

# Watch Me Write: Revealing Creative Process with Writing Replay

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The written word is an asynchronous form of communication in which static texts are exchanged. However, writing is a dynamic process in which evolving ideas are organized into a coherent narrative. This process is not shared with readers because they only see the final product. In this paper, we aim to explore the potential benefits of watching a real-time replay of writing that reveals this writing process. We conducted an online survey (n=78) to compare reading comprehension and readers' perception of watching writing replay with that of reading static text. We found that some styles of writing enhanced user engagement and the perceived quality of a text. In addition, we recorded the writing process of professional writers (n=13) and interviewed them about their and others' replays. These writers found replays universally engaging. They facilitated self-reflection and helped writers empathize with each other. Participants from both studies considered using replay regularly.

CCS Concepts: • **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

Additional Key Words and Phrases: datasets, neural networks, gaze detection, text tagging

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## 1 INTRODUCTION

Revealing the entire creative practice to spectators has proven to be a new, effective way to engage them. While it is a common practice for creators to only share refined final artifacts with consumers, the creative process itself can be a compelling artifact for a consumer. Such a culture has a in music, gaming, programming, graphics, crafting, and even painting through live streaming media, such as Twitch or YouTube [8, 13, 15, 16]. With the growing popularity of this live culture in mind, we present a study which investigate the effects of revealing the entire creative practice of writing.

The act of writing is a dynamic cognitive process in which writers organize changing ideas into a coherent narrative [10]. However, readers only ever see the polished final product of a work of writing. While polished writing may convey stories more effectively, a transparent view of the progression of the writer's mind is often missing from the final draft. We begin with the hypothesis that readers will find the real-time writing process more engaging to watch because it gives them a chance to intimately experience the writer's creative process. In addition, we test if watching writing replays negatively or positively impacts reading comprehension. Furthermore, we posit that watching someone writing may offer writers an opportunity to reflect on their own writing practice and learn from the practice of others. We explore the effects of revealing writing practice to readers and writers by recording and replaying the writing process of professional writers, and playing it back to both other professional writers and a general audience.

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The goal of the study is to understand how the process of creating written artifacts can be understood differently via writing playback from the reader’s perspective and where writers perceive values of documenting and reviewing the entire process of self and others continuously. To that end, we extended and used Live Writing, an online editor which augments a text editor with recording and replaying functionality [23]. We conducted two studies: (1) an online survey (n=78) to investigate how watching a replay of writing differs from reading static text, and (2) an interview study (n=13) in which professional writers were asked to write a short essay and review both their own writing replays and those of other professional writers. Our result suggests that writing playback of certain style can enhance readers’ engagement level but also can harm reading comprehension. However, writers uniformly enjoyed watching playback as they are also interested in the creative process beyond the content, helping them reflect their own writing practice and empathize with the author.

## 2 RELATED WORKS

### 2.1 Live Streaming and Revealing Creative Process

The emerging culture of live streaming has drawn increasing interest from researchers. [15, 16]. Existing social media — Facebook, YouTube, Instagram — and novel platforms dedicated to live streaming such as Twitch and Periscope have enabled greater immersion, immediacy, and interactivity among viewers [15]. In particular, revealing the creative process has become a new trend with these social media and live streaming platforms. [8, 9, 12, 13]

Documentation of creative process can improve our understanding beyond what is conveyed by the final draft. An observational study found the process of creating something conveys information not found in the resulting artifacts, which makes it essential in a collaborative setup [36]. However, revealing the creative process to passive viewers rather than collaborators creates new challenges and opportunities for artists working with this burgeoning form. While documentation of creative practice has the potential to be engaging, artists were concerned that some aspects of their creative practice would not be engaging for an audience to watch. As a result, they became more interested in making their creative process more performative [12, 13]. However, it is also worth noting that viewers of live creative streaming are also likely to be those who would be interested in the artistic practice, if not artists themselves [13]. While this study does not involve conscious efforts from the artist to make live creative streaming interactive and engaging — such as voice narration, behind-the-scenes preparation, and social interactivity through chat — this study aims to understand how revealing the creative process of writing affects readers’ engagement with the text.

The act of composing itself is a goal-directed thinking process where writers explore, develop, or regenerate as they write. It is therefore inherently dynamic [11]. Capturing this process has the potential to further engage readers or inspire other writers. In this study, we pose under-explored questions in writing research: what components of writing process might be “fascinating to watch” for readers? Which styles of writing practice may be more engaging to watch than others? How might this documentation of writing process impact readers’ comprehension and perception of the work?

### 2.2 Liveness in Interactive Systems

In this work, we explore the notion of liveness in the context of writing and reading. Despite being one of the most popular forms of creative work, liveness in reading and writing is rarely discussed. The notion of liveness has been studied in the domain of communication — mostly TV — in order to understand how media can use liveness to enhance audience engagement [1]. Researchers have discussed the quality of liveness in the context of distributed events [40],

remote monitoring [39], and general HCI [17]. However, nearly all of these works discussed liveness as a perceived quality of spectators, not as a characteristic of interactive system design.

The notion of liveness from a design perspective has been actively discussed in live programming community. In this community, liveness in programming environment indicates the extent to which a programmer can have immediate feedback from code change that they make [37]. The notion of liveness is useful in programming because there can be disparity between the artifact (the program state) and the creative practice (coding) depending on how they change the code since the last compile-and-run action [34]. Live coding is a unique performance practice where liveness plays an important role in programming-based computational arts [6]. In live coding performances, a programmer use programming language for an artistic means and the program outcome is typically audiovisual that is generated by on-stage programmers. In live coding, it is a Canonical practice to project their computer screen in a performance space and reveal their creative process, that is writing code on the fly, entirely revealed. This principle is well captured in the following statement of *TOPLAP*<sup>1</sup> (live coding community) manifesto; “*Obscurantism is dangerous. Show us your screens.*” The notion of live writing — writing in front of a live audience — was explored as as a form of performing art [24]. In this performance practice, writing a poem on stage generates sound, which feeds back to the visualization of the poem, creating an immersive audiovisual performance with the power of expressivity of creative writing. We apply the same ethos to writing so that readers would get to see the entire process and see the potential of writing as a real-time performing art.

One potential definition that can be used to account for liveness of media and interactive system was proposed in previous works [21, 22]. In these, liveness is defined as *the extent to which the process of creating artifacts and the state of the artifacts are immediately and continuously perceptible*. In this definition, three characteristics — *immediacy*, *continuity*, and *perceptibility* — constitutes liveness of an interactive system. Immediacy depends on the delay between the creative process and the time that the process is perceptible to spectators. Continuity indicates the extent to which the process of creation is revealed entirely, as opposed to partially. Lastly, perceptibility represents the ability to perceive the process as if they are co-located, which is similar to the sense of co-presence [31]. Recording of writing process explored in this work satisfies two qualities of liveness to some extent: *continuity* and *perceptibility*. Although writing replays do not occur immediately when the author writes thus have no immediacy, it simulates the scenario in which readers can continuously watch someone writing over the shoulder.

### 2.3 Real-time Aspects of Writing

Recording and reviewing the writing process with keystroke logging has become an effective technique in writing research, and has been instrumental in identifying writing strategies and understanding writers’ underlying cognitive processes [25, 26]. Recording the writing process provides a non-intrusive and inexpensive technique to monitor user input. Writing researchers have developed a number of keystroke logging applications. Inputlog [25] and ScriptLog [33] are two such programs used in the context of writing research<sup>2</sup>. Most keystroke logging applications include a feature that permits real-time playback of recorded keystrokes. Letting a writer watch this replay is an effective approach to help subjects account for their writing in retrospect, as an alternative to the think-aloud method, a common research method in human-computer interaction as well [20, 28, 29]. In addition, keystroke logging (compared to screen recording) provides rich data for further analysis of temporal patterns in writing practice. What distinguishes this work from previous works is that the purpose of our research is to investigate the effects of watching writing replays for general

<sup>1</sup><http://www.toplap.org/>

<sup>2</sup>See [http://www.writingpro.eu/logging\\_programs.php](http://www.writingpro.eu/logging_programs.php) for more complete list of keystroke logging programs.

audiences — both readers and writers — while previous works used this tool for researchers to understand the writing process.

Revealing the writing process has been underexplored in the context of written communication. On one hand, recording how a piece of writing evolves in real time can be seen as offering an extreme level of *change awareness*, given that viewers can see every change made at its finest resolution [35]. In this regard, transaction data hidden in the real-time dimension of writing may provide rich information on writers' states, and this information may be useful in communication, collaboration, and self-reflection.

### 3 LIVE WRITING: RECORDING AND PLAYBACK OF WRITING

We extended Live Writing, a web library which augments web-based editors with recording and replay functionality [23]. The Live Writing platform is a word processor and timestamped logger which records all keystrokes, all text cursor placements (whether by mouse or arrow keys), and all scrolling events. This recording data can be used to create a real-time replay of writing that functions in a web browser and stores its content as text (rather than a video). The live writing platform differs from a traditional screencast recording in that the actual text is recorded. For example, the viewable replay is composed of text and can be embedded in other web pages. It can also be reinserted into a CodeMirror text box, which permits the text to be copied and pasted or modified as needed.

The original system was proposed in the context of fostering asynchronous collaboration among live coding musicians. The extended system works on two popular web editors: CodeMirror<sup>3</sup> and Ace.io<sup>4</sup>, which are used in various web-based programming environments and other web-based writing environments (Wikipedia). New functionality was added to the replay interface of Live Writing in order to make it more closely resemble a video player and to support this research. The graphical user interface of Live Writing is shown in Figure 1

The following features were added:

- Timeline Interface (1): As in any video player, a user can drag and drop the playback head to navigate and skip to different parts of the replay.
- Skipping Inactivity (2): If this option is on, the video replay skips periods in which the writer did not interact with the editor at all.
- Playback Speed (3): A reader can adjust the playback speed to be slower or faster. Typical reading speeds are much faster than writing speeds; therefore, users tend to view the writing replay at a faster speed even when not explicitly prompted to do so.
- Visual Cue for Change Awareness (4) : We found that writers may jump between places while writing, making it difficult for viewers to realize where new changes are being made and locate the cursor. To signify the current location of changes, the editor highlights text being added in green. The highlight fades out over a few seconds.
- Interaction Logger: The Live Writing platform also tracks how users interact with the playback by logging all interactions with the platform with timestamps (e.g., how they skipped through the replay using the timeline, how they changed the playback speed). A simple visualization is also available to readers to demonstrate additions and deletions on the timeline. (See Figure 2, for example)
- Replay Embedding (5): A user can generate an `iframe` tag with which to embed a Live Writing replay in any web page; in our case, as part of the online survey.

<sup>3</sup><https://codemirror.net/>

<sup>4</sup><https://ace.c9.io/>

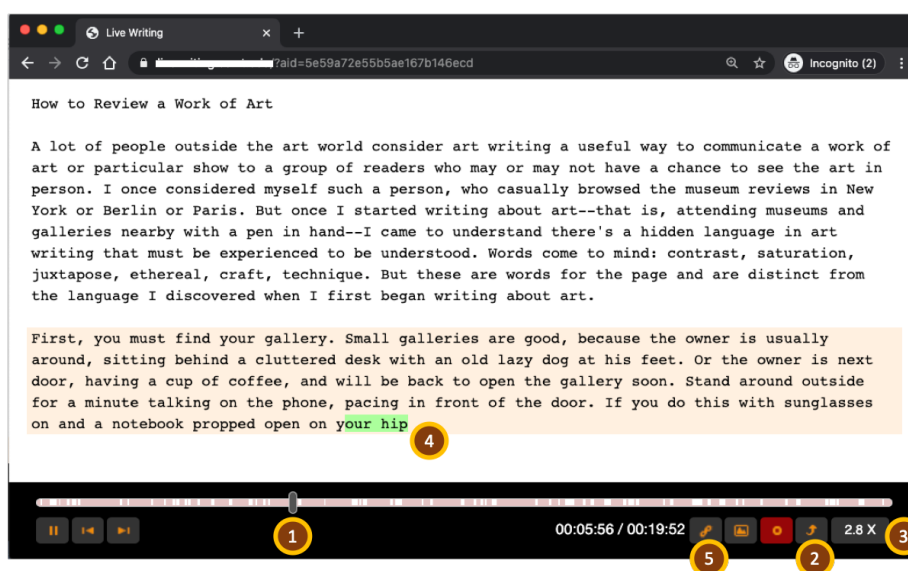


Fig. 1. Live Writing Replay application plays back the text in real-time as it appeared for the writer in the writing process. (1) Timeline Interface. (2) Skip Inactivity Button. If active, skips any part of replay in which text is not being generated or altered. (3) Playback Speed. (4) Visual Cue for Change Awareness. This highlights text green when it is newly added to the document, red if newly deleted. (5) Replay embedding. Generates an iFrame of the writing playback.

## 4 STUDY I: ONLINE SURVEY ABOUT WATCHING REPLAYS FOR READING

### 4.1 Method

The goal of Study I was to understand the effects of watching a writing replay in reading and how it influences readers' comprehension and perceptions of the content. We had the following initial research questions for this particular study.

- (RQ1) How does watching replays affect readers' engagement and the perceived quality of the writing?
- (RQ2) How does watching replays impact reading comprehension?
- (RQ3) How do readers perceive watching a replay?

To answer these questions, we conducted an online survey where we asked participants to read four different essays (two short fiction stories and two short essays).

**4.1.1 Generating writing replays.** Before conducting the online survey study, we recruited five Master of Fine Arts (MFA) students in the Creative Writing master program at our (i.e., the authors') university and asked them to write one short essay and one piece of short fiction (approximately 400 words each, in less than 30 minutes). The students were asked to use Live Writing for writing, but were not informed that it would record all their keystrokes and mouse interactions within the editor. We considered disclosing the recording function of the editor an impossibility, as doing so could have influenced the way the writers wrote. After data collection, we presented the writing replays to their respective authors and asked if they would be willing to share the replay data with us for the online survey study. We compensated them with \$40 electronic gift cards for their compositions.

We reviewed the writing and chose from among the replays two essays and two pieces of fiction, all with distinctive styles of writing relative to each other. The first author produced four reading comprehension problems per piece for

the reading comprehension test in the survey. The reading comprehension score is presented as a proportion of correct answers, 1.0 representing correct answers to all 4 questions. We refer to each text using the following labels: T1 (“How to review a work of art,” essay), T2 (“Horse Riding,” essay), T3 (“Rising from the bed,” fiction), and T4 (“Jewel Case,” fiction).<sup>5</sup>

Each text was written in a different way. T1 and T3 were written in a linear fashion: the writers wrote each text in an essentially uninterrupted session, with nearly no revisions. While the authors of T1 and T3 often revised expressions, those revisions were typically limited in scope to what they had most recently written. T2 and T4 were written in a more nonlinear fashion, with the writers jumping between and working on multiple paragraphs simultaneously. As they reached the end of each piece, they refined the existing writing more. We hypothesize that this may negatively impact reading comprehension scores. T2 and T4 were written in an unusual way in which the writer first outlined all the ideas or images in the piece and then used this outline as a queue during their writing process, taking each item from the list and turning it into a sentence. This makes the first 7 minutes of replay incomprehensible to most readers.

We quantified the non-linearity of the writing based on the average size of cursor jumps in the playback. Cursor jump size was measured as the number of characters between the expected cursor position after a change had been made to the document and the initial cursor position before the next change was made. Typically, this value is zero because users don’t move the cursor between each individual change they make to a document, but if the value is nonzero, we knew that the user had moved the cursor with either the mouse or arrow keys between these two changes. Metric for each text is presented in Table 1

We calculated the average distance between all these changes in the text, representing the extent to which the author of a text wrote it in a non-linear fashion; the lower the value, the more linear the writing was.

**4.1.2 Online survey.** We created an online survey featuring the four pieces of writing we chose. The survey begins with an interactive tutorial that teaches participants to play a recording, pause it, skip inactive writing periods, and change the playback speed within Live Writing. For each participant, two of the pieces of writing were randomly selected to be presented as static text, while the other two pieces were presented as Live Writing replays. Therefore, each participant read each text in only one format, making this a between-subjects study. We presented the four pieces in a random order, and we presented reading comprehension questions after each piece of writing. They were instructed to spend as much time as they need but they were not allowed to go back to the text when they were prompted with reading comprehension questions. Live Writing replays were embedded as part of the online survey. As part of the online survey, we asked 5-class Likert questions on the engagement of each piece (from 1 — not at all engaging, to 5 — completely engaging) and the quality of the piece (from 1 — poorly written, to 5 — very well written). We asked follow-up questions on participants’ format preferences (replay vs. static text) and the pros and cons of watching Live Writing replays. The survey was reviewed and approved by the internal review board at the authors’ university.

We recruited 100 participants from various university mailing lists. All participants were compensated with an electronic gift card (worth \$9). The average age of the subjects was 28.2 ( $\sigma = 6.8$ ), ranging from 19 to 59. 53 of the participants were female, 46 were male, and 1 identified as non-binary. After the responses, we excluded responses based on answers to attention check questions and survey completion speed (if they completed the entire survey at a speed beyond human reading capabilities) [2]. In the end, we were left with 78 responses.

<sup>5</sup>The static version of each text will be available at [https://livewriting.github.io/chi2021\\_statictext.html](https://livewriting.github.io/chi2021_statictext.html). The Live Writing replays are available at the following URL: [https://livewriting.github.io/chi2021\\_livewriting.html](https://livewriting.github.io/chi2021_livewriting.html).

Text	Type	Writing Speed(wpm)	Non-linearity	Engagement		Perceived Quality		Reading Comprehension	
				Replay	Static	Replay	Static	Replay	Static
T1	essay	37.6	0.05	2.76 (0.93)	2.68 (0.84)	3.16 (0.96)	3.59 (0.8)	0.82 (0.23)	0.87 (0.19)
T2	essay	21.8	3.23	<b>3.0 (0.99)<sup>+</sup></b>	2.64 (1.06)	3.03 (0.65)	3.10 (0.91)	0.78 (0.22)	0.74 (0.29)
T3	fiction	31.4	0.12	<b>3.36 (0.99)<sup>*</sup></b>	2.87(0.98)	3.51 (0.85)	3.41 (0.79)	0.85 (0.23)	0.92 (0.16)
T4	fiction	14.6	3.15	2.52 (1.09)	2.71 (0.87)	3.03 (0.86)	<b>3.44 (0.89)<sup>**</sup></b>	0.78 (0.23)	<b>0.88 (0.19)<sup>*</sup></b>

Table 1. The result of online survey study. We evaluated four text [T1–T4] in terms of writing speed and non-linearity. Online survey results was tested with Kruskal-Wallis Test (+  $p < 0.1$ , \*  $< 0.05$ , \*\*  $p < 0.01$ ). For T2 and T3, the group of respondents in Live Writing replay felt more engaged than the other group. For T4, the group who watched the replay had lower reading comprehension scores and lower perceived quality score than the static group.

#### 4.2 Result: Replaying certain styles of writing can enhance engagement levels, but harm reading comprehension

We ran Kruskal-Wallis tests on engagement scores and perceived quality scores; the results are shown in Table 1. For engagement scores, the participants found it more engaging to watch Live Writing replays than to read static text for T3, and the difference was statistically significant ( $p < 0.05$ ). A similar tendency was observed for T2 ( $p < 0.1$ ). However, the difference was not statistically significant for the other two pieces (T1, T4). The result suggests that the ways in which a text is written can positively influence readers' engagement levels. Interestingly, the difference in perceived quality was statistically significant for neither T2 nor T3. This reinforces our assumption that the creative process of writing can have components that can engage readers beyond the content itself. As for reading comprehension scores, we could not find any statistically significant result except for in the case of T4, where watching the Live Writing replay negatively impacted the comprehensibility of the text ( $p < 0.05$ ).

In the meantime, the perceived quality of T4 was lower when participants watched the Live Writing replay than when they read the static text. The difference was statistically significant ( $p < 0.01$ ). The potential reasons for these differences in engagement and perceived quality can be attributed to the ways that a Live Writing replay “unfolds” the text. For example, T3 was written linearly and with little revision. This linear writing process more closely resembled the way in which readers traditionally read from beginning to end. Only minor edits and small changes in the speed at which the text was generated distinguished the replay from traditional reading. On the other hand, T4 was written in a manner that made it difficult to follow. Not only was T4 non-linear, but the author composed a queue of moments at the bottom of the page which they then used to write the piece. For most readers, this queue of moments was likely confusing because it was unclear how they would be used, how they were related, and what they represented. Therefore, this may have affected readers' perceptions of the writing quality, as the listed items only made sense to the writer. Readers were likely baffled. Some participants directly addressed the difficulties that they had reading T4 in replay form.

- (P38) “I had to keep rereading passages to remember what was going on in them when the author returned. When the author created an outline before writing, it ruined the suspense of the story or sometimes confused me. I was concerned when the ‘reading comprehension’ part came up that I would remember old facts that had been deleted or revised.”

This trouble may account for the negative impact of watching the replay on the reading comprehension score for T4.

Meanwhile, T2 was written in a non-linear way, but still showed higher engagement levels when read in replay form. We believe that certain characteristics of T2 made it more engaging to watch. First, the tone of T2 is more informal than that of T3 and T4, which are works of literary fiction. This informal tone was also expressed in notes which the



author wrote to themselves in the act of writing, and these would not have been present in a static text. Second, the author created an organized structure within the text (e.g., subsection titles and the use of ordinal adjectives such as “first,” “second,” etc. ) that may have provided readers context during the replay, even as the author’s edits proceeded in a confusing, non-linear manner. While both T2 and T4 were written in a non-linear fashion (by the same author), T2 was a top-down essay in which paragraphs clearly linked back to the main topic of leading horseback rides. In contrast, T4 was a fictional story in which the narrative unfolds sequentially without a clear thesis and series of subordinate points. One participant who read T4 as a Live Writing replay left a comment reflecting this concern.

- (P75) *“The ‘serial’ nature of narration is not maintained, that’s a little unsettling. If you did not go back to edit what was previously written, it would not be so bad”*

Therefore, because T4 had autonomous paragraphs operating within a clear structure, it might have hindered the effect of writing replay on perceived quality and reading comprehension. It seems that the participants considered the writing process as part of quality evaluation given in the case of T4, the replay negatively impacted the perceived quality.

### 4.3 Result: Readers diverged in watching writing replays

We asked readers which format they would prefer for reading. Among 78 participants, 24 of them (30.8%) chose the replay format, 50 of them (64.1%) chose the static format, and 4 of them had no preference. Given their unfamiliarity with Live Writing replays, we believe the portion of respondents who preferred the replay format is not insignificant. This demonstrates the potential of writing replays as a new medium for reading. Furthermore, we conducted thematic analysis on the follow-up open-ended question responses [5]. The questions included *Why was this your preference?*, *What are the pros and cons of watching a replay?*, and *In what context do you believe watching a writing replay can be useful?* We present the themes that we found below.

**4.3.1 “Re-living the erratic and fluid nature” (P76) can be engaging but distracting.** Aligned with our own motivation, many of the participants (29/78, 37.1%) identified being able to “*witness the creative process*” (P62) as one of the pros of watching a Live Writing replay. Many people found it was engaging to watch the real-time creative process as it unfolded. The following comment by a participant is a good representation of their engagement with the writing process.

- (P26) *“The pros are that you can evaluate the natural and organic thought progression of the author, understand their initial thoughts, and see the progression to the final presentation of the passage. I think that also gives a lot of meaning to the text and unveils the author’s truer feelings or notions about the topic.”*

However, watching this creative process in action involves having to comprehend non-linear, exploitative, and rough edits, which a significant number of participants (43/78, 55.1%) found confusing, distracting, or even “*annoying*.” In particular, going back and forth between different parts of the writing was detrimental to not just comprehension, but also immersion in the story.

- (P25) *“The first section [T4] was confusing to read the editing as it was happening live. I preferred the second video [T3] that was just written out live.”*
- (P12) *“Watching a replay is very confusing and the going back and forth disrupts the flow of the reader to understand what the piece is about.”*

This not only impacted their cognitive load of needing to keep track of where edits were being made, but also was detrimental to conveying the narrative.



We believe that if the writers can “perform” writing in a certain way — typically linear, but dynamic — this real-time process can create engaging, comprehensible, and immersive reading experiences. A few participants (3/78), all of whom watched T3 in the replay format, mentioned that because it revealed the text gradually, the replay was able to produce suspense.

- (P58) *“the pros of watching a replay is like watching a movie. you don’t know whats going to happen. the suspense.”*
- (P19) *“I enjoyed the sense of suspense I got waiting for the text to be typed.”*

This shows the potential of recording writing as a performing art and watching a replay of it as a new expressive medium that static text does not afford.

**4.3.2 Perfect pacing exists, but is difficult to find.** A considerable number of participants (21/78, 26.9%) complained that watching Live Writing replays is slow, time-consuming, or daunting. Although this would have been addressed by adjusting the playback speed, which was part of the required interactive tutorial, it seemed that many participants were unable to find the perfect pace at which to watch the replay.

- (P16) *“waste a lot of time. I wouldn’t read in a video replay form unless I have a very strong motivation for it.”*
- (P29) *“It takes a lot of time and sometimes difficult to follow author’s thoughts. From the point of just reading the passage, normal is quick and efficient.”*

Some people found this extra work — fine tuning the setting for a perfect reading experience — to be a main flaw of watching a writing replay.

Evidently, reading text as it is written may not be ideal simply because of the disparity between the average human reading speed (150–250 WPM) and writing speed (average WPM [T1-T4]: 26.4). However, understanding what reading speed would be ideal remains as a separate challenge, not just due to individual differences, but also due to the temporally and spatially dynamic nature of writing. In fact, many participants (11/78, 14.1%) who preferred static text stated that they preferred it because they could read at their own pace. The following comment from a participant accurately reflects this challenge.

- (P24) *“Watching a replay - Replay speed could be slower or faster than my own pace of reading, which isn’t going to be the same speed throughout depending on the level of understanding texts.”*

While the expressivity enabled in the temporal dimension in watching a replay unfolds an exciting opportunity for a writer, writing at a pace that makes for a comprehensible text can be a limiting factor.

The potential existence of a distinct perfect pace for each individual was implied by some participants’ contradictory responses. 28 participants (35.9%) mentioned that the way the real-time replay revealed text gradually over time made it easier to comprehend and follow the text. The following responses exemplify such perceived values.

- (P51) *“Normal text is easier to just start to gloss over and skim, but watching a replay is more akin to listening to an audio book, where the speed is ‘set’ and you have to soak in every word, which aids in comprehension.”*
- (P27) *“I could set the pace to where I wanted. It was really cool to see the story adapt with the edits in real time. It wasn’t daunting or exhausting to see the whole passage and think ‘ugh I have to read all this.’”*
- (P71) *“You can’t read too ahead with a replay — you have to live in the sentence you’re on. You can’t get ahead of yourself. It kind of helps you focus more in a way.”*

Not showing the whole text and revealing it incrementally created a tension between not being able to skim and get the full picture (7/78, 9%) and the guided reading pace that helps hold people’s attention. There seems to be a similar effect in listening to an audiobook, where the listening pace is forced by the speaker. With the similar effects, Live

Writing replays allow users to skim and review when the replay is paused, whereas navigation and understanding the big picture are challenging in audiobook. One participant mentioned the potential benefits of watching replays for ESL readers.

- (P77): *“The replay as presented here may be useful to those who do not speak English as a first language, as the karaoke-style green highlighting may make it easier to keep pace with the thought process. This is particularly so if the reader lacks familiarity with standard English sentence structure or comes to the piece from a native language that differs significantly. I am uncertain if this benefit is undone by the “live” revisions.”*

The participant, at the end of their comment, pointed out that the non-linear edits made by the writer could be a potential barrier in this idea of guided pacing. Potentially, watching the right replays — those with fewer non-linear edits, consistence pacing, and a suitable replay speed — can be a way to provide a reading aid to those who struggle with concentration and reading fluency. However, the challenges of forcing a writer to compose at a constant, linear pace and knowing the right pace for each individual remain unsolved.

**4.3.3 Readers found various potentials for Live Writing in other domains.** We asked participants where they could see Live Writing being useful and got a wide range of responses. The most frequent type of answer (19/78, 24.4%) mentioned using it in the context of creative writing education or learning from someone else’s writing practice. As the writing process is typically solitary, perhaps personal, participants found value in it for learning writing practice. Another prominent theme (21/78, 26.9%) revolved around being able to add quasi-interactivity to existing, typically recorded, media: online lectures, tutorials, games, advertisements, presentations, digital story telling, and so on. Other minority views included a new art form for writing (14/78, 17.9%), reading aid / speed reading tools (12/78, 15.4%), context recovery tools (10/78, 12.8%), mining writing patterns, tools for learners of English as a second language (ESL), programming editors, chat communication, etc. (less than 10%). Only three participants could not think of any use for Live Writing; it is promising that a majority of the participants found some utility in watching replays in various domains.

## 5 STUDY II: INTERVIEW ABOUT THE VALUE OF WATCHING REPLAYS FOR WRITERS

### 5.1 Method

In Study II, we aim to understand how professional writers perceive this new ways of recording and replaying — as a way to document their writing practice for others. We had the following initial research questions for this study.

- (RQ4) What kinds of value do writers find in watching writing replays?
- (RQ5) Do writers find any difference in their perceived writing practice from their own writing replays?

We recruited professional writers from Twitter, Facebook groups, and the author’s university mailing list, as well as the writer group that participated in generating writing replays for Study I. During recruitment, we specifically mentioned that we wished to recruit “professional writers,” defined as those who have published (whether as a first author in journal, as part of a book, online, or for internal company documentation) and received monetary compensation (either directly for a piece or in the form of a fellowship, grant, stipend, as part of a job, academia, grad school, etc.) for writing within the last two years. We screened writers based on their availability and experience, and recruited 13 professional writers with various backgrounds. Each writer’s background is given in Table 2.

After the screening process, interviewees were asked to complete a short essay or piece of fiction (approximately 400 words in no more than 30 minutes), a prompt for which was given on the Live Writing platform. The provided prompts

Index	Gender	Age	Self-reported Occupation	Writing experience	Watched
W1	Female	25	M.F.A Student in Creative Writing	fiction, copy-writing (Author of T2 and T4)	T1
W2	Female	26	M.F.A Student in Creative Writing	poetry, fiction, nonfiction (Author of T3)	T4
W3	Female	44	Freelance Writer	nonfiction, journalism	T1
W4	Female	24	Writer	music journalism, poetry	T4
W5	Female	61	Journalist	tech writing, journalism	T1
W6	Female	30	Freelance Writer	comedy, television script	T3
W7	Male	44	Visiting Assistant Professor in Rhetoric	academic writing	T1
W8	Female	47	Reporter	nonfiction, journalism	T1
W9	Male	62	Writer	wine journalism, magazines	T3
W10	Female	35	M.F.A Student in Creative Writing	poetry, nonfiction, English high school teacher	T3
W11	Female	25	Video Editor	comedy, script writing	T1
W12	Female	29	M.F.A Student in Creative Writing	fiction, blogging	T3
W13	Female	30	M.F.A Student in Creative Writing	art journalist, nonfiction, fiction (Author of T1)	T4

Table 2. Information on interviewees in Study II

are available in the appendix. Writers were not informed that the Live Writing platform was recording their keystrokes or cursor movements. We conducted a 90 minute-long interview (via remote video call) with each writer. During the interviews, we followed the steps below.

- (1) Writers were asked to describe their writing process.
- (2) Writers were then shown a static version of the passages they composed and asked to remind us of the process of writing the passage.
- (3) They were then shown a Live Writing playback version of their writing and asked to compare their perceived writing process with what they remembered.
- (4) We showed them a writing replay created by someone else. We randomly chose one text from [T1, T3, and T4], these being the same texts we used in Study I. T2 was excluded because shares an author with T4.
- (5) Finally, we asked some general questions about their experience of watching the replays, the Live Writing platform, and possible uses.

The first author transcribed the interview and conducted thematic analysis on the transcription. The writing tasks and interview process were reviewed and approved by the internal review board at the authors' university.

## 5.2 Result: Writers consumed not the content, but the process as a creative artifact.

Of the 13 writers studied in the interview, all 13 expressed engagement with the platform. Writers differed in their reasons for why they were engaged with the platform. Some writers (5/13) simply expressed interest in the novelty of Live Writing playback, stating that they had “*never seen anything like that*” (W3) before. However, we believe that the novelty alone does not account for the reason why they uniformly felt engaged, compared to the divided responses from readers. This engagement came not only from watching others' replays, but also from their own replays. This might have been because they not only enjoy content as readers, but also enjoy watching the process of creating the artifact as a writer. Many participants gave examples of watching a writer making choices in the moment, rather than the content itself, to account for why they felt engaged.

- (W10) “*[after watching her own replay] I love that. It was really interesting. (...) I think the editing afterwards was especially interesting to watch because it was a lot of added details and it was moving out sentences. It was adding more syntactical variety. So it's very entertaining to see all of that happening even though I know I do it.*”

- (W8) *“You could see in the writing... the thought process. [Thinking] ‘Is this sentence complete enough?’ and then going back and not rewriting the whole sentence but just a key word that made it better. So there was a thoughtfulness in the editing process and it was pretty clean.”*

Even though the majority of the writers (8/13) noted that they enjoyed reading their pieces after they have been published or released, none of them had previously seen a recording of their own writing process. Even more so, they considered writing a “*very personal*” (W11) process, meaning that they rarely see other people writing in real time, save for a few people in classroom settings. In that regard, watching playback provided novel content that they were interested in; namely, the writing process as it unfolded.

### 5.3 Result: Revealing imperfections is a new way to connect to a writer.

Some writers expressed interest in an enhanced sense of connection with the author or with themselves. Of the 13 participants interviewed, 9 expressed a sense of connection with the author in multifaceted ways. Here, we present some prominent themes we found.

**5.3.1 Revision and mistakes foster empathy.** A number of participants expressed that watching other writers make edits and mistakes helped them connect with their process. Writers empathized with watching other writers struggle through the writing process in the same way they often do themselves.

- (W7) *“It was interesting to see this person almost second guessing themselves in certain parts of the writing... I think sitting down this person and viewing this and having discussions like that would strive to make this person a stronger writer... I sense there might be a little empathy that might not have been there had I just seen the finished project.”*
- (W6) *“He started to type fluorescent and typed ‘fol...floo... flou...” and then deleted it and typed bright. That made me laugh. Like “yeah, I can’t spell either.””*
- (W13) *“It looked like she was beginning a sentence one way and then changing her mind and then beginning it a different way and then changing her mind and then beginning again, which is something that felt really familiar to me.”*

By watching others’ replays, writers were able to reflect on their own practices and empathize with their fellow writers in the replays. Compared to readers, who regard these revisions as mere barriers to comprehension and attention — finding them distracting or annoying — writers were able to quickly connect to the creative efforts which the other writers were putting into their work, finding the experience of those real-time efforts “comforting.”

**5.3.2 The Live Writing playback humanized the author.** Of the 9 writers who expressed a sense of connection with the author of a replay, 3 additionally expressed that the playback humanized the authors. Readers only interact with writers through their perfected drafts, so writers can give the impression that they are naturally perfect at organizing and presenting their thoughts. Live Writing playback interested these participants because it allowed them to watch the writers make mistakes, thereby taking them off of a pedestal and allowing a viewing writer to see their process as messy and imperfect, like their own. The following comments accurately reflect the values they found in Live Writing playback.

- (W3) *“I think it would give you more of a sense this author is a real person. Because most people only see the finished product, after it’s been edited by multiple people, it’s been slaved over for months, and I think the average reader — including professional writers — we get the impression that everyone else is better at this than we are. We know the process we’ve gone through to get a good, finished piece, and yet we have a hard time remembering, sometimes, that*

*other writers are going through that exact same thing. This did not leap from their head fully formed. So I think as a writer it's comforting to see that process play out. It assures you that you are not alone."*

- (W13) *"I think it's useful for younger writers to see that things aren't perfect on the first try."*

By expressing interest in seeing these authors humanized by Live Writing playback, participants also expressed an interest in connecting with and empathizing with other writers. Seeing the imperfect nature of others' drafts allowed participants to find common ground between themselves and these other writers.

#### 5.4 Result: A non-live medium elicited liveness.

Out of the 13 participants, 7 expressed a sense that Live Writing playback felt more live than traditional static writing. One participant (W8) noted that watching the playback felt like they were *"having a conversation with the writer"*. Most of these expressions came in the form of comparisons to audible forms of media, including audiobooks and film.

- (W10) *"I think there's something to listening to a piece and reading a piece as it appears on screen that are similar. Like listening to an audiobook you don't know what's going on. "*
- (W12) (After watching T3 replay) *"Yeah. This piece is really, really good. (...) Well for something like this that she pretty much just went right through like it was almost like watching a movie like I mentioned. It was like watching a narrative unfold."*
- (W12) *"The writer doesn't know how it's going to end. I don't know how it's going to end. I'm just watching the story unfold. Nobody knows what's going to happen."*

Indeed, the writing process was *live* at the time of recording, and the participants were excited by the idea of watching a story unfold in front of them without being able to see what comes next. One piece of evidence suggesting that watching the replay elicited liveness, not as a system characteristic (as stated in 2.2) but as a perceived quality from viewers, was the existence of writers' evaluations in which they expressed that they felt as if they were there in the story or with the author. Six of the 9 writers expressed such a sense of presence.

- (W1) *"I certainly feel a stronger connection to a work I've seen play out in scene and be created... I get a greater understanding of this piece by seeing the individual steps and the individual decisions. You are right there beside them watching this happen. And I think there's a strong connection... To the creator, the piece—both. "*
- (W7) *"Watching this playback, I'm going on a defacto journey with this person as they're composing this piece of writing and you know, there's suspense and tension that builds after they wrote the title, and it's a good 30 to 40 seconds before more words appear... "What's going on? What are they doing?"... I feel — empathy would really be the best way to describe that."*
- (W2) *"It was kind of like peeping into her mind a little bit. It felt like kind of—in a way—because her process was so raw at the start and then becomes this finished product I felt kind of intrusive."*

One of the central causes appeared to be the continuous perceptibility — which is part of the definition of liveness — offered by the medium, even though the medium is technically *not live* because the playback did not occur at the same time as the writing itself. It is not uncommon to see engaged readers express that reading a work of fiction made them feel that the story came "to life." However, in this case, the interviewees expressed a sense of co-presence with the author, which we do not commonly observe as feedback.

### 5.5 Result: Live Writing playback facilitated self-reflection

In response to the question asking if writers learned anything new about their writing practice from watching their own replays, 7 out of the 13 participants noted that they recognized behaviors that they were not aware of from the playback. Many of them especially were surprised how much effort they put into finding the right expressions through writing, deleting, and rewriting a passage until it works.

- (W2) *“I don’t know that I self-identified that before: that I pay a lot of attention to word level choices, probably way more than large scale structural choices.”*
- (W10) *“This shows me things that I don’t realize that I’m doing. So for instance, when you were asking the questions beforehand (...) I saw that in a different way here, and saw that I very frequently... rewrite the last few words.”*
- (W12) *“I can actually see how my brain works... I didn’t know there were so many corrections I do on the spot.”*

These participants were both startled and pleased to discover that despite the fact that writing was their profession, watching the writing playback was able to help them glean new insights about their processes.

Furthermore, watching others’ replays helped some writers (5/13) notice how drastically one writer’s style can differ from another’s, again helping them to think about their own practice with the contrast.

- (W2) *“I never would have thought anybody would write like this. (...) I don’t know why it’s so shocking, but it’s just so different from mine. It was really cool to see this style of writing. I thought it was kind of cool to see how much it changed and to like see someone jump around their piece so much. When I wouldn’t do it, but it was cool.”*
- (W3) *“It was definitely more linear than mine. They seemed to do, it seemed more in line with what people probably think writers do which is just to sit down and type it out. I was surprised, also at the end, that the writer didn’t seem to go back and do any overall edits—they were just done. But it was it was a great piece of writing. It was surprising.”*
- (W13) *“Yeah, I thought I was reading a poem. And then, I realized that it was a sequence of events in a linear timeline from beginning to end. And it took me a while to figure out what notes were about the conflict and notes to self. So that surprised me. It surprised me that the details didn’t come with the first run through but it looks like she went back and added extra details to each section. So that surprised me because [writing in detail] is the kind of thing that I do on a first run.”*

When asked if what they saw in watching the replays of others made them want to adjust their writing practice, few participants said they would change anything. However, it clearly brought more awareness to their own practices. This suggests that watching writing playback could be a powerful tool for self-reflection, enabling writers to better understand their own writing practices.

### 5.6 Result: Applications of the platform

Many participants offered ways in which the writing playback could be applied in new contexts. The three most common contexts in which writers suggested writing playback could be useful were in their own writing practice, in watching the replays of other writers (particularly those writers which they admire), and in a pedagogical context.

**5.6.1 Incorporation in writing practice.** Seven of the 13 participants interviewed wanted to incorporate the playback in their own writing practice. Writers suggested this could take a number of forms. Some of them felt that this would be useful in the revision process, particularly because writing replays provide a new modality which allows the viewer to see what they’re writing in a new way. Others noted that for larger writing projects, writing replays

would enable them to more smoothly transition to a component of the project about which they may have otherwise forgotten.

- (W2) *"It was easier for me to spot [key details] versus when I was just on a page. So I would use [writing replay] drafting-wise."*
- (W7) *"I could see people that write for a living, like I do, using something like this much in the same way a football player will watch a film of themselves throwing."*
- (W6) *"It's a shortcut to what's going through your brain as you're writing. If I were editing something that I wrote a year ago and I was like 'what was I trying to do with this chapter?', I think it would be useful to go back and watch the playback."*

**5.6.2 Learning from and documenting other writers.** Six of the 13 participants expressed an interest in seeing the replays of other writers, particularly those that they admire. These writers were interested in having the process of these famous writers demystified, and believed that they would be very engaged if afforded the opportunity to see replays from writers that they admired.

- *"If I followed a writer, you know, like I do on Goodreads or Amazon and I knew they were Live Writing, I probably would jump over there..."*
- *"If a writer I admired wrote a poem using this software, I would think it's super cool to watch."*

**5.6.3 Pedagogical potential.** Five of the 13 participants believed that the platform would be a useful tool in the writing classroom. Participants generally expressed an interest in showing writing replays from successful writers or their own writing as a means of "modeling" what the writing process looks like for students. According to these participants, students often have an idealized understanding of the writing process in which they think good writers put their ideas fully formed on the page in a single draft, when in fact, writing is a long process which requires a number of revisions and changes to reach a final product. Some participants expressed interest in seeing student replays as well, as a means of diagnosing issues in students who are really struggling.

- (W1) *"I think in writing instruction, and lots of other instruction I'm sure, we talk about 'modeling' writing, and I think that this is the perfect way to do that. One of the problems with 'modeling' writing is that it takes awhile to do that. So when you're showing your students how to write an introductory paragraph you don't want to sit there for 20 minutes and write an introductory paragraph for them. So I think that this would be useful for sort of showing the concepts in a faster way."*
- (W13) *"I would love it in the classroom. I would love to teach it. And I guess like that would be more useful to students than it would be to me but I think as a teaching tool... I would love to show younger writers the process of writing."*
- (W7) *"It's a very common thing to hear [students] say, 'I don't know how to write, I'm not a good writer,' and that's where, you know, the demonstration that will show them that writing is a process and not a destination."*

## 6 DISCUSSION

### 6.1 Different attitudes in writers and readers towards writing playback

There were some common responses from both writers and readers. However, writers were generally more favorable to Live Writing than readers were. Again, we believe this is because the writers were able to find value from the process itself, beyond comprehending the story. In addition, the connection that the writer group was able to make with the replays' authors was stronger than the reader group's connection. This indicates that for those who write, a replay



is a novel way to consume both a written artifact and the process of creating it. This tendency is aligned with the previous finding that those who watch live creative streaming are another set of creators who are motivated to learn and get inspired [13]. Therefore, writing playback, as it is, can be a new form of content that writers would not only find entertaining to watch, but also enjoy reflecting on themselves.

## 6.2 Live Writing as a new expressive medium for writers

In the case of T2 and T3, it was more engaging even for readers to watch the replay than the static text. We believe that these texts were written in a way which did not negatively impact reading comprehension. Even though the writers who participated in this study to generate Live Writing replays did not do anything to actively engage the readers in the replays, the result demonstrated the potential for a writer to imbue the playback with “*suspense*”, “*humor*”, or “*thoughtfulness*”. The continuously unfolding nature of playback inherently has a unique engagement component that static text lacks. In addition, writers are given two additional dimensions that they can exploit for expressivity: *temporal* — when to write; and *spatial* — where to write.

The temporal dimension was already spotted by a few interviewees as a way to engage with the playback. Interestingly, they perceived the temporal dynamic available in playback to read the author’s state, even though the writers had no intention to use it.

- (W10) “*I didn’t want to skip the inactive parts. Yeah, I wanted to see where the stalling happened. I think one thing I was interested in is whether certain phrases poured out faster. (...) And so I was interested in seeing where those long pauses were and in seeing what what phrases just flew out, I’m sure.*”
- (W7) “*It was strange at first, but within the first couple of minutes that strangeness the streams feeling turned into more curiosity and then looking at my process, and seeing how things are happening at semi-regular cadences was, I found it very interesting and that was something I never even considered before doing this study.*”

If a writer intentionally writes a text for playback, it may be possible to exploit this temporal dimension to express the emotional state of the narrator. In that regard, this technique can be more effective for nonfiction or first-person fictional narratives. For example, various types of emotions (e.g., calmness, outbursts, rage) with the semantic meaning of the text can be presented through general variability between letters or pauses between sentences. In general, the affective arousal (low/high) and valence (negative/positive) model can be applied to a certain pace of writing. However, writers and the replay platform would have to consider the range of reading speeds that affects reading comprehension.

We also believe that non-linear edits can be exploited to help readers become more absorbed in emotions and heighten the drama of a character. One simple example might be a first-person narrator trying to find the perfect expression, or feeling hesitant to write something might be presented as repetitive revision of a sentence. Furthermore, extra details added to the earlier part of a text in the later stages of writing could be used to change nuances in recollection, or even to construct a reversal of the plot.

The interactive, ephemeral, and fast-paced nature of modern communication can inspire artists and developers to create a new medium. For example, a mobile phone-based chat fiction, written solely in the form of text messages or instant messaging conversations, drew attention with its unique modality and interactivity [41]. Similarly, we believe that a replay can potentially be a novel way to convey a story while challenging writers to develop virtuosity to exploit new expressive dimensions.

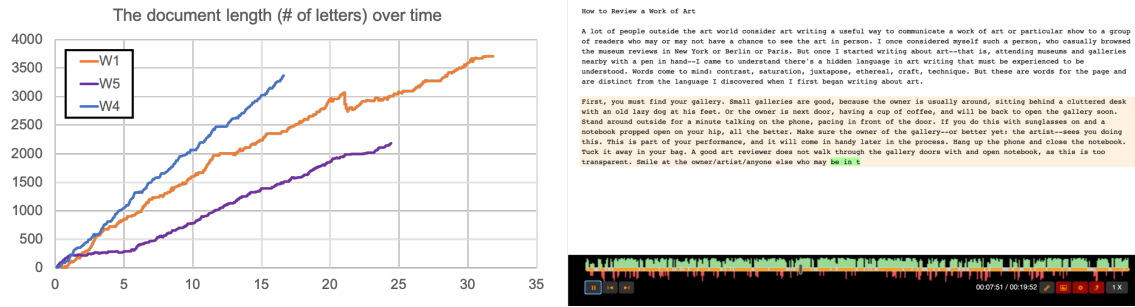


Fig. 2. Keystroke data can visualize the state a writer is in. (Left) Time-document length graph for participants W1, W4, W5. How a writer generates text over time can represent the writer’s activity. (Right) The Live Writing platform can visualize the number of additions and deletions as green and red bars on the timeline.

### 6.3 Playback as a Reading Aid

We witness that many people find Live Writing replays to be a useful tool for helping people to read, due to its incremental presentation. This is similar to the effects of using animation to provide only the necessary information at a given moment to reduce information overload and help students sustain their attention [3, 18]. The developers of a chat fiction app called *Hooked* also found that most of their target audience of teenagers failed to finish 1000-word excerpts, even though they read through stories of the same length written as text message conversations [14]. One survey participant suggested a similar idea.

- (P51) “(...) if the Live Writing was stripped down to just the text appearing on screen at a set rate (no going back and editing), then it could aid comprehension by forcing a fixed rate so that a reader doesn’t zone out. this could also be compared to an audiobook format, just without the audio.”

In this regard, Live Writing playback has the potential to create a new type of reading aid that augmented with the author’s live thought process and expressivity.

However, finding the perfect presentation rate for each individual may not be even possible, given the dynamic pace that a writer employ depending on their style. We believe that we can extend Live Writing to computationally pace playback for reading comprehension and normalize the variability of intervals without losing the human aspect of the playback. Also, reducing severely non-linear edits and replacing them with the final edits could be automated to promote reading comprehension in the context of reading aids.

### 6.4 Mining keystroke data for an intelligent writing environment

We believe that keystroke data can be used to learn not only the style of a writing practice, but also the writing stage at a given moment. Researchers have used keystroke data for various purposes, from modeling human performance [4] and recognizing users’ cognitive loads and emotional states [7, 30, 32, 38] to a behavioral biometric useful for identifying individuals [19, 27]. Keystroke data, with semantics available in the content, can provide rich information as to the stage the writer has reached. This can be useful to create adaptive writing environments and to support collaborative writing.

During the interviews, we found that some writers use different software at different stages of writing. Some writers stated that they used pen and paper during the ideation stage, and then used a writing environment with minimal functionality to reduce distractions, before transferring the text to a more advanced word processor for final publication or further collaboration.

Mining patterns from keystroke data can be used to understand writing activity. For example, Figure 2 shows various potentials for using keystroke data to understand writing. On the left, it shows the the document length over time for three interviewees' writing, clearly showing a difference in pacing. However, one can also see that W4 wrote in a linear fashion, while the other two writers (W1, W5) have a few points where their paces changed, appearing as plateaus on the line. W5 also decided to delete a chunk of text at 21 minutes and rewrite a part of the document. This information can be augmented with the content, the location of edits, and the writer's patterns from previous documents. To the right of the figure is a simple graph on the timeline of Live Writing visualizing the volume of additions (green bars) and deletions (red bars). Although this data may be difficult for a layperson to understand and reflect on, it can be used to make the writing environment more intelligent.

Based on this data, we plan to develop an intelligent writing environment in our future work. A particular stage that users are in — ideation, text generation, organizing thoughts, editing, proofreading — can be identified from writing activity data. Using this information, we can design an adaptive writing environment to provide functionality that is needed just in time. For example, the environment can offer drawing features in the ideation stage, hide toolbars when generating text, and toggle red wavy lines under misspelled words on during editing, off at other times. Such an adaptable writing environment based on keystroke patterns can “understand” a particular writer's style (e.g., improvisational vs. generate-and-organize) and help writers become immersed in the writing activity by reducing the display of irrelevant functionality at any given moment. Lastly, this temporal pattern can be useful in a collaborative setup; the change log that is available for replay at its finest resolution can be useful for collaborators to understand the context, to know what stage the document is in, and to have better change awareness.

## 7 LIMITATIONS

The findings in this study are limited. The texts that we asked writers to produce are short and not representative of texts they are motivated to write in the real world. Therefore, the controlled writing task could have made the writers behave differently compared to how they might have behaved in more ecologically valid settings. We would like to test the platform in more a long-term setting for us to validate if our findings are generalizable to a more realistic setting. Similarly, the findings from Study I are limited, as we do not know if readers would be able to remain engaged with similar kinds of playback for longer documents (e.g., a 10-page academic paper). In reality, articles or creative writing pieces are written in asynchronous ways, where the design of the replay and playback need to be changed accordingly.

Another limitation of this study is rooted in the methods used. Study I involves a reading comprehension test that combines comprehension and retention, where the result is the product of comprehensibility and memory — which may be affected by the playback format. Lastly, our pool of participants was limited, as they were mostly university students. The effects of watching writing replays have been investigated only in English, further limiting our findings to some extent.

## 8 CONCLUSION

In this work, we explored the effects of watching writing replays from both the reader's and writer's perspectives. We found that depending on the style of writing, replays can enhance the engagement level without hurting comprehensibility. However, non-linear edits and not knowing the right playback pace were major barriers that negatively impacted the reading experiences. In contrast, writers enjoyed watching writing replays, as they seemed to pay more attention to the process, rather than the content. They noted that they were able to connect with the author and that the replays facilitated self-reflection. Both groups proposed various applications of watching writing replays for more engaging and effective reading experiences.

## REFERENCES

- [1] Philip Auslander. 2008. *Liveness: Performance in a mediatized culture*. Routledge.
- [2] Laura C Bell and Charles A Perfetti. 1994. Reading skill: Some adult comparisons. *Journal of Educational Psychology* 86, 2 (1994), 244.
- [3] San Bolkan. 2019. Facilitating student attention with multimedia presentations: examining the effects of segmented PowerPoint presentations on student learning. *Communication Education* 68, 1 (2019), 61–79. <https://doi.org/10.1080/03634523.2018.1517895> arXiv:<https://doi.org/10.1080/03634523.2018.1517895>
- [4] Stuart K Card, Thomas P Moran, and Allen Newell. 1980. The keystroke-level model for user performance time with interactive systems. *Commun. ACM* 23, 7 (1980), 396–410.
- [5] Kathy Charmaz. 2006. *Constructing grounded theory: A practical guide through qualitative analysis*. sage.
- [6] N. Collins, A. McLean, J. Rohrerhuber, and A. Ward. 2003. Live coding in laptop performance. *Organised Sound* 8, 03 (2003), 321–330.
- [7] Clayton Epp, Michael Lippold, and Regan L Mandryk. 2011. Identifying emotional states using keystroke dynamics. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, 715–724.
- [8] Travis Faas, Lynn Dombrowski, Alyson Young, and Andrew D. Miller. 2018. Watch Me Code: Programming Mentorship Communities on Twitch.Tv. *Proc. ACM Hum.-Comput. Interact.* 2, CSCW, Article 50 (Nov. 2018), 18 pages. <https://doi.org/10.1145/3274319>
- [9] Travis Faas, I-ching Liu, Lynn Dombrowski, and Andrew D. Miller. 2019. Jam Today, Jam Tomorrow: Learning in Online Game Jams. *Proc. ACM Hum.-Comput. Interact.* 3, GROUP, Article 240 (Dec. 2019), 27 pages. <https://doi.org/10.1145/3361121>
- [10] Linda Flower. 1980. The dynamics of composing: Making plans and juggling constraints. *Cognitive processes in writing* (1980), 31–50.
- [11] Linda Flower and John R Hayes. 1981. A cognitive process theory of writing. *College composition and communication* 32, 4 (1981), 365–387.
- [12] C. Ailie Fraser, Mira Dontcheva, Joy O. Kim, and Scott Klemmer. 2019. How Live Streaming Does (and Doesn't) Change Creative Practices. *Interactions* 27, 1 (Dec. 2019), 46–51. <https://doi.org/10.1145/3372040>
- [13] C. Ailie Fraser, Joy O. Kim, Alison Thornsberry, Scott Klemmer, and Mira Dontcheva. 2019. Sharing the Studio: How Creative Livestreaming Can Inspire, Educate, and Engage. In *Proceedings of the 2019 on Creativity and Cognition* (San Diego, CA, USA) (C&C '19). Association for Computing Machinery, New York, NY, USA, 144–155. <https://doi.org/10.1145/3325480.3325485>
- [14] Prerna Gupta. 2017. How We Got 10 Million Teens to Read Fiction on Their Phones. <https://medium.com/@prernagupta/how-we-got-10-million-teens-to-read-fiction-on-their-phones-19a2a475084c>
- [15] Oliver L. Haimson and John C. Tang. 2017. What Makes Live Events Engaging on Facebook Live, Periscope, and Snapchat. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (Denver, Colorado, USA) (CHI '17). Association for Computing Machinery, New York, NY, USA, 48–60. <https://doi.org/10.1145/3025453.3025642>
- [16] William A. Hamilton, Oliver Garretson, and Andruid Kerne. 2014. Streaming on Twitch: Fostering Participatory Communities of Play Within Live Mixed Media. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Toronto, Ontario, Canada) (CHI '14). ACM, New York, NY, USA, 1315–1324. <https://doi.org/10.1145/2556288.2557048>
- [17] Jonathan Hook, Guy Schofield, Robyn Taylor, Tom Bartindale, John McCarthy, and Peter Wright. 2012. Exploring HCI's Relationship with Liveness. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems* (Austin, Texas, USA) (CHI EA '12). ACM, New York, NY, USA, 2771–2774. <https://doi.org/10.1145/2212776.2212717>
- [18] Douglas A Johnson and Jack Christensen. 2011. A comparison of simplified-visually rich and traditional presentation styles. *Teaching of Psychology* 38, 4 (2011), 293–297.
- [19] Rick Joyce and Gopal Gupta. 1990. Identity authentication based on keystroke latencies. *Commun. ACM* 33, 2 (1990), 168–176.
- [20] Muhammad M Abdel Latif. 2008. A state-of-the-art review of the real-time computer-aided study of the writing process. *IJES, International Journal of English Studies* 8, 1 (2008), 29–50.
- [21] Sang Won Lee. 2018. *Improving User Involvement through live collaborative creation*. Ph.D. Dissertation. University of Michigan, Ann Arbor, MI, USA.
- [22] Sang Won Lee. 2018. Liveness in Interactive Systems. *the CSCW 2018 workshop on Hybrid Events (CSCW) the CSCW 2018 workshop on Hybrid Events (CSCW)* (2018).
- [23] Sang Won Lee and Georg Essl. 2015. Live Writing: Asynchronous Playback of Live Coding and Writing. In *Proceedings of International Conference on Live Coding*. Leeds, United Kingdom.
- [24] Sang Won Lee, Georg Essl, and Mari Martinez. 2016. Live Writing : Writing as a Real-time Audiovisual Performance. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, Vol. 16. Queensland Conservatorium Griffith University, Brisbane, Australia, 212–217. <https://doi.org/10.5281/zenodo.1176060>
- [25] Mariëlle Leijten and Luuk Van Waes. 2006. Inputlog: New perspectives on the logging of on-line writing processes in a Windows environment. *Studies in writing* 18 (2006), 73.
- [26] Mariëlle Leijten and Luuk Van Waes. 2013. Keystroke Logging in Writing Research: Using Inputlog to Analyze and Visualize Writing Processes. *Written Communication* 30, 3 (2013), 358–392. <https://doi.org/10.1177/0741088313491692> arXiv:<https://doi.org/10.1177/0741088313491692>
- [27] Fabian Monrose and Aviel D Rubin. 2000. Keystroke dynamics as a biometric for authentication. *Future Generation computer systems* 16, 4 (2000), 351–359.
- [28] Daniel M Russell and Ed H Chi. 2014. Looking back: Retrospective study methods for HCI. In *Ways of Knowing in HCI*. Springer, 373–393.

- [29] D. M. Russell and M. Oren. 2009. Retrospective Cued Recall: A Method for Accurately Recalling Previous User Behaviors. In *2009 42nd Hawaii International Conference on System Sciences*. 1–9.
- [30] Sergio Salmeron-Majadas, Olga C Santos, and Jesus G Boticario. 2014. An evaluation of mouse and keyboard interaction indicators towards non-intrusive and low cost affective modeling in an educational context. *Procedia Computer Science* 35 (2014), 691–700.
- [31] John Short, Ederyn Williams, and Bruce Christie. 1976. *The social psychology of telecommunications*. John Wiley & Sons.
- [32] Pragya Shukla and Rinky Solanki. [n.d.]. Web Based Keystroke Dynamics Application for Identifying Emotional State. ([n. d.]).
- [33] Sven Strömqvist, Kenneth Holmqvist, Victoria Johansson, Henrik Karlsson, and Åsa Wengelin. 2006. What keystroke-logging can reveal about writing. *Computer key-stroke logging and writing: methods and applications (Studies in Writing)* 18 (2006), 45–72.
- [34] Ben Swift, Andrew Sorensen, Henry Gardner, and John Hosking. 2013. Visual code annotations for cyberphysical programming. In *2013 1st International Workshop on Live Programming (LIVE)*. IEEE, 27–30.
- [35] James Tam and Saul Greenberg. 2006. A framework for asynchronous change awareness in collaborative documents and workspaces. *International Journal of Human-Computer Studies* 64, 7 (2006), 583–598.
- [36] John C Tang. 1991. Findings from observational studies of collaborative work. *International Journal of Man-machine studies* 34, 2 (1991), 143–160.
- [37] Steven L Tanimoto. 2013. A perspective on the evolution of live programming. In *Live Programming (LIVE), 2013 1st International Workshop on*. IEEE, 31–34.
- [38] Lisa M Vizer, Lina Zhou, and Andrew Sears. 2009. Automated stress detection using keystroke and linguistic features: An exploratory study. *International Journal of Human-Computer Studies* 67, 10 (2009), 870–886.
- [39] Jinyi Wang, Mudassar Ahmad Mughal, and Oskar Juhlin. 2015. Experiencing Liveness of a Cherished Place in the Home. In *Proceedings of the ACM International Conference on Interactive Experiences for TV and Online Video (Brussels, Belgium) (TVX '15)*. Association for Computing Machinery, New York, NY, USA, 3–12. <https://doi.org/10.1145/2745197.2745198>
- [40] Andrew M. Webb, Chen Wang, Andruid Kerne, and Pablo Cesar. 2016. Distributed Liveness: Understanding How New Technologies Transform Performance Experiences. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (San Francisco, California, USA) (CSCW '16)*. Association for Computing Machinery, New York, NY, USA, 432–437. <https://doi.org/10.1145/2818048.2819974>
- [41] Wikipedia. 2020. Chat fiction – Wikipedia, The Free Encyclopedia. [https://en.wikipedia.org/wiki/Chat\\_fiction](https://en.wikipedia.org/wiki/Chat_fiction). [Online; accessed 17-September-2020].

## A APPENDIX

### A.1 Prompts for Professional writers

- Fiction Prompt 1: Please write a short fiction piece of about 400 words in which a character uncovers an object from their past that alters the course of their day
- Non fiction prompt 1: Please write a nonfiction piece of about 400 words in which you teach the reader how to do something which you consider yourself good at
- Non fiction prompt 2: Please write a nonfiction piece of about 400 words in which you describe a transitional moment in your life.

### A.2 Interview Questions for Writers

- What type of writing do you normally do?
- How often do you write?
- How often and how do you publish?
- How would you describe your writing process normally? Could you categorize these writing processes into modes (editing, generating, resequencing, etc..)?
- What do you think about while you are writing (if anything)? What are you aware of?
- What interfaces / applications do you normally use for writing? (e.g., pen, paper, Google Docs, Word) Why do you use these applications?
- **(Reading static text of their own)**
- Reading this passage again, what do you think of it?
- What was your process like in writing this passage?

- **(Reading Live Writing replay of their own)**
- Did you find watching this playback more or less engaging than static reading? Why or why not?
- What were you thinking about when you were watching this?
- What, if anything, was unexpected in watching this playback? Did you learn anything from these unexpected moments? (if they learned something)
- Does anything you've learned about your writing process make you want to try to adjust or try anything new in your writing process?
- Would you be ever intimidated writing if you knew a livewriting playback of the process would be distributed widely? If so, why?
- How would this change how you approach the writing process?
- Can you imagine some version of this feature into your writing or revision process?
- What playback settings did you find yourself using? Did you find yourself skipping ahead? Why?
- Do you have any other thoughts about watching your own playback?
- **(Watching Live Writing replay written by others)**
- How would you characterize this writer's playback?
- Did you find watching this playback engaging? Why?
- How does this person's writing process appear similar to your own?
- How does this person's writing process appear different than your own?
- What, if anything, did you learn from watching this person's playback?
- Did you find watching this playback more or less engaging than writing your own playback?
- How would you characterize your sense of connection, if any, with the author after watching this playback?
- In what situation do you think watching a live writing playback be useful for you?
- In what situation do you think having someone else watch your livewriting playback would be useful?
- What playback settings did you find yourself using? Did you find yourself skipping ahead? Why?
- Do you have any other thoughts about the experience of watching this person's playback?

### A.3 Live Writing replays

Live Writing playback of T1~T4 will be presented in the following url.

[https://livewriting.github.io/chi2021\\_livewriting.html](https://livewriting.github.io/chi2021_livewriting.html)

### A.4 Static Text

*A.4.1 T1: How to Review a Work of Art (essay).* A lot of people outside the art world consider art writing a useful way to communicate a work of art or particular show to a group of readers who may or may not have a chance to see the art in person. I once considered myself such a person, who casually browsed the museum reviews in New York or Berlin or Paris. But once I started writing about art—that is, attending museums and galleries nearby with a pen in hand—I came to understand there's a hidden language in art writing that must be experienced to be understood. Words come to mind: contrast, saturation, juxtapose, ethereal, craft, technique. But these are words for the page and are distinct from the language I discovered when I first began writing about art.

First, you must find your gallery. Small galleries are good, because the owner is usually around, sitting behind a cluttered desk with an old lazy dog at his feet. Or the owner is next door, having a cup of coffee, and will be back to

open the gallery soon. Stand around outside for a minute talking on the phone, pacing in front of the door. If you do this with sunglasses on and a notebook propped open on your hip, all the better. Make sure the owner of the gallery—or better yet: the artist—sees you doing this. This is part of your performance, and it will come in handy later in the process. Hang up the phone and close the notebook. Tuck it away in your bag. A good art reviewer does not walk through the gallery doors with an open notebook, as this is too transparent. Smile at the owner/artist/anyone else who may be in the gallery and walk around. Look at every object. Every painting has value. Every sculpture should be considered from all sides possible. Every piece of music heard. Furrow your brow.

When you are approached by the owner or the artist or other authority figure who happens to be hanging around the gallery, introduce yourself. Be nice. Tell them who you are, but not what you're doing in the gallery. Don't make it seem like you're there to buy a piece of art—you don't have that kind of money—but also don't tell them about the review you are writing. In the best case scenario, you will be on assignment for your local paper. You have a deadline to meet and a thousand words to crank out about what's hot and fresh in the scene. Don't say this. The gallery owner is a friendly if sometimes pushy individual, but will kindly step out of your way if you express the desire to simply enjoy the art in the room. Let them go back to their desk before you resume your assessment.

When they sit down in the chair, whip out your notebook and scribble furiously. This will shock the owner, but they will quickly realize it is more embarrassing to leap out of their chair and return to you than it is to sit and quietly pretend like nothing happened. Write as fast as you can about the art. Write about the size: this bronze lion is the size of a fist. Write about the color: its mane is painted purple. Write about the placement in space: it is perched on a pedestal, yet the painting behind the piece acts as a kind of implied backdrop. Write about the relationship: the small bronze lion with a rich purple mane seems to emerge from the destroyed landscape painted in luxurious oils that compose "Wasteland." Do this for each piece in the show, but spend the most time on the thesis piece. A thesis piece is the work of art in any show that behaves like a summation and synthesis of all the ideas in the gallery. This is your nut graf. Watch the owner sweat.

When you are finished, close the notebook and spend a few minutes enjoying the art without thinking about anything. Don't think about history. Don't think about subtext. Don't think about the sculptor you slept with in college who kept a book of Bernini under his bed. Thank the gallery owner and leave. Once home, sit on the couch you found on the curb with your laptop open on your lap and type all your notes as you have them written down. Soon, during this process, your own masterpiece will emerge.

#### A.4.2 T2: *How to Review a Work of Art (essay).*

The first thing to know about trail riding is that the occasion is important. If you work at a touristy trail barn like I have, there are three main types of rides: dates, "Grandma had a horse as a kid and is taking us out for a treat," and "The person I'm dating also has kids, and this is a good opportunity to get us all together."

If it is the first one, see entry for "Macho Guy."

If it is the second one, prepare for Grandma to not remember how many muscle groups are involved in horseback riding.



She will need some extra help, and she will be salty about it. Prepare for her to be frustrated with the children, who will definitely whine and who will definitely start screaming when a horse inevitably shits.

If it is the third occasion, prepare for the children to awkwardly call Mom's new boyfriend by his first name. The children of both families will be weirdly competitive with each other and will refuse to use each other's names, perhaps because they have forgotten and at this point it's too late to ask.

There are several kinds of people who go on trail rides besides grandmothers, whining children, and parents just trying their best. Stick around a trail barn for a few days, and you will find people like...

#### Person Who Is Extremely Vocal and Theatrical About Their Fears

You must put them on the chilliest horse you've got, one that won't mind it when they start screaming, and who won't try to pull any punches, because this person is going to be useless. They will not try at all—their passions lie in screaming and perhaps taking selfies. You must put them right behind you in line because they have no interest in controlling the horse, and, contrary to instinct, you want that ticking time bomb close to you. These people, oddly enough, are the most entertaining and hilarious people. Their friends and family members will rag on them and they will take it in stride. You will hear some top-notch ribbing and gain appreciation for it as an art form.

#### Macho Guy

Macho Guys come in two subspecies: "terrified but will never admit it" and "lacks a healthy amount of terror considering that there, you know, there's some danger involved in this whole horseback riding thing." Both species can be treated the same. You must put them on a gelding who walks at a reasonable speed and tell them, "This is [horse name here]. This right here is the boss horse. You gotta watch out for him, because he's the boss." This will bring them reassurance and affirmation. If they are on a date or their partner is present, they will begin to give advice to them, and this advice will usually be wrong. It is very important that you never correct them, because if they are happy at the end of a ride, they will make a big show of slowly pulling out their billfold and peeling off a twenty.

If you read this guide and come away with anything, remember this one fact: they can smell fear. Once, before a trail ride, a woman with Crossfit arms and a push-up bra walked right up to me, put her finger in my face, and bellowed, "If I fall off this horse, I'm going to cut you."

You must stay calm in these situations. You will smile and say, "You won't fall off."

"I. Will. Cut. You," she will say.

"Nah, it'll be great. I've got just the horse for you. This is Walter. He's one of my favorites."

You will show no fear even when, twenty minutes later, she tells you she loves you, then tells you she has the power to read minds, tells you she is certified in reiki and could give the horses a massage, maybe, if your boss lets her.

She will extend her stay at the resort just to go on more rides with you, and she will sign her daughter up for summer camp, and she will tag along every single day. But, most importantly, she will tip well.

*A.4.3 T3: Rising from the bed (fiction).* The man woke like every other day of his life. At seven am, he rolled out of bed, making sure to silence the alarm so as not to wake up his girlfriend. He trudged to the bathroom and let his eyes adjust to the bright lights as he brushed his teeth. He allowed himself to stare at his reflection during the two minute duration that his electric toothbrush took. The wrinkles under his eyes had grown, despite the extra hour of sleep he added to his night schedule. He was getting older and his face was starting to show it. He could count on one hand the things he felt lucky to have and that troubled him. At his age, he should have more to be proud of, more to hold in hands and claim, mine. He looked over his shoulder at his girlfriend sleeping and asked himself for the hundredth time this month if he loved her. He still wasn't sure. They'd been dating for a little over a year and he hadn't wanted to rush into anything, despite his age. If he was being honest with himself, he didn't care much about how he felt about her or other things lately. He'd gotten to the point in his life when everything seemed to plateau. Making his way to his closet, he got dressed and fixed the pocket of his pants. When he heard the crinkle of paper, he assumed it to be an old receipt but looked for a brief moment anyway. As he unfurled the note, he felt the color drain from his face. He hadn't seen this note in seven years, two weeks, and three days (if he wanted to be exact). He read it over and over again, letting his mouth whisper the words he had tried hard to forget. Stuffing it back into his pocket, he walked silently down the stairs and into the kitchen. He had forgotten what the loop of the "g" in her name had looked like, forgotten how it matched her wide smile when he cracked a joke. Pouring cereal into a bowl, he thought about the jokes he'd work on in his cubicle at work in the hopes of impressing her when they both went to the cafeteria salad bar. Wednesdays had always been his least favorite days until they had run into each other waiting for the cherry tomatoes to be refilled. He began eating the cereal dry, not bothering to fill the bowl with milk. As the dry cereal crunched in his mouth, he pictured her with her head thrown back laughing, the sun in her blonde hair. She was hard to forget. He pulled the note from his pants and reread the message once more before dumping the rest of the cereal down the garbage disposal.

*A.4.4 T4: Jewel Case (fiction).* The jewel case first bites her when she crawls under her bed to clean. Her arms sweep the ground like she is making a trash snow angel out of wrappers and worn pairs of socks and dust bunnies, sweeping them into a more manageable area. This is what she used to do as a child, and it's an indulgence she continues. The messy kid grew into a messy adult. An ex-boyfriend once said that she leaves a trail of breadcrumbs wherever she goes: hair ties, lipstick-stained coffee cups, receipts. She expected all of those things to be under the bed, but she did not expect to be bitten by a jewel case. As she swings her arm out, she feels a stinging and a breaking of skin as the case snaps at her.

"Fuck!" she says and puts her hand to her mouth. The jewel case has bitten her in the fleshy part between pointer finger and thumb. She sucks the blood and feels with her tongue the paper-thin flap of skin that has sliced loose.

A few feet in front of her, in the dim light of under-the-bed, the jewel case flexes the sharp plastic of its cover, its hinge squeaking with menace. She knows which CD this is by the Sharpie scrawled on the cover—she knows whose handwriting.

When she returns with a broom to flush it out, her cat, Lionel, sits atop his cat tree and watches with passive amusement, even when she pulls the broom away from the bed with the case clamped on to the bristles like a crab. She holds it close to get a better look, and it rattles, the CD clattering against its casing. She sees a speck of her blood in the paper

lining of the case, blurring out one of the track listings. The tracks are written in careful, sparking gel pen.

The jewel case is broken, and a small shard of plastic hangs down like a tooth. It snaps at her. She deposits the case into the trash and ties up the bag. She wonders what other objects in her apartment will bite at her—surely there's a lot here that holds a grudge.

But when it's later, and it's darker, she stands on tiptoe to bring down the ancient CD player from its place in her closet shelf. She fishes through the box of gardening supplies an old roommate left behind, and she dons a pair of coarse gloves.

Standing in her kitchen, she carefully unties the bag and handles the case. She tries to pry open its jaws to pluck out the CD like a tooth with pliers, but it fights her, flipping and shaking. Lionel hides. The case will not allow her to pull its glittering treasure. She fights the case more and more until the liner notes are ripped and the plastic case is full of fissures and the top third of the CD has snapped off, the Sharpied words disconnected. There is a scattering of plastic on the ground, sharp enough that when she leaves to throw herself on her bed, a piece cuts her foot.