

교육학석사학위논문

Korean EFL STEM Graduate Students'
Use of ChatGPT in L2 Writing Process:
A Case Study from an Ecological Perspective

한국 이공계열 대학원생의
L2 작문과정에서 ChatGPT 사용 양상:
생태학적 관점에서의 사례 연구

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ABSTRACT

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Recent months have seen intensive discussions about the implications of ChatGPT for second language (L2) writing. In spite of the heated debate among educators and researchers, and the mixed results emerging from studies on the usefulness of ChatGPT in L2 writing, there remains a notable gap in empirical research addressing how L2 learners engage with ChatGPT in their naturalistic writing practices. To deal with this gap, this study investigated how EFL STEM graduate students used ChatGPT when composing self-initiated academic writing tasks. Using webcam-based eye-tracking with screen capture technology, stimulated recall, and semi-structured interviews, this study analyzed cases of four participants from an ecological perspective.

The analysis of L2 writers' real-time evolution of ChatGPT use reveals four major findings. First, L2 writers' use of ChatGPT was entangled with various material and immaterial elements across the multiple layers of their writing environment including, attitude towards ChatGPT, English language proficiency, internal conventions of laboratories, and collaborative writing platforms. Second,

ChatGPT was not operated in isolation; rather, it emerged within an assemblage of online tools, including Notion, Overleaf, and Dynalist. Third, while its immediate affordance changed according to the other digital tools ChatGPT was utilized with, ChatGPT played different roles across various stages of the writing process from planning and formulating to reviewing. Finally, participants were more likely to dedicate time and effort to meaning-making activities occurring before and after the prompting process, while minimizing their efforts to create precise prompts.

These findings deepen our understanding of the actuality of students employing ChatGPT in academic writing. Emphasizing a shift from the previous attention towards the prompting phase, this study underscores the dynamics found before and after prompting. Furthermore, the methodological implications of webcam-based eye-tracking to observe the writing process in digital spaces are discussed.

Keywords: L2 writing process, ecological perspective, ChatGPT, CALL, MALL, webcam-based eye-tracking, artificial intelligence, technology-enhanced writing

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CHAPTER 1.

INTRODUCTION

1.1 Background of the Study

The exponential development of artificial intelligence (AI) is transforming various sectors of our society (Holmes & Tuomi, 2022). Triggered by the release of ChatGPT 3.5 (Generative Pre-trained Transformer) in November 2022, AI became more accessible to the general public, leading them to experience its potential as well as limitations (Adeshola & Adepoju, 2023; Lambert & Stevens, 2023).

Recent months have seen intensive scholarly debate about the implications of ChatGPT for second language (L2) writing (Cardon et al., 2023; Derakhshan & Ghiasvand, 2024; Gayed et al., 2022; Guo et al., 2022; Imran & Almusharraf, 2023; Semrl et al., 2023). Advocates praise ChatGPT's ability to generate high-quality, human-like texts, proposing its use as a tool for enhancing language learning through real-time personalized feedback and exposure to authentic language usage (Im, 2023; Lee & Shin, 2023; Park, 2023). However, critics raise significant concerns, claiming that its use might lead to a decline in critical and creative thinking skills (Cardon et al., 2023), erosion of authorial voice (Zou & Huang, 2023), and a potential risk to academic integrity (Barrot, 2023; Chan & Hu, 2023; Yan, 2023).

ChatGPT has also had a direct impact on the educational field. Some educational authorities, including New York City's Department of Education and Cambridge University, preemptively made decisions to ban the use of ChatGPT in educational settings over

plagiarism fears (Gordon, 2023). In contrast, the Seoul Metropolitan Office of Education (2023) in Korea officially endorsed the use of ChatGPT in English language classrooms on November 29, 2023, outlining a comprehensive plan to enhance public English education by integrating AI-based tools for students.

In spite of the heated debate surrounding ChatGPT and its rapid integration into educational settings, there is a lack of empirical studies addressing L2 writers' use of ChatGPT and its impact on their writing processes. Within the limited number of studies, the existing literature is largely confined to investigating language learners' perceptions of ChatGPT in their writing process, while the behavioral aspect of their real usage is left unexamined (Chan & Hu, 2023; Dahlström, 2019; Jeong, 2024; Ou et al., 2024; Zhao et al., 2024; Zou & Huang, 2023). Moreover, the influence of ChatGPT on L2 writing is being studied in classroom contexts with instructions that mandate the use of ChatGPT while following specific guidelines (Lee, 2023). While these controlled settings may be necessary for research purposes, they have limitations in terms of observing L2 writers' authentic use of ChatGPT in writing, as ChatGPT is widely used in out-of-class settings (Alharbi, 2023; Ou et al., 2024) or in "the digital wilds" (Sauro & Zourou, 2019).

As such, there remains a gap in understanding how language learners are actually utilizing ChatGPT in their writing. For instance, how long and when do L2 writers dedicate time to ChatGPT during the composition process? How do language learners benefit from ChatGPT in overcoming emerging challenges during the writing process? These questions should be answered to better understand the various possibilities or pitfalls it may bring to language education.

Especially, it should be noted that ChatGPT is a versatile, general-purpose tool that embodies a variety of potential (Godwin-Jones, 2023). Unlike previous writing assistant tools, which had predefined affordances set by pedagogical goals, ChatGPT's affordances are unpredictable, as they are shaped by its ongoing interaction with individual learners. Therefore, it is essential for educators and researchers to closely and contextually examine the role ChatGPT plays in L2 writers' real-life writing and its influence on their literacy practices. Before making decisions to restrict language learners' use of ChatGPT or to integrate it into language education, an in-depth understanding of how, why, and when L2 writers utilize this state-of-the-art tool is necessary.

1.2 Purpose of the Study

To address the gaps identified from previous research, the present study traced four Korean STEM EFL graduate students' use of ChatGPT while they undertook a self-initiated writing assignment. The study examined the role of ChatGPT in language learners' writing process from an ecological approach that views language learning as an emergent and situated meaning-making activity influenced by various factors constituting the learning environment. Based on this theoretical framework, this study conducted a case study to investigate the individual and contextual factors influencing L2 writers' use of ChatGPT.

Using webcam-based eye-tracking, screen capture technology, semi-structured interviews, and stimulated recall, this study observed language learners' moment-by-moment interactions with ChatGPT in detail, capturing the emergent strategies L2 writers deployed

during the writing process to meet their immediate needs. Through methodological triangulation, this study aimed to examine both the behavioral and perceptual aspects of L2 writers' use of ChatGPT. Moreover, to examine the use of ChatGPT by L2 writers in the naturalistic settings, this study traced participants' writing processes by utilizing innovative tracking methodologies (Gánem Gutiérrez & Gilmore, 2018), screen capture technology (Sérór, 2013; Sérór & Gentil, 2023), and webcam-based eye-tracking (Yang & Krajbich, 2021). These data captured the real-time evolution of the writing process and the dynamic behavioral patterns of the L2 writers as they interacted with ChatGPT. In line with the purpose of the present study, the following research questions were formulated:

1. What technological and writing strategies do L2 writers use while using ChatGPT in the L2 writing process?
2. What individual differences appear in the L2 writers' writing processes while using ChatGPT as a writing tool?

1.3 Organization of the Thesis

This thesis is organized into six distinct chapters. Chapter 1 introduces the topic and outlines the research objectives along with the research questions. Chapter 2 discusses the theoretical framework that supports the study. This chapter also reviews relevant literature and empirical research on digitally mediated L2 writing, ChatGPT and L2 writing, and process-tracing methodologies in L2 writing studies, identifying gaps that the current study aims to address. Chapter 3 delineates the methodology of this research. It covers the profiles of the participants, describes the data collection procedures, introduces the instruments used for data collection, and explains the data analysis methods. Chapter 4 presents the results of the study, describing the cases of four participants and their engagement with ChatGPT during their writing process. Chapter 5 extends the discussion from the previous chapter by presenting a cross-case analysis of the four participants' use of ChatGPT in their composition process. Finally, Chapter 6 serves as the conclusion, summarizing the primary findings and discussing the theoretical, pedagogical, and methodological implications of the study.

CHAPTER 2.

LITERATURE REVIEW

This chapter reviews the literature relevant to the main areas of interest in this study. Section 2.1 introduces the theoretical background, focusing on the ecological perspective of language learning. Section 2.2 examines the literature that explores the influence of online digital tools on L2 writing practice. Section 2.3 presents recent studies on the integration of ChatGPT in L2 writing. Finally, Section 2.4 discusses various process-tracing methodologies employed for researching L2 writing processes.

2.1 Ecological Approaches to Language Learning

This study adopts van Lier's (1997, 2000, 2004) ecological approach to language learning as the theoretical framework. van Lier's understanding of ecological language learning stems from a longstanding tradition of ecological approaches within social science, such as Bronfenbrenner's human development (1979), Gibson's visual perception (1979), and Vygotsky's cognitive development (1978). These theorists focus on observing the *context* where complex interrelationships between individuals and their surrounding environment occur to explain human activities of their interest (Chong et al., 2023). In particular, Bronfenbrenner (1979) emphasizes the importance of considering the intricate interrelationships among all components of both the immediate environment and the broader cultural and social contexts to fully understand the complex dynamics of human

development.

Building upon these theories that view human activity as a dynamic and complex phenomenon, the ecological perspective aims to look at language learning as a situated and emergent meaning-making activity that is co-constructed through the active interaction between the language learner and their surrounding environment (Berglund, 2009; Kramsch 2008; Larsen-Freeman, 1997; van Lier, 2004). Here, the concept of *environment* encompasses both material and immaterial elements. This includes immediate factors such as teachers, peers, and technologies, as well as individual learner characteristics, learning goals, and pedagogical approaches within the setting. Additionally, it extends to broader social and cultural factors, which influence the learning environment over multiple time scales.

According to this view, language learners draw on the affordances that the environment offers to engage in meaning-making activities (Liu & Chao, 2018). Affordance, a key tenet of the ecological approach, is defined as "a particular property of the environment that is relevant—for good or ill—to an active, perceiving organism in that environment" (Gibson, 1979, p. 127). In other words, affordance is an opportunity for a potential action that the environment or learning space provides to the learners (Berglund, 2009). While interacting with the physical and social world, learners perceive the *action potentials* that are available to them and enact the affordance to further pursue their meaning-making activity. What is perceived and performed as affordance can vary among individual learners depending on the complex interaction between contextual factors. Thus, the concept of affordance in part explains language learners' unexpected interaction patterns with peers or the unprecedented use of technologies during their language learning processes. Moreover, it

provides a new perspective on explaining the individual differences of language learners (Yoon, 2014).

Emphasizing the situatedness of language learning and the interconnectedness of various elements within the language learning environment, the ecological perspective challenges the traditional scientific way of thinking that simplifies and reduces the context, data, or complexity of a phenomenon (Bronfenbrenner, 1979; van Lier, 2004). Especially in terms of language learning, the ecological perspective critiques the conventional approach of isolating one or two discrete factors from a complex language learning system and attempting to observe them in a decontextualized manner (Kramsch & Steffensen, 2008; Liu & Chao, 2018; van Lier, 2000, 2004). Instead, the ecological perspective claims that "language must be studied as a phenomenon situated in context" (Lafford, 2009, p. 674). They underscore the importance of ecological validity in research and require studies to be "carried out in a natural setting and involve[d] objects and activities from everyday life" (Bronfenbrenner, 1979, p. 28). Moreover, to fully grasp the evolving and emergent nature of language learning, they place focus on process over product. Observing the process allows researchers a more nuanced understanding of the individual and contextual factors involved in language learning.

The ecological approach to language learning redefines the role of technology in Computer-Assisted Language Learning (CALL) and Mobile-Assisted Language Learning (MALL). In his paper *Toward an Ecological CALL: Update to Garrett (1991)*, Lafford (2009) asserts that technology is not merely a tool utilized by learners but rather functions as an active participant, engaging in dynamic interactions with learners and the surrounding environment. From an ecological perspective, technology is considered a dynamic component

that offers multifaceted affordances, which can either facilitate or constrain the learner's meaning-making activities. This view aligns with the recently prominent complex dynamic systems theory and socio-material theory in the context of L2 learning.

Consistent with this perspective, Tudor (2003) highlights the non-linear dynamic that technology creates within the language learning ecology. He claims that the incorporation of technology into language learning is inherently unpredictable and messy, making it risky to assume that the technology's potential can be predicted based solely on its internal logic. Tudor (2003) advocates for careful observation of the local context and real-time events during technology use in language learning. While these detailed, moment-to-moment observations may seem trivial and sometimes incoherent, he explains that those moments are valuable in that they project the reality of the complex nature of language learning.

Research adopting an ecological perspective has been well-established within the field of Second Language Acquisition (SLA) for decades. Moreover, the ecological approach has also been a topic of discussion in the CALL and MALL sector for an extended period, as highlighted by scholars such as Lafford (2009), Garrett (1991), and Tudor (2003). Despite the longstanding theoretical discussions, the systematic integration of the ecological perspective into empirical research within CALL and MALL has only recently begun to emerge (Huang et al., 2021; Thoms & Poole, 2018).

In the recent empirical studies of ecological CALL and MALL, researchers have investigated the intricate relationship between the learner and various digital learning environments including, web conferencing (Berglund, 2009; Cappellini & Hsu, 2022), digital

formative assessment platforms (Huang et al., 2021), and mobile learner-generated application for vocabulary learning (Song & Ma, 2021).

Meanwhile, several other studies are examining methodologies apt for unraveling the intricacies of learning ecology in CALL from an ecological perspective (Cappellini & Hsu, 2022; Solmaz, 2021). For example, Solmaz (2021) highlighted the need to gather both observational data—detailing language learners' interactions with digital tools—and perceptual data, which captures learners' reflections on their use of these tools. Additionally, Cappellini and Hsu (2022) proposed a methodology to incorporate eye-tracking techniques to capture the "emergence of affordance" in the CALL environment (p. 258). In light of these evolving methodologies, there is a call for new approaches to further refine our understanding of the learning ecology in CALL and MALL.

Consequently, the ecological perspective of Computer-Assisted Language Learning (CALL) and Mobile-Assisted Language Learning (MALL) provides a valid framework for investigating the unpredictable and dynamic role of ChatGPT in the L2 writing process. Adopting this perspective, the present study aims to observe L2 writers' interactions with ChatGPT in a naturalistic setting. Furthermore, in response to the call for new methodological approaches that capture the intricate dynamics of learner-technology interaction in digital learning environments, this study employs webcam-based eye-tracking.

2.2 Digitally Mediated L2 Writing

With the advancement of digital technology, the conventional practices of writing, once primarily mediated by pen and paper, are now carried out using digital devices (Jones & Hafner, 2021; Qin & Stapleton, 2023). Writing in digital spaces provides L2 writers with access to various resources and tools (Leijten et al., 2014) and such wide availability of resources is transforming the way language learners engage in meaning-making activities (Hamel & Séror, 2016). These technological advancements have profoundly impacted several facets of L2 writing, most notably by introducing technologies that support and scaffold the complex writing process of L2 writers.

Li and Hegelheimer (2017) categorize the diverse array of technologies associated with L2 writing into three primary groups: Web 2.0 applications, Automated Writing Evaluation (AWE) tools, and corpus-based resources. Firstly, Web 2.0 applications encompass internet-based technologies and platforms, including search engines, machine translation, Google Docs, and various social media tools, which facilitate interactive and collaborative learning environments. Secondly, AWE tools, such as Turnitin, Criterion, and Writing Pal, are specifically designed to analyze texts and provide real-time feedback to writers. Lastly, corpus-based tools provide essential references for writers, allowing them to analyze language usage within collections of electronic text. These tools, which include both corpora and the software necessary for searching language examples, are invaluable for accessing authentic language use.

Recent advances in AI have introduced entirely new categories of digital tools that extend beyond the framework established by Li and Hegelheimer (2017). Godwin-Jones (2021) presents a novel category labeled *automatic text generation* mainly represented by ChatGPT. This tool is distinct in its capability to generate full-length text based on user requests or prompts, differing fundamentally from prior technologies that merely helped learner writing. Floridi and Chiriatti (2020), describe ChatGPT as "the biggest transformation of the writing process since the word processor," highlighting the unprecedented consequences it will bring to our writing practices.

Empirical research in the field of L2 writing has primarily focused on evaluating the effectiveness of digital tools and how they contribute to language learners' writing competence (Fredholm, 2015; Gayed et al., 2022; Huang et al., 2020; Lee, 2019; Lee & Briggs, 2021; Link et al., 2022; Waer, 2021; Yang et al., 2023). Notably, Fredholm (2015) analyzed the impact of online translators on L2 writing fluency, complexity, and accuracy. Similarly, Huang et al. (2020) investigated the effectiveness of Grammarly, an automated writing evaluation tool, in enhancing students' writing skills. A comparable trend is observed in research concerning AI tools (Gayed et al., 2022; Pellas, 2023; Zhou et al., 2023). For example, Gayed et al. (2022) examined the influence of an AI-based writing assistant on ten Japanese adult EFL learners, noting an increase in lexical diversity and sentence fluency. Additionally, Pellas (2023) reported that a treatment group using generative AI platforms demonstrated higher performance in narrative intelligence scores in story creation tasks compared to a control group using conventional platforms.

While outcome-based research has provided promising results for L2 writing pedagogy, the highly individualistic nature of language learners' use of CALL software (Fischer, 2012) complicates its broader implementation (Stockwell, 2012). As a result, to fully understand the potential of these technologies in L2 writing, another strand of literature has emerged, posing a fundamental question: "What are students really doing when they interact with technologies?" (Caws & Hamel, 2016, p. 18).

A growing body of L2 writing scholars is shifting their focus from the final product of L2 writing to the actual writing process. There is now a heightened interest in investigating individual learner experiences to shed light on their behaviors and interactions with technologies during the writing process (Caws & Hamel, 2016; Lai & Chen, 2015; Manchón & Roca De Larios, 2023; Qin & Stapleton, 2022; Yoon, 2016a, 2016b).

In Ning's (2022) micro-level case study, the use of Google Translator (GT) by a Chinese student for writing emails in Catalan was examined. The results identified 10 different strategies employed during the participant's composing process. Notably, the participant used Google Search as a corpus to verify the translation suggested by GT. Moreover, the participant strategically pre-edited L1 sentences by eliminating unnecessary content or simplifying the complex words to manually reduce the strain of translation tasks for GT. The analysis also revealed that the student did not use GT in isolation but combined it with five other online tools—an online dictionary, Google Search, Wikipedia, a word processor, and Google Images—to enhance translation accuracy.

L2 writers' strategic integration of multiple tools was similarly noted in Yoon's (2016a) study, which examined six Korean L2 writers' use of concordancers and online dictionaries in academic writing. Yoon (2016a) illustrated that participants used various software for distinct purposes, often in combination, to meet their ongoing needs. Yoon (2016a) reported that L2 writers facilitated their linguistic problem-solving, such as finding appropriate collocates and confirming word choices by consulting multiple resources.

Lai and Chen (2015) conducted a similar study investigating 14 Taiwanese EFL writers' use of corpora and online dictionaries during academic writing. The results revealed that learners used each tool for a unique set of purposes. Bilingual dictionaries were employed for searching information on word form and meaning, while corpus tools were used for searching for word usage, collocation, and grammatical structures.

These studies each focus on different tools but collectively report that users employ tools systematically and strategically, rather than sporadically or without a clear purpose, during their writing process. They indicate that individuals assign specific roles to each tool and combine multiple resources with different technological affordances to address their immediate writing problems. These findings suggest that L2 writers do not passively integrate software into their writing process but strategically arrange tools and establish systems or patterns to effectively achieve their writing goals. In this regard, it is worthwhile to review: 1) what roles L2 writers designate to ChatGPT, and 2) what kind of individual usage patterns or strategies emerge as they integrate ChatGPT into their writing process.

Other studies extend beyond examining learner-computer interactions, focusing on how individual and contextual factors significantly shape learners' engagement with digital resources during the writing process. Ranalli's (2021) in-depth study of six L2 writers' use of Grammarly demonstrated that each participant's engagement with AWE was highly influenced by trust-related issues. He concluded that writers' trust in the technology significantly affected their willingness to engage with Grammarly, which, in turn, influenced the time they spent reviewing feedback from the AWE.

Hellmich and Vinall (2023) demonstrated how contextual factors shaped learners' attitudes toward Machine Translation (MT) tools, subsequently affecting their usage strategies. Hellmich and Vinall's (2023) study of 49 language learners revealed that instructors' policies on MT shaped the learners' attitudes toward this technology. These attitudes, in turn, led learners to develop specific strategies for using MT such as simplifying the language output generated by MT to avoid any academic misconduct or plagiarism issues.

Ranalli's (2021) and Hellmich and Vinall's (2023) findings emphasize that the software's affordances, learners' attitudes toward technology, and teachers' pedagogical strategies interact dynamically to influence learners' engagement with digital writing tools. These findings suggest that the use of technology by L2 writers should be understood as a complex and multifaceted activity that significantly varies depending on the context (Ranalli, 2021).

Meanwhile, Godwin-Jones (2022) specifically highlights a gap in the literature, noting the absence of ecological perspectives in discussions about AI tools. Indeed, to my knowledge, there are currently few studies investigating L2 writers' use of ChatGPT from a

holistic perspective. Consequently, a comprehensive analysis that incorporates contextual and situational factors is essential for fully understanding how L2 writers utilize ChatGPT.

2.3 ChatGPT and L2 Writing

In this part of the literature review, current research on the affordances of ChatGPT as a writing assistant tool and empirical studies investigating its use in the L2 writing context will be reviewed.

2.3.1 Affordance of ChatGPT in L2 Writing

ChatGPT is an artificial intelligence-generated content model (AIGC) developed by OpenAI, which is capable of understanding and processing natural language and completing generation tasks in a human-like interactional format.

Unlike the writing assistant tools discussed in the previous section which have confined affordance predefined by educational objectives, ChatGPT is a general-purpose tool that is designed to support a broad range of tasks. Thus, ChatGPT offers a realm of possibilities as its affordances are not fixed; instead, as a language model that produces responses based on users' input, the affordance of ChatGPT is shaped by interactions with language learners. This inherent flexibility allows ChatGPT to potentially offer individualized support to language learners. However, this same attribute poses challenges for practitioners and researchers in predicting how learners engage with the tool and in understanding its impact on the traditional writing process.

Recent studies have explored the potential affordance that ChatGPT can offer to L2 writers. A meta-analysis by Imran and Almuscharraf (2023) of 30 journal articles using AI tools as a writing assistant identified five key benefits: increased efficiency in content generation, enhanced idea creation, advanced language translation capabilities, guidance towards producing accurate and consistent content, and improved support for collaborative writing. Imran and Almuscharraf (2023) compared ChatGPT to a "complete package" (p. 2) for writing assistance as it can support writers from the initial idea generation to the final proofreading and editing stages.

Additional research by Su et al. (2023) and Zou and Huang (2023) suggested that ChatGPT surpasses earlier chatbots as it can comprehend natural language and produce human-like contextualized responses to the learner's request. Moreover, Ou et al. (2024) reported that ChatGPT excels in elaborating academic concepts, creating outlines, brainstorming ideas, and providing delicate writing assistance that user demands. Collectively, these studies acknowledge that the affordance of ChatGPT extends beyond the mere linguistic aspects of writing, influencing various stages of the writing process.

A group of researchers argues that the expansion of AI tools' technological affordances will significantly transform conventional writing literacy (Godwine-Jones, 2022; Kong et al., 2024; Warschauer et al., 2023). Warschauer et al. (2023) assert that new writing practices enabled by the affordances of AI tools will be "as transformational as was the original transition to digital writing." Moreover, Godwine-Jones (2022) contends that AI tools will not only support writers throughout the conventional stages of the writing process but "reshape[s] the process of authoring and editing" (Godwin-Jones, 2022).

Therefore, it is imperative to investigate how the enhanced technological affordances offered by ChatGPT will induce dynamic changes in L2 writing practices (Liu & Ma, 2024). To investigate this matter, examining solely the product of writing has limited value. Observing the use of ChatGPT in the L2 writing process will help identify at which stages language learners engage with the tool, the specific affordances they most frequently capitalize on, and the ways in which they utilize the outputs generated by ChatGPT. This comprehensive analysis will help elucidate the transformations that ChatGPT introduces to the traditional literacy practices.

2.3.2 Empirical Studies of ChatGPT as a Writing Assistant Tool

Researchers have initiated discussions on how to integrate ChatGPT into writing education (Barrot, 2023; Su et al., 2023). In his technology review on the potential affordances and limitations of ChatGPT in L2 writing, Barrot (2023) underscored the importance of informing L2 writers about the basic writing process. He argued that the step-by-step scaffolding of the writing process can provide students with opportunities to monitor their use of ChatGPT. Consequently, he recommended the process approach to purposefully and systematically integrate ChatGPT into writing courses.

While Barrot (2023) reviewed the potential uses of ChatGPT in general writing contexts, Su et al. (2023) proposed its integration into argumentative writing classrooms as a solution to complement the lack of time for teachers to provide detailed feedback. Su et al. (2023) demonstrated the writing process by simulating a composition of argumentative tasks

and issuing prompts with detailed rubrics at each stage of writing. Su et al. (2023) reported that ChatGPT can facilitate conceptual planning (pre-writing), expose L2 writers to various perspectives (during writing), provide feedback on the logical connection of arguments (post-writing), and provide linguistic assistance appropriate to academic writing (post-writing). However, the benefits mentioned by Su et al. (2023) should not be attributed solely to ChatGPT's inherent affordances, as they were fine-tuned by the detailed rubrics at each stage of the writing process.

Barrot (2023) and Su et al. (2023) both advocate for using a process approach to writing as a systematic way to integrate ChatGPT into writing instruction. They both suggest pedagogical attempts to integrate the use of ChatGPT between the stages of the conventional writing process.

Drawing on the potentials and pitfalls suggested in the above-mentioned studies, Warschauer et al. (2023) identified three types of contradictions prompted by ChatGPT that could eventually become burdens for L2 writers. First, they claimed that ChatGPT might inadvertently increase the risk of plagiarism, especially for L2 writers, as it provides a tempting affordance to easily produce native-like texts. Secondly, they noted that ChatGPT would not address linguistic inequality, as only those with access to the technology could benefit from it. Lastly, although using ChatGPT might seem like a personal choice, Warschauer et al. (2023) argued that mastering AI tools would eventually become essential to avoid being unprepared for the future. To mitigate the influence of such contradictions, they proposed an AI literacy framework that underscores the importance of understanding the

function, strengths, and weaknesses of AI tools and providing students with opportunities to reflect on their usage of AI tools.

Barrot (2023), Su et al. (2023), and Warschauer et al. (2023) provide a valuable theoretical foundation for understanding how ChatGPT can be integrated into writing processes. However, since their studies are based on preliminary interactions with ChatGPT, empirical validation of the theoretical assumptions they propose is necessary.

There is a growing demand for research that investigates language learners' genuine engagement with ChatGPT in L2 writing. Addressing this gap, several peer-reviewed articles have explored how L2 writers perceive the impact of ChatGPT on their writing. These studies utilized quantitative methods (Chan & Hu, 2023; Liu & Ma, 2024) and intervention approaches (Choi, 2023; Im, 2023; Zou & Huang, 2023).

Chan and Hu (2023) and Liu and Ma (2024) conducted large-scale quantitative studies to investigate how EFL learners perceive the impact of generative AI, specifically ChatGPT, on their writing process. Chan and Hu (2023) surveyed 399 undergraduate and postgraduate students from diverse majors across six universities in Hong Kong, exploring their attitudes toward generative AI. The findings revealed that students generally held positive views and were familiar with generative AI. This familiarity was influenced by their knowledge of generative AI and frequency of use, which were found to be positively correlated. In terms of generative AI's role in the writing process, students expressed a preference for support that extends beyond mere linguistic refinement.

In their study, Liu and Ma (2024) surveyed 405 Chinese EFL learners across various age groups to investigate their perceptions of using ChatGPT in informal digital learning of English (IDLE) activities. The questionnaire was developed based on the Technology Acceptance Model (TAM), focusing on five key areas: perceived ease of use, perceived usefulness, attitude towards technology, behavioral intentions, and actual usage. Three important findings emerged. First, they discovered that the ease of using ChatGPT does not automatically lead to a positive attitude. Secondly, they reported that while ease of use does not directly foster a positive attitude, learners develop a favorable attitude as they recognize its usefulness through consistent use. Lastly, Liu and Ma (2024) discovered that once learners develop a positive attitude, they are more likely to use ChatGPT in IDLE activities. The findings from Liu and Ma (2024) provide a sophisticated understanding of the dynamic process by which learners' decisions to use ChatGPT are shaped, and how their attitudes can change through consistent interaction with the technology.

Several intervention studies have explored how undergraduate and postgraduate students perceive the use of ChatGPT (Choi, 2023; Im, 2023; Zou & Huang, 2023). In these studies, participants participated in a survey or interview after completing a writing task using ChatGPT, following specific instructions provided for its use.

For instance, Im (2023) conducted an online survey encompassing 134 Korean EFL students who were enrolled in an English presentation course. The participants, all non-English majors, exhibited proficiency levels ranging from low to intermediate. After using ChatGPT to write a script for a presentation, they participated in an online survey. Employing statistical analysis, the study unveiled participants' positive attitudes toward ChatGPT in

terms of the time-saving attributes, the capacity to access extensive learning resources, and the convenience of error correction. However, these learners expressed a somewhat pessimistic view regarding ChatGPT's potential to enhance their English proficiency.

Conversely, Choi's (2023) study involving 25 undergraduate students majoring in English education produced contrasting results. These students exhibited English proficiency levels ranging from intermediate to advanced. During 4 weeks of the course, participants completed two composition tasks independently and used ChatGPT for revision followed by writing a reflective journal. The thematic analysis of the reflective journals revealed that the majority of participants reported an increase in their confidence levels regarding their writing abilities and expressed a willingness to incorporate ChatGPT into their future writing to enhance their language proficiency. The contrasting findings in the two studies suggest that ChatGPT's impact on language learning and its utilization patterns may differ based on the learners' English proficiency levels.

Whereas Im (2023) and Choi (2023) analyzed undergraduate students' perceptions of ChatGPT in writing, Zou and Huang (2023) explored how doctoral students, who hold higher standards for academic writing and domain expertise, perceive ChatGPT's impact on L2 writing. This study employed reflective journals and focus group interviews to gather insights from 219 doctoral candidates at a public university in China after they were involved in instructed writing using ChatGPT. The thematic analysis revealed that the majority of students viewed ChatGPT as a "personal tutor" or "learning partner." Common uses included "facilitating brainstorming" and "aiding in revision and proofreading." Additionally, students highlighted ChatGPT's role as a self-learning tool, providing extensive exposure to authentic

texts. However, potential drawbacks such as learning loss, dilution of authorial voice, generation of unintelligent text, and risks to academic integrity were also noted. Participants' concern about unintentional plagiarism echoes Warschauer et al.'s (2023) claim about an increased propensity for plagiarism among L2 writers using such tools.

These studies offer insights into how language learners perceive state-of-the-art technology. However, while they address how learners "think" about ChatGPT, they often fail to reveal what learners do, which is critical for understanding the impact of ChatGPT on the L2 writing process. Notably, in the above-mentioned intervention studies, the use of ChatGPT is structured by educators or researchers, requiring students to follow specific workflows. These studies prohibit the chance to observe personalized and strategic engagement that learners make in their real-life encounters with ChatGPT. Therefore, to fully comprehend both the perceptual and behavioral aspects of ChatGPT usage, case studies employing multiple data sources that capture the emergent and dynamic interaction between ChatGPT and L2 writers are needed.

To date, only a limited number of researchers have explored the writers' moment-to-moment engagement with ChatGPT during the writing process. Yan (2023) observed 8 Chinese EFL undergraduate students' usage of ChatGPT by analyzing classroom observation recordings, screen monitoring, paper-and-pen notes, learning logs, and interview data. For a week, a special practicum of learning and practicing ChatGPT in L2 academic writing was conducted by the researchers on December 12th to 18th, 2022, after a week ChatGPT 3.5 was released to the public. The participants were given a short lecture about the technological affordance of ChatGPT and protocols for academic honesty. In the classroom observation and

learning logs, Yan (2023) found three stages of developmental steps: becoming familiarized with ChatGPT, experimenting with basic functions, and finding advanced usage. During this stage students tended to show a general workflow of 1) generating a text, 2) copying and pasting to Microsoft Word, and 3) using external software to edit and revise certain parts of the ChatGPT output. Yan (2023) explained that participants utilized combinations of software such as paraphrasers, grammar checkers, and summarizers to enhance their quality of writing and to mitigate potential plagiarism or cheating issues by using ChatGPT. Analyzing multiple sources of data, this study made pioneering efforts to track the actual writing process of students in the use of ChatGPT, which aligns with the aim of this paper. However, as the author notes, the students' workflow may have been highly influenced by instructions provided by the researchers as learners did not have sufficient time to engage with ChatGPT.

In a nutshell, there is a notable scarcity of both theoretical and empirical literature on the impact of ChatGPT in L2 writing. Most existing studies have focused on L2 writers' perceptions of ChatGPT, relying predominantly on self-reported data from interviews or surveys. Furthermore, the few investigations that incorporate behavioral data on language learners' use of ChatGPT are constrained by their experimental designs. These studies were conducted in controlled settings where the use of ChatGPT was mandatory, and participants were required to follow specific guidelines set by researchers or instructors. This structured approach may not accurately reflect naturalistic usage patterns, thereby highlighting a significant gap in the field.

However, as Alharbi (2023) claims, L2 writers' use of ChatGPT in their day-to-day writing has now become an "inescapable fact" (p. 2). Due to its easy accessibility and

advanced functionalities, L2 writers are actively employing this tool regardless of the potential controversies or pitfalls that it might bring about. Hence, under such circumstances, it is imperative to investigate language learners' genuine interaction with ChatGPT in real-world contexts, beyond structured settings or language classrooms (Ou et al., 2024). Therefore, this study aims to fill the void in our understanding of language learners' authentic use of ChatGPT in their daily writing practices through an ecological and naturalistic research approach.

2.4 Process-Tracing Studies in L2 Writing

There has been growing enthusiasm for innovation in methodologies in applied linguistics (Latif, 2019; Li & Prior, 2022; Li et al., 2023; Manchón & Roca De Larios, 2023; Hyland, 2016). Referred to as the methodological turn, the demand for methodological innovation reflects a shift from viewing methodologies as ancillary to recognizing them as central to research (Byrnes, 2013). This increasing methodological consciousness calls for a systematic inquiry into domain-specific methods appropriate for investigating unique research aims of applied linguistics from various theoretical frameworks (Li & Prior, 2022).

Responding to these emerging needs, the annual meeting of the American Association of Applied Linguistics (AAAL), held on March 20, 2023, featured a colloquium that prominently addressed the topic of methodological innovation in applied linguistics (Li et al., 2023). Li et al. (2023) shared the preliminary results of an open-ended survey conducted with 39 researchers in applied linguistics, revealing that *eye-tracking* and

technology were the most frequently cited innovative data collection methods. These methods provide valuable insights into previously invisible or unrevealed processes and enable data collection on online platforms while enhancing authenticity. Such capabilities are consistent with the core features of methodological innovation in applied linguistics, specifically emphasizing multiplicity, individuality, and process investigation (Li et al., 2023).

In a related vein, there has been a notable increase in the use of innovative research methodologies within L2 writing process research (Manchón & Roca De Larios, 2023; Kessler, 2024). Process-tracing technologies such as screen capture technology, keystroke logging, and eye-tracking are being actively employed for methodological triangulation, enabling detailed observation and analysis of the L2 writer's digital composing processes (Hyland, 2016; Latif, 2019; Leijten & Van Waes, 2013; Manchón & Roca De Larios, 2023; Van Waes et al., 2016).

This methodological shift coincides with the reconceptualization of "process" in L2 writing, informed by socio-cultural, social semiotic, and socio-material perspectives (Manchón, 2021; Manchón & Roca De Larios, 2023). The construct of the writing process has expanded to encompass not only the traditional understanding of composition as a series of individual cognitive operations but also as a set of "socially situated, time-distributed, and source-based components of literacy practices" (Manchón & Roca De Larios, 2023, p. 25). The renewed recognition of the contemporary writing process as a "multi-resourced and multi-party activity" (Park & Kinginger, 2010) occurring in various contexts has brought forth new research agendas beyond cognitive-oriented studies. This expanded agenda includes an investigation into the utilization of space, visual, and semiotic elements during

digital composition (Hort, 2020; Smith, 2017), the use of online resources in the writing process (Bailey & Withers, 2018; Gilquin & Laporte, 2021; Séror, 2013), and writing in various settings such as working environments beyond academic or isolated laboratory condition (Leijten et al., 2014). Consequently, this shift necessitates the development of new research instruments and procedures.

Traditionally in writing process studies, methods such as interviews, think-aloud protocols, and stimulated recalls were utilized. These methods provided valuable insights into a writer's perceptions and intentions during the writing process. However, relying heavily on participants' self-reports restricted researchers from directly investigating the behaviors and strategies that occurred during the writing process (Michel et al., 2020; Révész et al., 2019). Therefore, to show rather than tell the orchestration of the composing process, direct observation methods emerged as alternatives (Hyland, 2016). Increasing numbers of studies have employed keystroke logging or screen recording technology together with verbal protocols (Bowen & Thomas, 2020; Hamel et al., 2015; Révész et al., 2017; Leijten & Van Waes, 2013). These methodologies have proven to be minimally invasive yet highly effective, allowing for the real-time capture of activities on writers' digital screens during the composition process. However, even when combined with keystroke logging or screen recording data, a significant gap persists in understanding the writing process, as these methods do not reveal where writers' visual attention is focused. Reading during writing, which is considered to be a prerequisite of the reviewing and planning process (Hayes & Flower, 1980), or gaze behaviors during writers' use of external sources (Leijten et al., 2014) remain undiscovered.

To address these issues, recent scholars are triangulating screen capture technology and keystroke logging with eye-tracking data. By recording the location, sequence, and length of gaze, eye-tracking technology shows how L2 writers "allocate, shift, or divide their attention between multiple channels" in a digital writing context (Godfroid et al., 2020, p. 248). Moreover, it can advance researchers' understanding of how L2 writers engage with and integrate multiple resources to create one coherent composition (Godfroid et al., 2020).

Gánem-Gutiérrez and Gilmore (2018) employed screen recording, eye-tracking, and stimulated recall to investigate the temporal dimension of writing—specifically, how long and when writers dedicate time to various activities—in a study involving 22 Japanese L2 writers. A gaze plot recording or a screen recording with overlaid eye-gaze data was collected during each participant's 35-minute essay-writing process. For analysis, each gaze plot recording was segmented and manually coded into episodes based on the coding scheme developed by the researcher. They identified six episodes emerging during composition: text construction, revising, re-reading, use of external resources, pausing, and others. Among these episodes, Gánem-Gutiérrez and Gilmore (2018) note that re-reading and pausing were observable through the eye-tracking data. The result indicated that participants dedicated the most time to text construction and revision, while re-reading showed a linear tendency with text construction.

Similarly, Liu and Yu's (2022) study used eye-tracking, stimulated recall, and reflective journals to investigate 24 Chinese EFL writers' engagement with an automated writing evaluation (AWE) system. They examined the impact of different feedback types (direct and indirect feedback) on their engagement with the AWE system during the revision

stage of writing. Liu and Yu (2022) collected 30 minutes of eye gaze plot recordings while participants revised their essays using the AWE system. Each gaze plot recording was manually coded based on a coding scheme developed by the researchers. The coding scheme consisted of 25 online behaviors such as reading images, switching between feedback and revision, and self-initiated revision. For analysis, the fixation duration on different types of feedback was extracted from the coding coverage, as it was impossible to fix a stimulus in AWE that provides real-time feedback for every participant. The findings from the gaze data revealed that participants invested more time and cognitive resources in processing indirect feedback compared to direct feedback.

Additionally, Ranalli et al.'s (2018) study discusses how process visualization obtained through keystroke logging and eye-tracking technology can contribute to individualized feedback in L2 writing pedagogy. The study asserts that detailed information on how L2 students produce their compositions—such as when writers initiate their formulation, consult external sources, and pause to re-read their writing—is essential for instructors to provide practical feedback. Ranalli et al. (2018) advocate for using process-tracing technologies for diagnostic and formative purposes in L2 writing instruction.

These above-mentioned studies suggest eye-tracking technology is beneficial in researching the writing process, especially as it allows for the fine-grained observation of reading during writing, engagement with external resources, and ultimately enables a concrete diagnosis of L2 writers' writing process. Despite the differences in the specific research questions in each study, these studies collectively demonstrate similar approaches to utilizing eye-tracking data, which is distinct from the quantitative use of eye-tracking in

psycholinguistic or SLA research. Typically, Gánem-Gutiérrez and Gilmore (2018) and Liu and Yu (2022) make full use of the affordance provided by gaze plot recording data that captures writers' dynamic interaction with multiple resources in the digital writing context. Their research demonstrates how "eye-tracking methodology is diversifying and breaking boundaries, its innovation fueled by different disciplinary traditions" (Godfroid et al., 2020, p. 245).

Although eye-tracking technology offers significant methodological advantages, it has not been widely used in L2 process research due to its high cost and lack of accessibility outside laboratory settings (Stickler & Shi, 2017). Having to be conducted in a lab with an expensive eye-tracker, field research in natural environments was impossible. In response to these constraints, webcam-based eye-tracking is emerging as a practical alternative (Hutt et al., 2024; Yang & Krajbich, 2021). Webcam-based eye-tracking offers a more cost-effective solution and enables observations in naturalistic environments by leveraging the webcams commonly integrated into laptops.

While webcam-based eye-tracking does not ensure the same level of accuracy and precision as traditional eye-tracking (Wisiecka et al., 2022), when complemented with screen recording and stimulated recall data, it can provide valuable insights into L2 writing process research. By enabling research in naturalistic settings, it can enhance the ecological validity of the research. Therefore, to closely observe L2 writer's use of ChatGPT in real-world conditions, this research will adopt a webcam-based eye-tracking method.

CHAPTER 3. METHODOLOGY

This chapter delineates the methodology utilized to explore the research questions outlined in Chapter 1. Section 3.1 describes the research design including participant selection and the study setting. Section 3.2 details the procedures of the study and the methods used for data collection. Finally, Section 3.3 explains the data analysis process, specifying the analytical strategies and software used to interpret the findings.

3.1 Research Design

3.1.1 Participants of the Study

A total of four Korean EFL STEM graduate students attending three different universities in Seoul, Korea, participated in the study. The potential participants were recruited through online advertising, which resulted in eight interested participants. Among the eight interested participants, this study used purposive sampling to select five participants. Data from four participants were available for the final analysis, as data from one participant who completed the process was excluded from this paper due to insufficient eye-tracking quality. Table 1 details the background information of the four participants included in the final analysis.

Table 1.*Participant Profile*

Name*	Degree, Field of Study	Gender, Age	Self-Initiated Writing Task	English Proficiency	Number of Publications	ChatGPT
Sam	MS, Smart Vehicle Engineer -ing	Male, 27	Journal Paper	Upper- Intermediate (B2) TOEIC 850	K: 2 E: 1	6 months
Jake	PhD, AI	Male, 27	Journal Paper	Advanced (C1) NEW TEPS 493	K: 0 E: 9	2 years (Since GPT 2.0)
Collin	MS, AI	Male, 26	Thesis	Advanced (C1) TOEFL 110	K: 0 E: 4	8 months
Thomas	PhD, AI	Male, 29	Research Proposal	Upper- Intermediate (B2) NEW TEPS 330 TOEIC 790	K: 0 E: 2	3 months

Note. K = number of articles published in Korean, E = number of articles published in English.

* All names are pseudonyms.

All participants were male, and their ages ranged from 24 to 29 years old. They had the same L1 background, Korean, and had studied English for an average of 10 to 15 years as a foreign language. Jake and Collin had experience living abroad in the United States for about 2 years while Sam and Thomas did not have any experience living abroad. The participants' English proficiency ranged from B1 to C2 according to the Common European Framework of Reference for Languages (CEFR) standards. Specific details regarding each participant's language background, English learning trajectory, and experience with L2 writing will be discussed in the results section.

The duration of ChatGPT usage among the participants varied from three months to two years. Thomas had the shortest usage period, lasting only three months. Both Sam and Collin started using the tool around the same time, with durations of six months and eight months, respectively. Notably, Jake, a PhD student in AI, has been using ChatGPT since version 2.0, which was two years before the public release of ChatGPT 3.5. He accessed the model through OpenAI's open-source sharing before it was available in a public application format.

The participants were all majoring in STEM (Science, Technology, Engineering, and Mathematics) fields. Jake, Collin, and Thomas majored in AI, and Sam majored in Smart Vehicle Engineering. Sam and Collin were enrolled in a master's program, and Jake and Thomas were PhD students.

The rationale for selecting STEM graduate students as participants in this study stemmed from two primary considerations: the pivotal role of English in scientific communication and the frequent engagement of these students with L2 writing tasks. English is recognized as the "international language of science" (Wood, 2001) and continues to be the predominant language for scientific communication. For researchers in the STEM fields, publishing an academic paper in an international journal is a critical endeavor. Proficiency in English, therefore, is essential for those aiming to publish in reputable journals (Kim, 2020). Given the significance of English writing skills in their academic and professional careers, it was expected that STEM graduate students would have strong intrinsic and extrinsic motivation to enhance their proficiency in L2 writing.

Additionally, STEM graduate students are frequently engaged in L2 writing for a variety of non-academic and academic purposes. They write in English for authentic purposes such as collaborating with international corporations on research projects, documenting code on GitHub, and composing academic papers and scientific reports. Given these diverse and immediate writing needs, STEM graduate students were considered to be ideal candidates for studying the authentic and natural writing processes of L2 writers.

3.1.2 Setting of the Study

To observe participants' use of ChatGPT during their writing process in an authentic and naturalistic setting, no fixed research site was established. Instead, by employing webcam-based eye-tracking technology, this study aimed to observe participants' writing processes in "natural, non-controlled, non-laboratory conditions" (Séror & Gentil, 2023). Consequently, each participant's usual place of writing—whether a personal space, cafe, or lab—served as the research site. Given that the webcam-based eye-tracking software was accessible via a simple link from their personal devices and could be used anywhere an internet connection was available, participants had the autonomy to decide when and where to record their writing process.

Granting participants the flexibility to decide the timing and location of their participation in the research was meant to ensure they engage in natural writing processes within their real work environments (Séror, 2013). Moreover, since the data collection involved screen recording on their personal devices, participants were given full control over the data collection process to avoid potential privacy concerns (Hort, 2020; Séror, 2013).

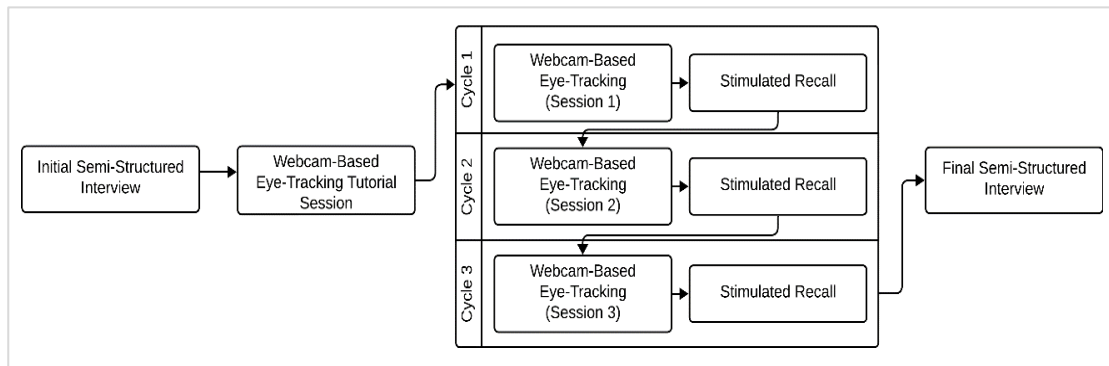
3.2. Data Collection

3.2.1 Procedures

The study was conducted according to the following procedure: 1) an initial semi-structured interview, 2) a tutorial on webcam-based eye-tracking, 3) three sessions of eye-tracking, with stimulated recall following each session, and 4) a final semi-structured interview. Figure 1 shows the procedure of the study in a flow chart.

Figure 1.

A Flow Chart of the Study



A short 30-minute tutorial session was conducted after the initial semi-structured interview. In laboratory-based eye-tracking studies, researchers can control factors such as camera quality and lighting placement. However, in this study, such controls were significantly limited. Therefore, based on the guidelines for webcam-based eye-tracking

proposed by Yang and Krajbich (2021) and findings from the pilot study of this research, instructions on how to use webcam-based eye-tracking software were provided. The instructions included how to position themselves for better eye-tracking quality, where to place the light source and the appropriate height for a laptop. After the instructions were given, participants used the demo function on the RealEYE website to practice the calibration process and to simulate the process they would undergo during the eye-tracking sessions. After the tutorial sessions, participants were instructed to complete a 3-minute eye-tracking demo to verify the accuracy of the webcam-based eye-tracking system in their respective environments individually. Participants proceeded with their eye-tracking sessions only if the demo results indicated a good or perfect level of accuracy.

3.2.2 Semi-Structured Interviews

A semi-structured interview is a commonly employed qualitative research tool where the researcher utilizes a pre-established set of questions as a guide but retains the flexibility to diverge from the script to explore deeper insights or follow the interviewee's responses (Mackey & Gass, 2022). Through a semi-structured interview, researchers can gain a deeper understanding of the learner's perception, belief, and emotion, which are not directly observable.

In this study, semi-structured interviews were conducted twice, at the beginning and the end of the data collection process. Both interviews were conducted one-on-one in Korean, and each lasted for about an hour. The initial interview was carried out face-to-face asking

questions regarding participants' language backgrounds, along with their experiences and perceptions of L2 writing (see Appendix A for the questionnaire). During the interview, participants were asked to draw their writing environments, including the software and hardware tools they used. Drawings, a visual method often employed in ethnography (Pink, 2007), provided insights into the overall relationship participants form with technology (Gourlay, 2015). Moreover, these drawings enriched the information about the materiality and the physical surroundings outside the screen where the participants engaged in writing, offering data that cannot be captured by eye-tracking technology. In the final interview, questions about participants' perceptions of using ChatGPT in L2 writing were asked (see Appendix B for the questionnaire). The final interview was conducted via Zoom. Using Zoom proved convenient for recording and facilitating the sharing of additional resources, such as past ChatGPT logs, during the interview. The audio data gained from the interviews were transcribed and analyzed.

3.2.3 Webcam-based Eye-tracking and Screen Capture Technology

Webcam-based eye-tracking and screen capture technology were employed to document the naturalistic, moment-by-moment aspects of ChatGPT use during the L2 writing process. The primary data source, gaze plot recordings, was collected using the webcam-based eye-tracking software RealEYE. Gaze plot recordings are a type of video data where screen capture data are overlaid with visualizations of participants' eye-gaze data. As a product of integrating screen capture technology and eye-tracking technology, gaze plot recordings effectively map the movement of participants' gazes across different areas of the

screen.

Screen capture technology records the actions visible on the digital screen (Hamel et al., 2015) and is widely utilized by L2 writing researchers to study real-time writing processes in digital environments. Eye-tracking technology records eye movement while a person is gazing at the computer screen, capturing rapid movements (saccades) and stationary events (fixations). Both technologies being unobtrusive, provide a holistic understanding of L2 writing without disturbing the writers' composition process.

Gaze plot recordings reveal two distinct aspects of the composition process (Séror & Gentil, 2023). First, they enable researchers to monitor the progression of *macro-processes* such as planning, formulating, reviewing, and monitoring, which contribute to the final writing product. Second, they facilitate a fine-grained analysis of *micro-processes*, including scrolling, reading, spell-checking, and consulting with various external resources (Bailey & Withers, 2018; Hort, 2020; Takayoshi, 2016).

In this study, RealEYE, a webcam-based eye-tracking software, was employed. RealEYE operates with a standard webcam to record gaze positions (Wisiecka et al., 2022) and utilizes AI to track the movement of participants' pupils and estimate their gaze focus. It functions within a web browser, eliminating the need for participants to download any software. Among the various tools RealEYE provides, the screen recording session was used in this study. The gaze data was captured at a sampling rate of 30 Hertz.

Following the webcam-based eye-tracking tutorial session, participants were given a link to access the eye-tracking session, which recorded 30 minutes of their writing process on

self-initiated tasks. Participants accessed this link through their personal devices at times and locations of their choosing. Upon accessing the link, participants were first required to complete a 40-point calibration, followed by a 9-point calibration. The eye-tracking session was initiated only when participants were successful in the calibration process. Each participant engaged in 30 minutes of the eye-tracking session, and after 30 minutes the data was automatically transmitted to the RealEYE dashboard. Over the approximately two-month research period, participants completed three eye-tracking sessions, resulting in 90 minutes of gaze plot recordings per participant.

3.2.4 Stimulated Recall Interviews

The screen capture data overlaid with eye-gaze data (hereafter gaze plot recordings) was supplemented with stimulated recall interviews. Stimulated recall is one type of introspective method that uses a video or audio recording as a stimulus to facilitate learners in recalling their thoughts and motivation while conducting their task (Gass & Mackey, 2000; Mackey & Gass, 2022). The verbalized data produced by participants allows the researchers to understand the reasoning behind the learners' behavior and view the event from the learners' point of view.

Séror and Gentil (2023) assert that complementing screen-recording technology and eye-tracking data with stimulated recall data is a powerful triangulation technique, that allows researchers to "explore the factors and beliefs at play during students' composition processes" (p. 142). Therefore, this study employed stimulated recall interviews to gain a holistic understanding of the influence of ChatGPT on the L2 writing process, taking into account

learners' attitudes and beliefs about ChatGPT. Triangulation with stimulated recall was particularly crucial in this study, as it enabled participants to validate the accuracy of webcam-based eye-tracking data.

For each participant, three sessions of stimulated recall were conducted. Each stimulated recall was conducted within 2 to 3 days after the participant's eye-tracking. The stimulated recall was conducted through the video conferencing platform Zoom. Through a pilot study, it was discovered that aligning the stimulated recall data with the gaze plot recordings using only audio recordings was challenging. Consequently, stimulated recall sessions were conducted via Zoom as it optimally aligned and stored participant comments from stimulated recall data with the corresponding stimulus videos.

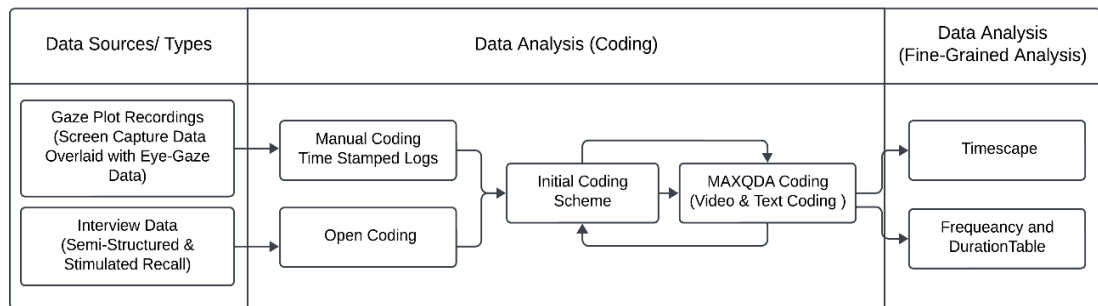
Before each stimulated recall session, the researcher read aloud the instructions about the stimulated recall process (see Appendix C), which were designed based on the examples suggested by Gass and Mackey (2000). The full 30 minutes of gaze plot recording was replayed using Zoom's screen-sharing function. Based on Guggenbichler et al.'s (2023) suggestion of "systematizing elicitation procedures for stimulated recalls" (pg. 252), participants were encouraged to self-report their thought processes, while the researcher also paused the recording to ask questions when predefined events occurred. The researcher paused the video for predefined events, specifically 1) the interaction with ChatGPT, and 2) periods of conspicuous fixation. Subsequently, the audio from each simulated data was transcribed into text.

3.3 Data Analysis

Based on the Grounded Theory (Strauss & Corbin, 1998), gaze plot recordings, stimulated recall interview transcripts, semi-structured interview transcripts, and participants' drawings of their writing environments were analyzed. Figure 2 presents a flow chart of the data analysis process.

Figure 2.

A Flow Chart of the Data Analysis Process



The two-step qualitative data analysis, frequently used in education research was applied. Initially, several rounds of open coding were conducted to distinguish the initial themes in participants' writing processes. Time-stamped logs were created for each gaze plot recording. Meticulously watching the gaze plot recordings, actions relevant to the use of ChatGPT were marked. Subsequently, revisiting the time-stamped log data with gaze plot recordings and stimulated recall interviews, the study established an initial coding scheme.

The coding scheme was categorized into two levels: tools and actions. The tool-level

code was comprised of software tools that emerged in the participants' writing process. The action-level code was again categorized into two levels; *Gaze behaviors* (e.g., ChatGPT Output Scanning, ChatGPT Output Reading, Zig-zagging) and *Non-gaze behaviors* (e.g., Text Construction in Korean, Text Construction in English, Revising Writing, Drag and Drop).

Gaze behaviors are micro-processes captured through the combination of eye-tracking and screen-recording data. These behaviors can only be observed through the integration of gaze data and screen capture data; they would remain unidentified if only screen recording were conducted without eye-tracking. Gaze behaviors primarily include the participants' reading, scanning, and transitioning across screens as they interact with linguistic and visual resources presented in various tools. In contrast, *non-gaze behaviors* refer to the micro-processes that are visible through screen capture data, independent of gaze plot information. These behaviors primarily include actions that involve typing or mouse movements. The coding scheme for action-level categorization was adapted from van Weijen et al. (2009), Gánem-Gutiérrez and Gilmore (2018), and Leijten et al. (2014).

In preparation for analysis, the gaze plot recordings (n=12) of the real-time L2 writing process were coded using MAXQDA 24 software. Each gaze plot recording was coded manually using the video coding function of MAXQDA 24 as shown in Figure 3. Once data had been coded, two more cycles of coding were conducted to ensure reliability. During the repeated cycles of coding the initial coding scheme was refined. Tables 2.1 and 2.2 describe the final coding scheme.

Figure 3.

Video Coding Process Using MAXQDA

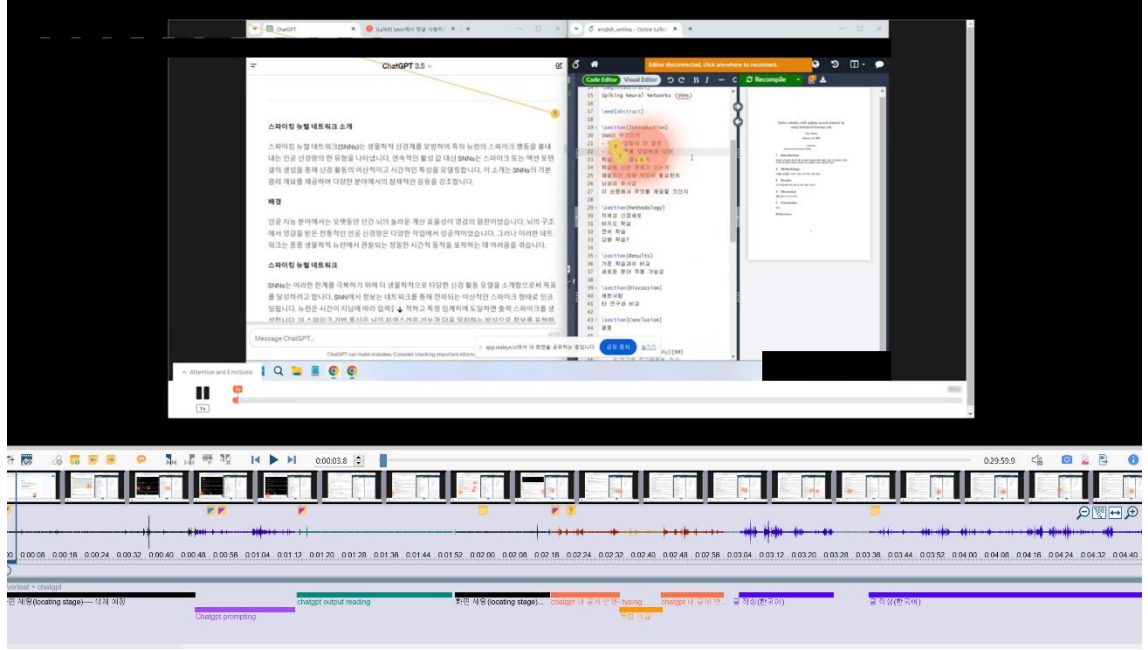


Table 2.1

Tool Coding Scheme for L2 Writing Process

Category	Code
Tools	1. ChatGPT
	2. Overleaf
	3. Google
	4. Dynalist
	5. Text Document Comparison Site (TDCS)
	6. ArXivGPT (ChatGPT extension for ArXiv website)
	7. Notion
	8. Others: Naver Dictionary, PDF

Table 2.2*Action Coding Scheme for L2 Writing Process*

Category	Code	Code Description
Gaze Behavior	1. ChatGPT Output Scanning	Fixate the words at the beginning of lines and swiftly move the gaze horizontally.
	2. ChatGPT Output Reading	Fixate on all or most words presented by ChatGPT.
	3. Zig-zagging	Continuously shift gaze back and forth between two software arranged on a split screen.
	4. Re-reading	Re-read segments of the text produced by oneself.
	5. Overleaf Compile and Reading or Scanning	Compile the document in Overleaf and read or scan the preview.
	6. Software Scanning	Scan the content in software other than ChatGPT. No typing or reading.
Non-Gaze Behavior	7. ChatGPT Prompting	Type texts into the input field of ChatGPT placed at the bottom of the chat window.
	8. Text Construction (Korean)	Type actual words in Korean
	9. Text Construction (English)	Type actual words in English
	10. Revising Writing	Revise texts written by oneself at word, sentence, or paragraph level.
	11. Drag and Drop	Copy text from one software (excluding ChatGPT) and paste it into another (including ChatGPT), such as from Notion to ChatGPT or Overleaf.
	12. Reflecting ChatGPT Output into Writing	Transfer text from ChatGPT to another software by copying and pasting or typing manually.
	13. Revising ChatGPT Output	Revise ChatGPT output after copying and pasting it into another software.
	14. Search	Search for information on Google.
	15. Locating	Change the spatial organization and align the software.
	16. Grammarly	Click on the Grammarly extension embedded in Chrome
	17. Other	Activities not related to writing.

After coding, the coded segments were exported into Excel. The coded segment data were processed in Excel to suggest two types of analysis.

First, a timescape (Smith, 2017) was created to visually represent the real-time evolution of the writing process. Using the code coverage data from the coded segments, the sequence and proportion of time that participants allocated to each action and tool were depicted in two separate timescape bars. Each code was assigned a different color to visualize the composition process across the three eye-tracking sessions (see Figures 6 and 7 for examples).

Secondly, a table indicating the temporal distribution of each code, both tools and actions, was created using the code area data. Following Gánem-Gutiérrez and Gilmore (2018) and Roca de Larios et al. (2008), the duration and frequency of each code were summed to show how much time participants dedicated to micro-behaviors such as Text Construction in English or ChatGPT Prompting during writing (see Tables 4 and 5 for examples).

CHAPTER 4.

RESULTS

This chapter provides a detailed analysis of the case studies involving four participants. Sections 4.1 to 4.4 delineate the use of ChatGPT in the composition processes of Sam, Jake, Collin, and Thomas, respectively. In each section, background information, an analysis of the writing process timescape, an examination of the time and frequency table, and dominant features characterizing each participant's use of ChatGPT will be presented.

4.1 Sam

4.1.1 Background

4.1.1.1 Language Learning Experience

Sam is a 25-year-old student enrolled in a master's program in Smart Vehicle Engineering at a university in Seoul, Korea. He is a member of a laboratory focused on researching automotive engineering and intelligent vehicles. Reflecting the convergent nature of autonomous vehicles, which integrate various advanced technologies such as sensors, mobile big data, and machine learning, research in Sam's lab is conducted collaboratively, with students from different research areas working together. Consequently, there is a collaborative culture in his lab where open communication, teamwork, and coherent workflow are valued.

Born and raised in Korea, Sam has never lived abroad and speaks Korean as his mother tongue. Sam started attending a private academy to learn English in 5th grade and attended two different English private academies until 11th grade. However, Sam stated that since both institutions were mainly focused on preparing students for the College Scholastic Ability Test (CSAT), the emphasis was primarily on grammar and reading. Consequently, he had no opportunity to receive formal education in English writing during his K-12 education. The circumstances were similar throughout his undergraduate and master's programs. Despite being enrolled in these programs, he had no opportunity to receive formal training in writing, whether through coursework or extracurricular programs.

Sam received a score of 850 on the TOEIC test, which corresponds to an upper-intermediate (B2) level on the Common European Framework of Reference for Languages (CEFR). When asked to self-rate his proficiency in the four language skills in English, Sam rated his abilities in the following order: reading, speaking, listening, and writing. He showed low confidence in his writing skills, stating that "Writing is the biggest problem" or "My writing skills are the weakest" (Sam, Initial semi-structured interview).

Sam has published three papers, two written in Korean and one written in English. The English article, which he co-authored as a second author, was his first formal attempt to write an academic paper in English. At that time, he used translation tools like Google Translate and Papago, along with the grammar-checking software Grammarly, to compose his paper. However, as can be inferred from his limited experience in writing, Sam received critical comments about his language use from all the reviewers of his paper:

When the paper came back with feedback from the reviewers, there were remarks about grammar and tone of the language. Every reviewer mentioned it at least once. So now I try to focus on the tone of my writing. To make it sound academic, not informal. (Sam, Initial semi-structured interview)

Additionally, his advisor critically assessed Sam's writing, recommending that he use more diverse transition words and sentence structures. The repeated feedback from reviewers and his advisor, which specifically highlighted the language aspects of his writing, motivated Sam to seek improvements. As a result, he was inspired to use ChatGPT to adopt the appropriate conventions of language required in the academic writing genre and to overcome his simplistic writing style with limited word choice and sentence structure.

4.1.1.2 Context of Writing

During the three eye-tracking sessions, Sam engaged in writing a journal article for submission to an international journal. This task was conducted to fulfill his lab's internal regulation, which mandates that one must publish a paper at the Science Citation Index (SCI) level to graduate.

Sam has already spent three months on this article, during which he has developed the basic outline, conducted a preliminary study, and evaluated the feasibility through experimental methods. Therefore, during the three sessions of eye-tracking, Sam was involved in the formulating phase, according to Hayes's (1996, 2012) categorization of the writing process.

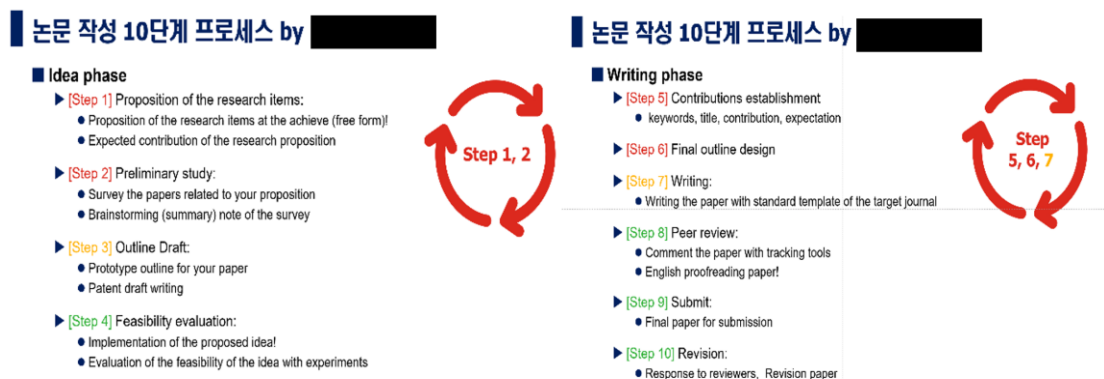
Sam's formulating process mainly involves two writing activities: 1) creating a sentence-level Korean outline and 2) translating the L1 outline into an English manuscript. Sam expresses a lack of confidence in English writing stating that "I'm not good at forming long sentences and tend to break them up with commas, so people say that it's uncomfortable to read," (Sam, Stimulated recall 1, hereafter SR1) or "Long sentences are still a bit difficult for me" (Sam, SR1). However, Sam's decision to translate rather than to write directly in English reflects more than just his personal writing ability; it also relates to the "task environment" (Leijten et al., 2014) of his laboratory, which adheres to a structured 10-step process for writing research papers.

In Sam's lab, all members are required to compose an academic journal according to the 10-step manual that the advisor has provided. Each step of the manual is detailed in

Figure 4. The three eye-tracking sessions show Sam's engagement in step 6, *Final outline design*, and step 7, *Writing*, recursively. The aim of step 6 is to create a final Korean outline at the sentence level. This step requires Sam to polish the draft outline that he worked on in step 3 by adding citations and developing his arguments to sentence level. Sam notes that step 6 is almost akin to composing a complete paper in Korean. Step 7 involves writing the article in English according to the format required by the journal to which one intends to submit it. Since step 1 through step 6 is recommended to be completed in Korean, translation becomes necessary in step 7. Accordingly, the most frequently observed pattern of Sam's writing process—translating Korean into English—is shaped by the social and institutional context Sam is situated.

Figure 4.

10-Step Manual for Academic Paper Composition in Sam's Lab

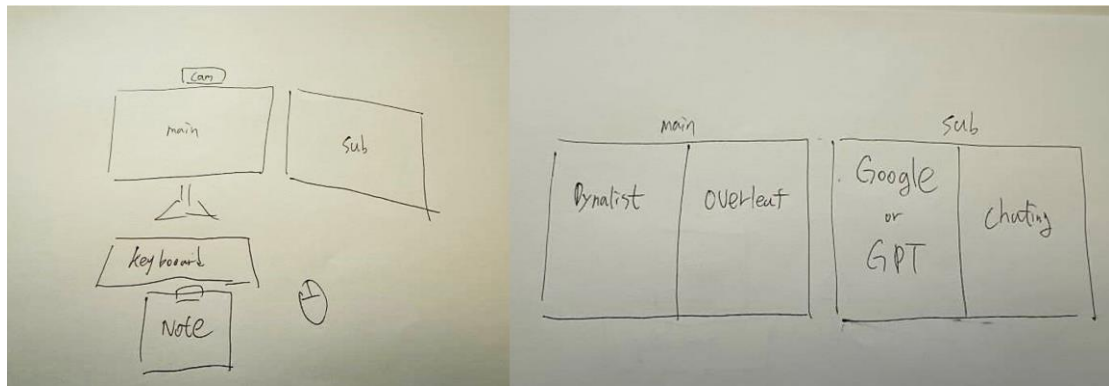


4.1.1.3 Tools in Use

Sam utilizes a Windows-based desktop computer, a dual monitor, a wireless keyboard, a wireless mouse, and simple paper notes for his writing tasks, as depicted in Figure 5. He does not use a laptop; instead, he opts for desktop computers both at home and in his laboratory, synchronized through cloud storage. This setup ensures a consistent writing environment regardless of his location. Although he typically uses a dual monitor setup during his regular writing sessions, he utilizes only the main monitor during the eye-tracking sessions.

Figure 5.

Sam's Representation of His Writing Environment



Note. Left: Hardware setup; Right: Software tools utilized

In terms of software, Sam primarily engages with four different tools: Dynalist, Overleaf, Google, and ChatGPT. Dynalist and Overleaf serve as the main digital platforms where Sam constructs his texts, whereas ChatGPT and Google are utilized concurrently to

serve various purposes during Sam's text construction. Depending on the task at hand, Sam typically splits his screen in half and arranges the tool that suits his immediate needs.

Dynalist is an online-based outlining tool designed for creating structured lists and organizing ideas. Its hierarchical structure is particularly useful for compiling complex information, making it ideal for brainstorming. All members of Sam's lab employ Dynalist, as recommended by their advisor. Sam utilizes Dynalist throughout his entire writing process to organize the key findings of the preliminary studies, jot down his findings, and compose Korean outlines. He writes and revises the Korean outline in Dynalist and consults it when creating prompts for ChatGPT for translation.

Overleaf is a web-based collaborative LaTeX editor extensively used within scientific communities for writing, editing, and publishing documents. In this study, all four participants, utilize Overleaf. This platform, operating on the LaTeX markup language, automatically formats writer's manuscripts in the style required for various journals. Scientific journals upload LaTeX templates, and researchers can download these templates and operate them on Overleaf to easily format their figures and texts into appropriate journal formats. While Dynalist is a dynamic space where Sam's writing progresses iteratively, Overleaf functions as a more static repository, where Sam documents the English translations of his Korean outline and previews the arrangement of figures and texts in this article for readability check.

Sam particularly values Overleaf's compile function, which offers a real-time preview of his document in PDF format. He emphasizes the critical importance of figure visibility and

readability in his articles, noting, "The small dots in this figure encapsulate the essence of my entire article" (Sam, SR1). Therefore, Sam regularly uses the compile function at every stage of his writing process to ensure that text, visual figures, and spatial elements are intricately orchestrated to effectively communicate his intended meaning to the audience.

Dynalist and Overleaf support real-time collaborative writing, allowing multiple users to work on a document simultaneously. For the writing task Sam is currently working on, his advisor has a co-editor access to his Dynalist pages. This enables the advisor to review Sam's work regularly and provide feedback directly on the documents. Such a collaborative environment influences Sam's attitude toward the outlining phase of writing and the purpose of utilizing ChatGPT. Since his professor reviews his Korean outline, he aims to polish and refine the L1 outline text, even though it is not his final draft. Therefore, Sam uses ChatGPT not only for translating but also for refining his Korean outline.

4.1.2 L2 Writing Process in Digital Space

4.1.2.1 Session Overview

During the three eye-tracking sessions, Sam is involved in a single phase of the writing process: formulating. Specifically, the main writing practices observed are formulating sentence-level outlines in L1 during session 1, translating the sentence-level outline into L2 manuscript during session 2, and both supplementing and translating the outline during session 3. Table 3 provides an overview of Sam's composition process.

Table 3.*General Overview of Sam's Eye-tracking Sessions*

Self-Initiated Writing Task (Writing Process)			
Journal Article (Formulating process)			
Sessions	Main Purpose of Writing	Role of ChatGPT	ChatGPT Version
Session 1	· Formulating sentence-level Korean outline	Korean Text Refiner, Placeholder Generator	ChatGPT 3.5
Session 2	· Translating Korean outline into English Manuscript	Sophisticated Translator	ChatGPT 4.0
Session 3	· Translating Korean outline into English Manuscript · Editing and enhancing Korean Outline	Sophisticated Translator	ChatGPT 4.0

In session 1, Sam focuses on creating a sentence-level outline in Korean for his paper's *system architecture* section. This section introduces the main algorithm proposed as the study's contribution. During this stage, Sam utilizes ChatGPT for two purposes; 1) to refine his Korean text and 2) to generate placeholders. Sam works on his L1 outline on a paragraph level and when he finishes outlining one paragraph, he issues a prompt asking for refinement of his L1 outline and translation into English. Although according to the 10-step manual, translation should occur after finalizing the Korean outline, Sam engages in a recursive process of outlining in L1 and translating simultaneously. This approach is specifically aimed at generating placeholder content for Overleaf. In Overleaf, the placement of figures is dependent on having a certain amount of text, as users cannot arbitrarily adjust figure positions. To address this, Sam uses ChatGPT to produce appropriately sized English text blocks to set up figure placement and assess the readability of figures early in the writing

process, given their significant role in his field of study. Therefore, in session 1, Sam's use of ChatGPT for translation serves a different purpose than that of typical L2 writers.

Session 2 and session 3 were recorded three weeks after session 1. During the 3 weeks, the sentence-level outline construction was nearly finished. Consequently, in sessions 2 and 3, Sam moves on to step 7, where he focuses on translating the outline into English and refining it to create the final draft. ChatGPT is utilized as a sophisticated translator during these two sessions, unlike session 1. Notably, during this period, Sam began subscribing to ChatGPT 4.0, which influenced his interaction with the tool.

In session 2, Sam works on translating the introduction section into English. During this session, he is quite content with the quality of his Korean outline. Therefore, he translates the outline paragraph by paragraph and incorporates the ChatGPT output right into Overleaf. Unlike session 1, Sam's purpose for using ChatGPT is for sophisticated translation. His primary concern is ensuring that "each paragraph has been accurately translated into English according to my [his] intended meaning" (Sam, SR2).

In session 3, Sam focuses on translating the previous work section into English. However, he is not entirely satisfied with the outline he had previously formulated. He recalls that his outline merely summarized research findings without any critical evaluation or discussion of intersections among the studies. To handle this issue, he translates the section sentence by sentence using ChatGPT, and then pastes the output into Dynalist for detailed revision, rather than directly into Overleaf. Subsequently, noticing that a particular section requires further explanation, Sam iteratively works on formulating the L1 outline and

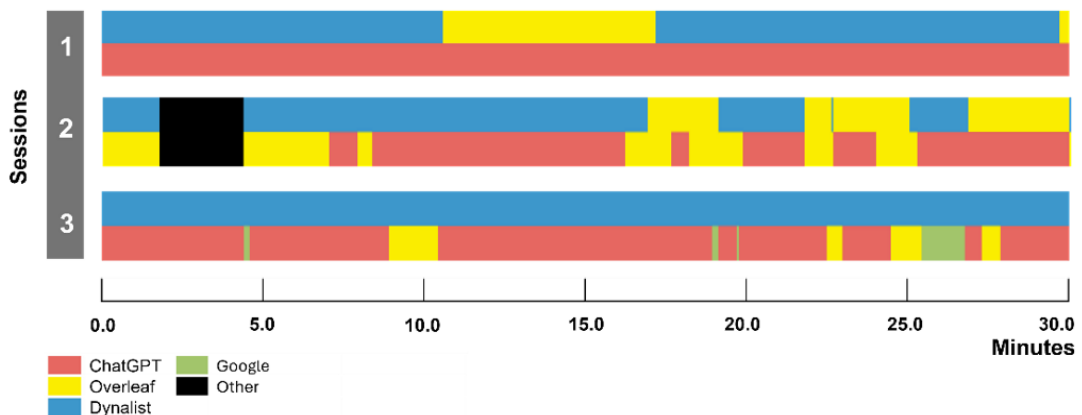
translation. Here again, his primary objective in using ChatGPT is to achieve precise and accurate translations that faithfully convey his intended meaning in an academic tone.

4.1.2.2 Tools

Figure 6 shows the timescape of the multiple online software programs that Sam utilizes during the three writing sessions. Throughout the sessions, Sam maintains a split-screen layout on his screen, each side running a different software program. Accordingly, the timescape presented in Figure 6 employs a dual-line format to illustrate the concurrent use of these software programs. This spatial arrangement allows for the proximity of the two software, enabling Sam to quickly "create relations between them" (Hort, 2020).

Figure 6.

Sam's Writing Process: Tool Timescape



In Session 1, Sam engages in constructing a sentence-level outline in Korean. ChatGPT consistently occupies half of Sam's digital writing environment throughout this period. On the other half, the tools alternate between Dynalist and Overleaf, although Dynalist is utilized more frequently. During the first 10 minutes, Dynalist and ChatGPT are used concurrently. Subsequently, Overleaf replaces Dynalist for approximately seven minutes. For the remainder of the session, Sam continues working on his outline using a combination of ChatGPT and Dynalist.

In Session 2, Sam systematically organizes different configurations of software in his digital writing space: Overleaf and Dynalist, ChatGPT and Overleaf, ChatGPT and Dynalist. The session begins in a newly assembled environment comprising both Dynalist and Overleaf. As the session progresses, there is an iterative emergence of tool pairings, including *ChatGPT and Dynalist* and *ChatGPT and Overleaf*, interspersed with periods where *Overleaf* is used independently. Although the arrangement featuring *ChatGPT and Dynalist* is utilized for the longest duration, its predominance is less pronounced compared to Session 1. Instead, the session is characterized by a repetitive transformation of the digital writing environment as various configurations emerge and disassemble.

In Session 3, Dynalist is used throughout the entire process, consistently occupying one half of the screen, while the other half alternates among ChatGPT, Overleaf, and Google. Notably, the combination of *ChatGPT and Dynalist* is the predominant workspace for writing activities.

Table 4 describes the duration and frequency of each pair of tools used during sessions 1 to 3. During sessions 1 and 3, the combination of *ChatGPT and Dynalist* is predominant, used for approximately 23 and 24 minutes, respectively. In these two sessions, the usage of Overleaf diminishes, being consulted for only 6 minutes and 3 minutes respectively. However, during session 2, the duration spent on *ChatGPT and Dynalist* decreases to almost half, at 12 minutes. In this session, the combinations of ChatGPT and Overleaf, Dynalist and Overleaf, and Overleaf by itself are consulted with greater frequency and duration. Thus, the usage of Overleaf increases significantly.

The results indicate varying patterns of writing activities across the three sessions. In session 2, where translation is the primary activity, there is an increased use of Overleaf. Conversely, in sessions 1 and 3, where translation is not the focus, the reliance on Overleaf decreases.

Table 4.

Tool Code Frequency and Duration Across Writing Sessions

Tool Codes	Session 1		Session 2		Session 3	
	#	Duration	#	Duration	#	Duration
ChatGPT + Dynalist	2	23:05.1	4	12:14.0	8	24:39.5
ChatGPT + Overleaf	2	06:54.9	4	05:01.8		
Dynalist + Overleaf			8	06:36.3	4	03:34.0
Dynalist + Google					4	01:46.5
Overleaf			4	03:31.6		
Other			1	01:26.8		

Note. # denotes frequency

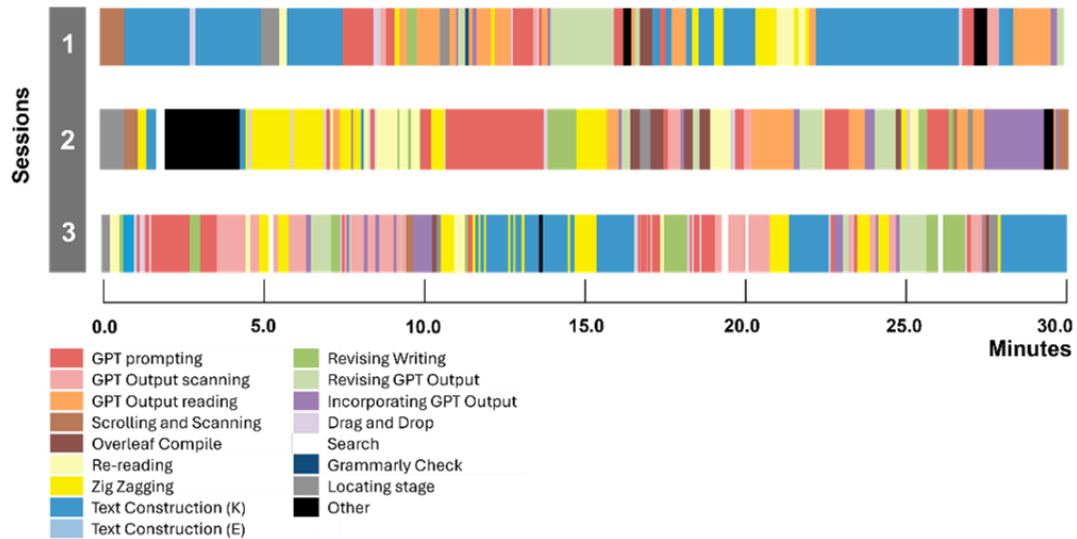
As writing progresses, the three tools ChatGPT, Dynalist, and Overleaf form a writing space through different combinations, with each tool performing distinct roles in the process. Combinations of two different tools with distinct affordances support various writing activities, such as generating translations, comparing ChatGPT-generated translations with self-written Korean outlines, and refining the final draft. In this process, ChatGPT is always assembled with other tools and is never used alone.

4.1.2.3 Actions

Figure 7 is a visual representation of Sam's writing behaviors or micro-processes during the three writing sessions. In session 1, where Sam is focused on finalizing the sentence-level Korean outline, *Text Construction in Korean* occurs dominantly. It occurs consistently throughout the entire session, from start to finish, except during the middle phase (7-minute mark to 17-minute mark). In this middle phase, ChatGPT Prompting, Zig-zagging, ChatGPT Output Reading, and Incorporating ChatGPT Output into Writing occur swiftly in a sequence. This is the moment where Sam creates a placeholder for Overleaf while constructing the Korean outline. Though in the 14-minute mark, a considerable time of Revising ChatGPT Output occurs, the revisions he makes are not intensive, as he places lower emphasis on the quality of the translations. After creating the placeholder, he resumes Text Construction in Korean from the 18-minute mark, accompanied by short moments of Zig-zagging and Re-reading. The gaze behavior of Zig-zagging appears throughout the entire session, as Sam always arranges two software tools concurrently side by side.

Figure 7.

Sam's Writing Process: Action Timescape



In session 2, there is a sharp decrease in the occurrence of Text Construction in Korean compared to session 1, with an increased frequency of ChatGPT Prompting throughout the entire session. As the main purpose of this session is to translate his L1 outline into an English draft, the following sequence of actions occurs frequently: Re-reading, Drag and Drop, ChatGPT Prompting, ChatGPT Output Reading, Incorporating ChatGPT Output into Writing, Revising ChatGPT Output, and Overleaf Compile.

Before embarking on the translation process, Sam commences session 2 in *Dynalist* and *Overleaf* combination, moving his eyes from *Dynalist* to *Overleaf* in a horizontal zigzag pattern "to see if I missed translating something. Or maybe I made corrections in the Korean text but didn't update the sentence in English" (Sam, SR2). By Zig-zagging, Sam aligns the

two software tools, their progress in writing, and even his state of mind before moving on to the translating phase with ChatGPT (5-minute to 7-minute mark). Then, for about 3 minutes (7-minute to 10-minute mark), the pattern of Re-reading and Revising Writing is repeated. Here, Sam revises his outline to clearly state his intention before consulting with ChatGPT for translation. From around the 10-minute mark, Sam starts to actively consult with ChatGPT. He traverses between ChatGPT Prompting, ChatGPT Output Reading, Incorporating ChatGPT Output into Writing, Overleaf Compiling, and Revising ChatGPT Output to compose his English draft.

In session 3, the traversal of actions becomes briefer and more frequent. While Sam's process may seem chaotic due to frequent shifts in actions, each action is systematically and strategically executed to enhance the quality of his writing. Unlike session 2, Text Construction in Korean reappears. Moreover, the sequence of 1) ChatGPT Prompting and Drag and Drop and 2) ChatGPT Output Scanning and Incorporating ChatGPT Output into Writing is briefly and continuously repeated, emerging as a prominent feature in session 3.

Sam begins session 3 by Dragging and Dropping the outline sentence by sentence into ChatGPT for prompting. During ChatGPT Prompting (1-minute to 3-minute mark), he revises and polishes the sentences to form a coherent paragraph. When ChatGPT provides the translation, ChatGPT Output Scanning occurs while Zig-zagging with the original Korean to ensure the translation's accuracy (4-minute to 6-minute mark). Afterward, he incorporates the English sentences one by one back into Dynalist (7-minute to 8-minute mark). Once all sentences are documented in Dynalist, Sam opens Overleaf and starts transferring the sentences to Overleaf, one by one (9-minute to 10-minute mark). The translated sentences are

mediated through Dynalist before being repositioned in Overleaf. Subsequently, he Re-reads his writing and decides to add a new section to the previous work. Hence, from the 11-minute mark, Text Construction in Korean, ChatGPT Prompting, and ChatGPT Scanning occur iteratively (11-minute to 30-minute mark). Sam constructs a new section for his L1 outline, issues ChatGPT prompts for translation, revises the L1 outline if the translation is unsatisfactory, prompts it again, and incorporates the result into Overleaf right away.

Table 5 presents the frequency and duration of the various micro-processes throughout the three sessions. As mentioned earlier, throughout session 1 to session 3, variability in the duration and frequency of online behaviors is observed.

In session 1, Sam focuses heavily on Text Construction in Korean (12:43.1 minutes) with moderate interaction with ChatGPT, as represented by activities such as ChatGPT Prompting, ChatGPT Output Reading, and Revising ChatGPT Output. However, in session 2, the time spent on Text Construction in Korean significantly decreases, while there is an increased focus on ChatGPT Prompting (05:24.7 minutes), Zig-zagging (04:40.3 minutes) and Re-reading (02:45.8 minutes). Lastly, in session 3, various activities are more evenly distributed throughout the 30 minutes. There is a continued trend of frequent ChatGPT Prompting (16 times for 03:53.6 minutes) and engagement in activities like ChatGPT Output Reading (14 times for 04:17.6 minutes) and Zig-zagging (15 times, 03:44.8 minutes).

Table 5.*Action Code Frequency and Duration Across Writing Sessions*

		Session 1		Session 2		Session 3	
Tool Codes		#	Duration	#	Duration	#	Duration
GB	ChatGPT Output Scanning	3	00:38.7	1	00:15.3	4	00:34.2
	ChatGPT Output Reading	11	04:25.7	8	03:18.5	14	04:17.6
	Zig-Zagging	7	01:39.4	9	04:40.3	15	03:44.8
	Re-reading	3	01:00.8	9	02:45.8	5	01:15.1
	Overleaf Compile and Reading or Scanning	1	00:24.3	5	01:26.8	2	00:15.2
	Software Scanning	1	00:46.6	3	00:39.2	2	00:16.6
NGB	ChatGPT Prompting	7	02:46.4	8	05:24.7	16	03:53.6
	Text Construction(K)	10	12:43.1	2	00:15.6	12	05:34.2
	Text Construction(E)	0	0	1	00:18.1	0	0
	Revising Writing	1	00:19.4	6	01:26.9	7	04:20.1
	Drag and drop	5	00:39.1	9	00:49.1	14	00:56.4
	Incorporating ChatGPT Output into Writing	4	00:26.3	7	02:38.2	10	01:43.0
	Revising ChatGPT Output	4	02:34.3	5	01:50.7	5	01:46.7
	Search	0	0	1	00:15.8	4	00:34.7
	Locating	2	00:51.2	4	01:16.1	3	00:40.7
	Grammarly	1	00:05.7	1	00:00.9	0	0
	Others	2	00:40.0	4	02:37.7	1	00:06.9

Note. GB= Gaze Behavior, NGB = Non-Gaze Behavior

As shown in Table 5, ChatGPT Reading is consistently observed as a time-consuming action in all sessions. Such a trend indicates that the act of reading accompanies Sam's usage of ChatGPT. Moreover, the increase in the frequency of Zig-zagging and Incorporating ChatGPT into Writing suggests an escalation in navigational or decision-making processes in sessions 2 and 3 as he is involved in the translation process. Especially,

the increase in Zig-zagging gaze behavior explains how Sam continuously compares his L1 outline with ChatGPT's translation to ensure his original intention is well conveyed in the translation.

Overall, the data reflects a dynamic integration of traditional writing activities and ChatGPT-assisted activities throughout Sam's academic writing process. Sam's interaction with ChatGPT is not only limited to prompting but extends to revising his L1 outline for prompting, reading the ChatGPT output, incorporating the ChatGPT-generated content into his writing, and finally revising ChatGPT's output.

4.1.3 Sam's Engagement with ChatGPT

4.1.3.1 ChatGPT as a "Booster" or "Translator that Gives Feedback"

To Sam, ChatGPT is a "Booster" that significantly reduces the time he spends on translation. He also likens ChatGPT to a "Translator that gives feedback," as he mainly utilizes ChatGPT for translation purposes:

First, the speed of the work is unbelievable, so it can be likened to a "Booster". Moreover, the best thing is that despite being a translator, it provides feedback. Cause before, translators didn't provide any feedback. So, would it be better to describe it as a translator that gives feedback? (Sam, Final semi-structured interview)

Sam explains that due to ChatGPT, the translation process has been facilitated as various processes like using Papago for translation and searching for other articles to find

academically appropriate phrases have been condensed into one. Additionally, he regards his back-and-forth dialogue with ChatGPT to refine the translation as a form of feedback.

Despite acknowledging that ChatGPT has been helpful in terms of speed improvement, he also recognizes that his English writing skills might have improved more if he had not used ChatGPT. He explains that if he had translated his article using the "traditional method" (Sam, SR1), such as consulting with Papago and reading existing articles to search for the appropriate style and expressions used in the academic genre, his writing skills might have been better developed. Nevertheless, despite these drawbacks, Sam continues to use ChatGPT because the reduction in time and the ability to produce effective results are more valuable to him than enhancing his English writing skills.

Although ChatGPT has streamlined the translation process, it did not facilitate every aspect of writing, particularly the crucial tasks of clearly articulating and logically presenting one's thoughts. Consequently, Sam's primary investment while engaging with ChatGPT lies in formulating a Korean input and revising the ChatGPT-generated translation to convey his opinions accurately.

4.1.3.2 Prompting as an Active Revision Process

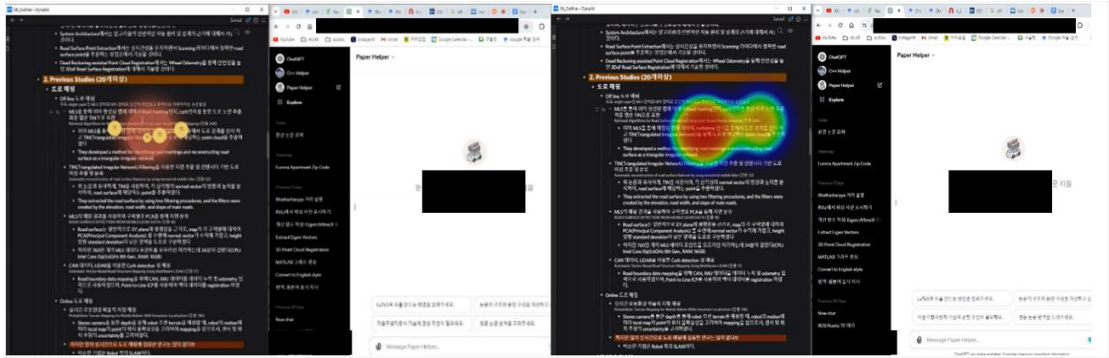
Sam's main purpose of using ChatGPT in sessions 2 and 3 is to translate his outline into English so that it fully conveys his thoughts. To attain a satisfactory result from ChatGPT, it must be ensured that his Korean outline, which he provides as the input, is well written enough to reflect his intentions. Sam comments "I try to include all my thoughts in the content and then ask GPT to write it in a way that would seem natural to a foreigner" (Sam, Initial semi-structured interview).

Sam revises his L1 outline continuously throughout the session 2 and session 3. He first initiates to revise his L1 outline before he issues a prompt in ChatGPT for translation. The activity then reaches its peak during the prompting stage and continues intermittently after the ChatGPT output is generated.

Before prompting, Sam thoroughly reads the L1 outline sentence by sentence, evaluating whether his writing is sufficiently detailed and clearly states his arguments. The gaze plot and heatmap in Figure 8 depict a series of tightly clustered fixation with minimal vertical movements, indicating that Sam is reading his outline thoroughly, not swiftly scanning. If the sentence seems to convey his intention well, he proceeds to the next stage, copying and pasting into ChatGPT for prompting. However, if he notices the "incongruities between intention and execution" (Sommers, 1980) he makes minor and major revisions to his L1 outline in Dynalist. The types of revision he makes vary from, revisions on the linguistic level (words, clauses, sentences) to the organizational level (changing the order of sections or formatting).

Figure 8.

Gaze Plot and Heatmap of Sam's Re-Reading Before Prompting (Session 3, 00:00:25)



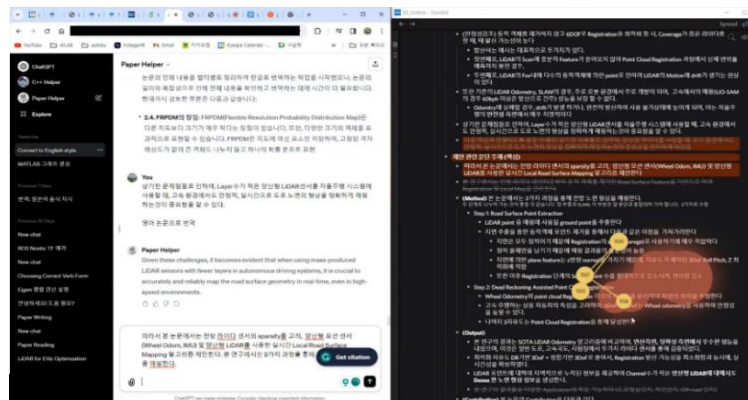
After re-reading and revising one section of his L1 outline to some extent, Sam proceeds to formulate a prompt in ChatGPT. Notably, for Sam, prompting is not an act of giving instructions or queries. Instead, prompting is an active revision process where he intensely reflects on his writing. While copying and pasting the L1 outline written in Dynalist to ChatGPT, Sam revisits his past work, revises the L1 outline, and contemplates the flow of the thesis. Therefore, sometimes it takes a great deal of time to create a single prompt.

For instance, in session 2, it takes 5 minutes and 47 seconds for him to build one prompt. Sam begins to build a prompt at 0:08:26 by copying and pasting a sentence from Dynalist to ChatGPT. Moving on, his gaze begins to hover on Dynalist, and he starts to revise the L1 outline, as shown in Figure 9. He adjusts the order of the bullet points, deletes the first sentence, and revises each sentence. After repeating this process for about two minutes, his gaze returns to ChatGPT. Sam removes the initially added sentence in the ChatGPT input field and starts typing the revisions made in Dynalist into ChatGPT, zig-zagging his gaze

continuously between Dynalist and ChatGPT. Subsequently, he stops the manual typing and copies and pastes the remaining section from Dynalist into ChatGPT. Finally, Sam's gaze remains in the ChatGPT input field for about 2 minutes as he reads the text line by line, adds punctuation, converts bullet points into full sentences, and refines the overall paragraph. When this process is done, he submits the prompt at 0:13:52.

Figure 9.

Sam Revising Dynalist while Issuing a Prompt (Session 2, 00:10:48)



As this process suggests, prompting serves as a stage for Sam to finalize his Korean draft before translating it into English. Sam notes that the very act of transferring the text from one interface to the other triggers him to detect errors and discover unsatisfactory parts:

What I've written on the right [Dynalist] is the screen I see every day, and you know how it is. It takes way longer to find what's wrong than it does to create it. So, I don't really know what's wrong with what I've written on the right [Dynalist] unless I read it very carefully. But when I

transfer it to a different interface, then I can see the issues right away. That's why I often make changes just before translating ... I don't like it once it's moved to ChatGPT. (Sam, SR2)

Sam comments that as he moves his writing from Dynalist to ChatGPT, deficiencies in his work suddenly become more visible. Relocation of his text to a new interface causes a defamiliarization of his text, stimulating more critical review from a novel perspective. Furthermore, Sam speculates the color contrast between Dynalist's dark mode (black background with white text) and ChatGPT's light mode (white background with black text) might influence his perception of the text. He infers that this striking contrast in the colors may cause him to see the text from a different point of view. Consequently, he revises his outline again during the prompting stage, even if he had already made revisions before issuing a prompt.

After dedicating substantial effort to revising his L1 input Sam issues a prompt that includes only a minimal task description or query. The internal structure of Sam's prompt during translating consists of two main components: 1) an explanation of the task and 2) Korean text for translation. As the session progresses, Sam invests more in refining the *Korean text for translation* while he reduces the time and effort spent on the *explanation of the task*. This change becomes more pronounced after Sam subscribes to ChatGPT 4.0 and creates a personalized GPT using the "GPTS function" (OpenAI, 2023) from session 2. Examples of his prompts across sessions 1 to 3 are provided in Table 6.

Table 6.*Changes in Sam's Prompt Across Sessions 1 - 3*

Session	Example of Sam's Prompt
Session 1	I am writing an academic paper regarding the topic of Road surface mapping through LiDar. I will be presenting paragraphs from a paper I'm writing in Korean. Adjust the tone to suit academic paper and provide refined Korean version. Then translate it into English. [LiDar Sensor 를 통한 Road surface mapping 을 주제로 논문을 작성하고 있어. 앞으로 한글로 작성중인 논문의 문단을 제시할 텐데, 이를 논문이라는 성격에 맞게 어투를 수정해서 작성해줘. 그리고 이걸 영어로 번역해서 다시 작성해줘.] Paragraph A written in Korean.
Session 2	Paragraph B written in Korean. Translate it into an English article. [영어 논문으로 번역.] Paragraph C written in Korean.
Session 3	Paragraph D written in Korean. Translate it into English so that it fits the related works section. [위의 내용을 relative works 에 넣을 수 있게 영작]

Table 6 indicates that during session 1 Sam provides a precise instruction to ChatGPT detailing the context ("I am writing an academic paper regarding the topic of Road surface mapping through LiDar. I will be presenting paragraphs from a paper I'm writing in Korean"), preferred style and tone of the output ("Adjust the tone to suit academic paper") and the task ("and provide refined Korean version. Then translate it into English"). However, in sessions 2 and 3 his prompt significantly decreases in length. He only adds requirements on the tone and task such as "Translate into English academic paper" or only enters the Korean text without any other explanation. Sam explains his changes in his prompt as follows:

Recently I've been doing it less, but back when I was using 3.5, I really went all out being nice... like, 'This is a paper on such and such a topic, and I need it done in this style.' I used to say all that, but since I started using 4.0, with my own helper attached, it seems like I don't go that far anymore... I've become less kind. (Sam, SR3)

After building a customized GPTS, the *explanation of the task* component of his prompt became concise, as his personalized GPT is already aware of the specific tasks Sam requires. With the help of GPTS, he does not need to give a precise instruction for every prompt he issues, which further enhances ChatGPT's role as a "booster."

4.1.3.3 Refining ChatGPT Output with a Focus on Technical Jargon

After receiving translations from ChatGPT, Sam primarily assesses whether the translation utilizes terminology appropriate for his field. Sam states, "I just move it to Overleaf if there is no problem with the word choices" (Sam, SR2).

He first briefly scans the ChatGPT output and if he finds no issues with word choice, he copies and pastes the output into Overleaf or Dynalist for further examination. Then, after incorporating ChatGPT's output into his writing space, Sam reads the text word by word, stating, "I read it as I read someone else's article" (Sam, SR1). This review helps him ensure that the lexical choices are appropriate, and that the translation accurately reflects his intended meaning.

Sam makes revisions while he reads the ChatGPT output in the new digital space. Edits are primarily made on word and phrase levels. Typically, this stage involves Sam

replacing ChatGPT's word choices with terminologies more commonly used in his field.

Examples of Sam's revisions to ChatGPT output are described in Table 7.

Table 7.

Example of Revisions Made to ChatGPT Output

ChatGPT Output	Revision made by Sam
recognized	detected
point outside the ground	non-ground point
expressway	highway
align	registration

Table 7 provides four examples of the word-level revisions made by Sam. For example, Sam revises the verb *recognized* generated by ChatGPT into *detected*. Sam explains the reason behind his revision as the following:

Yes, I just changed it to a word we use more frequently. We often use the word perceive [인지하다] in our field. Normally, people might translate perceive [인지하다] as "recognize", but we translate it into "detect" or "detection" in our field. It does sound more natural to say a person "recognized" something than "detected" something, but in our case, the subject is always a sensor. (Sam, SR1)

Drawing on his content knowledge and the registers familiar to him, Sam makes sophisticated revisions to the nuances of words to better fit his academic discipline. He addresses ChatGPT's limitation in understanding the terminologies specific to his field stating that "These are areas where ChatGPT is not quite knowledgeable of" (Sam, SR2).

Interestingly, Sam reports a gradual change in his dissatisfaction with ChatGPT's word choices. Although he is unsure whether this improvement is due to his frequent questions or the provision of PDF files containing text from his field of study, he notes that ChatGPT has progressively adapted, producing outputs with terminologies more familiar to his field. Therefore, in his last stimulated recall interview, Sam mentioned:

On my first eye-tracking session, I really didn't like the words and made a lot of changes to the ChatGPT output. But I think that kind of feeling disappeared. Now I like most of the words. (Sam, SR3)

It can be anticipated that through his in-depth engagement with ChatGPT and the technical sophistication offered by ChatGPT 4.0, the results produced by ChatGPT have become more fine-tuned to his field of study.

However, despite these positive changes, in the final semi-structured interview, Sam comments that his revisions, which were solely limited to refining the terminologies, were insufficient. He points out that his "construct" of translating and making revisions section by section on paragraph level was problematic, leaving problems related to coherency and clarity across the entire manuscript. To elaborate, during the ChatGPT revision process, he was focused on carrying out "within sentence operation," (Galbraith & Al-Saadi, 2020) making syntax adjustments or phrase replacements for each paragraph. Consequently, he was less involved in examining the global structure of the text to ensure coherence and consistency between each paragraph. Sam notes that this approach ultimately resulted in a lack of thoroughness and necessitated substantial revisions later:

Before submission, I found that the terminology wasn't consistent since the translation was done section by section. There was also some redundancy within the paragraphs. (Sam, Final semi-structured Interview)

Sam observed that ChatGPT was not effective in helping him refine his entire manuscript to maintain a consistent tone and terminology. He attempted to copy and paste his entire manuscript for revision in terms of coherence, but the process was unsuccessful due to the word limit that ChatGPT can handle, resulting in the system freezing. Consequently, he had to conduct the global-level revisions manually.

Moreover, Sam mentioned that he received feedback from his advisor and PhD colleagues about the clarity and wordiness of his writings. Although problems with his informal writing and the redundant use of simple sentence structures were resolved, new issues arose. Especially, Sam's advisor recommended him check whether the wordy or unfamiliar expressions generated by ChatGPT are used in academic contexts. Acting on his advisor's suggestions, during the final revision process right before submission, Sam intentionally avoided using ChatGPT. Instead, he utilized Google Scholar's quotation search function as a reference to validate the output generated by ChatGPT.

4.2 Jake

4.2.1 Background

4.2.1.1 Language Learning Experience

Jake, a 26-year-old student, is in the 7th semester of an integrative PhD program in Artificial Intelligence. He is currently affiliated with a laboratory that focuses on multimodal artificial intelligence. While researching in the field of AI, Jake has been accessing ChatGPT since version 2.0 and possesses extensive knowledge about ChatGPT's training methods and internal algorithms. Unlike Sam's collaborative work environment, Jake's laboratory tends to pursue a more individualistic culture in terms of conducting research.

Born and raised in Korea, Jake received his education from elementary through university in Korea. However, during his elementary school years, Jake lived abroad in the United States for two years, in his first grade and fifth grade. When asked to self-evaluate his English competence, Jake ranked his skills in the following order: speaking and writing, listening, and reading. Although he excels at reading in absolute terms, his comparative performance within the Korean context makes him feel that he is better at writing. His high score on the TEPS (Test of English Proficiency developed by Seoul National University), 493, which corresponds to the C1 CEFR level, supports his strong reading ability. However, Jake describes himself as a slow reader and reports that he has faced challenges with time-constrained reading tests in the past. These experiences have significantly influenced his overall perception of his English skills. Compared to reading, he feels more comfortable with writing, as it typically allows for more time to formulate his thoughts and complete the work.

Drawing from his struggles with reading, he sets readability as his primary goal to achieve when writing academic papers. He prizes papers that are clear and easily comprehensible and aims to emulate this style in his writing.

Regarding his writing education, Jake explained that he took three academic writing courses during his undergraduate and PhD programs. However, he found these courses to be of limited benefit, as he retains little from them. Instead, Jake emphasized that engaging in authentic tasks during his PhD was more effective in enhancing his writing skills. Through writing scientific reports, documentation for code sharing on GitHub, and journal articles, he progressively developed the scientific writing skills required in his discourse community.

Jake has published 11 journal articles, with a distinct language distribution: two in Korean and nine in English. This stark difference reflects his strategic choice to reach a broader audience. Jake is highly aware of his audience and is deeply concerned about the scientific discourse community to which he belongs, aiming to write high-impact articles. He reports investing minimal effort in his Korean articles, knowing they will not reach many readers. In contrast, for his English papers, he undergoes an intensive two-week proofreading process, during which he solicits feedback from colleagues and makes revisions himself to ensure high-quality writing. Additionally, Jake dedicates significant effort to crafting powerful titles, understanding their importance for attracting readers and improving searchability.

Regardless of his numerous experiences in publishing papers and relative confidence in writing, Jake expresses that writing an academic paper is always challenging:

I constantly feel that writing is challenging. The difficulty often lies in how to *structure* the content about a specific topic in a clear, concise, and effective way. Additionally, since it's in English, before using ChatGPT, I was always uncertain about my grammar, always sure that there was an error. Also, I often feel frustrated thinking there must be better ways to express my ideas. (Jake, Initial semi-structured interview)

Despite being an experienced writer, he remains concerned with effectively organizing his ideas and is always attentive to grammatical and lexical aspects. Consequently, he employs ChatGPT to address the challenges he faces as an L2 writer, aiming to achieve significant outcomes within the international academic community.

4.2.1.2 Context of Writing

During the three eye-tracking sessions, Jake focused on composing a journal article intended for submission to an international journal. On the first day of eye-tracking, he started a new research project. Therefore, during the three eye-tracking sessions, Jake was engaged in the planning and formulation phases of the writing process (Hayes, 2012). Beyond the conventional writing stages, he has developed structured stages of journal writing based on his experience:

1. Identifying the Research Topic
2. Reading Papers and Organizing Previous Research
3. Brainstorming Research Ideas and Initiating Writing
4. Coding and Experimentation
5. Writing Drafts
6. Conducting Ancillary Experiments and Writing Additional Drafts
7. Completing the Draft
8. Undergoing 2 Weeks Review Process
9. Submitting to a Journal
10. Posting on ArXiv and Writing Related Code Documentation on GitHub

Jake explains that he actively utilizes ChatGPT across all stages of his research. Although Jake does not strictly adhere to the sequence outlined above, during the eye-tracking sessions, he primarily focused on the initial stages of his writing process: *Identifying the Research Topic, Reading Papers, Organizing Previous Research, and Brainstorming Research Ideas and Initiating Writing*.

4.2.1.3 Tools in Use

Jake uses a MacBook (or I-Mac in a laboratory), a wireless keyboard, and a wireless mouse when working on his writing as illustrated in Figure 10. Jake usually works on writing both in his laboratory and at home, and in each environment, he uses triple monitors. Each monitor has a defined spatial organization, as written in Figure 10. However, during the three eye-tracking sessions for this research, Jake utilizes a MacBook only without additional monitors. Therefore, he uses various tools sequentially on a single screen.

In terms of software, Jake primarily uses ChatGPT, Notion, Overleaf, and ArXivGPT. ChatGPT is used across his entire writing process along with Notion and Overleaf which serves as the main digital space for constructing texts. Notion is a software application that serves as an all-in-one workspace for documentation, data management, task management, and project planning. Users can create customized pages that may include text, database tables, images, and videos. As the diverse affordance it offers, Notion serves various purposes in Jake's writing process. Jake schedules his writing, brainstorms ideas, organizes previous works by creating a database, and constructs an outline for his writing in Notion.

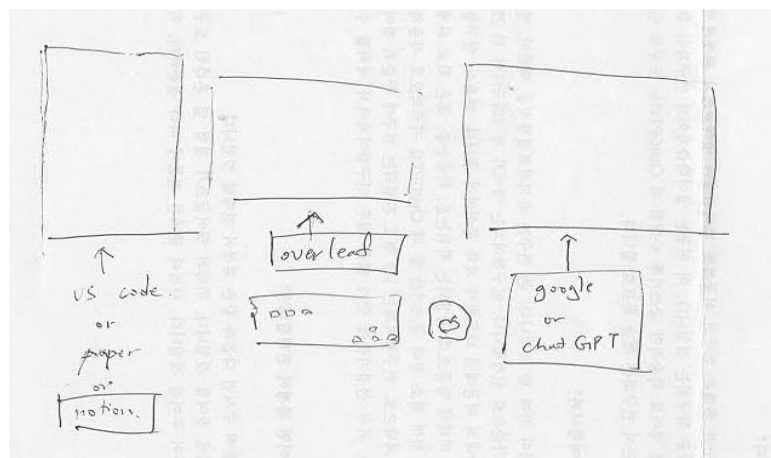
Unlike Notion, which supports a broad range of tasks, Overleaf is utilized for the more specific task of writing; it serves as a space where Jake can articulate his organized thoughts. After jotting down various ideas and searching for relevant literature in Notion, he transitions to Overleaf for the formulating phase. When further organization or brainstorming is needed, he returns to Notion.

ArXivGPT is a Chrome plug-in that summarizes the paper uploaded in ArXiv according to the prompts that the user set up. Jake uses ArXivGPT along with Notion when organizing papers for literature review.

In sum, Notion, Overleaf, and ArXivGPT are utilized for specific purposes at distinct stages of the writing process, while ChatGPT, a software with versatile affordances, interacts with all these tools throughout the entire writing process.

Figure 10.

Jake's Representation of His Writing Environment



4.2.2 L2 Writing Process in Digital Spaces

4.2.2.1 Session Overview

During the three eye-tracking sessions, Jake is involved in two phases of the writing process: planning and formulating. Specifically, these phases encompass brainstorming or ideation (sessions 1 and 2), drafting the manuscript (first half of session 3), and organizing articles for a literature review (second half of session 3). Table 8 provides an overview of Jake's composition process.

Table 8.

General Overview of Jake's Eye-tracking Sessions

Self-Initiated Writing Task (Writing Process)			
Journal Article (Planning and Formulating Process)			
Sessions	Main Purpose of Writing	Role of ChatGPT	ChatGPT Version
Session 1	• Brainstorming Research Ideas	Domain Specific Knowledge	ChatGPT 3.5
Session 2	• Brainstorming Research Ideas and Journal Titles	Domain Specific Knowledge	ChatGPT 3.5
Session 3	• Drafting English Manuscripts • Organizing Articles for Literature Review	Text refinement, Summarizing Articles	ChatGPT 3.5

In session 1, Jake brainstorms the fundamental direction of his paper. He is trying to utilize a methodology he is unfamiliar with, so he employs ChatGPT to search for domain-specific knowledge. Jake recorded session 2 consecutively on the same day. Naturally,

session 2 directly followed session 1 as part of an extended brainstorming segment. During this session, Jake organizes his thoughts into a 4-5 sentence long prompt based on the brainstorming he had done in session 1 and uses it to discuss ideas for the title of his article with ChatGPT.

Session 3 was recorded 2 weeks after session 1 and session 2. During the two weeks, Jake worked on reading related literature and sophisticating his ideas. In the first half of session 3, Jake works on writing and revising the first section of the literature review. Jake uses ChatGPT to polish his work and improve readability. In the following second half, he moves back to the planning stage of writing and starts to organize relevant literature to prepare for composing the second section of the literature review. During this phase, Jake uses ArXivGPT to summarize and organize new articles.

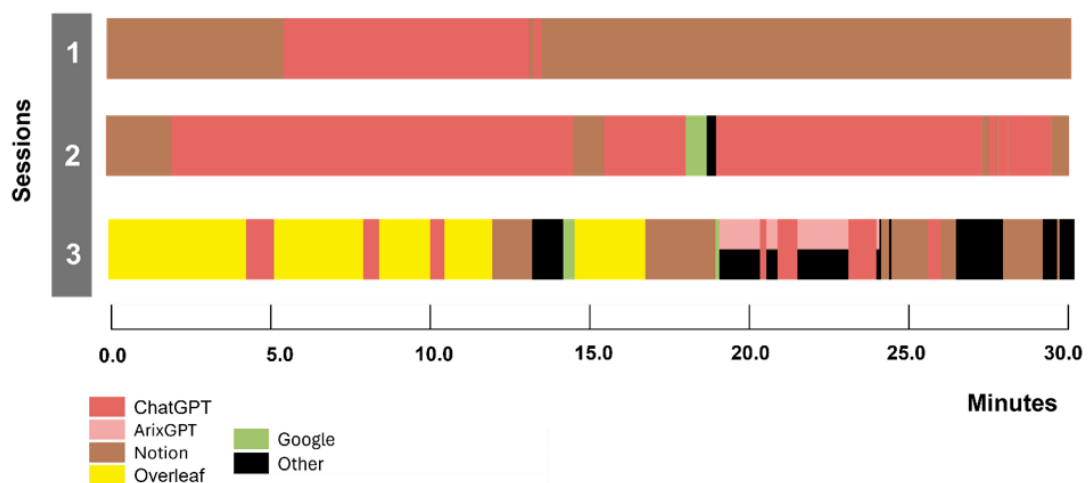
4.2.2.2 Tools

Figure 11 illustrates the timescape of the various online software programs that Jake utilizes during the three eye-tracking sessions. The figure reveals that Jake predominantly employs a single software at a time. Rather than spatially arranging multiple tools on one screen, he prefers to switch between different software by toggling screens.

In session 1, Notion is the primary platform where Jake brainstorms and formulates his thoughts. Jake initiates and concludes his brainstorming process in Notion. After approximately five minutes of brainstorming in Notion, he transitions to consulting with ChatGPT. He interacts with ChatGPT for about 8 minutes. Subsequently, for the remainder of the session, he returns to Notion to complete his work.

Figure 11.

Jake's Writing Process: Tool Timescape



During session 2, another brainstorming phase, the use of tools contrasts significantly with session 1. In this session, ChatGPT is used predominantly, while Notion is accessed only briefly and intermittently. Jake initiates his session in Notion but swiftly transitions to ChatGPT, where he spends the majority of the 30-minute period. He briefly shifts back to Notion during his consultation with ChatGPT, indicating that he uses Notion to record the outputs from ChatGPT.

As Jake transitions to a new phase of writing, in session 3, new tools such as Overleaf, ArXivGPT, and Others (PDF and ArXiv website) emerge alongside his existing use of ChatGPT, Notion, and Google. In the first half of the session, he primarily uses Overleaf as his main workspace for writing. His visits to ChatGPT occur briefly and less frequently compared to earlier sessions. In the second half of the session, Jake shifts his focus to organizing the relevant literature for his related works section. This change in task leads to a significant reduction in his use of Overleaf. Instead, his digital workspace now comprises a variety of tools including Notion, ChatGPT, ArXivGPT, and PDF files accessed through the ArXiv website. During this phase of his work, Notion acts as Jake's central hub, where he frequently returns after exploring other resources. As he reenters the planning stage of his writing, he increasingly relies on Notion. ArXivGPT and ChatGPT appear in a consecutive sequence, as the output of ArXivGPT is automatically transported to Jake's ChatGPT account.

Table 9 details the frequency and duration of use for each digital tool throughout the three sessions. During sessions 1 and 2, when Jake is involved in brainstorming, he predominantly works within Notion and ChatGPT, without consulting Overleaf. Specifically in session 1, he spends 22 minutes in Notion and 7 minutes in ChatGPT. Conversely, in Session 2, the usage times reverse, with Jake spending 24 minutes in ChatGPT and 3 minutes in Notion. However, in Session 3, which focuses on the drafting process, Jake's use of Overleaf increases significantly, totaling 12 minutes and 18 seconds.

Data from Table 9 indicates that for each stage of writing—brainstorming, drafting, and organizing literature review—distinct sets of software assemble and disband to create a workspace tailored specifically to the needs of each task. However, throughout all phases, ChatGPT remains a constant tool, demonstrating its versatile application regardless of the specific task.

Table 9.

Tool Code Frequency and Duration Across Writing Sessions

Tool Codes	Session 1		Session 2		Session 3	
	#	Duration	#	Duration	#	Duration
ChatGPT	2	07:51.2	7	24:27.2	7	03:53.7
ArXivGPT + Other					4	03:16.4
Notion	3	22:08.8	6	03:43.6	7	06:36.5
Google			1	00:38.7	2	00:29.1
Overleaf					5	12:18.6
Other			1	00:16.1	6	03:25.7

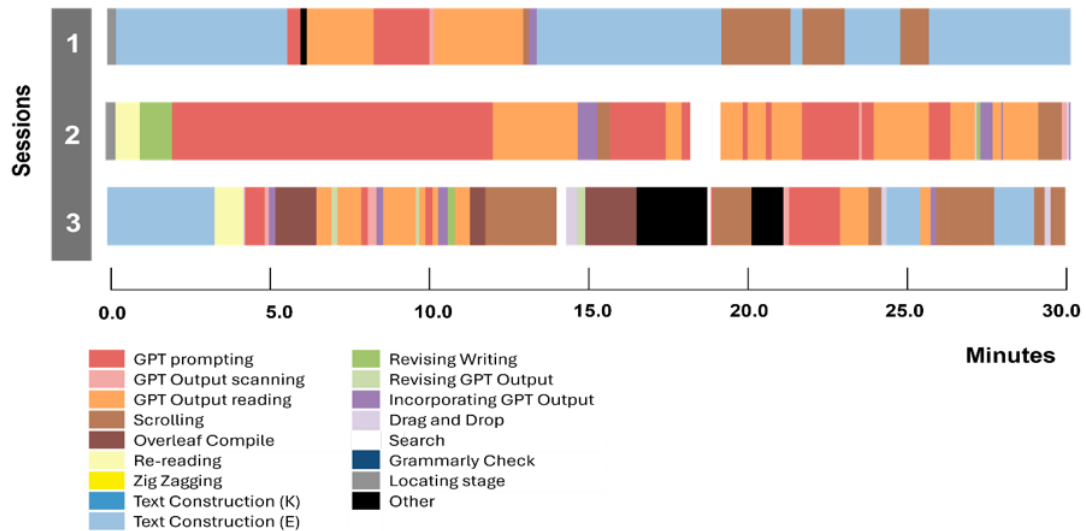
4.2.2.3 Actions

Figure 12 presents a timescape that visualizes the micro-processes occurring throughout the three writing sessions. In session 1, Text Construction in English is the dominant action followed by ChatGPT Output Reading and Scrolling. Jake starts session 1 by constructing text in Notion. Text Construction in English at this stage is not a composition of full sentences but rather a jotting down of short phrases of ideas. For the first five minutes, he focuses solely on Text Construction in English without consulting any external sources. Subsequently, the sequence of *ChatGPT Prompting and ChatGPT Output Reading* occurs twice in succession. Then, Incorporating ChatGPT Output into Writing follows briefly, and he proceeds back to Text Construction in English. As Jake continues to work on constructing text, he occasionally scrolls around the screen. During these moments, the data reveals only the hovering movements of his gaze, without any accompanying text construction. This likely indicates a period of contemplation in his writing process.

In session 2, ChatGPT Prompting and ChatGPT Output Reading occur with the highest frequency. The sequence of ChatGPT Prompting and ChatGPT Output Reading is repeated continuously from the start to the end of the session. Notably, during the timeframe of 3 to 13 minutes, ChatGPT Prompting proceeds for a long duration, as it is crucial for him to thoroughly explain his intention to ChatGPT to discuss a title that encompasses the key ideas of his article. Incorporating ChatGPT Output into Writing happens at irregular intervals. This micro-process does not follow every sequence of *ChatGPT Prompting and ChatGPT Output Reading* but occurs selectively.

Figure 12.

Jake's Writing Process: Action Timescape



In session 3, a more complex and dynamic sequence of actions is executed, as anticipated by the frequent changes in the digital environment. During the first half, Jake is involved in drafting a section in related works. Jake starts with Text Construction in English, and when he finishes writing one section, Re-Reading follows. Then, Jake copies and pastes his writing into ChatGPT, and ChatGPT Prompting for refining his writing takes place. As the session progresses, an increased swiftness of various actions is observed. After briskly scanning the ChatGPT output, he incorporates the ChatGPT output into his writing space in Overleaf. This is followed by a repeated pattern of *ChatGPT Output Reading and Revising ChatGPT Output*. In the second half of the session, a distinct set of actions emerges. *Other* in this session indicates that Jake is consulting with Notion to create a new template for organizing his literature review. Once the template is ready, he engages in a recursive process

involving ChatGPT Prompting, ChatGPT Output Reading, Scrolling, and Text Construction in English to create an annotated bibliography in Notion based on the new articles he summarized through ArXivGPT.

Table 10 describes the duration and frequency of gaze and non-gaze behaviors during sessions 1 to 3. In session 1, Text Construction in English predominates, consuming about 17 minutes, while engagement with ChatGPT, indicated by ChatGPT Prompting (2 times, 02:09.7 minutes) and ChatGPT Output Reading (2 times, 04:50.9 minutes), accounts for the remaining time. However, in session 2, Jake's consultation with ChatGPT peaks significantly as evidenced by the notable increase in both the frequency and duration of ChatGPT Prompting (8 times, 15:07.3 minutes), ChatGPT Output Reading (9 times, 09:11.8 minutes), and Incorporating ChatGPT Output into Writing (4 times, 01:02.7 minute). In contrast, in session 3, Jake's interaction with ChatGPT shows a notable decrease in both frequency and duration, while other actions such as Scrolling and Overleaf Compile increase in time and occurrence.

This trend reflects an adaptive approach to ChatGPT usage, where Jake engages with ChatGPT more actively during the planning stage (sessions 1 and 2) and less during the formulation process (session 3).

Table 10.*Action Code Frequency and Duration Across Writing Sessions*

		Session 1		Session 2		Session 3	
Tool Codes		#	Duration	#	Duration	#	Duration
GB	ChatGPT Output Scanning	1	00:08.6	2	00:13.8	3	00:35.6
	ChatGPT Output Reading	2	04:50.9	9	09:11.8	8	04:17.1
	Zig-Zagging						
	Re-reading			1	00:45.5	1	00:54.2
	Overleaf Compile and Reading or Scanning					4	03:22.6
	Software Scanning	5	04:32.3	2	01:08.4	7	06:27.8
NGB	ChatGPT Prompting	2	02:09.7	8	15:07.3	5	02:41.5
	Text Construction(K)						
	Text Construction(E)	5	17:35.7			3	05:40.3
	Revising Writing			2	01:07.2	1	00:13.9
	Drag and drop			2	00:08.0	5	00:45.4
	Incorporating ChatGPT Output into Writing	1	00:15.6	4	01:02.7	4	00:50.9
	Revising ChatGPT Output					3	00:32.1
	Search			2	00:56.8	2	00:25.4
	Locating	1	00:16.0	1	00:18.5		
	Grammarly						
	Others	1	00:11.1			3	03:13.2

Additionally, a consistent pattern across sessions 1 and 2 is the relatively low frequency and duration of Incorporating ChatGPT Output into Writing compared to ChatGPT Prompting and ChatGPT Output Reading. For instance, in sessions 1 and 2, the frequency of Incorporating ChatGPT into the Writing (1 and 4 times, respectively) is about half that of ChatGPT Prompting (2 and 9 times, respectively) and ChatGPT Output Reading (2 and 10 times, respectively). These numbers suggest that the output generated by ChatGPT is not automatically included in Jake's writing after each prompt or reading; rather, its inclusion is

selectively determined by Jake. However, it is interesting to note that in session 3 the frequency of ChatGPT Prompting (5 times) and Incorporating ChatGPT into Writing (4 times) is quite similar, unlike in sessions 1 and 2. This suggests that ChatGPT's output may be more directly incorporated into the writing during the formulating phase, compared to the planning phase.

4.2.3 Jake's Engagement with ChatGPT

4.2.3.1 ChatGPT as a "Genius Sidekick"

Jake extensively utilizes ChatGPT throughout the entire journey of completing his journal article. He discusses paper ideas, summarizes articles by ArXivGPT, and improves his writing through ChatGPT. He refers to ChatGPT as a "Genius Sidekick" with whom he can discuss his article and command to perform any tasks 24/7:

The biggest strength of ChatGPT is that it seems that it knows everything, it gives me the impression of a genius, yet it is approachable and easy to converse with. I can even command it to do my work at any unusual time, such as 5 a.m., so, I guess I would say it is my genius sidekick. (Jake, Final semi-structured interview)

While Jake acknowledges the constraints of ChatGPT, he notes that it serves as a versatile tool that assists him at any needed moment. Jake even suggests that if ChatGPT were human, it would merit co-authorship recognition due to its significant contributions to his projects. Jake's interaction with ChatGPT occurs in every session of writing regardless of

the writing phase he is involved in, and his use of ChatGPT differs across each session from asking for domain-specific knowledge to summarizing articles for writing relevant literature.

Jake reported that initially, he anticipated that having a "Genius Sidekick" would shorten his writing time. However, after experiencing ChatGPT for quite a long time he feels that with the use of ChatGPT the entire time spent on writing has increased, while his quality of writing has also improved:

Initially, I thought using ChatGPT would shorten my writing time. In fact, at the beginning of using ChatGPT, I believed it did reduce the time. However, after using it for quite a while, I no longer think so. This is because I write my drafts as I normally would and then have ChatGPT revise them. After ChatGPT makes the revisions, I review them again. Then, I have ChatGPT revise the text once more and review it again. This process feels like an additional step has been added, and as a result, it seems to have increased the overall time spent. However, the quality of my writing has improved, with more accurate grammar and more appropriate expressions. (Jake, Final semi-structured interview)

The increase in overall writing time due to ChatGPT usage highlights Jake's approach of engaging in in-depth interactions with ChatGPT rather than merely conducting superficial question-and-answer exchanges. This characteristic underscores his meticulous and thorough use of ChatGPT in his writing process.

4.2.3.2 ChatGPT as a Conversation Partner for Research Idea Generation

In the planning stage (sessions 1 and 2), the purpose of using ChatGPT is to gain information and insights about his research topic. Jake explains that when he encounters a new concept or term he is unfamiliar with, he prefers to consult ChatGPT first before reading other sources such as journal articles or blogs:

J: Well, the reason I ask ChatGPT first about these concepts is that it organizes them better than anyone else. When I first come across a concept and need an explanation, it explains it quite well and easily, you know? Better than directly looking at papers or blogs.

R: Why do you think so?

J: I guess because it tries to convey the information I ask for within a limited length. Like, if it's an article, the explanation might go on for ten pages with lots of detailed writing, but ChatGPT just gives the necessary information, which feels just right. (Jake, SR1)

Jake converses with ChatGPT to gain a concise overview of a new concept he encounters before he reads articles or papers for more detailed and specific information. This type of prompt that seeks domain-specific knowledge is possible because Jake trusts the accuracy of the answers provided by ChatGPT. He mentions that he trusts the domain-specific output generated by ChatGPT 96% of the time:

Since I know how ChatGPT is trained, and I've used it quite a bit... If we're talking about how well it handles specialized knowledge, I'd generally say it's not great. However, it can be very specialized in certain areas, and artificial intelligence is a prime example. There's a lot of recent literature on artificial intelligence included in its training data. So, for example, if we

talk about music, there are far fewer documents on music than on artificial intelligence, so if I were curious about music, I probably wouldn't ask about it to ChatGPT. But if it's about artificial intelligence, I generally trust it about 96% of the time (Jake, SR1)

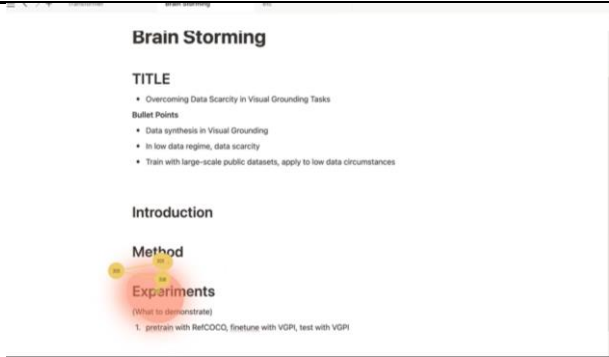
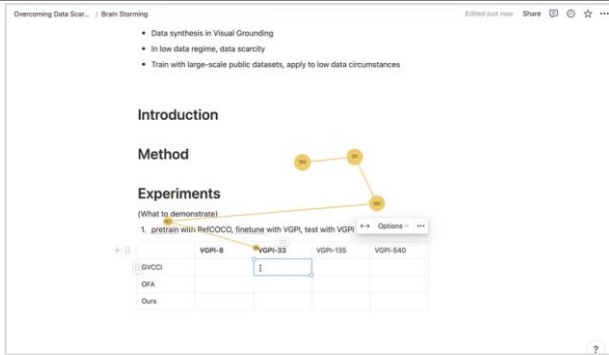
As a doctorate student majoring in AI, he understands that a significant portion of the data ChatGPT has been trained on consists of documents from the AI field, including recent literature. Having a precise understanding of ChatGPT's training mechanism, he believes ChatGPT can provide answers or insights to the question he is curious about.

During session 1, Jake queries ChatGPT about the potential key hypothesis or core concept of his paper. Table 11 illustrates the sequence of interactions between ChatGPT and Jake during this process.

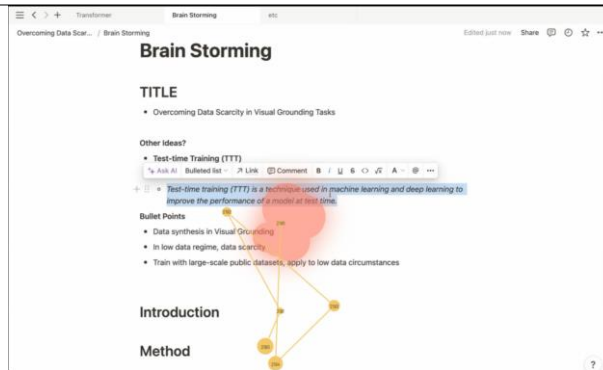
In scene 1, Jake starts to brainstorm about a new topic for a journal on Notion. He jots down bullet points about the arguments that he wants to make. He writes "Overcoming Data Scarcity in Visual Grounding Task," which is the main theme of the paper he is trying to write. After a while, in scene 2, Jake begins to organize a table of potential experiments to compare which training method could be more effective in solving the "visual grounding task". He fills in the table independently, without referring to any external sources. After establishing the general structure of the table, he pauses again with his gaze hovering uncertainly. Suddenly he scrolls up and types in a new subheading "Other ideas?" and writes "Test-time Training (TTT)" underneath. He tries to elaborate on Test-Time Training but stops there. Then in scene 3, Jake switches the page from Notion to ChatGPT.

Table 11.

Excerpt from Session 1

Scene	Screen Shot
Scene 1.	
Jake initiates brainstorming in Notion.	
Scene 2.	
Jake outlines experiments in a table	
Scene 3.	
Jake issues his first prompt at 0:05:42 and converses with ChatGPT until 00:13:12.	

Scene 4.



Jake copies the ChatGPT output and pastes it on Notion. He then italicizes the copied segment.

Jake explains that he wanted to find a method for efficiently training an artificial intelligence model called *visual grounding* with limited data. While contemplating possible solutions, he recalled an idea he was not familiar with but had recently heard about in a seminar. Consequently, he decided to inquire about it through ChatGPT:

I was thinking, 'What could be the ways to solve visual grounding?' Then, a method called Test-Time Training which I learned about recently at a seminar popped into my head. Since I only heard about it at the seminar and haven't read any papers on it, I didn't really know what it exactly was. So, I thought, 'Could Test-Time Training be a solution?' and that's when I started discussing it with ChatGPT. (Jake, SR1)

Thus, in scene 4, Jake issues a prompt to ask for an explanation of the term Test-Time Training. When the ChatGPT generates the output, Jake reads it thoroughly. The eye-tracking data and the mouse cursor movements depicted in the gaze plot recording indicate that Jake reads the ChatGPT output meticulously, from start to finish. While it is reported that many readers tend to exhibit a spotted or bypassing pattern when reading in a web environment

(Pernice, 2017), Jake's gaze and mouse cursor move horizontally along every sentence as he reads. This consistent reading pattern, observed throughout the entire eye-tracking session, indicates that he thoroughly reads the content generated by ChatGPT without skipping or bypassing any sections (Kirsh & Joy, 2020).

After Jake gains an understanding of Test-Time Training from ChatGPT's explanation, he returns to Notion (see Scene 4). At this point, Jake copies and pastes the definition of Test-Time Training provided by ChatGPT into Notion, which is a very small portion of the part he has read. However, Jake remains cautious about plagiarism when utilizing ChatGPT's output from the brainstorming stage of writing. In scene 4, to indicate the source, Jake italicizes the text when incorporating it into Notion, his personal writing space. He is reluctant to use the exact phrases generated by ChatGPT in his article. To prevent such incidents in advance, he routinely uses semiotic resources such as italicizing or coloring to differentiate ChatGPT-generated text from his writings. This demonstrates his attempts to maintain academic integrity while actively engaging with ChatGPT.

4.2.3.3 Facilitating Pre-prompting Writing and Filtering Post-prompting Outputs

Jake's interaction with ChatGPT during the formulating process differs from the planning stage. Three key aspects are shown in his use of ChatGPT during the formulating phase. First, Jake reports that the presence of ChatGPT accelerates his text construction process before prompting, as it alleviates the immediate burden of grammatical accuracy and

meticulous word selection. Secondly, ChatGPT alters Jake's revision process, shifting his focus from correcting grammatical errors to filtering out ChatGPT-like expressions. Lastly, Jake employs specific strategies to ensure seamless integration between Overleaf and ChatGPT, both of which are crucial components of his digital writing environment during the formulating phase. Table 12 presents an excerpt from session 3, illustrating these three aspects of Jake's engagement with ChatGPT during the formulating stage of writing.

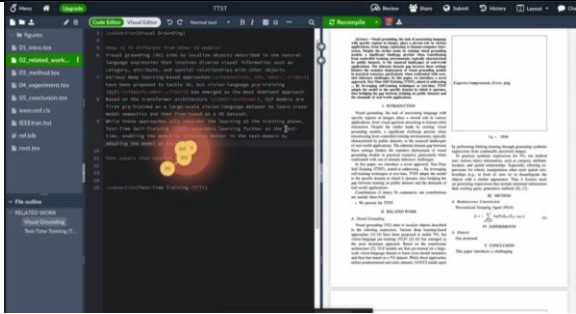
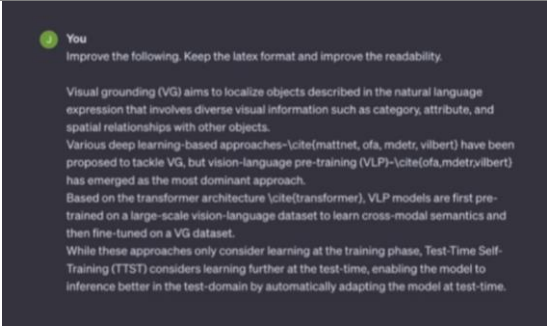
In scene 1, Jake works on writing the first section of the related works. For about three minutes, he crafts a single sentence. Jake states that while he was writing the sentence, he was not sure about his usage of prepositions but proceeded without hesitation knowing that ChatGPT would correct it later. Jake claims that ChatGPT's existence allowed him to write unwaveringly and without hesitation:

I'm writing without hesitation now, quite different from how I used to write papers. The reason I can do this is because I'm only focusing on what to write... I'm not worrying about the quality of the sentences but just filling in the content. I'm writing this way because I plan to ask ChatGPT to improve it later. Even with word choice, I used to try to think of the most appropriate words, but now I'm just writing with a 'this should be good enough for them to understand' kind of attitude. It seems that the writing process has become faster. (Jake, SR3)

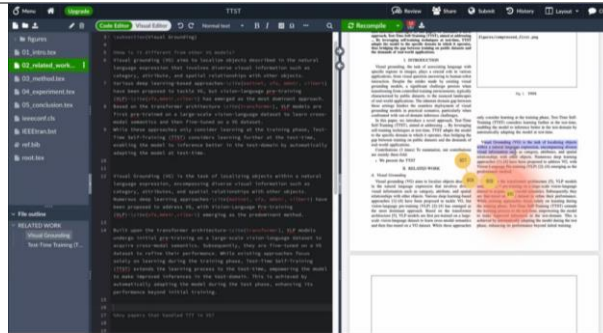
Although Jake does not directly utilize ChatGPT at this stage, its presence in his writing process enables him to draft more freely and rapidly. He can concentrate on content without being constrained by concerns over grammatical accuracy or optimal word selection.

Table 12.

Excerpt from Session 3

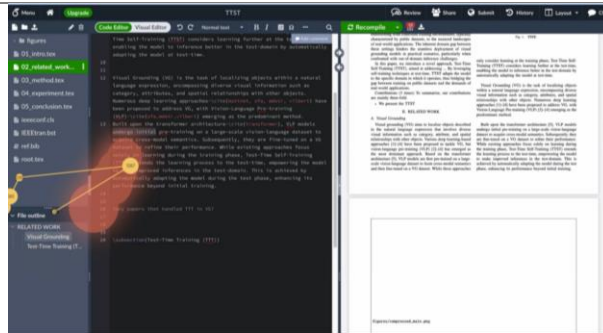
Scene	Screen Shot
Scene 1.	
	Jake constructs a text for approximately 3 minutes.
Scene 2.	
	Jake issues a prompt for revision.
Scene 3.	
	Jake reads the output and clicks the copy code.

Scene 4.



Jake pastes the copied code on the left pane of Overleaf, compiles, and reads the output on the right pane.

Scene 5.



Jake revises the ChatGPT output in the left pane.

(Before revision) VP models ~~undergo initial pre-training~~ on a large-scale vision-language data set to acquire cross-model semantics.

(After revision) VP models **are pre-trained** on a large-scale vision-language data set to acquire cross-model **semantics**.

Next, in scene 2, after he finishes drafting a section, Jake turns to ChatGPT and drags and drops the section he just finished writing. He then carefully crafts the following prompt: "Improve the following. Keep the LaTeX format and improve the readability."

This specific instruction is crucial for maintaining seamless integration between ChatGPT and Overleaf, a platform that utilizes the LaTeX markup language for scientific

document formatting. By including the directive to "keep the LaTeX format," Jake ensures that ChatGPT does not make changes to the LaTeX language that is incorporated in Jake's input. Without this specification, Jake would face the cumbersome task of manually adjusting the formatting when transferring the content back to Overleaf. This strategic use of ChatGPT not only saves time but also preserves the continuity and integrity of his document formatting, allowing for seamless interaction between the two tools.

With the specific condition in the prompt, in scene 3, ChatGPT generates the revisions in a code box formatted for LaTeX. Jake clicks the *Copy Code* button and simply pastes it into Overleaf. Then in scene 4, Jake compiles the text in Overleaf and reviews the final content in the right pane, where the LaTeX codes are processed to display only the formatted text. This is to meticulously read the ChatGPT output word by word fluently without any LaTeX code interfering.

After reviewing the revisions made by ChatGPT, in scene 5, Jake moves back to the left pane of Overleaf to make necessary adjustments. During this stage, the grammatical and lexical capabilities of ChatGPT significantly change Jake's approach to the revision phase. Instead of focusing on correcting grammatical errors or organizational issues, as he typically would, Jake now shifts his efforts to two specific tasks: 1) ensuring that ChatGPT has not altered his original meaning, and 2) removing any elements of the text that might suggest it was written by ChatGPT. For example, regarding scene 5, Jake reports:

I deleted words like *undergo*... They just seem too unusual, you know? I think there are certain *ChatGPTish* words. I want to avoid people reading my work and guessing it was written by ChatGPT. So, yeah, I find it necessary to fix stuff like that. (Jake, SR3)

Jake revises the sentences to remove words like "undergo", which he perceives as a *ChatGPTish* language. He also adjusts the revisions made by ChatGPT to ensure that his original intent is accurately conveyed. In scene 5, he changes "initial pre-training" into "pre-trained" because the former word suggested by ChatGPT is a technical term with a different meaning that is not appropriate in the given context. This process represents a new literary practice that has been integrated into Jake's writing process due to the adoption of ChatGPT. Jake's revision process now focuses on controlling the degree of agency that ChatGPT exerts on his writing, specifically to maintain the purpose of his text and his style of writing.

4.3 Collin

4.3.1 Background

4.3.1.1 Language Learning Experience

Collin, a 25-year-old student, recently earned a master's degree in Artificial Intelligence. He is knowledgeable about the internal logic of ChatGPT, as his research interest lies in large language model (LLM) adapters. Although Collin's lab is not as collaborative as Sam's lab in terms of research, their advisor engages actively with lab members by organizing a weekly seminar for the entire group.

Born and raised in Korea, Collin pursued all his formal education here, from elementary school through to his master's degree. He does, however, have international experience, having lived in Oregon, U.S. for a year during his fourth grade and again for six months during his undergraduate studies as an exchange student. Regarding his writing experience, Collin recalls that during his first visit to America, he experienced various genres of writing such as personal essays, book reports, and argumentative essays at school. After he returned to Korea, he attended a private school in Korea that operated an English immersion curriculum from 6th grade to 9th grade. Half of the class time was taught by a Korean teacher following the national curriculum, while the other half was taught by an English teacher using a separate curriculum designed by the school. Under this English immersion program, Collin experienced a lot of writing. In Math class, he had to write his problem-solving process in English. During Science class, he wrote reports describing the experimental results, and in Social Studies class, he wrote argumentative essays on current social issues. Contrary to his

experience in middle school, Collin explains that he "almost gave up on studying English" (Collin, Initial semi-structured interview) during his high school years. He attended a science high school for gifted students in math and science. As their English grades were not critical for university admissions, Collin recalls that he barely studied English during his high school years. Therefore, he naturally had no opportunity to learn or practice writing in English. Collin explains that during his undergraduate studies, while he took many English-mediated courses, the assignments primarily involved explaining mathematical equations in English rather than engaging in extensive English writing. Furthermore, during his master's program, he did not have the opportunity to take any writing courses.

Collin's self-evaluation of his English competencies ranks his skills in the following order: listening as the strongest, followed by writing, reading, and speaking. This self-assessment aligns with his TOEFL scores, where he achieved an overall score of 110 (corresponding to the C1 level in CEFR), with individual scores of 30 in listening, 28 in writing, 26 in reading, and 24 in speaking. Unlike many Korean learners who excel in reading, Collin finds reading more challenging because it requires adapting to another person's flow and logic. Conversely, he considers writing easier than reading, as it allows him to follow his own logical flow and express his ideas more freely.

Collin has published four journal articles, all in English. While he explained that writing was not stressful for him, he reported struggling with finding appropriate academic phraseology and registers. Initially, he would write independently and use Google to search for synonyms when a word didn't meet his expectations. If he still couldn't find a satisfactory phrase or register, he would then review various research papers in his field to discover

nuanced expressions that better suited the context of his writing. Collin recalls that searching for appropriate expressions by reviewing articles took an extensive amount of time. Hence, as an alternative to this process, Collin started to deploy ChatGPT.

4.3.1.2 Context of Writing

The three sessions of eye-tracking and screen recording captured Collin's process of finalizing his master's thesis paper. Collin has previously published an article and he is now converting this journal article into a thesis format. According to Hayes (2012), Collin is situated in the reviewing stage of writing. As he has completed the formulation of elements in all sections of the article and is now focused on revising it, his writing process is considered to be in the reviewing stage.

Collin explains that his advisory professor requires lab students to follow a specific procedure for conducting research. His professor believes that students come up with better writing when they first draft their article in Korean and then translate it into English. Therefore, he requires all his students to complete a Korean draft during the very initial stage of research. Collin describes the recommended writing process as follows:

Our lab, as directed by our professor, starts writing in Korean first. He considers it is better to start with Korean than English. So, we write the entire paper in Korean first, from the introduction to the conclusion, even before the entire experimental results are available. ... Then after completing this Korean manuscript, we go back to conduct our experiments, and when the experiment finishes, it's like, we translate the Korean manuscript into English

draft... but in fact when you translate it, you have to of course write it all over again. So, I usually write as if I am starting to write a new English manuscript from scratch. I quite don't agree with this process, but since the professor asked me to turn in the Korean draft, so I just got to do it. (Collin, Initial semi-structured interview)

Although the process he described was not apparent in the eye-tracking data, it provides a comprehensive understanding of his approaches to English academic writing. Notably, it highlights his preference for writing directly in English instead of translating from his L1.

4.3.1.3 Tools in Use

Collin uses a laptop and a wireless mouse when writing. During the period he was finalizing his thesis paper, space was limited in his lab, and he was not assigned a seat. Consequently, Collin worked on his paper at a cafe near his home. Naturally, his portable laptop became his main tool for writing. The right side of Figure 13 depicts Collin's drawing of the hardware he uses and the environment in which he writes. The setting is quite simple as he does not work in a fixed place. The drawing depicts a cellphone, a laptop, a wireless mouse, and coffee from left to right. Collin later reported that the three eye-tracking sessions were also conducted in the cafe he usually visits for writing, using the same laptop.

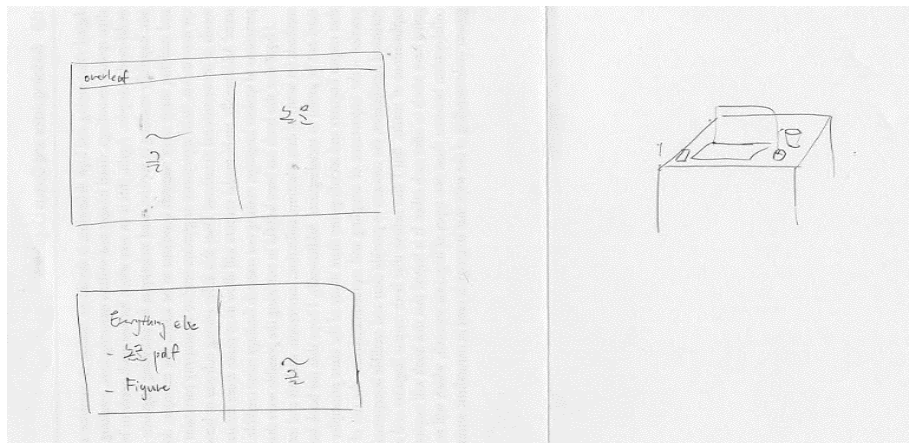
Collin primarily uses four software tools for writing: ChatGPT, Overleaf, Google, and Grammarly. He explains the role that each software plays in his composition process:

Basically, I use Overleaf for writing. So, Overleaf is the tool for drafting documents. During this process, if I need to supplement or modify something or I'm looking for a specific expression, I use ChatGPT or various features of Google. Then as I continue to polish the document, I use Grammarly to check the final version. (Collin, Final semi-structured interview)

Moreover, he distinguishes the purpose of using ChatGPT and Google. Collin explains that he uses Google when he wants to see expressions in short units, and ChatGPT when he wants to see expressions in longer units. Especially, he emphasizes that he heavily relies on Google for factual searches, implying that he does not use ChatGPT for fact-checking inquiries.

Figure 13.

Collin's Representation of His Writing Environment



4.3.2 L2 Writing Process in Digital Spaces

4.3.2.1 Session Overview

Across the three sessions of eye-tracking, Collin is involved in a single stage of writing: reviewing. More specifically, it is to adapt his journal article into a thesis by paraphrasing and adding new insights. Throughout the three sessions, Collin exhibits a consistent sequence in both the utilization of tools and the execution of actions. Table 13 provides an overview of Collin's composition process.

Table 13.

General Overview of Collin's Eye-tracking Sessions

Self-Initiated Writing Task (Writing Process)			
Journal Article (Reviewing process)			
Sessions	Main Purpose of Writing	Role of ChatGPT	ChatGPT Version
Session 1, 2, 3	Revising and paraphrasing a pre-written journal article into a thesis format	"Expression Dictionary"	ChatGPT 3.5

During sessions 1, 2, and 3, Collin revises his original article by employing three distinct writing strategies. First, to mitigate plagiarism concerns, he extensively paraphrases his sentences and paragraphs. This paraphrasing activity is the most frequently observed across the three sessions. Collin executes paraphrasing at various levels, including individual words, phrases, and entire sentences. Secondly, Collin restores details to his manuscript that were previously reduced for brevity during the journal publication editing process. Due to length constraints, many details were omitted, so he now seeks to add more information to

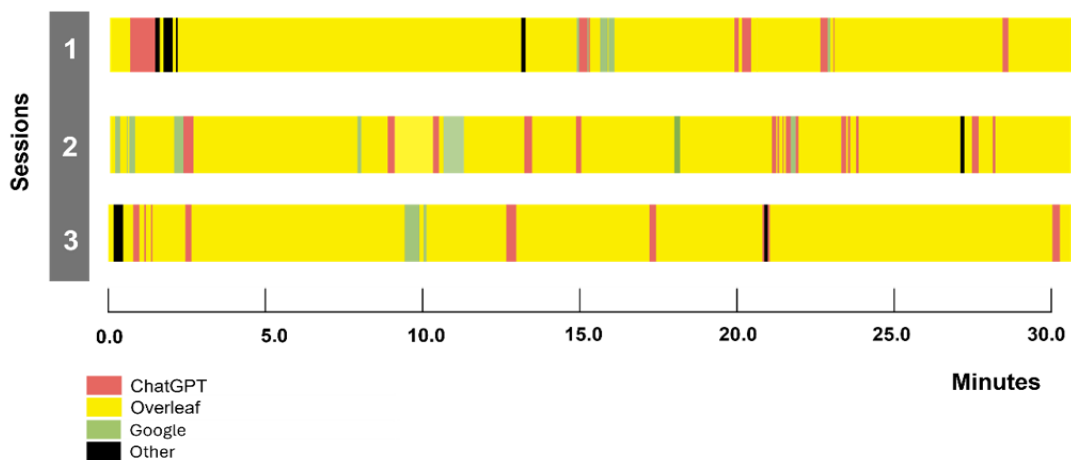
provide a deeper context. Finally, Collin revises and clarifies points he found insufficient in the original manuscript. Having presented this paper at conferences more than five times, he discovered better ways to explain his motivations and results more logically. Thus, he incorporates the insights gained from these presentations into his thesis paper.

4.3.2.2 Tools

Figure 14 presents a timescape that illustrates the array of tools Collin utilizes across the three writing sessions. As indicated by the single line in Figure 14, Collin uses one tool at a time and switches between tabs when consulting different tools. For example, he does not display Overleaf and ChatGPT side by side. Instead, he opens ChatGPT when needed and then switches the tab back to Overleaf after completing the consultation.

Figure 14.

Collin's Writing Process: Tool Timescape



The utilization pattern of tools demonstrates consistency throughout the sessions. Primarily, Overleaf serves as the central platform in each session, underscoring its significance as Collin's main writing environment. Intermittently, short and shift engagements with ChatGPT, Google, and Turnitin (represented as Others in the figure) are observed. His consultations with ChatGPT or Google are always brief, with each consultation only lasting less than a minute.

Table 14 presents the frequency and duration of use for various digital tools throughout the three sessions. It illustrates that both the duration and frequency of each tool's usage remain remarkably consistent across the sessions. Overleaf is used most extensively, averaging about 26 minutes and 50 seconds per session. This is followed by ChatGPT, with an average usage of 1 minute and 48 seconds, Google at an average of 41 seconds, and Others at an average of 31 seconds per session. This consistent pattern in the usage times and frequencies indicates that they were employed for specific tasks throughout the writing process.

Table 14.

Tool Code Frequency and Duration Across Writing Sessions

Tool Codes	Session 1		Session 2		Session 3	
	#	Duration	#	Duration	#	Duration
ChatGPT	9	01:54.2	15	02:11.0	9	01:19.8
Google	5	00:36.8	6	00:55.5	2	00:32.0
Overleaf	14	26:51.6	22	25:57.7	12	27:44.3
Others	4	00:15.9	3	00:55.9	2	00:23.9

Note. # denotes frequency

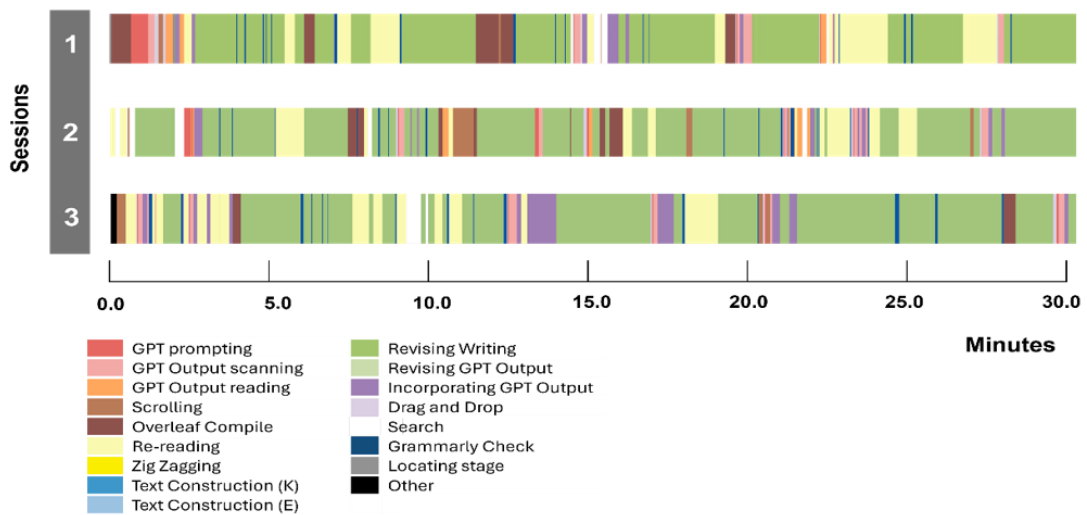
Despite their relatively short usage durations, ChatGPT and Google are accessed frequently. For instance, in session 1, ChatGPT is used 9 times for a total of 1 minute and 54 seconds. In session 2, ChatGPT is used 15 times for a total of 2 minutes and 11 seconds. The frequent visits over such a short period suggest that each interaction with ChatGPT lasts an average of 6 seconds, reflecting Collin's targeted and specific engagement with ChatGPT for each brief consultation.

4.3.2.3 Actions

Figure 15 presents a timescape that visualizes the micro-processes occurring during the three writing sessions. As evidenced by the consistent pattern in tool usage, Collin exhibits similar behaviors throughout the three sessions. During these sessions, Revising Writing and Re-reading predominate. Intermittently, actions related to ChatGPT and Grammarly also occur.

Figure 15.

Collin's Writing Process: Action Timescape



During sessions 1, 2, and 3, the sequence of actions involving ChatGPT—ChatGPT Prompting, ChatGPT Output Scanning, and Incorporating ChatGPT Output into Writing—occurs at regular intervals, typically after Collin completes a section of revision. After

revising his manuscript at the paragraph level, Collin copies and pastes each section into ChatGPT as a prompt. ChatGPT Prompting is so brief that it is barely visible in the timescape, as Collin simply copies and pastes his text into ChatGPT without adding any further instructions. He expects ChatGPT to provide a paraphrased version of his text. After prompting, he swiftly scans the output without checking the entire output but focusing on a targeted expression he was expecting. After shortly checking the ChatGPT output, Collin shifts his page back to Overleaf and integrates the suggestions into his writing. He prefers to manually type ChatGPT's suggestions into his writing rather than copy and paste them.

Frequently, a Search action occurs between ChatGPT Output Scanning and Incorporating ChatGPT Output into Writing, such as at the 15-minute mark in session 1 and the 21-minute mark in session 2. This indicates that Collin uses Google to verify the appropriateness of ChatGPT's suggestions before incorporating them into his document. Additionally, consultation with Grammarly is sporadic, appearing throughout the session without a discernible pattern.

Table 15 presents the duration and frequency of micro-processes during sessions 1 to 3. The table indicates that Revising Writing is the most time-consuming activity in each session, averaging 17 minutes, followed by Re-reading, which averages 4 minutes. In contrast, activities such as ChatGPT Output Scanning, ChatGPT Prompting, and Search each last less than a minute per session. Additionally, the use of Grammarly remains relatively consistent, suggesting it is a standard part of Collin's revising process, with minimal variation in time usage.

Table 15.*Action Code Frequency and Duration Across Writing Sessions*

		Session 1		Session 2		Session 3	
Tool Codes		#	Duration	#	Duration	#	Duration
GB	ChatGPT Output Scanning	6	00:57.8	7	00:50.4	8	00:59.3
	ChatGPT Output Reading	3	00:33.0	8	0:00:42	0	0
	Zig-Zagging						
	Re-reading	10	05:12.2	12	03:51.6	14	04:36.7
	Overleaf Compile and Reading or Scanning	5	02:21.0	7	01:18.8	2	00:38.1
	Software Scanning	3	00:14.1	4	0:01:00	3	00:32.0
NGB	ChatGPT Prompting	5	00:36.3	8	00:33.6	6	00:13.6
	Text Construction(K)						
	Text Construction(E)						
	Revising Writing	24	17:26.3	30	18:57.4	23	18:27.7
	Drag and drop	6	00:18.6	5	00:19.1	6	00:18.6
	Incorporating ChatGPT Output into Writing	8	00:57.9	9	00:56.7	12	02:37.0
	Revising ChatGPT Output						
	Search	5	00:36.2	6	00:56.0	2	00:32.3
	Locating	2	00:09.2			1	00:10.6
	Grammarly	16	00:37.5	15	00:35.2	15	01:09.5
	Others						

Collin's engagement with ChatGPT is characterized by frequent but brief interactions. For example, in session 2, ChatGPT Prompting occurs five times within 33 seconds, averaging 6.6 seconds per prompt. A similar pattern is observed in ChatGPT Output Scanning during the same session, with each instance lasting about 7.1 seconds, conducted seven times over 50 seconds. This brief engagement with ChatGPT indicates Collin's interactions with ChatGPT are minimal and purpose-driven.

Additionally, Revising ChatGPT Output is not observed in Collin's writing process; only Incorporating ChatGPT Output into Writing occurs, as he integrates small segments of ChatGPT output into his writing rather than utilizing the entire paragraph or sentence generated by ChatGPT.

The consistent pattern observed in the use of tools and sequence of actions across the three sessions suggests that Collin maintains a coherent writing goal throughout. Furthermore, the brief duration spent on the ChatGPT underscores that Collin employs ChatGPT for specific and limited purposes.

4.3.3 Collin's Engagement with ChatGPT

4.3.3.1 ChatGPT as an "Expression Dictionary? English Expert?"

Collin describes ChatGPT's role in his writing process as an "Expression Dictionary" assisting him in finding refined academic phraseologies and registers. Before using ChatGPT, Collin spent considerable time revisiting and searching through academic papers to find common phrases or registers used in his field to express his arguments. However, with ChatGPT, Collin states that he has simplified this process with a simple act of prompting.

Throughout the three sessions, Collin's goal of writing is to revise his manuscript into a thesis. During this process, he utilizes ChatGPT to search for expressions that can enhance his pre-written manuscript. Through ChatGPT, he searches for a "pretty" or refined way of expressing his thoughts. Collin explains how he uses ChatGPT as a "reference":

After I revise my writing by myself like this, I put this into ChatGPT. That is my main purpose of using it. I always first start by writing my own thoughts, and then use ChatGPT to see how they make it pretty. It's like I want to look at a reference, to see how they can be polished. (Collin, SR2)

Collin's use of ChatGPT is strictly confined to finding phrase-level references for expressions that he finds challenging to revise or repetitive in his writing. He states, "What I want is just a paraphrase of the expressions I've written, not at the sentence level, but at the level of individual phrases" (Collin, SR1). Therefore, the incorporation of full sentences or paragraphs from ChatGPT output does not occur during the three sessions. Moreover, no

other purposes for using ChatGPT, such as inquiring about domain-specific knowledge, are observed throughout the sessions as he limits ChatGPT's role to that of an "English Expert."

Collin's limited usage of ChatGPT is related to his affect and perception of the tool. He repeatedly mentions that he wants to minimize ChatGPT's influence in his writing as he does not want to lose his unique writing style. He reports that it took him a long time to start using ChatGPT in research due to a sense of rejection toward ChatGPT:

First off, I haven't really had many positive emotions toward GPT. Beyond the efficiency of the results, when I consider the situation of writing, I can't help but feel a sense of rejection. It feels like I'm not fully authoring my papers, as if I'm using a shortcut, especially since the time that it takes to find the right expressions is shortened immensely. These concerns make me wonder, 'Is this really okay?' Initially, I was quite skeptical about using ChatGPT, and it took me a long time to start using it in my research. But even then, in my situation, I couldn't just use it because of the efficiency it offers. Using it significantly reduces the time I spend on writing my papers. Looking at all these factors, in the end, I just compromised. (Collin, Final semi-structured interview)

Initially very skeptical, it took him a considerable amount of time to begin using ChatGPT in his research. Nevertheless, the undeniable productivity gains offered by ChatGPT led him to a compromise. Consequently, as a middle ground, Collin employs various strategies to use ChatGPT conservatively. In the following sections, specific examples of how Collin strategically uses ChatGPT to minimize its intervention will be described.

4.3.3.2 Increased Fluency of Writing Before Prompting

Collin states that since adopting ChatGPT, he has "developed a habit of writing carelessly" (Collin, SR2). He notes that during his revision process, his focus was to fully articulate his thoughts in written language by writing "whatever pops into mind," while paying less attention to grammatical sophistication, redundant vocabulary usage, and even typographical errors. Collin elaborates:

I just write whatever pops into my mind. The quality is not that satisfactory. But if I can't think of a word to replace, for example, *propose* right away, I just write *propose* down even though it is redundant, because it still conveys the meaning that I want to express. I write everything to make sure the meaning I want to convey is communicated, even if the expressions or sentences might be repetitive or grammatically incorrect. Because, once I put it into ChatGPT, it will eliminate those issues. Then, I can refer to them as a reference to make revisions. (Collin, SR 2)

It can be inferred that Collin sacrifices linguistic sophistication or accuracy for fluency in writing, given that he uses ChatGPT to compensate for accuracy. Although he does not directly use ChatGPT for writing, the anticipation of its use in the upcoming phase has changed his attitude toward writing. With ChatGPT integrated into his writing process, he focuses more effort and time on the fundamental aspect of writing, specifically on articulating his thoughts into language.

4.3.3.3 Brief Interaction with ChatGPT and Meticulous Verification of

Output

When consulting with ChatGPT, the basic attitude he holds is to "try to use ChatGPT as conservatively as possible" (Collin, SR 1). During the stimulated recall, Collin repeatedly mentions the words "my work" or "my style of writing." He draws a clear distinction between his writing and ChatGPT's output, making strategic efforts to ensure that ChatGPT does not overly influence his unique writing style. The following excerpt reveals Collin's attitude toward using ChatGPT:

When I read the articles that I wrote, I have that sense of feeling that it's my work, written by me. However, if I change my writing based on what ChatGPT provides, I lose that sense. It feels like it's not my work anymore. So, I try to use ChatGPT as conservatively as possible.
(Collin, SR1)

Consequently, during the writing process, Collin deliberately limits his interactions with ChatGPT. He allocates minimal time to formulating prompts and reviewing the generated responses, instead focusing extensively on verifying the output from ChatGPT and manually integrating it into his work.

Reflecting on his purpose of using ChatGPT as an "Expression Dictionary" Collin's prompting is very simple and quick, similar to searching for a word in an electronic dictionary. Among the 23 prompts he formulated during the three sessions, apart from the first prompt in session 1 and one word-search prompt in session 2, the remaining 21 prompts

involved merely copying his paragraph without adding any further instructions. Table 16 provides examples of Collin's prompts in session 1.

Table 16.

Examples of Collin's ChatGPT Prompt in Session 1

Order	Example of Collin's Prompt
1	Can you provide a proper paraphrase of the following paragraph to be included in a research paper?
2	Paragraph A written by Collin
3	Sentence B written by Collin
4	Sentence B written by Collin
5	Paragraph C written by Collin

Although he uses ChatGPT 3.5, which lacks the feature to set a premise prompt like ChatGPT 4.0, no additional prompting is given beyond inserting his own written paragraphs. His prompting is completed in less than a second as only two actions are accompanied: *Ctrl* + *V* and *Enter*. Collins describes his minimalist prompting strategy as follows:

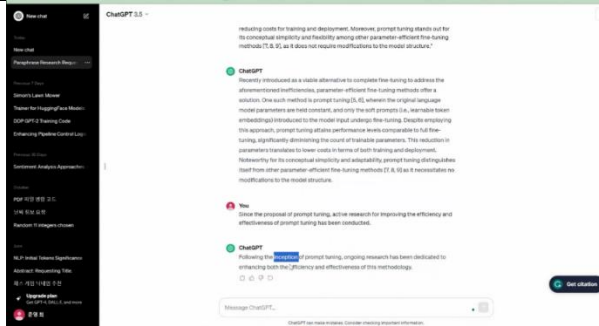
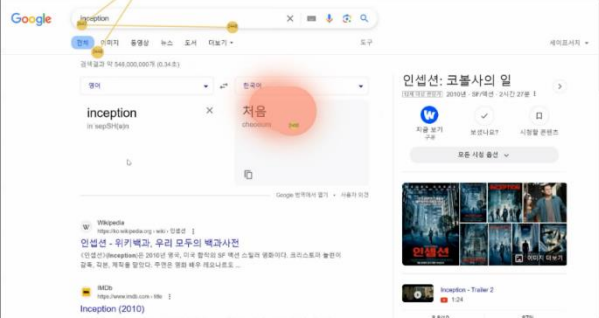
Honestly, I don't think much about it [prompting]. I don't carefully craft my prompts. I just go in and type whatever comes to mind. I just give the prompt depending on my mood. Tools like these should be easy to use. (Collin, SR1)

Collin positions ChatGPT as a tool that aids him, emphasizing that it must be "easy to use" to fulfill its purpose. Since he is the final arbiter who determines whether to incorporate ChatGPT's changes into his writing, he sees careful and sensitive prompting as unnecessary. Collin's conservative approach becomes apparent after prompting, as he reads the output and

selectively incorporates it into his own composition. Table 17, an excerpt from Collin's usage of ChatGPT in session 3, well represents his overall use of the tool.

Table 17

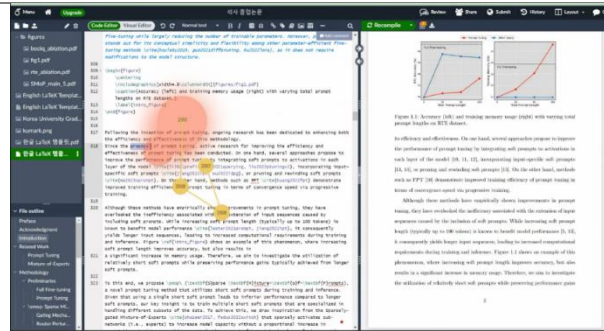
Excerpt from Session 3

Time	Screen Shot
Scene 1.	
Scene 2.	

Collin gazes and highlights the word "Inception" from ChatGPT's Output.

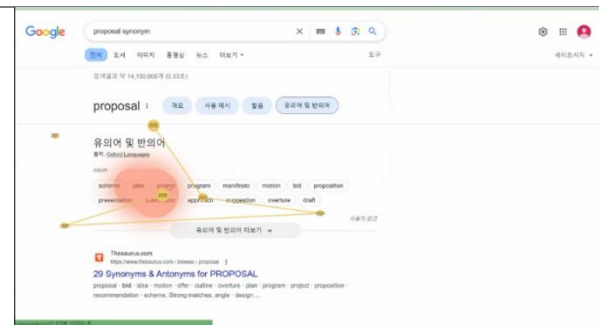
Collin searches "Inception" in Google and looks for its meaning and use.

Scene 3.



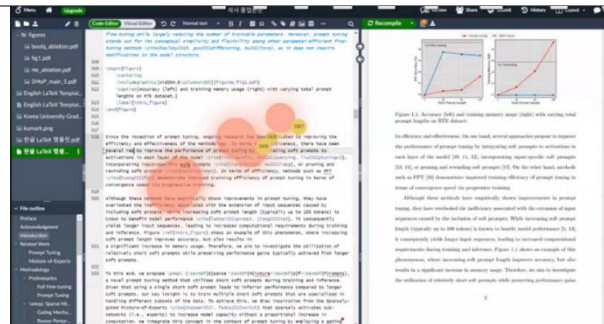
Collin shifts back to Overleaf and types in "Inception" instead of "Proposal."

Scene 4.



Collin searches "Proposal Synonym" in Google to check if "Inception" is presented as a synonym of "Proposal."

Scene 5.



Collin leaves the "inception" and works on revising other parts of the paragraph by himself.

In Table 17, Collin issues a prompt to find an alternative expression for the word *proposal* which repeatedly appears in his text. In scene 1, when the ChatGPT output is given,

Collin does not carefully read the entire response. He focuses primarily on the highlighted expression, *inception*, giving little attention to the rest of the sentence. Collin explains that once he finds the targeted expression, the rest of the output is useless to him.

In scene 2, Collin shifts his tab to Google and searches for the word *inception* suggested by ChatGPT. Here, he employs another strategy for conservative usage. He consults with Google to verify the appropriateness of ChatGPT's suggestion. Uncertain whether *inception* is an appropriate academic synonym for *proposal*, he searches for example sentences using *inception* in his context. However, his first consultation yields unsatisfactory results, showing only the Korean translation. Therefore, after his initial verification through Google, he re-visits Google in scene 4, this time searching for synonyms of *proposal*. His eye gaze reveals that he is checking the synonyms to see if *inception* is listed.

When questioned about his preference for using Google for verification, Collin explained that he relies on Google for fact-checking instead of consulting ChatGPT. He specifically notes his distrust in ChatGPT's search capabilities:

Collin: But honestly, since I majored in AI, I can't really trust AI's ability to search and deliver facts. That, I need to do it myself.

Researcher: Why do you think you can't trust it?

Collin: I believe there's always a chance it could be wrong. It can't be 100% accurate, the model's performance isn't perfect. So, if I find something and it can provide me with incorrect or potentially misleading information, I'd rather search directly on Google and interpret the information myself. It's better than leaving it to GPT, that's the mindset I have. (Collin, Final semi-structured interview)

Still uncertain about the appropriateness of *inception*, he eventually revises it to another word, *introduction* which he finds to be more appropriate to his context after scene 5.

In scene 3, after his initial consultation with Google, he shifts back to Overleaf and types *inception*, replacing the former word *proposal*. It is important to note that he does not copy and paste ChatGPT's output directly but types it manually. Collin explains that his preference for typing in rather than copying and pasting is a deliberate restriction he set for himself to use ChatGPT conservatively:

One thing that I promised myself was to draw a line between my work and ChatGPT's output. So, I don't directly copy and paste ChatGPT's output into my work. Instead, I borrow a word or two, refer to the sentence structures, and type them in by myself. My constant struggle was that I really didn't want to just copy and paste. I guess that's the result of my deliberations.
(Collin, Final semi-structured interview)

In every instance he uses ChatGPT, he identifies the targeted expression, shifts the screen back to Overleaf, and manually types the expression into his work. He does not juxtapose Overleaf and ChatGPT on the same display but shifts back and forth to maintain a physical distance between his writing and ChatGPT's output.

Moreover, to avoid indiscriminate textual borrowing or patchwriting, he does not simply replace his words with synonyms or paraphrases suggested by ChatGPT. Instead, after integrating ChatGPT's suggestions into his writing, he revises the flow and structure of the surrounding sentences to coherently assimilate the borrowed phrase. This approach is evidenced by Table 13, which shows that he spends more time on *Revising Writing* than on *Incorporating ChatGPT Output into Writing*.

Although no established standard yet exists for the ethical incorporation of AI-generated texts into writing (Warschauer et al., 2023), Collin has developed his own set of patterns and guidelines to maximize the utility of ChatGPT while preserving his unique authorial voice and agency. Collin's unique interaction with ChatGPT provides insight into how ChatGPT or AI tools may contribute to L2 writers' enhancement of academic writing, without deteriorating their individual voice or authenticity.

4.4 Thomas

4.4.1 Background

4.4.1.1 Language Learning Experience

Thomas, a 26-year-old student, is in his first semester of a PhD program in Artificial Intelligence. Affiliated with the same laboratory as Jake, his research focuses on addressing the hallucinations of Large Language Models (LLMs). As noted in Jake's case, the laboratory he works tends to pursue an individualistic culture in terms of conducting research.

Born and raised in Korea, Thomas has no experience studying abroad. His English learning trajectory primarily revolved around preparing for standard English tests, resulting in limited experience with English writing. He began learning English in the 3rd grade, following the national curriculum. By 6th grade, he attended an academy that taught grammar and reading, using TOEIC workbooks. In middle school, he moved to a smaller-scale academy where he received more personalized instruction. Here, he engaged in writing short essays and received simple feedback from his tutor. However, upon entering a science school for gifted students, the time and effort devoted to English decreased significantly. As English was a low-priority subject, the classes were not intensive, and the curriculum was based on the TEPS workbook. Naturally, he did not have much chance to practice English writing.

During his undergraduate and master's studies, Thomas only spent time studying English during graduation season to meet the graduation requirements. In his master's program, he felt the need to improve his English since he had to use it daily for reading and

writing articles. However, due to the demanding coursework, he could not dedicate additional time to studying English and ended up preparing for the TOEIC test at the last minute. He barely met the graduation requirement with a TOEIC score of 790, slightly above the minimum cutline of 780. His limited English proficiency posed a challenge to him when he applied for his PhD program. The program required a minimum NewTEPS score of 327, but he did not meet this criterion on his first attempt and had to enroll in the following semester after achieving a score of 330 in NewTEPS.

Thomas lacks confidence in his English proficiency. He describes his reading approach as relying on familiar words to infer the content. He struggles with long sentences that have unfamiliar structures. In terms of writing, Thomas faces even greater challenges. He finds it difficult to convey subtle nuances in English, which leads him to adopt a more defensive and simplistic writing style to avoid potential misunderstandings by the audience. While he can assertively argue his findings in Korean, he tends to merely describe his results in English, avoiding deeper discussions due to concerns that his true intent may not be clearly articulated.

Thomas has published four academic papers, two in Korean and two in English (one journal paper and one thesis). He explained that he used translators such as Google and Papago to compose the two English articles. However, he reported persistent doubts about the accuracy and clarity of the translations. His advisor even strongly recommended that he consult an English editing service to proofread his thesis and articles, noting that his English sounded unnatural and awkward.

Following these experiences, Thomas became concerned that his limited English proficiency might undermine the credibility of his academic work. Determined to address this issue, he resolved to improve his English skills upon entering his PhD program. He observed that his lab colleagues, despite not being highly proficient in English, were successful in publishing their papers. Curious about their approach to academic writing, Thomas inquired about their strategies. His colleagues praised ChatGPT for its effectiveness in assisting with writing tasks, prompting Thomas to incorporate ChatGPT into his writing process.

4.4.1.2 Context of Writing

Enrolled in his first year of a PhD program, Thomas is preparing to write an academic paper. He has not yet targeted a specific publication and is focused on developing his research idea into a concise 3–4 page document before discussing it with his professor. In Thomas's lab, the research process is flexible, allowing graduate students to work autonomously on their projects without adhering to a rigid protocol.

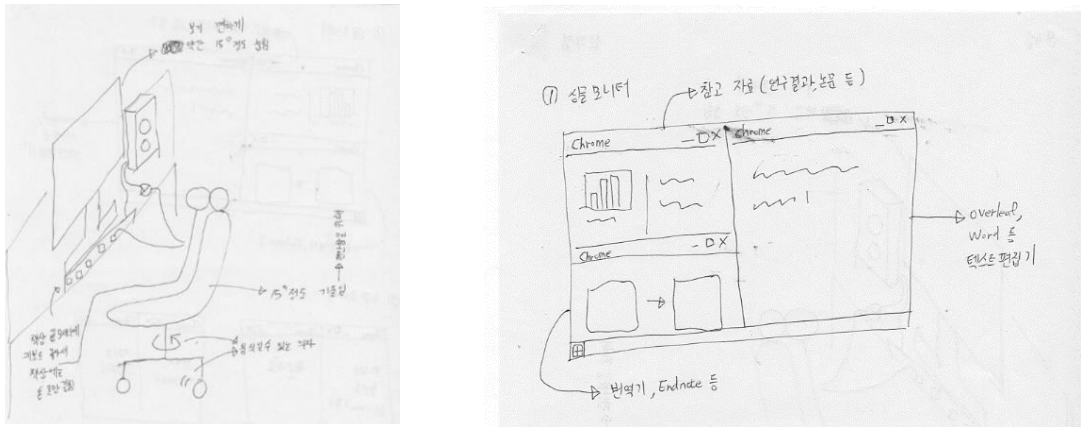
During the three eye-tracking sessions, Thomas engages in the planning and formulating process (Hayes, 2012). While he has an abstract idea for a research topic, he has not yet considered specific methodologies or directions. Through these sessions, he gradually develops his ideas further. His aim is not to produce a complete draft but rather to write a 3–4 page proposal paper that outlines the expected scope of a full-length paper.

4.4.1.3 Tools in Use

Thomas uses either a desktop or a laptop, along with a keyboard and mouse, when working on his writing, as depicted in Figure 16. He has meticulously structured his writing environment both at his laboratory and at home. In the laboratory, he uses a Windows-based desktop with a single monitor, while at home he operates a Windows-based laptop. Figure 16 details his predefined system for his writing environment. For instance, Thomas always adjusts his chair to tilt 15 degrees backward for comfort. To maintain eye level in this reclined position, he similarly tilts his monitor by 15 degrees. This sophisticated setup indicates that Thomas is highly attuned to the conditions of his writing environment.

Figure 16.

Thomas's Representation of His Writing Environment



Thomas mainly utilizes ChatGPT, Overleaf, Google, and the Text Document Comparison Site in his writing process. Reflecting his systematic approach to his physical

writing environment, he has developed a specific method for organizing these applications on his screen. As illustrated in Figure 16, Thomas places reference materials such as ChatGPT on the left and his main writing platform, Overleaf, on the right. He explains this arrangement facilitates an efficient workflow, as our eyes typically move from left to right.

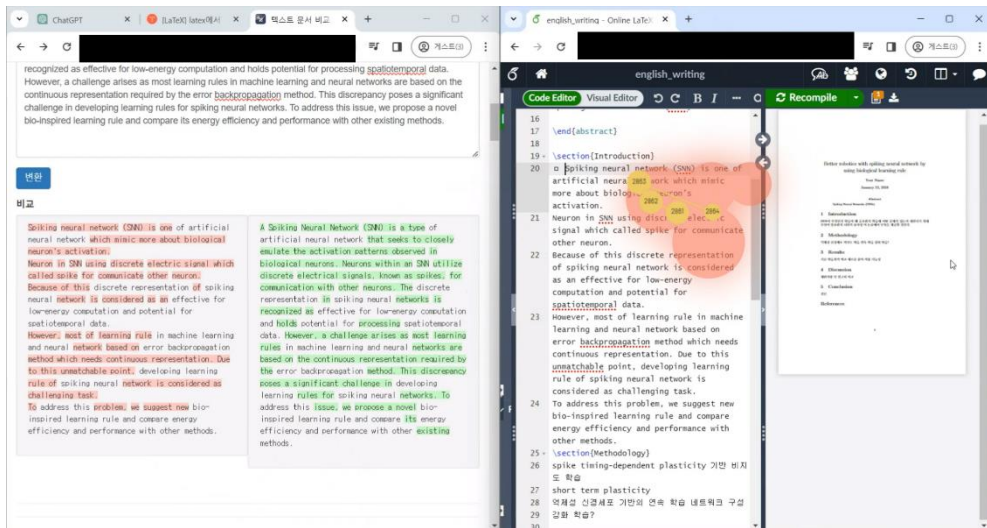
Overleaf is the platform where his writing is primarily constructed. He uses a single Overleaf page to brainstorm ideas, formulate an outline, and expand this outline into a manuscript. Rather than using multiple pages for distinct phases, all text construction activities are carried out on a single page as he systematically expands his writing.

ChatGPT is consulted throughout the entire process of planning and formulating. Thomas engages with ChatGPT to discuss research ideas, find appropriate expressions, and refine his English draft.

A distinctive aspect of Thomas's writing process is his use of the Text Document Comparison Site (TDCS). As shown on the left side of Figure 17, TDCS is a web application accessible online without requiring installation. Its primary function is to compare two documents and highlight the differences between them using colors, enabling users to intuitively identify discrepancies between two versions of a document. As a software engineer, Thomas frequently used this tool for comparing code lines. During the writing process, he utilizes TDCS to easily compare his writing with ChatGPT's refinements.

Figure 17.

Thomas's Use of Text Document Comparison Site (TDCS)



4.4.2 L2 Writing Process in Digital Space

4.4.2.1 Session Overview

The three eye-tracking sessions were conducted over three consecutive days, demonstrating the gradual development of Thomas's writing. During sessions 1, 2, and 3 Thomas is actively engaged in the planning and formulation process. Specifically, he participates in brainstorming, constructing an initial outline (L1), and drafting an English manuscript. Table 18 presents an overview of Thomas's composition process.

Table 18.

General Overview of Thomas's Eye-tracking Sessions

Self-Initiated Writing Task (Writing Process) Journal Article (Planning and Formulating Process)			
Sessions	Main Purpose of Writing	Role of ChatGPT	ChatGPT Version
Session 1	• Constructing the structure of his Korean outline.	Domain Specific Knowledge	ChatGPT 3.5
Session 2	• Expanding on the initial L1 outline composed in session 1.	Domain Specific Knowledge	ChatGPT 3.5
Session 3	• Formulating an English manuscript based on the L1 outline	Text refinement	ChatGPT 3.5

During Session 1, Thomas refines his abstract idea into a specific research topic. He interacts with ChatGPT to gain insights and clarify his vision. Following this consultation, Thomas breaks down his complex idea into subpoints, creating subheadings for the introduction, methodology, and expected result sections.

In session 2, Thomas elaborates on the outline by adding specific details under the subsections he established in session 1. This process is conducted in Korean, and he consults with ChatGPT by asking specific domain-related questions to enrich his outline with detailed information.

In session 3, Thomas converts his Korean outline into an English manuscript, focusing on drafting the introduction section. He adds English translations line by line beneath the pre-structured Korean outline, expanding the phrase-level L1 outline into a sentence-level L2 manuscript. Throughout this process, he consults ChatGPT to find appropriate vocabulary and expressions. Once he finishes drafting his introduction, he utilizes ChatGPT for additional editing and refinement.

4.4.2.2 Tools

Figure 18 visually represents Thomas's utilization of different software tools throughout the three writing sessions. Across the three sessions, Thomas's digital writing environment consistently features a similar setup, typically split into two sections. Overleaf and ChatGPT are the primary tools used across all sessions, indicating their foundational role in Thomas's writing process. In sessions 2 and 3, combinations such as *ChatGPT and TDCS* and *Overleaf and TDCS* become prevalent during the later stages of each session. This configuration emerges in the latter phase of each session when Thomas, having made substantial progress, prompts ChatGPT for refinement of his English writing.

Figure 18.

Thomas's Writing Process: Tool Timescape

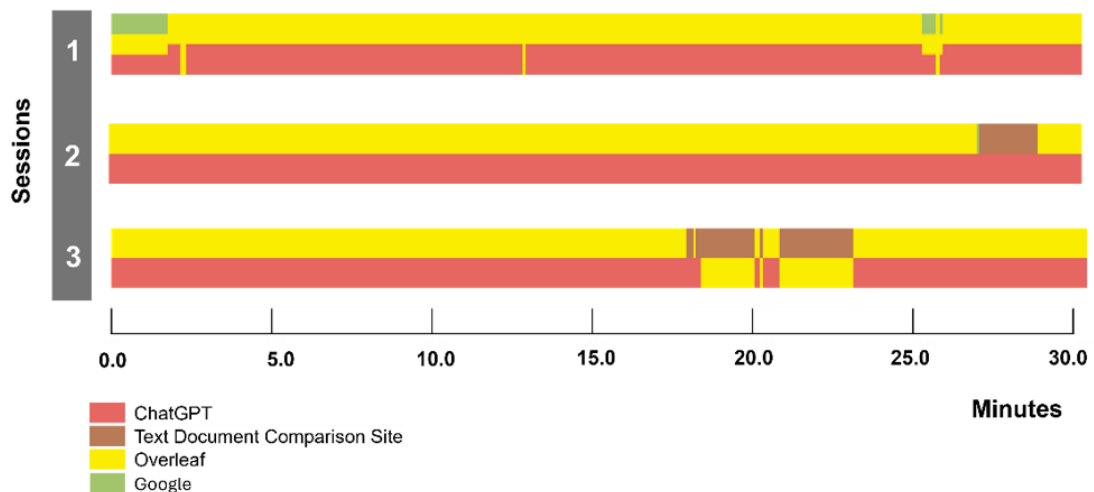


Table 19 summarizes Thomas's use of various online tools in terms of duration and frequency. Throughout sessions 1, 2, and 3 Thomas consistently uses ChatGPT as a central tool, particularly in combination with Overleaf. On average, Thomas spends approximately 26 minutes on the *ChatGPT and Overleaf* setup during the 30-minute eye-tracking sessions. Thomas's use of TDCS increases gradually as the session progresses. The combination of *TDCS and ChatGPT or Overleaf* is particularly prevalent during session 3 when Thomas is engaged in the formulating phase.

Table 19.

Tool Code Frequency and Duration Across Writing Sessions

Tool Codes	Session 1		Session 2		Session 3	
	#	Duration	#	Duration	#	Duration
ChatGPT + Overleaf	4	27:21.9	2	28:07.2	5	25:36.1
ChatGPT + TDCS			1	01:49.0	2	00:23.3
Overleaf + TDCS					3	04:00.6
ChatGPT + Google + Overleaf	3	02:15.6				
Overleaf	3	00:22.5				
ChatGPT + Google			1	00:03.8		

4.4.2.3 Actions

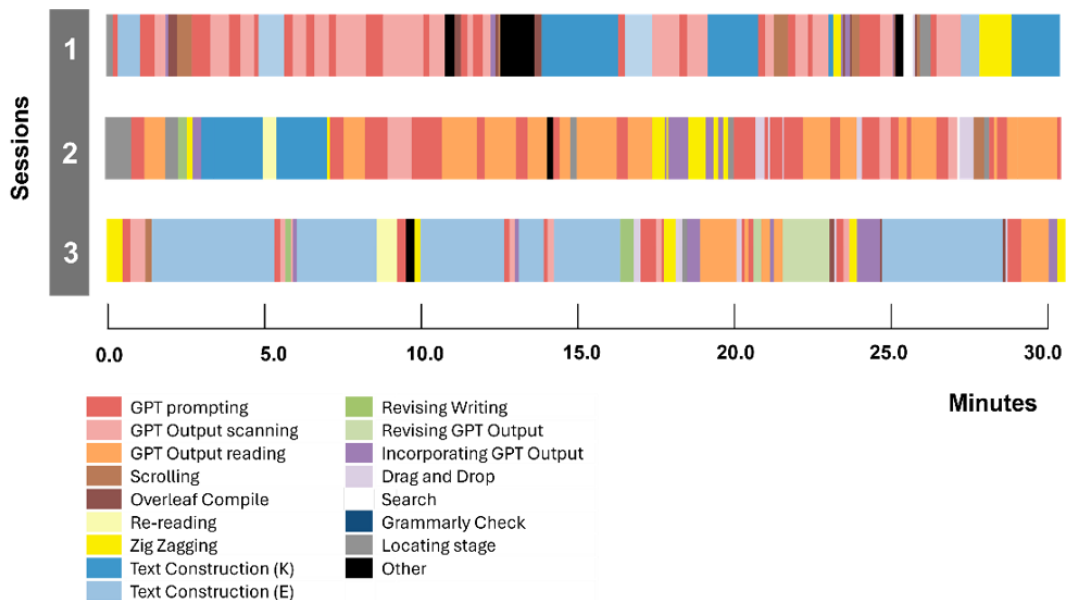
Figure 19 depicts the micro-actions or compositional actions Thomas conducts throughout the three writing sessions. In session 1, ChatGPT Prompting and ChatGPT Output Scanning are the primary activities observed. Additionally, there are periodic instances of Text Construction in Korean, which typically persist for extended durations. During the first ten minutes, a cyclical pattern of *ChatGPT Prompting and ChatGPT Output Scanning* emerges repeatedly. During this phase, Thomas engages with ChatGPT to facilitate his brainstorming process by seeking domain-specific knowledge. Subsequently, lengthy blocks of Text Construction in Korean begin to appear from the middle phase onwards. This is when Thomas starts to formulate an outline for his paper in Korean after refining his idea through interaction with ChatGPT. After the 20-minute mark, ChatGPT Prompting and ChatGPT Output Scanning occur intermittently. At this stage, ChatGPT is consulted for technical guidance on LaTeX code, which is essential for drafting, as he has limited experience with Overleaf.

During session 2, Thomas predominantly engages in ChatGPT Prompting and ChatGPT Output Reading. Additionally, Incorporating ChatGPT Output into Writing often follows ChatGPT Output Reading. Thomas begins the session with a sequence of *ChatGPT Prompting and ChatGPT Reading*. Then he works on Text Construction in Korean for about six minutes. Subsequently, the cycle of ChatGPT Prompting and ChatGPT Output Reading persists for about ten minutes. After this extensive interaction, at the 17-minute mark, Thomas begins to incorporate the ChatGPT responses into his writing in Overleaf, by manually typing them rather than merely copying and pasting the text. Starting from the 20-

minute mark, the sequence of ChatGPT Prompting and ChatGPT Output Reading begins to recur. At this point, Thomas uses ChatGPT to translate his completed Korean outline into English and experiments with various prompts.

Figure 19.

Thomas's Writing Process: Action Timescape



In session 3, *Text Construction in English* is the most frequently observed behavior. In the first 15 minutes, there is a noticeable pattern of long blocks of Text Construction in English followed by brief consultations with ChatGPT, which include ChatGPT Prompting, ChatGPT Output Scanning, and Incorporating ChatGPT Output into Writing. This sequence illustrates how Thomas independently translates the introduction of the outline and turns to

ChatGPT for assistance with challenging expressions or words. After completing his translation individually, he requests revisions to ChatGPT and uses the Text Document Comparison Site to evaluate the differences between the original input and the modified output generated by ChatGPT. Following this sequence, the block of Text Construction in English reappears as Thomas continues to translate the following methodology section into English.

Table 20 describes the frequency and duration of micro-processes throughout the three sessions. During sessions 1 and 2, which involve brainstorming and outline creation, ChatGPT is used more frequently and for longer durations compared to session 3, where the outline is translated. The time dedicated to ChatGPT Prompting also shows significant differences: in session 1, it amounts to 5 minutes and 30 seconds; in session 2, it increases to 7 minutes and 37 seconds; and in session 3, it reduces markedly to just 2 minutes and 25 seconds. This trend shows that Thomas is more involved with ChatGPT during the brainstorming process, while he tends to write more independently during the formulating phase.

Moreover, the durations of ChatGPT Output Reading and ChatGPT Output Scanning in sessions 1 and 2 show a clear reversal in trend. In session 1, the duration for ChatGPT Output Scanning is 9 minutes and 16 seconds, while ChatGPT Output Reading is only 1 minute and 38 seconds. In contrast, session 2 features ChatGPT Output Scanning for just 1 minute and 40 seconds and ChatGPT Output Reading for a significantly longer 10 minutes and 28 seconds. This significant shift in reading strategies reflects changes in Thomas's approach and intentions when utilizing ChatGPT.

Table 20.*Action Code Frequency and Duration Across Writing Sessions*

		Session 1		Session 2		Session 3	
Tool Codes		#	Duration	#	Duration	#	Duration
GB	ChatGPT Output Scanning	18	09:16.9	3	01:23.8	7	01:24.2
	ChatGPT Output Reading	2	01:40.1	16	10:28.7	5	02:59.3
	Zig-Zagging	2	01:14.3	7	01:32.7	5	01:34.3
	Re-reading			1	00:25.4	1	00:37.8
	Overleaf Compile and Reading or Scanning	9	01:02.6			3	00:16.6
	Software Scanning	5	01:17.3	1	00:18.9	1	00:12.6
NGB	ChatGPT Prompting	19	05:30.6	20	07:37.5	11	02:25.3
	Text Construction(K)	4	05:40.7	3	03:31.9		
	Text Construction(E)	2	01:16.8			6	15:20.2
	Revising Writing					2	00:35.7
	Drag and drop	1	00:04.1	5	01:00.1	7	00:43.7
	Reflecting ChatGPT Output into Writing	5	00:29.2	6	01:39.0	7	01:57.6
	Revising ChatGPT Output					1	01:27.8
	Search	1	00:17.3	1	00:03.9		
	Locating	2	00:31.8	5	01:46.0	1	00:08.6
	Grammarly						
	Others	3	01:38.4	1	00:12.1	1	00:16.3

4.4.3 Thomas's Engagement with ChatGPT

4.4.3.1 ChatGPT as an "Uncanny Valley"

Throughout the stimulated recall, Thomas consistently draws parallels between ChatGPT's interactive qualities and those of human beings. Unlike other participants, such as Sam and Jake, who assign specific functional roles to ChatGPT, like "Booster" or "Expression Dictionary," Thomas does not limit ChatGPT to a particular function. Instead, he anthropomorphizes it, treating it as a human entity.

Thomas highly values the dialogue format of ChatGPT, which allows for conversational interaction. He notes that without this interactive capability, he would not use ChatGPT due to significant concerns regarding data privacy and the potential for hallucinations:

If it weren't for the conversational format, I think using Google Translate might be better in terms of work efficiency and or privacy issues. Of course, the sentence quality would be terrible, but at least there wouldn't be issues like hallucinations or data breach concerns. That's why I kept interacting with GPT as if it was a human being. Even though I initially inputted the data thinking of it as a machine, the way ChatGPT animates text as if it's typing in real-time and responds in colloquial language made me continually feel like I was having a conversation with a human being. (Thomas, Final-semi structured interview)

Thomas explicitly states that ChatGPT's animation feature, which displays output generation in real-time as if someone is typing, is the primary factor that leads him to perceive it as a human being.

Thomas's perception of ChatGPT as a human-like entity significantly shapes his interaction pattern with the tool throughout the writing process. For example, as a novice user, Thomas is not fully acquainted with the robustness and responsiveness of ChatGPT's system. Consequently, he experiments with various prompt engineering techniques he has encountered in seminars or articles to better understand and utilize its capabilities. In session 2, Thomas issues a prompt as follows: "Thank you. Please write a conclusion based on the paper I previously wrote." Thomas explains that he intentionally added "Thank you" to experiment with whether positive feedback influences the interactional pattern with ChatGPT, as it often brings about elevated mood and increased performance in human-human interaction.

In a related vein, Thomas expects interactions with ChatGPT to reflect human-like communication patterns. When ChatGPT's responses deviate from these patterns, he reacts negatively, often comparing the experience to the "Uncanny Valley" or describing it as "a machine pretending to be human." He specifically dislikes ChatGPT's repetitive and formulaic responses, such as "Here is the answer," which make him feel that ChatGPT's outputs are produced mechanically without fully engaging with his input. This diminishes his trust in the technology.

While Thomas appreciates the interactive features of ChatGPT, ongoing encounters with technical limitations create a dynamic relationship between him and the tool throughout the three sessions of eye-tracking. His perception of ChatGPT changes over time, evolving from seeing it as "a human-like entity with intrinsic intelligence" to viewing it as "a machine pretending to be human." The following sections will describe the distinct characteristics

Thomas reveals while engaging with ChatGPT during the brainstorming and formulating stages.

4.4.3.2 Prompting as an Opportunity for Articulation and Prior Knowledge

Activation

In traditional literacy environments, writers had to resolve minor and major writing concerns alone as they arose during the writing process. Although they could indirectly consult other sources to address their issues, they lacked direct interlocutors to discuss their specific problems, leaving questions to linger internally in an abstract format. However, Thomas explains that now having an interlocutor, ChatGPT, to whom he can speak, he can articulate his contemplation into prompts. Thomas emphasizes that the process of verbalizing his unorganized thoughts into a prompt allows him to diagnose the concerns he experiences during his writing process. Therefore, for Thomas, the value lies not just in the output generated by ChatGPT but in the act of prompting itself, which serves as a tool to organize his thoughts. Thomas explains:

When you're writing alone, you're just thinking to yourself. You don't ask questions to others, and you don't organize the problems you have into words. But sometimes, you know, when you have concerns in your daily life, just talking them through with a friend can help you organize and resolve them, right? Chatting with GPT felt similar in that way. Since GPT can converse with me interactively, it really seemed to help. (Thomas, SR2)

Comparing his interaction with ChatGPT to counseling with a friend, he emphasizes the interactional value of ChatGPT, which provides him a chance to articulate his abstract

ideas into concrete words. This dynamic clarifies why Thomas primarily scans the text in session 1 rather than reading the ChatGPT output thoroughly. The main goal of session 1 is to structure the overall direction of the paper. Consequently, the output from ChatGPT is not as valuable to him as a direct source of knowledge. Rather, the very act of prompting is more important to Thomas as it helps organize and clarify his thoughts.

While issuing a prompt to ChatGPT allows Thomas to articulate and organize his thoughts, he confesses that reading ChatGPT's output also facilitates his domain-related knowledge:

When I'm wondering, 'What should I write?' and just stuck, issuing a prompt and reading ChatGPT's output stimulates my brain ensemble, and then I think, 'Yeah, that's it, I should write about that'. (Thomas, SR2)

Thomas explains that swiftly scanning the domain-related text generated by ChatGPT activates his prior knowledge, helping him progress in his brainstorming. Interestingly, Thomas notes that ChatGPT's hallucinations sometimes provide insights by presenting ideas he had never considered before. For example, in session 2, Thomas asks a domain-specific inquiry: "Explain about the contribution of inhibitory neurons to reinforcement learning." To Thomas's knowledge, no current research integrates these two concepts *inhibitory neurons* and *reinforcement learning*. However, ChatGPT provides a long answer describing various possibilities. Thomas reacts to ChatGPT's hallucination as follows:

In this case, the hallucinations were rather helpful. Since there hadn't been any research proposing a link between *inhibitory neurons* and *reinforcement learning*, when ChatGPT talked about it as if it existed, it made me think, 'Maybe this could be possible?' It ended up

being a source of inspiration. ... When I read the ChatGPT's output I don't consider every single word they produce to be true. I just try to get a grasp of what it is trying to say.

(Thomas, SR3)

Thomas notes that when one possesses the ability to discern the truthfulness of information, ChatGPT's hallucinations may rather provide inspiration by producing novel ideas. Therefore, for Thomas, the two fundamental actions involved in interacting with ChatGPT—prompting and reading the responses—greatly enhance his brainstorming process by offering opportunities to articulate his ideas and stimulate his prior knowledge.

4.4.3.3 Complementing ChatGPT's Confined Modality with Other Digital Resources

While Thomas mainly works on his writing in the combination of ChatGPT and Overleaf during the brainstorming process, a new tool, the Text Document Comparison Site (TDCS), emerges in his digital writing space during the formulating stage, creating a new configuration with ChatGPT. To address the constraints imposed by ChatGPT's reliance on text as its sole output modality, a new tool TDCS is employed.

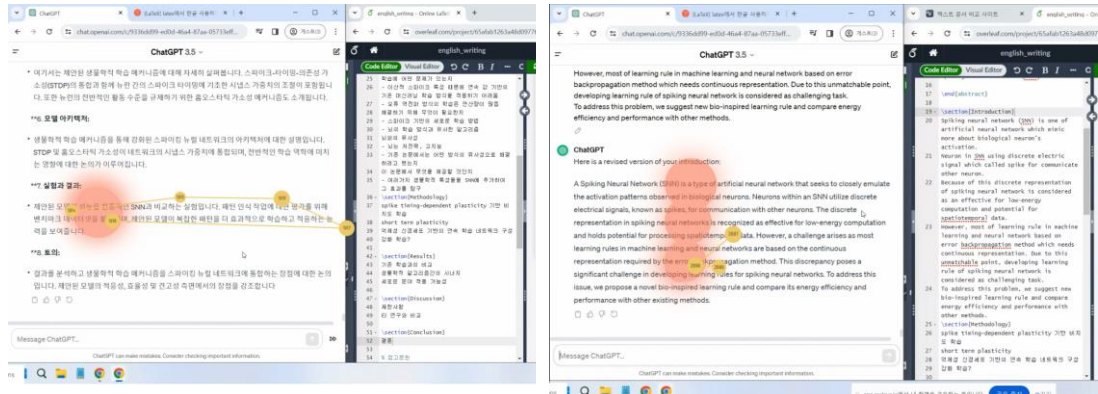
Thomas explains, "People who are not proficient in English feel a bit fatigued when long texts appear in English" (Thomas, SR3). Due to his limited English proficiency, Thomas avoids processing extensive English texts. His conversations with ChatGPT during the brainstorming phase were conducted in Korean. However, during the formulation phase,

where he seeks refinement of his English drafts, engagement with extensive English texts becomes inevitable.

The gaze plot data reveals a notable difference in Thomas's reading patterns depending on the language of the output. Figure 20 indicates that when encountering a Korean output, his gaze pattern moves horizontally, suggesting meticulous reading of each word. However, when the output is in English, the gaze plot tends to move vertically, indicating more scanning-like behavior rather than careful reading. This implies that Thomas tends to *read* the Korean output but *scan* the English output.

Figure 20.

Thomas's Reading Patterns

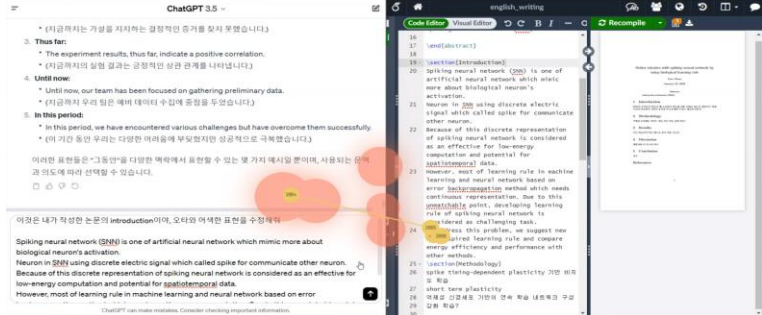
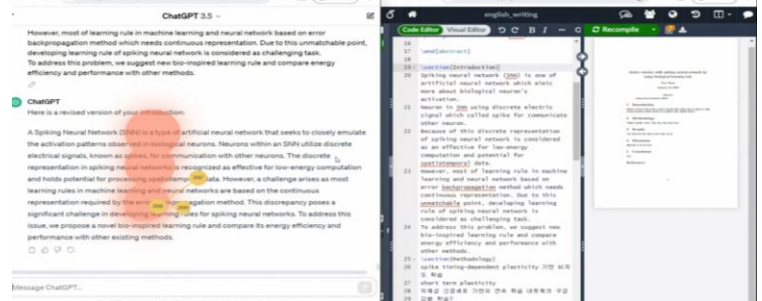


Note. Left: Reading Korean output (Session 1), Right: Scanning English output (Session 3)

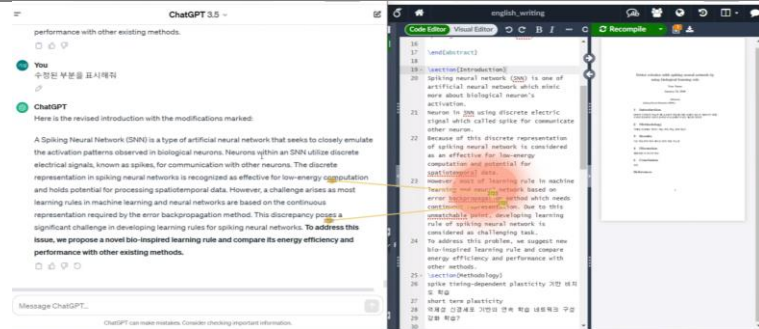
Thomas's *fatigue* is also related to ChatGPT's affordance of providing output in a limited modality, only in text. To effectively overcome this discomfort, Thomas adopts various strategies. Table 21 is a representative excerpt from session 3 that shows Thomas's engagement with ChatGPT and TDCS.

Table 21.

Excerpt from Session 3

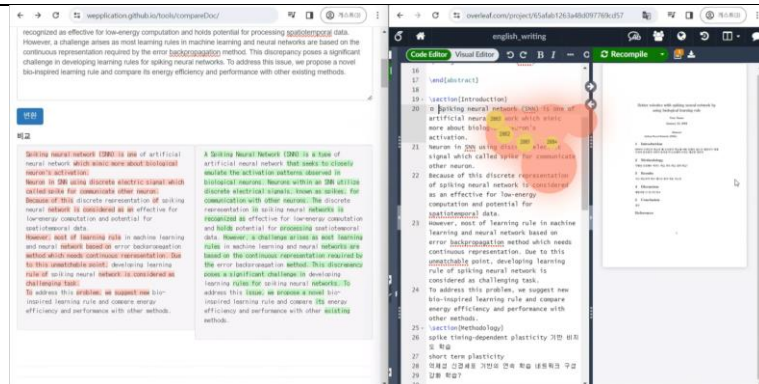
Scene	Screen Shot
Scene 1.	 Thomas issues a prompt "This is an introduction from an article that I wrote. Refine the typos and unnatural expressions. [이것은 내가 작성한 논문의 introduction이야. 오타와 어색한 표현을 수정해줘]" and copy and paste his draft.
Scene 2.	 Thomas scans the output without meticulous reading.

Scene 3.



Thomas issues a new prompt "Mark the modified segment [수정된 부분을 표시해줘]" and zigzags between ChatGPT and Overleaf for a moment.

Scene 4.



Thomas forms a new configuration of TDCS and Overleaf. Thomas checks the highlighted parts in TDCS and makes revisions to Overleaf manually while zigzagging the two interfaces.

In scene 1, after completing writing his English draft, Thomas issues a prompt asking for a revision of the introduction he had just written. ChatGPT generates the output; however, in scene 2, Thomas swiftly scans the output without much effort and immediately issues another prompt: "Mark the modified segment." Thomas tries to mitigate the burden of processing long texts by requiring ChatGPT to use a semiotic resource, such as coloring or highlighting, to mark the changes visibly. However, the output ChatGPT provides is not sufficient as it only selectively boldfaces the last sentence, leaving other minor revisions

unmarked. As an alternative strategy to facilitate his reading process, he employs the TDCS. He opens the TDCS and inserts his original manuscript alongside ChatGPT's revised output. The tool immediately highlights the differences using two distinct colors, as shown in scene 4. Thomas then starts to type the changes into Overleaf one by one, checking the highlighted colors on the left side of the screen.

By using the TDCS, Thomas can intuitively detect the points at which changes have been made without having to meticulously read the output. This approach streamlines his review process and reduces the cognitive load associated with processing long texts. Interestingly, Thomas explains that his use of TDCS aims to prevent his interactions with ChatGPT from being distracted by irrelevant requirements:

Another reason is that if I consistently ask ChatGPT to emphasize certain aspects, it might disrupt the flow of the conversation and cause it to lose track of the previous dialogue. I'm concerned that asking unnecessary questions could clutter the conversation. So, for simple tasks, I prefer to use existing tools without making additional requests. (Thomas, Final semi-structured interview)

He is concerned that by requesting additional prompts for modifying the output modality, he might disrupt his previous interactions with ChatGPT, which are focused on refining his work, a priority for him. In this context, ChatGPT's distinctive capability to remember the conversation paradoxically becomes a reason not to use it for such modifications. Therefore, he decides to employ TDCS rather than requesting another prompt to prevent possible communication breakdown. This approach also reflects Thomas's perception of ChatGPT as an interactive entity.

CHAPTER 5.

DISCUSSION

This chapter summarizes the major findings of the study. Section 5.1 revisits the individual cases of the four participants presented in the previous chapter. Subsequently, Sections 5.2 through 5.4 provide a cross-case analysis of these cases, discussing the findings in relation to previous research.

5.1 Summary of Individual Cases

The comprehensive case study of four L2 writers' use of ChatGPT in their academic writing process revealed a range of distinct personal writing and tool usage strategies. Each participant demonstrated a unique pattern of engagement with ChatGPT. The following is a summary of the individual case studies of Sam, Jake, Collin, and Thomas.

As an intermediate English learner, Sam uses ChatGPT mainly for sophisticated translation. His use of ChatGPT as a translator emerges within the dynamic interplay of factors such as his motivation to address criticisms about informal writing styles and his lab's collaborative research culture. Throughout the three sessions, Sam combines ChatGPT with tools like Dynalist and Overleaf to streamline his translation process. Analysis of his micro-processes indicated that the activities of ChatGPT Output Reading, Zig-zagging, ChatGPT Prompting, and Incorporating ChatGPT into Writing were consistently present throughout his translation process. For Sam, prompting serves as an active revision session where he revisits

and finalizes his L1 outline. Conversely, he invests less time and effort in crafting detailed instructions for ChatGPT, relying on the personalized functionality of ChatGPT 4.0. When reviewing ChatGPT's output, Sam makes only minimal word-level adjustments to ensure the translation aligns with the specialized terminology of his field. Nonetheless, he notes the need to manually review the global structure of the manuscript after translating it using ChatGPT.

Contrary to Sam, who utilizes ChatGPT primarily for translation, Jake, an advanced English learner and AI graduate student has seamlessly incorporated ChatGPT into his entire writing process, referring to it as a "Genius Sidekick." With a deep understanding of both the benefits and pitfalls of ChatGPT, he skillfully leverages its affordances to achieve optimal writing outcomes. During the three eye-tracking sessions, he uses ChatGPT for consulting domain-specific knowledge and refining his text. Analysis of his micro-processes shows that he engages with ChatGPT at a high and meticulous level, carefully reading all generated content and making thorough decisions on whether to utilize its suggestions. Jake reports significant improvements in his writing fluency before prompting, due to ChatGPT's influence. Moreover, he demonstrates a different approach in his revision process. Previously focused on grammar and word choice, he now scrutinizes for "ChatGPTish" words and thoroughly checks the alterations made by ChatGPT to ensure that his original intent is preserved.

Despite sharing a background of advanced English proficiency and extensive knowledge of AI, Collin's pattern of ChatGPT usage differs markedly from Jake's. Collin's use of ChatGPT is confined to serving as an "Expression Dictionary" for academic phraseology, rather than engaging it for other purposes such as searching for domain-specific

knowledge. He employs various strategies to use ChatGPT as conservatively as possible, driven by his strong desire to maintain his authorial voice and skepticism about ChatGPT's ability to fact-check. Analysis of micro-process data shows that Collin's interactions with ChatGPT, including prompting or reading its output, are typically brief, each encounter lasting less than 10 seconds. He often cross-references ChatGPT's output with Google searches to validate the information. Consequently, Collin's interaction with ChatGPT is characterized by specific strategies aimed at minimizing its influence on his writing style, ensuring that his voice remains prominent.

Unlike the previous three participants, Thomas's use of ChatGPT is largely characterized by his engagement with ChatGPT as a human-like entity. Thomas, an intermediate English learner with limited experience in academic writing, particularly appreciates the conversational dynamics offered by ChatGPT. Analysis of micro-process data shows that Thomas interacts with ChatGPT more actively during the brainstorming phase compared to the formulating phase. By likening his use of ChatGPT to consulting a friend, Thomas indicates that the process of issuing a prompt helps him articulate and organize his thoughts coherently. Furthermore, in the formulating stage, he leverages the Text Document Comparison Site to address the limitations of ChatGPT's output presentation.

The summary of the four cases highlights how the usage patterns of ChatGPT vary among the participants, with each assigning different roles to ChatGPT within their respective writing processes. The following section will present a cross-case analysis of the factors contributing to these individual differences.

5.2 Factors Influencing the Use of ChatGPT: Individual and Contextual Factors

The results reveal that participants' English language proficiency, attitudes towards ChatGPT, and internal writing conventions of laboratories intricately interacted to influence writers' use of ChatGPT in their writing processes.

All participants in this study were members of distinct laboratories at a Korean university. Sam and Collin's lab had a specific writing manual or workflow they were required to adhere to. The research process was scaffolded into specific steps that involved interactive feedback from their advisors. In contrast, Jake and Thomas's lab allowed for more freedom and autonomy in conducting research without a predefined workflow. Consequently, while Jake and Thomas's writing processes were determined by their own volition, Sam and Collin had to follow certain prescribed steps, which in their case included writing a Korean manuscript before drafting in English. Thus, in accordance with the laboratory workflow, Sam and Collin's writing processes inevitably involved L1 mediation or translation.

However, here a dynamic interaction between learner factors and contextual factors emerges. Sam and Collin act upon such conventions in different dynamics. Sam, who has an intermediate level of English proficiency and limited experience in L2 writing, conforms to the laboratory convention stating, "I think not many people in our lab can start writing in English from scratch" (Sam, SR2). Following the lab manual, Sam primarily uses ChatGPT as a translator. On the other hand, Collin, proficient in English with profound writing experience, disagrees with his professor's suggestion. While he does submit a Korean

manuscript to his professor for feedback, he works on writing in English all over again rather than translating from his L1 manuscript. Moreover, as a conservative user who is concerned about data breaches and the influence of AI on his writing style, Collin tends to be cautious in utilizing ChatGPT. Therefore, he does not use ChatGPT during his initial formulating process but employs it during the reviewing process as a reference tool to assist in revising his English manuscript. The difference shown in Sam and Collin's approach to using ChatGPT echoes previous studies (Chen et al., 2020; Wang et al., 2024), which suggest that learners of different English proficiency levels perceive the affordances of AI tools differently.

For Jake and Thomas, who enjoy greater independence in their research within the laboratory, their writing processes were influenced by individual factors such as their own writing goals, proficiency in English, and attitude toward ChatGPT. Jake, possessing high English proficiency has developed his own structured stages of writing through the extensive experience of publishing multiple articles. As an AI expert with a deep understanding of its internal logic, he holds a positive view of its capabilities. Based on his trust in ChatGPT's competence, he has integrated ChatGPT into all stages of his writing process. He employs ChatGPT from the brainstorming phase through to the formulating stage and also uses it to help construct code for his experiments. Moreover, the eye-tracking data reveals that he deeply engages with ChatGPT, reading every output thoroughly with attention. On the other hand, Thomas, who lacks proficiency in English, is highly motivated to enhance his writing skills in the language. As a novice user unfamiliar with ChatGPT's affordances, he harbors ongoing doubts about its competence. While he appreciates the interactive interface and ease of use of ChatGPT, he continuously questions its robustness. Therefore, mistrust of

ChatGPT's robustness intertwined with his motivation to practice English writing, he tends to write English manuscripts by himself during the formulating stage.

Jake and Thomas's use of ChatGPT echoes the findings of Liu and Ma (2024) and Ranalli (2021). Jake's extensive use of ChatGPT reflects their study, which suggests that once learners develop a positive attitude towards ChatGPT, they are likely to demonstrate a higher level of engagement. On the other hand, Thomas's attitude toward ChatGPT aligns with their analysis which states that "perceived ease of use" does not always lead to a positive attitude.

In observing the differences between the two groups—Sam and Collin, and Jake and Thomas—it can be anticipated that the presence or absence of writing instruction may significantly impact the role of ChatGPT in the writing process. When formal writing guidelines or scaffoldings are provided, there is a higher likelihood that ChatGPT's involvement is typically restricted to specific, predefined tasks, as shown in Sam and Collin's case. However, in environments lacking structured writing instructions, ChatGPT's role can expand to include a wider range of contributions, adapting more flexibly to the writer's needs. Meanwhile, the influence of such instructions may be mitigated by personal factors of the learner, such as English language proficiency or their attitude toward ChatGPT as shown in the cases of Collin and Thomas.

The present study reveals that instructors' scaffolding of L2 writers' writing processes and the extent of their engagement such as keeping track of students' writing process or providing feedback influenced L2 writers' use of ChatGPT. This overall trend is consistent with earlier studies (Hellmich & Vinall, 2023; Lai, 2015; van Alten et al., 2020; Wang et al.,

2024) that claim teachers are crucial agents who mediate and shape learners' self-directed use of technology for learning outside of the classroom. Currently, most research on using ChatGPT in writing (Choi, 2023; Im, 2023; Lee, 2023; Warschauer et al., 2023) focuses on providing explicit pedagogical and metacognitive guidance on how to use ChatGPT for composition. Notably, Warschauer et al. (2023) propose an AI literacy framework, which suggests a systematic approach to integrating AI tools into writing, such as understanding the basic functionalities of AI tools and scaffolding the prompting process to aid students in creating precise and expert prompts. However, the current study shows that instructors' sophisticated scaffolding of the complex academic writing process into smaller assignments, and their engagement with students in between the sequencing of the scaffolded assignments, can largely contribute to shaping L2 writers' use of ChatGPT. This aligns with Barrot's (2023) suggestion that underscores the importance of returning to the basics of writing pedagogy to highlight the value of the writing process to the students.

Another contextual influence is found in participants' employment of tools. According to the research findings, along with ChatGPT, all four participants used the tool Overleaf in their writing process. Since this research was conducted in a naturalistic setting, the researcher did not control the use of any tools. However, all participants consistently utilized Overleaf alongside ChatGPT throughout their writing process. As Collin stated, "Overleaf is fundamental across STEM fields" (Initial semi-structured interview). Nearly all journals in the field of computer engineering require submissions in either LaTeX or Word format. Renowned publishers such as Nature, Springer, and Cambridge University Press partner with Overleaf to streamline the submission process. Given these publishing practices

in the STEM academic community, the use of Overleaf has become a prerequisite for writers.

The findings of this study, reveal a complex interplay of personal, technological, and institutional factors influencing the use of ChatGPT in academic writing processes. This is a unique aspect of the study, as most previous research on ChatGPT in L2 writing has not captured learners' autonomous writing behaviors outside of the classroom from an ecological perspective. Participants' language competence and attitude toward ChatGPT interact actively with internal regulations of laboratories to attribute ChatGPT a certain role in the writing process. Concurrently, publishing practices mandated by major journals, which require submissions in formats supported by Overleaf, significantly influence the L2 writers' choice of digital tools. The use of Overleaf, in turn, influences how ChatGPT is utilized or positioned in the writing process. Such results confirm the findings of previous studies (Godwin-Jones, 2022; Hellmich & Vinall, 2021; Larsen-Freeman, 2018; Li & Zhang, 2023), which claim that a single tool used in different contexts is likely to show a wide variety of results due to the dynamic interplay of layered relationships among the writing ecology.

5.3. Use of ChatGPT in L2 Writing Process: An Assemblage of Writers, Tools, and Actions

The results reveal that ChatGPT is not utilized in isolation but integrated within a dynamic assemblage of tools to support L2 writers' specific and immediate writing tasks.

Participants in this study utilized different sets of tools, assigning distinct roles to

each based on their affordances. For instance, Sam and Jake employ Overleaf exclusively for the documentation of final drafts that meet satisfactory text quality standards. Conversely, for early-stage activities such as brainstorming, outlining, or composing initial drafts, they turn to tools like Dynalist or Notion, which offer affordances more aligned with structuring and organizing ideas. In contrast, Thomas and Collin utilize Overleaf as their primary platform throughout all stages of text creation, from initial drafts to final documents. Identification of a range of digital software and resources used by L2 writers is a distinctive feature of this research, an aspect not explored in studies that limit and control the resources available to participants. The current research's ecological and naturalistic research design enabled a more authentic examination of the tools employed by learners.

The timescape of tools and actions reveals that these heterogeneous tools with different affordances and internal logic continuously assemble and disassemble across the writing process to serve the writer's immediate needs. As the session progresses, the configurations of tools emerge and transform in a non-linear manner. These patterns parallel earlier investigations (Gánem-Gutiérrez & Gilmore, 2018; Lai & Chen 2015; Leijten et al., 2014; Ning, 2022; Séror & Gentil, 2023; Yoon, 2014, 2016a, 2016b), which reported that participants used multiple resources in combination to address emerging writing problems.

Participants exhibit distinct patterns in assembling their tools, either by spatially forming a configuration or temporally forming a sequential arrangement. For instance, Sam and Thomas prefer a spatial assemblage, arranging tools on the same screen for seamless interaction between ChatGPT and other applications like Notion or Overleaf. For Sam, who uses ChatGPT as a translator, the spatial organization of arranging ChatGPT and Dynalist

side by side allows him to effortlessly compare his Korean outline in Dynalist with the translation provided by ChatGPT. This layout not only streamlines the workflow but also supports Sam in ensuring his original intent in writing, as he can immediately identify and make modifications if any discrepancies exist between his L1 outline and the translation generated by ChatGPT. This finding aligns with previous research by Séror and Gentil (2021) and Hort (2020), who report that writers strategically organize their digital workspace to scaffold their writing process, thereby creating new opportunities for making meaning.

On the other hand, Jake and Collin opt for a temporal assemblage, systematically switching between ChatGPT and Notion or ChatGPT and Overleaf rather than displaying them simultaneously. While this method might appear less efficient, it serves a strategic purpose for Collin. By intentionally distancing his writing space, Overleaf, from ChatGPT, he can focus more deeply on revising his compositions independently, ensuring that his unique writing style is prominently reflected in his work.

Such an assemblage is shaped not only by the arrangement of tools but also by the participants' micro-actions. These include Zig-zagging, Drag-and-drop, and Incorporating ChatGPT Output into Writing. When transferring their composition from platforms like Overleaf or Notion to ChatGPT, all participants engage in the same action: copy and paste. However, when it comes to incorporating ChatGPT's output into their own writing spaces, participants display different attitudes. Sam and Jake tend to directly copy and paste the ChatGPT output into their writing spaces, whereas Collin and Thomas are more cautious, choosing to manually type results from ChatGPT into their writing spaces. Although these behaviors may seem trivial, they are significant indicators of the writer's agency, which

influences the dynamic network emerging within the digital writing space. During the writing process, ChatGPT, other digital tools, and participants spontaneously intersect at specific moments, forming an assemblage where new meanings emerge (Ou & Malmström, 2023; Pennycook, 2017). Within these assemblages, writers align their composition skills, linguistic repertoire, and spatial repertoire with ChatGPT affordances to optimize the outcomes of their academic writings (Canagarajah, 2018, 2021; Ou & Malmström, 2023).

Interestingly, as the writing process evolves, the tools that form the assemblage vary, but ChatGPT remains constant. However, ChatGPT's constant presence does not imply it serves a static role. Depending on the writing context and the other tools it is used with, ChatGPT's role continuously changes. In other words, the affordances of ChatGPT vary depending on *which stage of the writing process it is situated* and *which other tools it is used with*.

Jake and Thomas, who work on the planning and formulating stages of writing during the three sessions of eye-tracking, utilize ChatGPT for inquiring about domain-specific knowledge and editing respectively. Notably, during the planning phase, Thomas uses ChatGPT in conjunction with Overleaf. In this setup, ChatGPT additionally serves as a technical advisor by providing LaTeX template code, assisting Thomas who is not familiar with Overleaf's formatting capabilities. Thomas's case shows how the affordances of ChatGPT are shaped by both the writing process and its surrounding material, Overleaf.

Moreover, Sam uses ChatGPT for two different purposes during the gradual evolution of his writing process. During the initial phase of writing, when Sam is constructing

a Korean outline, ChatGPT serves as a placeholder generator. However, as the writing progresses and Sam moves on to translating his Korean outline into an English manuscript, ChatGPT serves as a sophisticated translator. The use of ChatGPT for translation during the latter phase of writing is predictable, as machine translation is one of the key affordances of ChatGPT. However, its utilization as a placeholder generator during the planning phase is unexpected, as it diverges from the more typical application of ChatGPT for assisting the construction of an outline. In the initial stage, where Sam is constructing a Korean outline, the translating function of ChatGPT is not inherently required. However, Sam uses ChatGPT for translating purposes and it generates a considerable amount of English text. This unexpected use of ChatGPT emerges due to the constraints imposed by the Overleaf tool integrated with Sam's desire to preview the arrangement of figures. In Overleaf, the placement of figures depends on having a certain amount of text, as users cannot arbitrarily adjust figure positions. Consequently, Sam employs ChatGPT to generate appropriately sized text blocks to facilitate figure placement in Overleaf and to check the readability of the figure. Again, Sam's case highlights how ChatGPT's affordances vary throughout the writing process, depending on the other tools that it is surrounded by and the process it is situated.

These findings confirm reports from the interview or survey-based studies on L2 writers' perception of the role of ChatGPT in writing, such as a thinking partner (Warschauer et al., 2023; Zou & Huang, 2023), facilitator of the ideation process (Chan & Hu, 2023; Warschauer et al., 2023; Zou & Huang, 2023), and manuscript polisher (Chan & Hu, 2023; Zou & Huang, 2023). By tracking the moment-to-moment writing process and capturing both gaze and non-gaze behaviors, the current study provides additional behavioral evidence

supporting these findings. Moreover, the current study expands on previous research, demonstrating that ChatGPT's role evolves throughout the writing process and is influenced by other digital resources actively participating in the digital writing space.

5.4 L2 Writing Process around the Use of ChatGPT: Before and After Prompting

The results indicate that participants generally dedicate more time and effort to activities occurring before and after the prompting process. This pattern is particularly evident during the formulating stage of writing, where all participants, except Jake, typically offer prompts with limited input beyond their own writings.

While prompting occurs frequently during the brainstorming stage, in other stages of writing, such as formulating and reviewing, there is a noticeable decline in engagement with prompting. In the formulating phase, most participants exert minimal effort in crafting prompts. For instance, Collin, who primarily focuses on reviewing his manuscript during three eye-tracking sessions, spends an average of just 27 seconds on prompting per 30-minute session. During the three sessions, except for the one prompt he gave in the first session, all prompts involved simply copying and pasting his paragraph without any other instructions added. Similarly, Sam, who is engaged in the formulating stage across three sessions, spends an average of four minutes on prompting in each 30-minute session. Although Sam spends more time on prompting than Collin, this additional time is not spent providing specific instructions for precise prompting but rather revising his writing given as input to ChatGPT

to better clarify his intentions. Notably, Sam's investment in formulating a prompt decreased drastically after he subscribed to ChatGPT 4.0, which supports a personalized GPTS function. Participants' simplistic effort in formulating prompts reflects Fischer's (2007) study, which revealed that despite various components designed in CALL tools, learners tend to overuse a single basic function that they find most efficient and appropriate for their immediate tasks.

This observation shows a different trend from the recent literature (Knoth et al., 2024; Hwang et al., 2023), which argues that *prompt literacy*, "an ability and skill to generate precise input for generative AI, interpret the output, and modify prompts to achieve desired results" is crucial. Instead, participants in this study seem to prioritize articulating their thoughts over spending time crafting precise prompts with specific conditions, capitalizing on additional time afforded by ChatGPT's assistance.

In a similar vein, participants prioritize *pre-prompting* activities that precede the issuance of a prompt. During this phase, their primary goal is to convert their abstract thoughts into coherent and logical language, ensuring their intentions are clearly articulated. Especially, Jake and Collin report changes in their writing style during the pre-prompting stage; they note increased fluency in writing as they shift their focus from grammatical precision and perfect word selection to expressing their ideas more freely. Knowing they will use ChatGPT to refine their text, they invest their attention in accurately articulating their core thoughts. Contrary to concerns reported in several studies suggesting that ChatGPT might hinder critical thinking skills, L2 writers seem to benefit from more opportunities to invest in logical thinking, as they are now less burdened by concerns about grammatical accuracy and lexical diversity. This result aligns with Zou and Huang's (2023) discussion

about how ChatGPT can allow learners to allocate more cognitive resources toward critical thinking by providing linguistic aid. Moreover, it extends Warschauer et al.'s (2023) and Vygotsky's (1991) argument that asserts that tools do not merely cause new actions but bring changes to the overall structure and cognition of human activity.

Furthermore, during the process that follows prompting or the *post-prompting* stage, reading becomes a central focus for participants, each adopting their own strategic approach. Sam and Jake report that they read the ChatGPT output as if it were an article written by someone else, meticulously checking for any deviations from their intentions and making the necessary revisions. Conversely, Collin, concerned about ChatGPT's output infringing on his unique writing style, strategically avoids reading the output thoroughly and instead focuses on specific phrases he intends to revise. Notably, Thomas, who experiences fatigue from processing long English texts, utilizes another software, the Text Document Comparison Site (TDCS), to visualize the modifications ChatGPT has made to his original input.

After reviewing the output, participants employ various strategies to incorporate the ChatGPT-generated output into their writing. Primarily, they make revisions to clarify their original intentions. Sam and Jake copy and paste ChatGPT's translation or polished manuscript into their own writing space, making revisions such as deletion and paraphrasing. They adjust the text to ensure the use of terminology specific to their field and address any nuances that ChatGPT may have overlooked or altered during the translation or refinement process. Additionally, Jake makes further revisions to reduce the tone of ChatGPT in his writing, which he refers to as ChatGPTish words. On the other hand, instead of making direct revisions to ChatGPT's output, Collin and Thomas make changes to their own writings while

referring to ChatGPT's output. By alternating between two software applications or toggling between screens, they seek different phrasing options or grammatical revisions suggested by ChatGPT to enhance the quality of their writing. Typically, Collin consults Google to verify the appropriateness of ChatGPT's suggestions before incorporating them into his writing. These processes observed in the post-prompting stage resemble the post-editing strategies (Shin & Chon, 2023) and machine translation output analysis strategies (Hellmich & Vinall, 2023) specified in previous studies on L2 writers' usage of machine translators.

Taken together, the findings show that the use of ChatGPT in writing does not merely signify *prompting*. Processes that occur before and after prompting involve a more dynamic interaction between the learner, ChatGPT, and other tools, ultimately leading to richer meaning-making activities. Consequently, to fully grasp how ChatGPT integrates and transforms L2 writers' composition processes and to expand our understanding of prompting's role in writing, it is essential to understand prompting from a broader perspective, shedding light on writers' pre-prompting and post-prompting processes.

CHAPTER 6.

CONCLUSION

This chapter presents the conclusion of this research. In Section 6.1, the major findings of this study will be summarized. Section 6.2 offers the theoretical, pedagogical, and methodological implications of the present study. Section 6.3 will discuss limitations and suggestions for future research.

6.1 Major Findings

The principal goal of this study was to understand the reality of how L2 writers employ ChatGPT in their natural writing processes. To examine the situated practice of STEM graduate students' use of ChatGPT in writing, this study adopted an ecological perspective of language learning. This perspective provided a holistic lens to understand ChatGPT's dynamic interaction with L2 writers and their surrounding environment. Employing an unobtrusive observation method via webcam-based eye-tracking, the study meticulously documented the moment-to-moment engagement of four participants with ChatGPT as they undertook self-initiated writing tasks. This approach minimized researcher interference, preserved the authenticity of the writers' interactions with ChatGPT, and offered profound insights into their real-world writing processes.

The fine-grained analysis of students' writing processes reveals that L2 writers' use of ChatGPT is entangled with various material and immaterial elements across multiple layers of their writing environment, including attitudes towards ChatGPT, English language

proficiency, internal conventions of respective laboratories, and collaborative writing platforms.

Notably, the affordances of ChatGPT vary depending on the stage of the writing process and the other tools it is used alongside. The results indicate that ChatGPT is not utilized in isolation; rather, it operates within a dynamic assemblage of heterogeneous tools, each with distinct affordances and internal logic. These tools continuously assemble and disassemble throughout the writing process to serve the writer's immediate needs.

Furthermore, participants generally did not spend much time crafting precise prompts but engaged with ChatGPT more actively before and after issuing a prompt. Rich meaning-making activities emerged during the pre-prompting and post-prompting phases, where participants dedicated considerable time and effort to articulate their abstract thoughts into words. Moreover, they made efforts to control the extent of ChatGPT's intervention in their writing to enhance their authorial voice. These findings suggest that the boundaries of prompting are ambiguous within the academic writing context. It is necessary to understand L2 writers' use of ChatGPT from a broader perspective, beyond merely developing prompts to efficiently utilize language models.

6.2 Implications

6.2.1 Theoretical Implications

The current study offers several theoretical implications regarding the suitability of adopting an ecological perspective to comprehend L2 writers' utilization of ChatGPT. The ecological approach has significantly contributed to capturing the subtle dynamics of the interplay between L2 writers, ChatGPT, and their surrounding environment. The findings of the present study demonstrate that the affordances of ChatGPT are emergent and context-dependent, evolving according to the specific tools it is integrated with and the unique needs of L2 writers. The nature of this tool is inherently multifaceted, and its interactions with L2 writers, who themselves are evolving, result in highly dynamic and unpredictable usage patterns. By adopting an ecological approach, the study was able to identify previously unrecognized contextual dynamics that shape ChatGPT's role in the composition processes of L2 writers.

Considering the affordances and agentive roles of ChatGPT, it may become imperative to conduct research from an ecological perspective in the future when AI is introduced into educational environments or developed for educational purposes. The ecological perspective will contribute to the investigation of unpredictable or unforeseen interaction patterns that AI, including ChatGPT, may introduce into classrooms or language learning environments.

6.2.2 Pedagogical Implications

The findings of the present study highlight several key pedagogical implications for the evolving educational landscape, which is currently experiencing the integration of AI tools into language education.

Firstly, as detailed in previous sections, individual participants independently formulated unique strategies for integrating ChatGPT into their writing processes. Without direct intervention or external guidance on how to use ChatGPT effectively, participants adapted their approaches based on the dynamic challenges they encountered throughout the writing process. Through constant interaction with ChatGPT, they gained knowledge about its robustness to their input. Moreover, by experimenting with various linguistic, spatial, and digital resources, they progressively refined their usage patterns to optimize the utility of ChatGPT in various stages of writing. This observation offers significant implications for educators and L2 writing instructors. Rather than solely focusing on inducing effective methods for using ChatGPT in L2 writing, it might be more beneficial to observe and consider the strategies L2 writers have already forged through their trial and error in real-world writing contexts. By doing so, teachers and practitioners can develop more practical and authentic ChatGPT usage strategies that better align with the needs of language learners with different proficiency levels situated in various contexts.

Second, despite considering the integration of these model strategies into their learning objectives or curriculum design, it is crucial that educators understand and recognize the diversity of individual learner behaviors. As illustrated in the case of the four participants,

in an everyday context, there are a variety of factors that influence students' approaches to utilizing ChatGPT. Therefore, trying to standardize the ChatGPT usage pattern into a one-size-fits-all method would be impractical. Consequently, teachers should acknowledge L2 writers' differences and aim to identify effective strategies within this diversity.

Nevertheless, if educational interventions are deemed necessary, careful consideration could be made regarding what instructions can be offered to L2 writers during the pre-prompting and post-prompting stages. As discussed in the previous chapter, active and dynamic meaning-making activities emerge during the pre-prompting and post-prompting stages. Therefore, contemplation of instructional methods suitable for these two processes, where composition actively takes place, could be meaningful in directly contributing to L2 writers' enhancement in writing competence.

6.2.2 Methodological Implications

The present study's findings suggest that, when triangulated with screen recording and stimulated recall data, webcam-based eye-tracking can provide benefits to writing process research in two key aspects.

First, webcam-based eye-tracking allows for an unobtrusive and ecologically valid investigation of the L2 writing process. By using webcam-based eye-tracking, research can be conducted in the space and time most convenient for the participants, thereby enhancing the ecological validity of the data collected. Moreover, the use of participants' personal devices in webcam-based eye-tracking allows them access to their habitual digital tools and

resources. Within their own digital settings, participants' authentic tool usage and writing behaviors can be observed.

Secondly, the gaze plot recordings obtained from webcam-based eye-tracking provides profound insight into the dynamic interaction occurring within the digital writing space. For instance, L2 writers' reading patterns traced by gaze plot recordings offer insights into their engagement level with ChatGPT. The extent of a learner's involvement and engagement with ChatGPT is identifiable through the reading patterns revealed by the eye-tracking data. Gaze data, triangulated with screen recording and stimulated recall interview data, can offer a robust understanding of L2 writers' decision-making processes when they incorporate outputs from ChatGPT into their writings. Additionally, eye-tracking data is instrumental in identifying where participants' attention is directed in environments characterized by the spatial organization of multiple tools. As Hort (2020) claims, writers tend to navigate and move between multiple resources in academic writing. During this navigation, often no mouse movement or typing action accompanies. Hence, only with screen recording data, it may seem the writer is pausing. However, with the aid of eye-tracking, various behaviors such as Re-reading, Zig-zagging, ChatGPT Output Reading, ChatGPT Output Scanning, Scrolling, and Overleaf Compile, can be identified. Identification of these gaze-behaviors allows for a more comprehensive understanding of L2 writers' interaction with ChatGPT.

6.3 Limitations of the Study and Directions for Future Research

This study has shed light on L2 writers' naturalistic usage of ChatGPT by observing their moment-to-moment emergent writing processes. However, there are three major limitations in this study that could be addressed in future research.

First, while the rationale for selecting EFL STEM graduate students as the participants was explicitly justified, the homogeneity of this group limits the generalizability of the findings. This study investigated graduate students characterized by three features: 1) knowledge in the AI domain, 2) consciousness of academic integrity, and 3) utilization of various online tools. These distinct features were indicated in the results as significant factors that shaped the four participants' usage of ChatGPT. Therefore, the current study's findings may not extend to other demographic groups, such as younger EFL learners or undergraduates, whose attitudes, goals in writing, and consciousness of academic integrity differ significantly from the participants of the present study.

Secondly, there was great variability in participants' writing tasks and writing processes. While this variability enriched the insights into how ChatGPT is used across various tasks and stages of writing, it complicated the direct comparison of usage patterns among participants. Consequently, the frequency and duration data of tool and action codes had limited value in only explaining each participant's usage pattern, although it had the potential to suggest meaningful comparisons in how much time and attention each participant allocated to micro and macro processes, as suggested in Gánem-Gutiérrez and Gilmore (2018).

Finally, the study also had some methodological limitations. As webcam-based eye-tracking requires participants to keep their heads still throughout the recording, 30 minutes was considered the maximum duration for each session to ensure participants' convenience and the accuracy of the gaze data. Consequently, with eye-tracking conducted three times, 90 minutes of each participant's writing process was investigated. Although this time frame provided profound insights, it only captures a brief segment of the lengthy academic writing process. Therefore, participants might exhibit different usage patterns at various stages of their writing.

Given these limitations, further research is recommended to explore the use of ChatGPT across various population groups with different motivations and contexts for writing. Moreover, a longitudinal study that investigates L2 writers' use of ChatGPT throughout the entire academic writing process, utilizing more sustainable methodologies, is recommended. Such longitudinal tracing of L2 writers' usage of ChatGPT may provide insight into the influence of ChatGPT on L2 writers' language development or the gradual changes ChatGPT brings into L2 writers' writing processes.

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APPENDICES

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Appendix A

Initial Semi-Structured Interview

1) 개인정보

- 나이, 성별, 학교 및 전공(소속 랩실)
- 석사/박사 학기, 연구주제

2) 영어실력

- 공인인증 시험을 본 적이 있나요? 성적에 대해 말해주실 수 있나요?
- 영어권 국가에 체류하신 경험이 있나요?
- 학창시절의 영어학습 과정에 대해 설명해 주세요.
- 본인의 영어실력을 어떻게 평가하시나요? (읽기, 듣기, 말하기, 쓰기)

3) 영어글쓰기

- 평소 영어글쓰기를 어떤 목적으로 얼마나 자주하시나요?
- 영어논문작성과 관련된 수업을 수강한 적이 있나요?
- 총 몇 편의 학술 논문 기고 경험이 있으며, 그 중 몇 편이 영어로 작성되었나요?
- 본인이 영어로 논문을 쓰는 과정을 준비 단계부터 마무리 단계까지 구체적으로 묘사해 주세요.
- 영어로 논문을 작성할 때 가장 어려운 부분이 무엇인가요? 이 문제를 해결하기 위해 어떤 방법을 사용하시나요?

4) 환경 및 도구

- 영어로 글을 쓸 때 어떤 하드웨어(윈도우 노트북, 맥, 아이패드 등)를 사용하시나요?
- 영어로 글을 쓸 때 어떤 소프트웨어(워드, 엑셀, 등)를 사용하시나요?
- 도구들을 선정할 때 가장 중요하게 생각하는 기준은 무엇인가요?
- 영어로 논문을 쓸 때의 환경에 대해 설명해 주세요. 어떤 도구들을 어떻게 배치하여 사용하시나요? 그림을 그려서 설명해 주세요.

5) ChatGPT 관련

- 영어로 글을 쓸 때 ChatGPT를 사용하시나요? 사용하신다면, 무료와 유료 버전 중 어떤 것을 사용하시나요?

Appendix B

Final Semi-Structured Interview

1. ChatGPT의 사용

- ChatGPT의 사용으로 나의 영어글쓰기 과정에 어떤 변화가 생겼나요?
- 영어글쓰기를 할 때 ChatGPT가 어떤 부분에서 가장 큰 도움이 되었나요? 반면 어떤 부분에서 도움이 되지 못했나요?
- 영어글쓰기를 보조하는 도구로서 ChatGPT를 어떻게 평가하시나요? 장점과 단점을 말씀해주세요.
- 학술적인 영어글쓰기를 보조하는 도구로서 ChatGPT를 어떻게 평가하시나요?
- ChatGPT를 사용할 때 가장 중요한 점은 무엇이라고 생각하시나요?
- ChatGPT를 활용할 때 프롬프팅에 따라 결과물의 품질이 차이가 있었나요?
- 나의 영어 논문 작성 과정에서 ChatGPT의 역할을 한 단어로 표현한다면 어떻게 표현할 수 있을까요?
- 앞으로도 영어글쓰기를 할 때 ChatGPT를 사용하실 것 같나요?
- ChatGPT가 나의 영어글쓰기 실력의 향상에 기여한다고 생각하시나요?

2. ChatGPT와 연구윤리

- 영어논문을 작성하면서 ChatGPT를 사용할 때 연구 윤리적인 문제를 고민하신 것이 있나요? 있다면 어떤 지점에서 고민을 하셨나요?
- ChatGPT를 사용해서 논문을 작성한 후에 ChatGPT의 사용을 명시했나요? 혹은 명시가 필요하다고 생각하시나요?

Appendix C

Stimulated Recall Interview Instructions

- 함께 시선추적 영상을 보며 글을 작성할 당시를 떠올리고자 합니다.
- 영상을 보면 글을 작성하는 과정과 시선의 움직임은 보이지만, 글쓴이의 당시 생각과 의도는 알 수 없기 때문에 함께 영상을 보며 글을 쓰는 당시의 생각들을 회상해보고자 합니다.
- 시선추적 영상을 시청하며 글이 구성되는 과정을 보면서, 이 당시로 돌아가 참여자분의 머릿속에 어떤 생각이 있었는지, 무슨 생각을 하고 있었는지를 최대한 구체적으로 말씀해 주시면 됩니다. 예를 들어, 아래와 같은 내용들에 대한 생각을 이야기해 주실 수 있습니다. 다만 아래의 항목에 제한하지 않고, 생각나는 것들을 모두 말씀해주세요.
 - 글을 구성하는 당시에 작성자 본인이 했던 생각, 글을 구성해 나가는 과정에서 생각의 흐름
 - 당시에 특정한 행동을 했던 의도
 - 그리고 ChatGPT를 글쓰기 과정 중에 사용하면서 했던 생각
- 당연해 보이는 부분, 쓸데없다고 판단하거나 아주 사소한 생각이더라도 말씀해 주세요.
- 연구자가 영상을 2-3분 단위로 재생할 것입니다. 영상이 재생되는 와중에 하고 싶은 말이 있다면 바로 말씀해 주시고, 2-3분 단위의 재생이 모두 끝난 후에 말씀해 주셔도 됩니다. 연구자 또한 질문이 있으면 중간에 질문 드릴 것입니다.
- 당시의 생각을 묻는 것이기에, 기억이 나지 않으면 기억이 나지 않는다고 말씀해 주시면 됩니다.

국 문 초 록

한국 이공계열 대학원생의 L2 작문과정에서 ChatGPT 사용 양상: 생태학적 관점에서의 사례 연구

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2022년 11월 30일 오픈에이아이(OpenAI)의 챗지피티(ChatGPT) 공개 이후, 영어 교육계는 생성형 인공지능의 도구적 유용성에 주목하며 이를 교육현장으로 도입하려는 시도를 가속화하고 있다. 챗지피티를 영어교육에 적극적으로 활용하고자 하는 논의가 활발하게 이루어지고 있는 한편, 실제 영어 학습자들이 챗지피티를 어떻게 사용하고 있으며, 그들의 읽기와 쓰기 관행에 챗지피티가 어떤 변화를 가져오고 있는지를 살피는 시도는 드물게 이루어지고 있다. 챗지피티로 대표되는 생성형 인공지능은, 교육적인 목적이 아닌 범용적인 목적을 위해 개발된 도구로, 사용자와 상호작용하는 방식에 따라 그 도구의 가능성이 무한히 변모한다는 점에서, 교육현장에서 사용되었을 때의 결과가 예측이 어렵고 이것이 영어학습자에게 어떠한 영향을 미칠지 예단하기 어렵다. 따라서 본 연구는 영어교육 현장에서 챗지피티의 도입이나 금지와 같은 의사결정을 내리기 전에 해당 도구에 대한 면밀한 탐구가 선행되어야 한다는 문제의식에서 출발하였다. 이에 본 연구는 실제 영어 글쓰기 과업 수행 중 영어 학습자들이 챗지피티를 언제, 어떻게, 왜 사용하고 있는지, 그리고 이러한 도구의 개입이 그들의 영어 작문 과정에 어떠한 변화를 가져왔는지, 그 현상을 분석하는 것을 목적으로 하였다.

본 연구는 정형화된 학습 맥락이 아닌, 디지털 와일드(Digital Wild; Sauro & Zourou, 2019) 속에서 챗지피티가 영어학습자의 의미형성 과정(meaning-making activity)에 미치는 영향을 생태학적인 관점에서 탐구하였다. 따라서, 학술적 영어 글쓰기를 일상적으로 수행하는 4명의 이공계열 대학원생을 대상으로 사례연구를 진행하였다. 실험실 환경이 아닌 일상

적인 환경에서 영어학습자의 작문과정을 추적하기 위해, 웹캠기반 시선추적, 화면녹화, 회상 자극면담, 그리고 반구조화 면담의 방법론을 활용하였다.

연구의 결과는 다음과 같다. 먼저, 챗지피티 사용 양상은 참여자들의 영어 능력 수준, 연구실의 글쓰기 절차 관행, 영어 글쓰기의 목표, 챗지피티에 대한 인식, 그리고 함께 배치되는 다른 온라인 도구와의 복잡한 상호작용의 영향을 받는 것으로 나타났다. 두 번째로, 참여자들은 연구 주제의 설정, 개요 작성, 영어 작문, 그리고 수정의 과정 전반에 걸쳐 챗지피티를 사용하였다. 이때 챗지피티의 잠재적 기능은 '글쓰기 과정의 어느 단계에 위치하는가' 그리고 '어떤 다른 도구와 함께 사용되는가'에 따라 지속적으로 변화하였다. 참여자들은 글쓰기 과정의 계획, 작성, 검토 단계에서 마주하는 문제상황이나 즉각적인 글쓰기 과제에 대응하여 챗지피티를 노션(Notion) 혹은 오버리프(Overleaf)와 같은 다양한 온라인 도구와 결합하여 디지털 글쓰기 환경을 구성하였다. 이러한 변화하는 맥락 속에서 챗지피티는 언어적 정제, 학술 장르에 부합하는 번역, 전공지식 산출, 그리고 오버리프 사용을 위한 코딩 등의 역할을 수행하였다.

마지막으로, 참여자들은 영어 작문 과정 중 프롬프트 생성을 위해 최소한의 시간과 자원을 사용하면서도, 프롬프트 생성 전과 후에 더 활발한 의미형성 과정에 몰두하는 경향을 보였다. 특히, 프롬프트 생성 전에는 자신의 생각과 주장을 보다 구체적인 언어로 표현해 내는 데에 집중하였고, 챗지피티가 프롬프트에 대한 응답을 출력한 이후에는 자신의 텍스트에 대한 저자성(authorship)과 통제를 유지하며 학문적 진실성을 보장하기 위해 새로운 검토 및 수정 전략을 도입하였다. 이전의 쓰기 관행과 달리 문법과 어휘적 선택에 많은 인지적 노력을 기울이기 보다, 자신의 추상적인 생각을 온전히 언어로 표현하는 것, 그리고 챗지피티에 의해 매개된 글이 본래의 의도에서 벗어나지 않는지를 확인하는 것을 영어 작문의 주요한 과업으로 삼았다.

본 연구의 주요 결과는 생성형 인공지능의 부상으로 변화하는 영어교육 지형 속에서 영어 교수자와 연구자들이 지향해야 할 방향성에 대한 교육적 및 방법론적 시사점을 제공한다. 먼저, 본 연구는 생성형 인공지능 시대의 영어 글쓰기 핵심 역량을 효과적인 프롬프트 작성 능력으로 바라보는 관점에서, 프롬프트 생성 전후의 영어 글쓰기 과정까지 포괄하는 관점으로 확장해야 할 필요성을 시사한다. 나아가, 영어교육 현장에 인공지능 기반의 도구를 도입하거나 교육 목적의 인공지능 도구를 개발할 때, 해당 도구가 교육의 실천에 미치는 영향과 예측하기 어려운 기계와 학생 간의 상호작용 양상을 탐구하기 위해 생태학적 관점의 접근이 필

요함을 제안한다. 마지막으로, 웹캠기반 시선추적의 연구 방법이 디지털 공간에서의 영어 작문 과정 연구를 위한 유용한 도구가 될 수 있음을 보여준다.

주요어: 챗피지티, 인공지능, 영어작문과정, 영어글쓰기, 과정 중심 영어 작문, 생성형 인공지능 기반 글쓰기, 시선 추적, 웹캠기반 시선추적, 생태학적 관점

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