on the reasons for doing something during the writing process, on the intentions to do. Of course, as I will continue to emphasise, my interpretations of the writing actions remain hypothetical.

Nanogenesis in Action/the Action of Nanogenesis

It is evident that despite its bad reputation amongst authors, the 'bastard' of a cursor does provide much information about the writing process. First, the blinking cursor can indicate a pause or an interruption in the writing process, which in turn are "associated with either monitoring processes, where the accuracy and appropriateness of the emerging text is evaluated, or with planning processes, where the content and form of future text segments are reflected upon" (Wengelin et al. 2019, 31). Second, the location of the cursor tells something about the author's movement through the text, which can indicate triggers for text production and revision. Nanogenesis is the study of the fine-grained, sequential writing actions and movements involved in text production and revision, as captured through keystroke logging. This text genetic perspective focuses on the precise movements of an author through the text, including the 'jumps' they take, the order of typing, the way deletions and additions were performed, how sentences are abandoned midsentence but finished at a later stage, the exact sequence of new text production and revisions,

and the state of the text in any point in the writing session.[7] In short, nanogenetic analysis follows the cursor through the digital document to draw hypotheses on the reasoning behind revisions and new text production.

Below, I will illustrate three possible lines of nanogenetic research: a) how nanogenetic analysis provides insights into how the affordances of the word processor are being used during writing, b) how a nanogenetic analysis provides insights into the different aspects of the writitng process, specifically the function of reading, and c) how a nanogenetic analysis provides insights into narratological aspects of a text.

a) Nanogenesis and Technology

Writing has always involved the use of technologies, yet as we have seen above, the digital writing environment introduced the ability to 'suspend the inscription'. A line of nanogenetic research can address the affordances of word processing in relation to the writing process. For Faraj and Azad, "[t]echnology affordances come about from the confluence between an actor's line of action and the generative action possibilities in the technology" (2012, 254) and thus link the design with usage. They emphasise that "affordances represent possibilities of using select features or combinations of features in a way meaningful to the user's goals, abilities, and lines of actions" (254). Applied within a nanogenetic perspective, this would involve an analysis of the way the writer utilises the functionalities of the word processor, including the suspended inscription, to achieve their writing 'goals' and 'intentions'.

Mahlow et al. (2022) point out that the production process of written text is highly nonlinear: "during production, writers are free to modify the text at any place and at any point in time, without leaving any traces in the final product" (2022, 'Introduction'). This is precisely made possible by the suspended inscription. One of the many ways in which Meijen beneficially utilises this feature of word processing is by interrupting text production to immediately address self-diagnosed 'problems' in the text. In the example above, Meijen interrupted new text production to introduce the narrator's quest earlier in the story. A similar dynamic can be seen in the following example, where Meijen halts his linear text production when—during text production—he encounters a small information gap in his text.

[7] My definition of a nanogenetic analysis (Bekius 2021; 2023) differs subtly from Van Hulle's adoption of the term (2021; 2022). We have both utilized the term nanogenetic research, yet whereas Van Hulle's usage of the term emphasises the analysis of the unit of the keystroke, I rather accentuate the movement that can be deduced from the sequence of keystrokes and mouse movements that have been captured by keystroke logging. For me, it is not the keystroke itself but the keystroke dynamics patterns that form the essence of nanogenetic research.

Meijen begins his second writing session by describing how the narrator crosses the street to approach an insurance agency building. A man on an electric scooter passes him speedily, shouting something that sounds like 'con', which the narrator thinks sounds like a duck quacking. After writing this one-way interaction (the narrator being shouted at), Meijen pauses for just over 1 minute and 40 seconds and then writes that someone inside the insurance agency is looking outside: "Iemand van in het verzekeringskantoor kijkt naar buiten om te zien" ["Someone from inside the insurance office looks outside to see"] (n26-n32). The sentence is not finished, but Meijen stops writing for 5 seconds. When he starts writing again, it is not to finish the incomplete sentence, but to add a sentence before it. In this new sentence, written with a few immediate revisions in which Meijen searches for the best insulting words, the narrator shouts at the man on the electric scooter to shut his 'fat, lazy mouth': "Ik roep dat hij zijn vette luie muil moet houden" ["I shout for him to shut his fat lazy mouth"] (n33-n41). Only after this new sentence had been inserted did Meijen finish the sentence about the person in the insurance agency. The insurance man looks out to see what is happening outside and puts his hands on the glass as if to check that the window is indeed glass and not a force field designed to keep the employees inside.

The nanogenetic analysis can lead to the following hypothesis: Meijen needed to interrupt the writing of a new sentence since the writing of this sentence made him aware that something was missing in the preceding descriptions. The person inside the insurance agency looks outside, but he has no reason to do so. So when Meijen wrote "Iemand van het verzekeringskantoor kijkt naar buiten om te zien", he did not know how to continue the sentence. Meijen leaves the unfinished sentence to describe the narrator shouting back at the man on the electric scooter, thus giving the person inside a reason to come to the window to see where the noise is coming from – and ultimately giving himself a way to continue writing.

From an affordance perspective, this particular writing action could only arise from the conjunction of the suspended inscription feature of the word processor and Meijen's awareness of this possibility. On paper, such an approach to writing would not be possible and would at least require the deletion of the beginning of the unfinished sentence in order to write the narrator's reaction to the man on the electric scooter. Moreover, other writers might have performed this writing action quite differently, for example, by also deleting the beginning of the sentence. What the example also suggests is that the suspended inscription reduces the need to plan before writing. In their study to identify differences between writing with pen and paper and writing on a computer, Van Waes and Schellens (2003) observed a higher degree of fragmentation in digital writing: "The large number of short pauses within the sentence which occurred in rapid succession in the writing of computer writers resulted in a writing process in which planning, formulation, and

revision were strongly focussed on relatively small units of text" (848). According to Van Waes and Schellens, this is the result of what they call 'word processing comfort': "During the writing process, writers are aware of the fact that, at any moment during writing, they can alter their text without creating an illegible jumble of crossed out and inserted words" (848). This therefore illustrates how word processing affordances affect the processes involved in writing.

b) Nanogenesis and the Writing Process

The second line of nanogenetic research can address processes involved in text production, such as reading. During text production, we constantly move back and forth between writing and reading (Haas 1996, 55), and the text produced so far can function as a basis "for building internal coherence, generating ideas, and/or visualizing possible revisions" (Quinlan et al. 2012, 350). Lindgren et al. (2019) thus state that there are dynamic ways in which the text produced so far can feed into the writing process. Besides evaluating and revising the text produced so far, writers also tend to 'look back' at the previously written text to generate new text (Wengelin et al. 2023). In this way, the text produced so far functions as "a catalyst for invention" (Leijten et al. 2014, 325) and the production of new text, for example at the leading edge, can also evoke the urge to reread the text, to find out what to write next. The latter can be observed through a nanogenetic analysis of a part of Meijen's second writing session.

At one point in the story, the narrator finds himself on a market. He talks to various market vendors. First, he talks to a vendor who sells colourful eggs of various animals, and later to a vendor who only sells Bob Dylan records. A second encounter with the egg vendor follows. The vendor accompanies the narrator on a walk across the market, as the narrator explains that he is investigating the disappearance of his uncle and that he, at first, did not even know he had an uncle. Meijen pauses for almost 20 seconds and likely unsure about how to continue the conversation between the vendor and the narrator, he begins to refer to the setting—the market—when he writes: "Aan de rand van de markt" ["At the edge of the market"] (n1253). This instance of new text production might have made him wonder whether he had written something about the market that he could refer to, something near the edges of the square. Therefore, after a pause of about 10 seconds, he moves the cursor to the place in the text where the market is mentioned for the first time. He revises this text and then adds a new sentence to the description, describing that at the edge of the market, there was written in large letters MARKET, but in Dutch instead of French, which is strange since the narrator is in Paris: "Aan de rand van het plein staat in het groot MARKT op de grond gekalkt – gek dat het er niet in het Frans staat" ["At the edge of the market square,

MARKET is written in large letters on the ground—strange that it is not written in French"] (n1256-n1262). He continues to revise the description of the square and the market in the text produced so far, after which he returns to the point where he was writing to continue text production. He finishes the unfinished sentence "Aan de rand van de markt", with "net op de gekalkte T van MARKT, staat" ["just on the chalked T of MARKET, stands"] (n1271). Eventually, after a pause of more than 2 minutes, he revises the unfinished sentence into "Aan de rand van de markt, net op de gekalkte T van MARKT stopt hij" ["At the edge of the market, just on the chalked T of MARKET, he stops"] (n1272-n1273). The reference to the setting is thus used to end the conversation between the narrator and the vendor and therefore serves as a transition indicator. Moreover, this detour to describe the setting also led to new inspiration on how to continue the conversation between the narrator and the vendor.

Meijen often uses a description of the narrator's action or the setting to indicate a transition, for example, to bring the text back from the narrator's internal thoughts to the narrator's external observations. The same description will therefore be repeated a number of times throughout the story. In this way, he can use this tiny clue both as a transition indicator and as a means of creating cohesion. The chalked word MARKT has this function, and after its first introduction, it will serve as a reference point twice in the story. The nanogenetic analysis showed when Meijen invented this reference point and that a lack of a clear reference point in the descriptions of the market triggered it. Additionally, the chalked word MARKT can be read as a reference to the metafictional element of the story and the uncle's theory that 'everything is a word'. However, Meijen has not yet written the conversation with the neighbour that would introduce this theory. The nanogenetic analysis is therefore also relevant from a narratological point of view.

c) Nanogenesis and Narratology

The third line of nanogenetic research starts from the text's narratological aspects instead of the writing actions. The critical dimension of genetic criticism entails the reconstruction of the genesis of a text from a chosen point of view, like, for instance, a narratological perspective. According to Bernaerts and Van Hulle, combining narratological analysis and genetic criticism can be productive in at least two ways:

> On the one hand, if one's object of study is a text's discourse, genetic criticism's reconstruction of the writing process can be an aid to the narratological analysis of texts: and not just of narrative text in their finished form but also in any of their preceding

> versions, since any textual version can be the object of narratological analysis. On the other hand, if one's aim is to study the development of a work's writing process, then narratological tools and insights can contribute to an understanding of how narratives evolve through notes, sketches, drafts, and other textual versions (such as fair copies or corrected proofs). (Bernaerts and Van Hulle 2013, 285)

In contrast to analogue versions of a text, the visualisations of the keystroke-logged writing process allow for an exact reconstruction of the text at any given point in the writing process. As such, it becomes possible to trace the emergence and evolution of the focal points in narratological analysis through a nanogenetic analysis. For "Constellaties", a nanogenetic analysis sheds light on the writing movements leading to the implementation of the motif of the wall into the story.

The wall is an important motif in "Constellaties" and appears in various ways throughout the story: words on walls guide the narrator through Paris, as he searches for 'the wall' to discover who murdered his uncle. Moreover, the wall is one of the building blocks of the text's metafictional aspect. In the notes section, Meijen included his idea that the architecture of the story is the architecture of the city.[8] Therefore, the wall that the narrator must find can be seen as marking the border of the story, the boundary between the fictional and the real world. Additionally, the story was planned to appear in an issue of *DW B* with the theme 'the wall'. A relevant question from the point of view of the internal organisation of the text is therefore when the wall was introduced into the story.

First of all, it is worth noting that the wall did not appear in the notes section. However, one of the functions of the wall was included in the story from the beginning. Meijen began the composition process in the first session by writing a passage in which the narrator sees words on the wall of a café, which then appear on the wall of the insurance company across the street. By the end of the first session, the wall has already entered the story, but its role is merely to carry the words that guide the narrator's way. The absence of more references to the wall is not unexpected for such an early draft, only one paragraph into the composition process.

In the second writing session, during which Meijen wrote a large part of the story, the wall gradually becomes more prominent. The wall is first mentioned in this session after a metafictional reflection in the story. The narrator wonders if the words are leading him from one dimension to another, or if they are showing him that we do not live on a flat sheet of paper, but rather we are a flattened collection of symbols "in een wereld die ook in de hoogte en diepte groeit, die daar

[8] In the notes section, he already wrote in the first session: "meta: architectuur van het verhaal is de architectuur van de stad" (n235-n243).

moerassen maakt, jungles laat groeien, wortels uitstrekt om doorheen een galactische leegte te woekeren – plekken die we nooit zullen zien" ["in a world that is also growing in height and depth, making swamps there, growing jungles, sending out roots to fester through a galactic void—places we will never see"] (n206-n235). This leads to the insertion of an additional function of the wall: "Ik ken enkel de muren van deze stad, de zoektocht die maar niet lijkt te eindigen" ["I know only the walls of this city, the quest that just doesn't seem to end"] (n236-n238). Is the narrator already slightly aware of the walls of his fictional world?

Over an hour into the writing process, Meijen starts to implement more references to the wall. First, he writes: "Is de stad zichzelf in me aan het projecteren?" ['Is the city projecting itself inside me?'] (n1416-n1420). Six seconds later, he scrolls to the top, and another two seconds later, he writes: "Kijk naar de muren, kijk naar de muren: ze spreken" ["Look at the walls, look at the walls: they speak"] (n1421-n1425). After this addition to the beginning, Meijen continues producing new text at the bottom of the document. Several revisions later, he begins to write a description of Alain. He was an ice skater who practised on the Seine in winter and swam there in summer to catch rats and carve messages into the wall just below the surface. This description now also links the messages on the wall to the uncle.

A little later in the session, Meijen writes a passage in which the narrator is in a kebab shop and sees a message on the kebab meat: "'Je verspilt je tijd,' staat er" ["'You're wasting your time,' it says"] (n1683). Meijen then pauses for almost 30 seconds before scrolling to the passage with the fortune-teller. The fortune-teller had first pulled a card showing 'a tower, a flash of lightning and bones falling from the windows of the tower'. Meijen changes the tower to a wall (n1684-n1685) and revises the sentence to "een muur, een bliksemschicht die insloeg op de muur, en botten die aan de andere kant van de muur opgestapeld lagen" ["wall, a flash of lightning striking the wall, and bones piled up on the other side of the wall"] (n1684-n1689). Adding the wall to the card turns the fortune teller's prediction into a possible prediction of the story. In response to the card, the fortune teller warns the narrator has to be careful, that the realisation could imply his downfall. This is the preamble for two revisions that turn the wall into the key-element of the story.

After the revisions regarding the fortune teller's cards, Meijen scrolls back to the bottom of the document and changes the kebab-meat's commandment "Je verspilt je tijd" ["You're wasting your time"] into "Ga naar de muur" ["Go to the wall"] (n1693-1695). Next, Meijen scrolls up to the beginning, where he changes the sentence "Nu staat er 'Zoek de gletsjer'" ["Now it says, 'Find the glacier'"] into "Nu staat er 'Zoek de muur'" ["Now it says 'Find the wall'"] (n1696-n1697). The message in the meat to 'find the wall' was the first time the wall also became the destination of the

narrator's quest, which in turn triggered the need to address it earlier in the story as well, leading to the revision changing 'glacier' into 'wall'.

After replacing 'glacier' with 'wall', Meijen scrolls back to the bottom of the document and continues the story by having the narrator ask the kebab vendor where he can find the wall. In this way, he begins to write parts of the end of the story. At the end of the writing session, the narrator has finally found the wall, which seems to represent the end of the story. Finding the wall brings with it the realisation that everything is an illusion and that the end of the quest is merely an idea of an end. As the fortune-teller predicted, this will lead to his downfall, because he has reached the end of the story and his life as a character will end there.

The nanogenetic analysis thus showed how, during the second session, Meijen gradually made the wall more prominent in the story and how this eventually led to the implementation of the idea that the wall should be the narrator's destination. What the keystroke logging data cannot tell us is whether Meijen had this idea in mind all along or whether he 'discovered' it while writing and revising the passage with the fortune-teller. Thus, even when every keystroke is logged, there remains uncharted territory, and it is the task of the geneticist to draw hypotheses on the genesis of the text. Despite the changes keystroke logging brings forth in the materiality of the text genetic material as well as the granularity of analysis, the general result of text genetic research has not changed: it still constructs "a series of hypotheses on the operation of writing" (Grésillon 1997, 106).

Conclusion: Nanogenetic Prospects

Keystroke logging data will never be the standard traces left behind by the digital writing process, but the rare occasions when keystroke logging has been used provide compelling insights into how writers interact with the digital environment during the writing process. Above, I have illustrated three ways in which a nanogenetic analysis can create new knowledge about the genesis of the text and the creative process. This includes analysing the affordances of the word processor within the writing process; the effects of reading on the writing process and how narratological aspects are implemented into the text. Yet, nanogenetic analyses are not limited to these three approaches. Another fruitful nanogenetic approach involves an analysis of the cognitive processes involved in writing, including a closer examination of the process of discovery in writing (Bekius 2023).

If we can continue to persuade writers to incidentally log their writing processes with a keystroke logger and additionally even make a screen recording, future research could also address how technological advancements keep affecting the writing process. The ever-evolving

technological landscape introduces questions surrounding individual preferences in digital workflows as well as larger, general technological advancements. Meijen, for example, used Facebook Messenger to take notes during his Paris residency or share those notes across devices. But would he still be using this social media platform four years later, or would he use a different app? How do writers incorporate different devices—their phones, tablets, laptops, and desktop PCs—into their writing process? And how do various apps structure the writing process? Furthermore, at the time of the logging of Meijen's writing process, generative AI was not yet publicly available through chatbots such as ChatGPT but is likely making its way into the writing processes by now. In what way are writers currently utilising AI? The digital writing environment will continue to pose new challenges to genetic criticism, but we should not shy away from addressing them if we want to refine our understanding of the writing process and the literary text itself.

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