COGNITIVE PATHWAYS: FROM LANGUAGE PROCESSING TO PEDAGOGICAL PRACTICE

by

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Abstract

This dissertation examines cognitive mechanisms underlying learning and evaluates strategies to optimize educational outcomes across three domains: single-word processing, flashcard-based learning strategies, and the integration of generative artificial intelligence (GenAI) tools in postsecondary education.

In the first investigation, a mixed factorial experimental design assessed whether recurrent childhood otitis media produced lasting phonological processing deficits in young adulthood. Participants completed a degraded speech word recognition task with varying phonological congruency while group differences were analyzed via mixed factorial ANOVA. Results revealed significant effects of congruency on word recognition accuracy but no residual phonological deficits attributable to early otitis media, suggesting the operation of compensatory cognitive mechanisms.

The second investigation comprised three experiments evaluating flashcard-based learning strategies. Using between-subjects designs, retrieval practice, spaced practice, and the elaborative Flashcards-Plus method were compared in both paper-based and digital formats. Outcomes measured included test performance, Judgment of Learning (JOL) accuracy, test anxiety, and cramming tendencies. Across experiments, structured retrieval practice and elaborative encoding promoted superior retention, enhanced metacognitive monitoring, and decreased reliance on cramming compared to traditional study methods.

The third investigation explored the application of GenAI tools in education. Experimental studies evaluated how AI-assisted learning influenced cognitive load, learning efficacy, metacognitive engagement, and test anxiety. Students critically assessed AI-generated explanations and writing samples, and quantitative analyses demonstrated that structured AI use

improved learning outcomes and academic confidence while underscoring the need for AI literacy to prevent shallow cognitive processing.

Collectively, the findings contribute to cognitive psychology, educational research, and the Scholarship of Teaching and Learning (SoTL) by elucidating the adaptability of cognitive systems, the efficacy of active retrieval-based study strategies, and the pedagogical opportunities and challenges presented by emerging AI technologies in higher education.

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Dedication

To Devon and Eliyanah — for your love, patience, and the joy you bring to every step of this journey.

1. Introduction: Exploring Diverse Aspects of Cognitive Mechanisms in Learning

How does the human mind navigate the complexities of acquiring, processing, and applying knowledge? From recognizing patterns in sensory input to constructing advanced conceptual frameworks, cognitive mechanisms form the foundation of our ability to learn, adapt, and innovate. These mechanisms drive essential processes such as attention, memory, problem-solving, and decision-making, enabling us to understand and interact with the world. Learning is not a singular, uniform process but rather a multifaceted interaction of cognitive functions, each contributing uniquely to knowledge acquisition, retention, and application (Anderson & Krathwohl, 2001). This dissertation investigates the underlying cognitive mechanisms of single-word processing, examines the efficacy of memory-enhancing learning strategies, particularly flashcards and retrieval-based methods, and explores the role of GenAI in education. Through a series of experiments, the research aims to provide empirical insights into how these domains support human learning and adaptation.

Among these cognitive functions, single-word processing is fundamental to reading and language comprehension, engaging orthographic, phonological, and semantic mechanisms. Chapter 2 of this dissertation focuses on single-word processing, examining how individuals recognize and interpret words through orthographic and phonological processing. It highlights how phonological activation occurs even in silent reading, as supported by recent cognitive and neuroimaging research (Perfetti & Helder, 2022; Seidenberg et al., 2022). This chapter draws on Stanovich's (1980) interactive-compensatory model, which conceptualizes reading as an adaptive and interactive process. Within this framework, cognitive subcomponents such as orthographic, phonological, and semantic processing operate flexibly and in coordination, so that strengths in others can compensate for weaknesses in one area. This perspective supports the

investigation of how individuals with early auditory disruptions may achieve reading fluency through reliance on alternative pathways.

In addition to reviewing theoretical models and empirical findings, this chapter includes an experimental study that explicitly evaluates the long-term impact of early auditory deficits, specifically recurrent otitis media, on phonological activation during silent reading in young adults. By integrating cognitive theory with experimental data, the chapter explores how early disruptions in auditory input may influence the development of phonological awareness and reading ability and whether individuals with a childhood history of otitis media exhibit long-term phonological processing differences in adulthood, offering insights into cognitive compensatory mechanisms. These questions are further contextualized through the lens of the interactive-compensatory model (Stanovich, 1980) that suggests that even in the presence of early phonological deficits, readers may adapt by increasingly relying on orthographic or semantic information to support fluency. In parallel, the Matthew Effect (Stanovich, 2009) highlights how early delays in reading development, if unaddressed, may lead to widening gaps in literacy and cognitive outcomes. Together, these frameworks provide a dual lens for interpreting whether the effects of early auditory disruption are sustained, compensated for, or eliminated over time.

Research on word recognition highlights the interconnected roles of orthographic, phonological, and semantic processing within visual word recognition. In this context, the current work specifically refers to orthographic processing. Various theoretical models, including those proposed by Brysbaert (2022) and Perfetti and Helder (2022), offer distinct perspectives on how these cognitive processes interact to support reading and comprehension. Theories of reading, such as the dual-route model (Coltheart, 2006) and connectionist models (Seidenberg et al., 2022), provide competing explanations for how individuals recognize written words. The

dual-route model suggests that readers rely on two pathways: a lexical route that allows for direct word recognition and a phonological route that involves letter-to-sound decoding. In contrast, connectionist models propose a probabilistic learning mechanism, where neural networks dynamically adjust to linguistic input, strengthening connections between orthographic, phonological, and semantic representations through experience.

The scientific exploration of reading dates back more than a century, with early contributions from James (1890), who examined perception, consciousness, and how the mind interprets written symbols. While James acknowledged the role of both automatic and conscious processes in reading, it was Huey (1908) who first provided an in-depth analysis of word recognition, eye movement patterns, the role of prior knowledge in reading comprehension, and the application of such research to an educational context. This early foundation has since evolved into contemporary models of reading that emphasize the interactive nature of word recognition. The Reading Systems Framework (Perfetti & Helder, 2022) underscores how orthographic, phonological, and semantic components interact dynamically, influencing reading efficiency. The Visual Word Form Area (VWFA), located in the left fusiform gyrus, has been identified as playing a crucial role in recognizing written words by linking orthographic patterns with phonological and semantic information (Perfetti & Helder, 2022). Event-related potential (ERP) studies indicate that phonological activation occurs within 200 milliseconds of word presentation, even in silent reading, reinforcing the view that orthographic and phonological processing are tightly coupled (Seidenberg et al., 2022).

Beyond general reading models, research has examined how early auditory deficits can disrupt phonological processing and, consequently, reading development. Otitis media, a common childhood condition, interferes with consistent auditory input during phoneme

acquisition, potentially leading to weaker phonological representations, mental codes for language sounds, and subsequent reading difficulties (Mody et al., 1999). These findings are consistent with early work by Petinou et al. (2001), who reported that children with a history of otitis media demonstrated significantly poorer phonological and morphophonological perception compared to their peers without such histories. Their results provide empirical evidence that transient hearing loss in early childhood can disrupt the formation of phonological categories, which are foundational for later reading and language skills.

Since phonological awareness, the ability to recognize and manipulate spoken components of words, is a key predictor of literacy outcomes (Carroll & Breadmore, 2018), disruptions in early auditory experience may have lasting consequences. Experimental studies have demonstrated that children with a history of recurrent otitis media struggle with phoneme discrimination tasks, perform poorly in non-word reading assessments, and exhibit delayed phonological awareness (Winskel, 2006). While some findings suggest that these deficits persist into adulthood, others indicate that compensatory mechanisms may allow for partial recovery of phonological skills over time (Zumach et al., 2010). This developmental vulnerability is underscored by Stanovich's (2009) Matthew Effect framework, which posits that early disadvantages in reading can compound over time. Children who fall behind in phonological decoding may encounter less print exposure, slower vocabulary growth, and reduced reading motivation, leading to an escalating cycle of academic underperformance.

These outcomes echo the core claims of the Matthew Effect (Stanovich, 2009), which proposes that initial differences in reading ability, especially in phonological decoding, are magnified over time due to reciprocal relationships between reading proficiency, cognitive development, and exposure to print. Children who develop phonological awareness early gain

greater access to meaningful reading experiences, which in turn accelerate vocabulary growth, syntactic knowledge, and background knowledge. Conversely, those with early phonological deficits are likely to experience slower reading development, reduced engagement with text, and cumulative academic disadvantages. Understanding these cognitive mechanisms has practical applications, particularly in designing interventions for individuals with reading difficulties. Structured phonological training programs and adaptive AI-driven literacy tools have been developed to reinforce grapheme-phoneme correspondences, helping mitigate phonological deficits and improve literacy outcomes (Snowling et al., 2022).

Beyond word recognition, learning and memory play a crucial role in the acquisition and application of knowledge, with flashcards serving as a long-established self-testing tool that leverages retrieval practice, spaced repetition, and elaborative encoding to enhance learning. Chapter 3 of this dissertation systematically evaluates the effectiveness of flashcard-based learning strategies through three experiments. The first experiment compares retrieval practice with spaced practice in digital learning environments to determine which technique optimally supports long-term retention. The second experiment investigates the Flashcards-Plus strategy, a structured flashcard approach that incorporates elaborative encoding, requiring students to paraphrase definitions and generate personalized examples to enhance comprehension (Appleby, 2013; Senzaki et al., 2017). The Flashcards-Plus strategy builds on traditional flashcard use by incorporating elaborative encoding techniques, requiring students to paraphrase definitions and generate personalized examples, which enhances cognitive engagement and promotes deeper learning (Appleby, 2013; Senzaki et al., 2017). The third experiment integrates the Flashcards-Plus strategy with spaced repetition algorithms in digital tools such as Anki, examining whether this combination optimizes learning and reduces test anxiety.

Collectively, these studies provide empirical evidence on how structured study methods impact student performance, self-regulated learning, and academic confidence.

Research has consistently demonstrated that retrieval-based learning strengthens memory pathways by requiring active recall, reinforcing neural connections and reducing forgetting over time (Carpenter et al., 2022). Spaced practice further optimizes memory consolidation by strategically timing review sessions just before forgetting occurs (Cepeda et al., 2006). These techniques engage the hippocampus and prefrontal cortex, reinforcing retrieval cues and minimizing cognitive overload (Yuan, 2022). While traditional flashcards primarily support simple memorization, structured approaches such as the Flashcards-Plus strategy have been shown to enhance retention, comprehension, and application by engaging students in deeper cognitive processing (Senzaki et al., 2017).

The Flashcards-Plus strategy builds on retrieval-based learning by requiring students to paraphrase definitions and generate personalized examples, promoting deeper encoding and metacognitive awareness (Appleby, 2013; Senzaki et al., 2017). Research supports that elaborative encoding strengthens retrieval cues, making recall more automatic and durable (McDaniel, 2023). Experimentally, Flashcards-Plus have been shown to improve knowledge retention beyond traditional flashcards, particularly when combined with spaced repetition. Digital flashcard platforms such as Quizlet (Quizlet, n.d.-a), Cram (Cram.com, n.d.-a), and Anki (AnkiWeb, n.d.) further enhance these benefits by integrating adaptive learning algorithms that automate spaced repetition schedules to optimize review timing (Özdemir & Seçkin, 2024; Fursenko et al., 2021).

Despite the well-documented advantages of retrieval-based strategies, they remain underutilized, often overshadowed by passive study methods such as rereading and highlighting,

which can create a false sense of mastery (Brown-Kramer, 2022). Research indicates that structured flashcard techniques, particularly those incorporating retrieval practice and spaced repetition, not only enhance knowledge retention but also promote deeper cognitive engagement, fostering self-regulated learning (Dunlosky et al., 2013). Furthermore, these strategies have been shown to mitigate test anxiety by reinforcing a sense of control over the learning process, ultimately improving both confidence and academic performance (Rana et al., 2020).

While these strategies improve individual learning, technological advancements have introduced new opportunities to enhance education through artificial intelligence. The role of GenAI in postsecondary education presents a significant shift in the way students engage with learning, offering new opportunities to strengthen study strategies, personalize instruction, and alleviate cognitive challenges such as test anxiety and information overload (Chiu, 2024; Sheikh et al., 2023). As AI-driven tools evolve, they continue to expand their applications in self-testing, writing proficiency, and knowledge retention (Tahiru, 2021). However, despite their growing presence in educational settings, empirical research on their direct impact on learning efficacy, metacognitive awareness, and self-regulation remains in its early stages, highlighting the need for further scrutiny of their influence on academic performance and student well-being (Zawacki-Richter et al., 2019).

This dissertation explores the cognitive impact of GenAI in postsecondary education, with a focus on metacognition, learning efficiency, and self-regulated study strategies. Chapter 4 examines how AI-driven tools shape student engagement with learning materials, analyzing both their cognitive benefits and potential challenges. By investigating how students can integrate AI into their study practices, this research identifies the conditions under which AI enhances or impedes learning, providing insights for optimizing its role in education. Through a series of

experimental studies, the research evaluates the effectiveness of AI-assisted study techniques in improving retention and knowledge application compared to traditional methods. Additionally, it explores students' perceptions of AI-generated content, assessing their ability to critically evaluate, adapt, and effectively incorporate AI assistance into their academic workflows.

A central feature of GenAI in education is its ability to generate new content through deep learning models, ranging from text and images to interactive tutoring responses that align with user input (Chiu, 2024). Chatbots such as ChatGPT function as conversational AI assistants, utilizing pre-trained transformer models to analyze prompts and produce human-like responses (OpenAI, 2023). These tools have demonstrated potential in facilitating content comprehension, supporting self-testing, and enhancing writing skill development, making them valuable academic study aids. Research has increasingly emphasized the ability of AI-enhanced learning environments to develop critical thinking, digital literacy, and independent study habits (Kee et al., 2024; Muthmainnah et al., 2022).

Chapter 4 presents an experiment evaluating the effectiveness of AI-generated explanations in improving conceptual understanding. It examines how students engage with GenAI-integrated interactive assignments, where they critically assess AI-generated content, cross-reference responses with reliable sources, and refine their understanding through iterative self-directed inquiry. The study also explores students' confidence in AI-assisted learning, investigating whether structured dialogues with AI enhance concept clarification, reinforce learning through retrieval practice, and deepen overall comprehension of course material. These applications align with constructivist learning theories, emphasizing active knowledge construction through exploration, problem-solving, and reflection (Piaget, 1952; Vygotsky, 1978).

Beyond its role in content comprehension, another experiment in Chapter 4 explores GenAI's potential to support the development of writing skills and academic self-regulation. The students in this experiment were tasked with assessing AI-generated essays using instructor-provided rubrics with the goal of enhancing students' analytical thinking, structural awareness, and the ability to recognize well-supported arguments.

The ability of GenAI to generate multiple writing samples allows students to compare different writing styles, assess coherence, and refine their compositions based on structured feedback. Despite these advantages, concerns arise regarding cognitive offloading, where students rely excessively on AI-generated text without critically engaging with the material. Studies on cognitive offloading suggest that over-reliance on external tools may reduce active engagement, potentially weakening memory retention and problem-solving skills (Risko & Gilbert, 2016). This passive interaction can weaken retention and hinder the meaningful application of knowledge, underscoring the need for AI literacy training to ensure that students approach AI-generated content with analytical rigour rather than unquestioning acceptance.

From a cognitive load perspective, GenAI offers both advantages and challenges. AI tools have the capacity to reduce extraneous cognitive load by streamlining access to information, automating repetitive tasks, and providing instant clarification of complex concepts (Sweller, 2010). By offloading mechanical cognitive processes, students can allocate more cognitive resources to higher-order learning activities such as critical thinking, application, and schema development (Lombardi & Oblinger, 2007). However, the potential for over-reliance on AI-generated content without active engagement raises concerns about shallow processing and diminished long-term retention. Ensuring the effective implementation of AI in education

requires guiding students toward metacognitive awareness so that they actively interrogate, analyze, and refine AI-generated information rather than passively accepting it.

One of GenAI's most compelling potential benefits is its role in alleviating test anxiety, which has been identified as a significant barrier to academic success, impacting both self-efficacy and performance (Cassady & Johnson, 2002; Gerwing et al., 2015). Structured study interventions such as self-testing, guided study strategies, and real-time feedback mechanisms have been shown to mitigate anxiety by reinforcing students' sense of control over their learning (Rana & Mahmood, 2010). GenAI-powered chatbots may offer a novel approach to reducing test anxiety by creating low-stakes, personalized learning environments that allow students to assess their knowledge gaps and reinforce their understanding without external pressure (Tahiru, 2021). A key research question in Chapter 4 investigates whether AI-driven study companions can reduce test anxiety and enhance students' confidence in their preparedness.

Although students report positive perceptions of AI-assisted study tools, research suggests that test anxiety is influenced by broader psychological factors, including prior knowledge, self-efficacy beliefs, and perceived academic control (Connonn et al., 2016). This indicates that while GenAI can improve learning confidence, it may not fully address the emotional dimensions of anxiety, such as fear of failure or test-related cognitive distortions. Consequently, the most effective approach to integrating AI into education would combine AI-assisted learning with self-regulation training and cognitive-behavioural strategies to manage anxiety.

Despite the clear potential of GenAI to enhance educational outcomes, ethical concerns and institutional policies remain critical considerations in its integration. Research suggests that while students find AI-generated responses useful in understanding complex topics, both

students and educators express concerns about accuracy, misinformation, and the ethical implications of AI use (Eaton, 2023; Mahmud, 2024). A significant issue is AI-generated "hallucinations," where chatbots produce plausible but factually incorrect responses (Chiu, 2024). To counteract this risk, students must be trained to critically evaluate AI-generated content, cross-reference it with peer-reviewed sources, and engage in reflective analysis (Reich & Ito, 2017). Encouraging transparent discussions about AI use and integrating AI literacy programs into curricula can help students navigate its strengths and limitations while fostering responsible engagement with emerging technologies.

As the role of GenAI in higher education continues to evolve, its integration requires a balanced approach that aligns technological innovation with pedagogical rigour (Sana et al., 2020). The findings in Chapter 4 contribute to the broader discourse on AI in education by providing empirical evidence on its efficacy, highlighting potential pitfalls, and offering recommendations for responsible implementation. These findings are particularly relevant to educational and cognitive psychology, as they shed light on how AI tools influence learning strategies, student motivation, metacognitive judgments, and perceptions of credibility and trust in automated systems.

Building on this perspective, this dissertation examines the cognitive mechanisms that underpin learning by exploring single-word processing, retrieval-based learning strategies such as flashcards, and the role of AI in education. The integration of orthographic and phonological processing in word recognition, the application of structured self-testing techniques, and the potential of AI-driven adaptive learning highlight human cognition's intricate yet interconnected nature. By adopting an interdisciplinary approach, this research contributes to the broader effort

of optimizing learning strategies, improving educational outcomes, and leveraging AI-driven tools to support knowledge acquisition and application.

Drawing from cognitive psychology, psycholinguistics, and SoTL, this work integrates empirical findings to refine instructional methodologies and enhance learner engagement. By examining how structured retrieval-based learning strengthens memory retention, how orthographic and phonological processing facilitate efficient word recognition, and how AI-driven adaptive learning tools personalize instruction, this research bridges theoretical insights with practical applications. Ultimately, these findings inform evidence-based pedagogical strategies that support diverse learners, foster metacognitive awareness, and maximize the effectiveness of both traditional and technology-enhanced educational approaches. This dissertation presents three related but methodologically distinct investigations into cognitive processes in postsecondary learners: single-word recognition, flashcard-based learning strategies, and GenAI-supported learning.

A fundamental starting point in this exploration is the process of single-word recognition — a cognitive function essential to reading, language comprehension, and learning at large. Understanding how individuals perceive, decode, and interpret written words requires examining the underlying orthographic and phonological mechanisms that support fluent reading. The next chapter focuses on these processes, investigating theoretical models of word recognition and the neural and cognitive pathways involved in single-word processing. The final section will present an experimental study designed to answer the central research question, whether early auditory disruptions impact phonological processing in young adults, and discuss its findings and implications.

2. Cognitive Mechanisms of Single Word Processing

Recognizing and processing single words is a fundamental aspect of human cognition, forming the basis of reading and language comprehension. This chapter investigates the cognitive mechanisms involved in single-word processing, with a particular focus on orthographic and phonological processing. Specifically, it asks whether early auditory disruption resulting from recurrent otitis media has a lasting impact on phonological awareness and reading ability in adulthood. Drawing on theoretical models and empirical research, it explores how individuals recognize and interpret words and examines whether early auditory disruptions influence phonological awareness and reading ability in adulthood. Understanding the cognitive processes involved in word recognition, particularly orthographic and phonological processing, is crucial for clarifying how reading develops, how early auditory disruptions impact reading ability, and how theoretical models account for individual differences.

Research on single-word processing has highlighted the interplay between visual word recognition, phonological activation, and semantic retrieval, with different theoretical models offering insights into how these processes interact. Recent findings suggest that phonological activation occurs even in silent reading, influencing both word identification and meaning retrieval (Brysbaert, 2022). Masked priming studies have demonstrated that phonological representations are automatically activated even when the reading task does not require pronunciation, reinforcing the importance of phonological processing in fluent reading (Perfetti & Helder, 2022). These findings are further supported by neuroimaging evidence from Pattamadilok et al. (2017), who demonstrated that phonological and semantic systems are activated in a task-independent manner during visual word recognition, providing robust support for the automaticity assumptions underlying connectionist models. Theories such as the dual-

route model (Coltheart, 2006) and connectionist models (Seidenberg et al., 2022) provide frameworks for understanding how readers navigate the complexities of written language. A distinction must be made between these models: the dual-route model posits separate lexical and phonological pathways for reading, whereas connectionist models emphasize a distributed and probabilistic approach to word recognition. Clarifying these distinctions helps contextualize experimental findings. Additionally, studies on individuals with a history of recurrent otitis media offer valuable insights into how early auditory deficits may affect phonological processing and, subsequently, reading outcomes.

This chapter will first discuss major theories of reading, followed by an exploration of the cognitive and neural mechanisms involved in word recognition. It will then review the long-term effects of recurrent otitis media on reading ability, highlighting its implications for phonological awareness. The final section will present an experimental study investigating whether early auditory disruptions impact phonological processing in young adults and discuss its findings and implications.

Theories of Reading

Reading is a fundamental skill that plays a significant role in our everyday lives. From navigating through textbooks in schools to comprehending thought-provoking literary works, deciphering written text is essential to our cognitive development and intellectual growth. However, the reading process is not just a simple act of decoding letters and words; rather, it encompasses a highly complex interaction between cognitive, linguistic, and perceptual systems (Duke & Cartwright, 2021). As such, theories of reading seek to contribute to our understanding of how individuals engage with written texts, their cognitive processes during reading, and the implications for pedagogical practices.

The scientific exploration of reading dates back more than a century, with early contributions from James (1890), who examined perception, consciousness, and how the mind interprets written symbols. Although James touched on the automatic and conscious processes involved in reading, his work lacked the experimental rigour and systematic approach seen in later cognitive research. A more comprehensive analysis of reading was later presented by Huey (1908), whose seminal work provided one of the first in-depth discussions of word recognition, eye movement patterns, and the role of prior knowledge in reading comprehension. Huey's findings laid the foundation for modern theories of reading by demonstrating that reading is an active cognitive process that requires attention, memory, and the integration of visual input with linguistic knowledge rather than a simple visual recognition task.

Building upon this foundation, contemporary reading research has expanded to examine multiple levels of text processing, ranging from word recognition to sentence and discourse comprehension (Snowling et al., 2022). A growing body of studies highlights the dynamic interplay between orthography, phonology, and semantics in skilled reading, demonstrating that word identification is not an isolated process but an integral part of a broader linguistic network (Perfetti & Helder, 2022).

At the core of reading lies the intricate coordination of cognitive processes, including visual, phonological, and semantic processing, all of which contribute to fluent word recognition and comprehension. The Reading Systems Framework proposed by Perfetti and Helder (2022) provides a structured model for understanding these interactions, emphasizing that word identification is not a linear sequence but a dynamic, interactive system. Within this system, orthography enables recognition of printed word forms, phonology facilitates the mapping of written symbols to spoken sounds, and semantics supports the retrieval of word meanings.

Rather than operating in isolation, these processes function in parallel, continuously influencing one another to enable efficient meaning extraction from text (Grainger, 2022).

However, for a comprehensive theory of reading, evidence from word, sentence, and text recognition and comprehension needs to be better integrated (Snowling et al., 2022). Word recognition is a complex process that incorporates orthographic, phonological, and semantic processing. Empirical evidence strongly supports the role of phonology in silent reading, with studies demonstrating that phonological activation occurs automatically during word recognition (Brysbaert, 2022; Perfetti & Helder, 2022). Theories such as the dual-route model and connectionist frameworks offer differing perspectives on how readers navigate the complexities of written language. Furthermore, the effects of early auditory deficits, such as recurrent otitis media, highlight the significance of phonological awareness in reading development. Understanding these cognitive mechanisms can contribute to more effective literacy interventions and educational practices for individuals with reading difficulties.

Recent research underscores the importance of phonology in silent reading, suggesting that it plays a more central role than previously assumed. Studies on bilingual readers and individuals with dyslexia further demonstrate that phonological processing is a core aspect of word recognition and that deficits in phonological awareness can lead to reading difficulties (Brysbaert, 2022). This chapter builds on current reading research by first examining the cognitive mechanisms involved in single-word processing, with a focus on phonological and orthographic processing. It then extends into exploring whether developmental auditory deprivation results in long-term disruptions to these processes, particularly in the efficiency and accuracy of phonological decoding and lexical access.

The investigation of single-word recognition begins with one of the central debates in reading science: how are individual words recognized during reading? While some early theories proposed that words are identified as whole visual units, more recent evidence suggests that letter-based processing plays a crucial role in word recognition (Grainger, 2022). The interactive activation model, for example, suggests that visual features activate letter representations, which then trigger whole-word recognition through a hierarchical process (Perfetti & Helder, 2022). This model supports the idea that word recognition depends on both bottom-up processing (from visual input to letter encoding) and top-down influences from prior linguistic knowledge (Perfetti & Helder, 2022).

Connectionist models challenge the notion of fixed pathways in reading and instead propose that word recognition is based on probabilistic learning (Seidenberg et al., 2022). According to this view, neural networks dynamically adjust to linguistic input, gradually strengthening connections between orthographic patterns and their phonological and semantic representations through experience (Seidenberg et al., 2022). This perspective aligns with findings that suggest reading development is shaped by exposure to print and spoken language rather than the application of pre-defined rules.

In this chapter, several established theories of reading are discussed to provide a foundation for understanding the cognitive processes involved in word identification and comprehension. These theoretical frameworks are then used to guide an empirical investigation of reading mechanisms in two distinct groups of young adults. The first group includes individuals with a childhood history of otitis media, a condition marked by recurrent ear infections that can interfere with auditory processing and phonological development. By comparing this group with a control group of individuals without such a history, the study aims

to assess potential differences in cognitive processing and reading outcomes. Understanding these differences may shed light on how early auditory disruptions influence the development of reading skills and their long-term impact on language processing.

Orthographic Processing and Visual Word Recognition

One of the fundamental components of reading is orthographic processing, which allows the mind to convert visual input into linguistic representations (Murray, 2016; Grainger, 2022). Unlike the outdated "word shape" hypothesis, which suggested that words are recognized holistically, contemporary research supports the letter-based recognition hypothesis. According to this view, word recognition relies on encoding letter identities and positions rather than overall word shape (Grainger, 2022).

Visual word recognition also depends on the Visual Word Form Area (VWFA), a specialized neural region in the left fusiform gyrus that processes orthographic information (McCandliss et al., 2003; Dehaene & Cohen, 2011). Eye-tracking studies have demonstrated that skilled readers adjust their fixations to optimize word recognition efficiency, relying on para-foveal preview and rapid lexical access (Perfetti & Helder, 2022). Furthermore, computational models of word reading have shown that probabilistic mappings between spelling, sound, and meaning govern the efficiency of word recognition (Seidenberg et al., 2022).

The word superiority effect, first demonstrated by Cattell (1886) and later explored in detail by Reicher (1969) and Wheeler (1970), provides additional evidence for the interactive nature of word recognition. This effect suggests that letters within words are more easily recognized than letters in isolation or in random strings, supporting the idea that orthographic processing is influenced by lexical knowledge (Perfetti & Helder, 2022).

Phonological and Dual-Route Models of Reading

While orthographic processing is crucial for word recognition, phonological processing also plays a key role, particularly in early reading acquisition (Grainger, 2022). Phonetic theories are based on the premise that all word orthographies systematically represent phonology, making phonological processing the primary mechanism of word recognition (Liberman et al., 1977; Gough, 1972). These theories propose a bottom-up reading process, in which readers decode written words by associating phonemes (speech sounds) with their corresponding graphemes (letters or letter combinations). As such, phonological awareness, the ability to recognize and manipulate spoken components of words, exists at multiple levels, including word, syllable, onset and rime, and phoneme levels (Gillon, 2017). These phonological decoding theories are primarily grounded in alphabetic languages and may not fully capture the reading processes involved in logographic systems such as Chinese, where orthographic-to-phonological mappings are less systematic; however, both systems rely on mapping visual word forms to meaning, engaging universal cognitive processes that are shaped by language-specific constraints and demands (Perfetti & Helder, 2022).

In contrast, whole-word theories emphasize that skilled readers recognize entire words as meaningful units rather than deconstructing them into phonemes. Sometimes called the sight-word approach, this perspective focuses on the memorization and visual recognition of words rather than phoneme-grapheme correspondence (Gough, 1972; Gough & Hillinger, 1980). This theory differs from phonetic theories, arguing that word recognition relies on stored lexical representations rather than phonological decoding.

A more comprehensive explanation of word recognition is offered by the dual-route model of reading, which suggests that written words can be processed through two parallel

pathways (Coltheart, 2006). The lexical route accesses the semantic lexicon directly, enabling fluent word recognition without phonological mediation. In contrast, the phonetic (sublexical) route deciphers words through a letter-to-sound conversion process (Perfetti & Helder, 2022). This model accounts for differences in how regular (i.e., those that follow standard phonetic rules and therefore can be easily decoded using common letter-sound correspondences) and irregular words (i.e., those that do not follow common phonetic rules and often must be memorized) are read, as well as how phonology influences silent reading.

Figures 1 and 2

Dual-Route Theories of Reading.

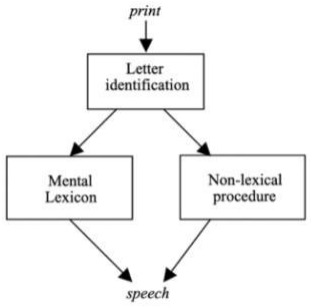


Figure 1. The dual-route theory of reading aloud

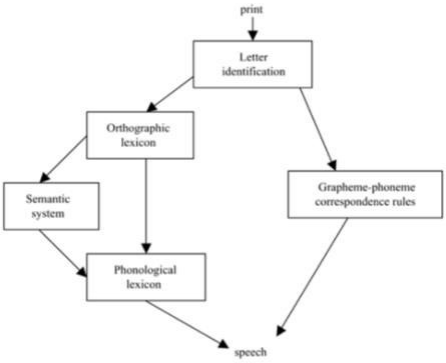


Figure 2. Elaboration of the dual-route theory of reading aloud

Note. Reprinted from "Dual Route and Connectionist Models of Reading: An Overview," by M. Coltheart, 2006, *London Review of Education, 4*(1), 5–17. Reprinted under fair dealing provisions for the purpose of research and education.

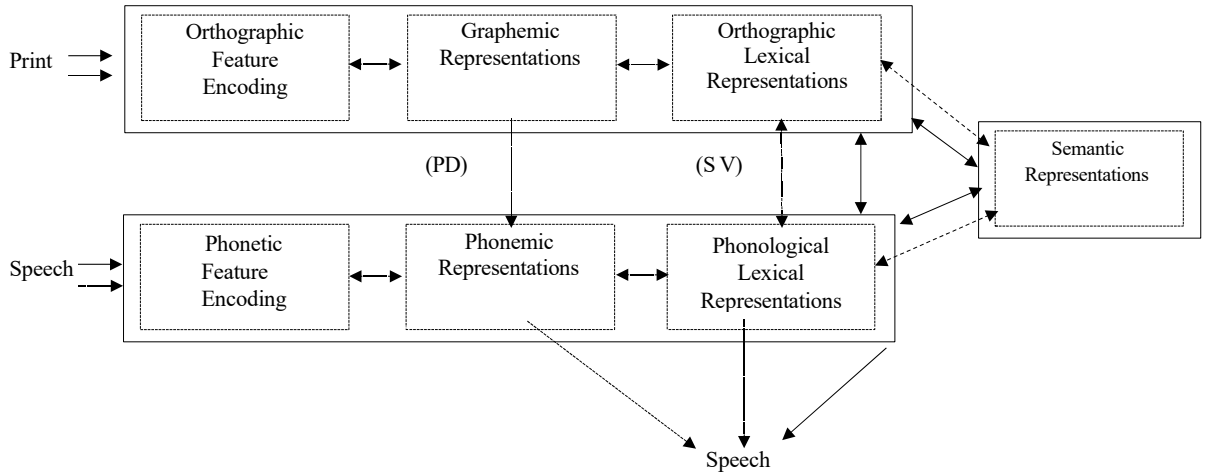
However, recent research suggests that phonological activation occurs even in silent reading, influencing both word identification and meaning retrieval (Seidenberg et al., 2022). Perfetti and Helder (2022) argue that phonological representations are automatically activated

even in tasks that do not require pronunciation, as demonstrated by masked priming studies showing early and involuntary phonological involvement during silent reading. Their Reading Systems Framework highlights the rapid and interactive integration of orthographic, phonological, and semantic processes during word recognition. Drawing on behavioural, computational, and neuroimaging evidence, they show that phonological codes are accessed almost immediately, before a word is fully identified, and contribute not only to decoding but also to comprehension. They further note that while reliance on phonology may vary across writing systems, phonological processing remains a universal component of skilled reading. These findings challenge earlier assumptions that phonology plays only a post-lexical role in reading and instead support a parallel activation model, where phonology, orthography, and semantics interact dynamically during word recognition (Seidenberg et al., 2022).

Expanding upon the dual-route model, Grainger (2018) proposed that orthographic processing serves as an interface between visual perception and linguistic processing in what he terms a "mid-level vision of reading." According to this view, visual features activate letter representations, which then provide input to three pathways for meaning retrieval: (1) orthography-to-semantics via whole-word representations, (2) orthography-to-morphosemantics via morphological representations, and (3) orthography-to-phonology through sublexical spelling-sound correspondences (Grainger, 2018). These pathways interact, demonstrating the complexity of how phonology and orthography contribute to reading comprehension.

Figure 3

Dual-Route Model of Visual Word Recognition.



Note. Reprinted from "Examining the Interactivity of Lexical Orthographic and Phonological Processing," by W. J. Owen & R. Borowsky, 2003, *Canadian Journal of Experimental Psychology / Revue canadienne de psychologie expérimentale, 57*(4), 290. Reprinted under fair dealing provisions for the purpose of research and education. PD = phonetic decoding (i.e., sublexical, assembled phonology) route, SV = sight vocabulary (i.e., lexical, addressed phonology) route.

Within this framework, Owen and Borowsky (2003) conducted a series of experiments to examine the relationship between orthographic and phonological processing in reading. They found compelling evidence that orthographic processing plays a dominant role in activating phonological representations — a stronger influence than previously assumed. Specifically, their results indicated that visual word forms automatically activate corresponding phonological representations, facilitating word recognition.

Their findings revealed an asymmetrical effect: seeing a word strongly influenced how participants recognized its spoken form, but hearing a word had much less impact on recognizing its written form. This asymmetry suggests that orthographic (visual) information has a greater impact on phonological processing than phonological information has on orthographic processing.

Owen and Borowsky (2003) further examined how phonology and orthography interact during word recognition. They found both facilitatory and inhibitory effects by presenting three-letter word triplets (e.g., cap/map/rap) as orthographic stimuli simultaneously with spoken word targets. When the visual word matched the spoken word (e.g., seeing "cap" while hearing "cap"), word recognition was faster and more accurate. However, when the visual and spoken words conflicted (e.g., seeing "cap" but hearing "rap"), participants experienced interference, leading to slower and less accurate recognition.

Crucially, their results showed that orthographic processing (seeing a word) had a stronger influence on phonological discrimination (recognizing the spoken word) than the reverse. This supports models suggesting that reading involves dominant connections from orthographic to phonological processing, rather than equally bidirectional pathways. These findings challenge models assuming equal interaction between phonological and orthographic processes and suggest that reading relies more heavily on learned mappings from print to sound rather than the reverse.

Connectionist Models

Connectionist models, also known as parallel distributed processing models, offer a fundamentally different framework than dual-route theories. Rather than relying on two distinct processing routes, connectionist models emphasize a single, interactive system in which word

recognition emerges from patterns of activation across a distributed network (Seidenberg & McClelland, 1989; Plaut et al., 1996). These models propose that orthographic, phonological, and semantic information is processed simultaneously, with representations learned gradually through repeated exposure and statistical regularities in the language.

Unlike dual-route models, connectionist frameworks reject the idea of modular processing. Instead, they highlight probabilistic learning, through which readers become sensitive to regularities in the mapping between orthography and phonology. Word recognition is thus shaped by how frequently a word has been encountered, how consistent its spelling-to-sound correspondences are, and how strongly it is connected to other representations in the language system.

Computational models further support the probabilistic and interactive nature of word recognition. The connectionist approach proposes that repeated exposure to words enables the mapping of orthographic inputs onto phonological and semantic representations (Seidenberg et al., 2022). This view is reinforced by earlier work from Seidenberg (1987), who demonstrated that readers become sensitive to frequently occurring sublexical structures, such as letter clusters, not because they act as symbolic access units, but because of their statistical regularity across the lexicon.

Recent findings from Perfetti and Helder (2022) also align with the connectionist view. Their Reading Systems Framework emphasizes the automatic and rapid activation of phonological codes during silent reading. Drawing on behavioural and neuroimaging evidence, they show that orthographic, phonological, and semantic processes become active in parallel, even before full word identification is achieved. This challenges the notion that phonological

activation is purely post-lexical and reinforces the idea of dynamic, interactive processing during reading.

Similarly, Seidenberg et al. (2022) assert that phonological activation is a universal feature of skilled reading across writing systems, though the degree of reliance may vary. For instance, while alphabetic languages like English involve strong phoneme-grapheme mappings, logographic languages such as Chinese depend more on morpho-semantic information. Nevertheless, phonology remains integral across orthographic systems.

Connectionist models have also been instrumental in explaining developmental reading disorders, including dyslexia. Rather than attributing such difficulties to deficits in discrete reading pathways, these models view them as disruptions in learning the statistical structure of written language. This perspective offers a more flexible and individualized understanding of reading development and is especially useful for modelling variability in literacy acquisition across different orthographies and learner populations.

Cognitive and Neural Mechanisms in Word Recognition

Advancements in cognitive neuroscience have provided significant insights into how the brain processes written language. Rather than following a strictly sequential path from visual perception to comprehension, word recognition involves the parallel activation of orthographic, phonological, and semantic representations, supported by specialized neural regions (Perfetti & Helder, 2022).

One of the most critical brain regions for word recognition is the VWFA, located in the left fusiform gyrus. This region is responsible for processing orthographic patterns and interacts with other language-related areas to facilitate fluent reading (Grainger, 2022). Rather than simply

storing static word forms, the VWFA dynamically integrates visual information with phonological and semantic cues, supporting efficient lexical access.

Eye-tracking and neuroimaging studies have demonstrated that word recognition is a highly interactive process, with multiple linguistic representations activated simultaneously rather than sequentially (Perfetti & Helder, 2022). For example, event-related potential (ERP) studies indicate that phonological activation occurs within 200 milliseconds of word presentation, even in silent reading, suggesting that orthographic and phonological processing are tightly coupled (Seidenberg et al., 2022).

Additionally, beyond the VWFA, broader cortical networks, including the inferior frontal gyrus (linked to phonological decoding) and the middle temporal gyrus (associated with meaning retrieval), play key roles in reading (Price, 2012). These findings reinforce the idea that word recognition is a distributed process, engaging multiple brain areas in a coordinated manner. This view is further supported by neuroimaging evidence from Petersen et al. (1990), who used PET imaging to demonstrate that medial extrastriate cortex is activated by both real words and pseudowords, reflecting sensitivity to orthographic regularity, whereas only real words elicited activation in the left inferior frontal cortex, a region associated with semantic processing.

These results suggest a functional dissociation between visual word form recognition and semantic access, lending support to the distinction between early, automatic visual processing and higher-order, meaning-based activation in the reading network. By considering both neurobiological and computational perspectives, it becomes clear that word recognition is not merely a visual task but a dynamic process that integrates multiple cognitive systems, allowing for rapid and accurate word identification.

Effects of Recurrent Childhood Otitis Media on Reading in Young Adulthood

Ear infections (otitis media) can influence the typical development of language acquisition and language processing mechanisms. According to Carroll and Breadmore (2018), the chance that children will have at least one episode of otitis media is 83%, with 46% having recurring otitis media episodes before age three.

Clinical subtypes of otitis media include acute otitis media, otitis media with effusion, and recurrent otitis media (Aarhus et al., 2015). Acute otitis media is the first presentation of otitis media that occurs and is associated with a brief onset and duration, fever, intense pain, and increased pressure in the ear (Winskel, 2006). Acute otitis media affects almost 80% of all children before age four or five (Stålnacke, 2022; Jamal et al., 2022).

Acute otitis media can lead to middle ear effusion, where fluid remains in the middle ear after the infection subsides. This residual fluid can obstruct sound wave transmission, resulting in mild to moderate hearing loss that may impair early auditory processing and language development during infancy and toddlerhood (Winskel, 2006; Cai et al., 2018). Although otitis media with effusion typically resolves within three months without intervention, children may still experience a critical period of reduced auditory input during this time (Cai et al., 2018).

Recurrent otitis media occurs when there are multiple episodes of acute otitis media or otitis media with effusion. Recurrent otitis media is defined as three or more episodes of acute otitis media during a six-month time frame or four or more in a period of twelve months (Krakau et al., 2017).

It is critical to note that otitis media has a peak incidence rate at 16 months, coinciding with the critical period of learning language sounds known as perceptual narrowing, when infants “tune in” to the sounds of their native language before the age of 16 months (Winskel,

2006). If otitis media with effusion occurs during the critical period of language development, the infant may experience transient hearing loss and receive inconsistent auditory signals (Mody et al., 1999). Fluctuating speech signals may result in difficulty drawing out consistencies from the speech stream, making the acquisition of phonological awareness more difficult (Mody et al., 1999). Difficulties distinguishing and acquiring phonemes (i.e., the smallest speech units) may lead to phonological deficits (Carroll & Breadmore, 2018). Limited auditory input can lead to a weak encoding of auditory-based phonological distinctions, and underspecified phonological representations may also lead to insensitivity to phonetic characteristics of sounds, affecting the ability to identify and discriminate between sounds (Mody et al., 1999).

Significance of Phonological Awareness

Phonetic categories are essential for recognizing phonemes across a variety of contexts. The development of phonological awareness allows children to implicitly understand that words are constructed from a limited number of sounds (Carroll & Breadmore, 2018). Phonological representations are essential for identifying and discriminating sounds (Mody et al., 1999). The formation of phonological representations is thought to occur between the ages of 12 months and three years and further becomes classified into phonological categories (Carroll & Breadmore, 2018). Partial auditory input resulting from recurrent otitis media can disrupt the formation of phonetic categories and phonological representations, causing them to be limited (Carroll & Breadmore, 2018).

Phonological deficits in children with a history of recurrent otitis media may stem from reduced auditory exposure in early childhood, which can disrupt the formation of stable phonological representations (Mody et al., 1999). In a study using speech perception and verbal short-term memory tasks, Mody et al. (1999) found that these children performed less accurately

than controls when identifying syllable pairs with subtle phonetic differences (e.g., *ba* vs. *da*). They made significantly more errors when the sounds differed by only one phonetic feature (such as voicing or place of articulation), suggesting difficulty distinguishing fine-grained phonological contrasts. These contrasts form the basis of phonological categories — groupings of similar sounds that support word recognition and language development (Berti et al., 2020). Without consistent early auditory input, these categories may remain underdeveloped, leading to long-term challenges in speech perception and processing. Supporting this, Zumach et al. (2010) found that children who experienced more frequent and severe episodes of otitis media in early life performed significantly worse on speech-in-noise recognition tasks at age 7. This suggests that early auditory disruptions may have lasting effects on higher-order auditory processing, which plays a critical role in distinguishing speech sounds in everyday environments.

Phonological awareness, the ability to consciously recognize and manipulate the sound structures of language, such as syllables, onsets, rimes, and phonemes, is essential not only for distinguishing words in auditory form but also for understanding the relationship between print words and their corresponding sounds (Carroll & Breadmore, 2018). As noted earlier, reading is a multimodal activity that engages orthographic, semantic, and phonological processes. Phonological impairments may contribute to the development of reading difficulties. Phonological encoding is an essential foundation for learning how to read because to decode words, children must implicitly learn that words are made up of a limited number of similar sounds across different words and are governed by a specific set of rules (Carroll & Breadmore, 2018). Thus, phonological awareness impacts not only listening to language but also reading.

Winskel (2006) assessed phonological awareness in children aged six to eight by administering a non-word reading task — a standard measure that tests a child's ability to decode

unfamiliar letter strings. Children with a history of recurrent otitis media performed significantly worse than their peers without such a history, suggesting difficulty in mapping phonemes to graphemes. In addition to poorer phonological decoding, these children showed weaknesses in expressive vocabulary and word definition tasks, indicating broader semantic deficits. However, because the children were still in the early stages of reading acquisition, Winskel noted that some impairments may not have been fully developed or detectable at the time of testing. This possibility is supported by findings from Mody et al. (1999), who emphasized that phonological impairments are often subtle and can go undetected by standardized assessments.

While reading typically involves decoding written words using phonological rules, the complexity of this process becomes apparent when considering irregular words — those that do not follow predictable spelling-to-sound correspondences. For example, the word “pint” cannot be reliably decoded using standard phonological strategies and must instead be memorized as a whole. This highlights the importance of phonological awareness, the ability to identify and manipulate the sound structures of language, for both decoding regular words and recognizing irregular exceptions. However, research suggests that children with a history of recurrent otitis media may struggle to develop stable phonological categories due to inconsistent early auditory input, making it more difficult to distinguish similar-sounding words and increasing their reliance on rote memorization for irregular items (Carroll & Breadmore, 2018).

To examine the relationship between auditory experience and reading-related skills, Carroll and Breadmore (2018) compared two groups of school-aged children: those with a history of recurrent otitis media and those identified as poor readers. While both groups demonstrated phonological weaknesses, the otitis media group showed a distinct pattern of impairments, particularly in tasks requiring phoneme segmentation and blending. These findings

suggest that although both groups experienced reading difficulties, the underlying causes differed. Children with recurrent otitis media appeared to have phonological deficits linked specifically to reduced early auditory input, distinguishing their profile from that of age-matched poor readers with broader language impairments.

Complementing this focus on phonological processing, Cai and McPherson (2016) conducted a systematic review to investigate how auditory disruptions associated with otitis media influence children's ability to perceive speech, a foundational skill for developing accurate phonological representations. Their findings revealed that children with otitis media with effusion often experience mild to moderate conductive hearing loss, which negatively affects speech perception in both quiet and noisy environments. Despite variability in assessment methods, the review emphasized that many children are underdiagnosed and untreated, leaving them vulnerable to developmental delays. Extending these findings, Cai et al. (2018) compared speech perception in children with actual otitis media-related hearing loss, simulated hearing loss, and normal hearing. Results showed that while both real and simulated hearing loss impaired speech understanding in quiet, children with actual hearing loss performed significantly better in noisy conditions than those with simulated hearing loss, suggesting that real-world auditory experience may lead to partial compensatory strategies. Together, these findings demonstrate that even mild hearing loss from otitis media can have immediate and measurable effects on speech perception, which in turn may disrupt the acquisition of phonological representations critical for reading.

Importantly, these early disruptions appear to have long-term consequences. Delage and Tuller (2007) found that adolescents with mild-to-moderate hearing loss do not follow typical language development trajectories. Their study of poor readers identified distinct profiles

between adolescents with a history of hearing loss and those with specific language impairments. While both groups showed language difficulties, adolescents with hearing loss exhibited persistent deficits in morphosyntactic skills and sentence repetition — deficits that had not resolved with age. These findings provide compelling evidence that the effects of early auditory deprivation, such as that caused by recurrent otitis media, can extend well beyond the early years and may persist into adolescence and beyond.

Collectively, these studies underscore a critical point: early auditory input plays a foundational role in the development of phonological awareness, speech perception, and higher-level language abilities. The evidence suggests that even temporary or mild hearing disruptions during sensitive developmental windows can have lasting effects. This supports the central argument of the present research that phonological development in individuals with a history of otitis media may follow an atypical trajectory, with implications for reading and language outcomes well into later childhood and adolescence.

Long-lasting Effects of Otitis Media

Recurrent otitis media is suspected to have long-lasting impacts on speech and language skills, including language delays, phonological impairments and reading difficulties. One large cohort study indicated that acute recurrent otitis media in childhood is associated with adult hearing loss (Aarhus et al., 2015). However, not all research findings have been conclusive regarding the long-lasting effects of childhood recurrent otitis media: despite several studies revealing long-lasting phonological impairments resulting from childhood recurrent otitis media (Carroll & Breadmore, 2018; Mody et al., 1999). Zumach et al. (2010) conducted a longitudinal study following 65 Dutch children from infancy to school age and found no significant long-term differences in language comprehension or production between children who experienced early-

life otitis media and those who did not. The authors concluded that while otitis media and related hearing loss may temporarily affect early language development, these effects resolve over time, with children achieving age-appropriate language outcomes by ages 6 to 10. This finding contrasts with earlier studies and suggests that the long-term impact of otitis media on language skills may vary depending on factors such as the duration and severity of hearing loss, intervention timing, and individual resilience.

Investigating the effects of recurrent otitis media in early childhood on phonological processing in adulthood is crucial for understanding its long-term impact on language perception. Examining how early auditory disruptions influence phonological skills over time can provide valuable insights into the cognitive mechanisms underlying language comprehension and production in adults. This research can also inform educational and clinical approaches aimed at supporting individuals who may experience subtle but lasting effects on their phonological processing abilities.

Experiment

Method

Participants. Research participants aged 18 to 30 were recruited via the UNBC Department of Psychology's research participation system in return for course credit. Before taking part, the participants were requested to confirm their exact history of childhood ear infections with their caregivers. Based on their self-reported history of otitis media, participants were categorized into (1) a group with childhood recurrent otitis media if they experienced three or more recurring episodes of ear infections in childhood (N = 22) and (2) a group that never had otitis media in childhood (N = 36). Participants who reported one or two instances and those who were unsure about their history of childhood otitis media were excluded from the analysis (N =

26). Both groups included male and female participants who had normal (or corrected to normal) vision, were native speakers of English, and had no learning or reading disabilities, comprising a total of 58 research participants.

Materials. This section describes the experimental design, stimuli, software, and procedures used to examine phonological processing in participants with and without a history of recurrent otitis media.

Design and Stimuli. The two-alternative forced-choice paradigm developed by Owen and Borowsky (2003) served as the foundation for the present study's design to investigate facilitation and inhibition effects in young adults and determine whether individuals with a history of recurrent otitis media exhibit impaired phonological awareness, defined as the ability to recognize and manipulate the sound structure of words. This study used a mixed factorial design, with one within-subjects factor (context condition: congruent, incongruent, irrelevant) and one between-subjects factor (group: recurrent otitis media history vs. control). The primary independent variables were context condition and group, and the dependent variables were response accuracy and reaction time.

The hypothesis predicted that participants without a history of early recurrent otitis media would demonstrate a facilitation pattern, where congruent orthographic and phonological information enhances accuracy more than incongruent information hinders it, a pattern consistent with the results reported in Owen and Borowsky's (2003) original study. They found that phonological congruency effects in word recognition tasks typically follow a quadratic trend, with the highest accuracy in congruent trials, moderate performance in irrelevant trials, and the lowest accuracy in incongruent trials. This graphical pattern provides a diagnostic indicator of facilitation versus interference effects in phonological processing. In contrast, participants with a

history of early recurrent otitis media were expected to show comparable levels of facilitation and inhibition, suggesting that disrupted early auditory input may have resulted in weaker or incomplete phonological representations — the mental sound-based codes — that enable phonological awareness.

To evaluate these hypotheses, the analysis used a mixed factorial ANOVA to compare mean accuracy across the three context conditions (within-subjects) and between the two groups (between-subjects). If supported, such findings would provide evidence that recurrent otitis media can produce subtle but lasting effects on phonological processing and broader language development.

Software and Presentation. Owen and Borowsky (2003) added low-level white noise to spoken word targets to degrade auditory stimuli, increasing task difficulty and sensitivity to context effects. The present study adopted this approach using noise-masked auditory stimuli to evaluate phonological processing under challenging listening conditions. Clinical speech-in-noise tests often incorporate background conversations or multi-talker babble (Brady & Calcus, 2021), but such stimuli can introduce semantic interference known as the "cocktail party effect." To minimize this confound, the study employed white noise instead of spoken distractors, ensuring that signal degradation occurred without introducing linguistic content that might redirect attention. The experiment was designed and administered using the Gorilla Experiment Builder (gorilla.sc), and all participants conducted the sessions on a desktop computer in the psychology lab at the University of Northern British Columbia (UNBC).

To measure facilitation and inhibition effects, the experiment presented an orthographic "context" word in the visual modality simultaneously with a degraded target word in the auditory modality. Context-target pairings fell into one of three conditions: congruent (e.g., context:

"cap"; target: /cæp/; response options: "cap"/"map"), incongruent (e.g., context: "cap"; target: /mæp/; response options: "cap"/"map"), or irrelevant (e.g., context: "cap"; target: /mæp/; response options: "map"/"rap"). The stimulus degradation was performed in Audacity by applying white noise to the signal level measured at 60 dB.

Procedure. The participants were greeted by a research assistant at the lab and seated in front of the computer with the experiment start screen. The research assistant was seated within one meter of the participant to guide them through the instructions and answer any questions they had. Before beginning the experiment, the participants provided consent, with an option to withdraw from the experiment at any time by closing the web browser. Data on basic demographics (gender, age, first and second languages) were collected. The whole experiment took approximately 20 minutes to complete[1].

Each trial followed a consistent sequence: (1) a fixation mark ("&&") appeared at the center of the screen; (2) participants pressed the space bar to initiate the trial; (3) following a 100-ms interstimulus interval, a clearly visible orthographic stimulus (i.e., either "cap", "map", or "rap") appeared in the centre of the screen simultaneously with the degraded auditory target (i.e., either /cæp/, /mæp/, or /ræp/), both presented for 500 ms; and (4) after another 100-ms interstimulus interval, a two-alternative forced-choice response probe appeared in bright white text against a black background, two lines below the original context word (e.g., heard "cap" [press left arrow]; heard "rap" [press right arrow]). The software controlled all timing parameters and recorded both response accuracy and reaction time. Participants completed a total of 36

[1] Several conditions differed in the replication study as compared to the original experiment, including the lighting in the lab, the speakers, the hardware, the software, and the decibel level of the white noise used in the stimuli.

practice trials followed by 504 experimental trials, with 168 trials presented in each of the three conditions (congruent, incongruent, and irrelevant).

Ethics Approval

Research ethics approval was obtained from UNBC (approval number E2022.0107.001.00 – Appendix 1) to ensure adherence to the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* as outlined by the Panel on Research Ethics (2023). All responses were anonymized to protect participant confidentiality, and data were stored securely on password-protected institutional servers. The consent form included a separate section allowing participants to opt out of having their data included in the final analysis. No identifying information was linked to individual responses, ensuring that all data remained confidential throughout the study.

Data Analysis

A Mixed Factorial analysis of variance (ANOVA) was conducted to analyze the results, with groups (participants with or without a childhood history of otitis media) as the between-subjects factor and congruency (congruent, irrelevant, or incongruent) as the within-subjects factor. Data preprocessing and visualization were performed using the R programming language in R (version 4.3.1 GUI 1.79 Big Sur ARM build (8238), R Core Team, 2023) and R Studio (version 2023.06.1+524 (2023.06.1+524), 2023) and its associated packages. Data analysis was performed in Jamovi (version 2.3.21.0).

Results

Accuracy scores, defined as the percentage of correct responses out of the total number of trials, served as the primary dependent variable. Table 1 displays mean accuracy scores and

standard deviations for all three congruency conditions — congruent, irrelevant, and incongruent — across the two participant groups.

Table 1.

Experiment Demographics

OM in childhood	M(SD) Congruent	M(SD) Irrelevant	M(SD) Incongruent
Never (N = 36)	0.787(0.124)	0.654(0.131)	0.537(0.183)
OM Group (N = 22)	0.761(0.0767)	0.661(0.104	0.574(0.111)

Note. Descriptive statistics. The "Never" group consists of participants who have never had ear infections; the "OM" group consists of participants with three or more instances of ear infections in childhood.

A mixed-factor ANOVA for congruency and the presence of otitis media in childhood revealed a significant main effect for congruency, $F(2, 112) = 83.12$, $MSE = 0.01$, $p < .001$, partial $\eta^2 = .597$, indicating a large effect. There was no significant two-way interaction, $F(2, 112) = 1.75$, $MSE = 0.01$, $p = .18$. The between-subjects factor, the presence of otitis media in childhood, was not significant, $F(1, 56) = 0.0373$, $MSE = 0.04$, $p = .85$.

Post hoc analysis using the Tukey method revealed significant differences among all three conditions, with all p-values < .001. The mean differences were as follows: congruent vs. irrelevant condition of 0.117, congruent vs. incongruent of 0.218, and irrelevant vs. incongruent of 0.102.

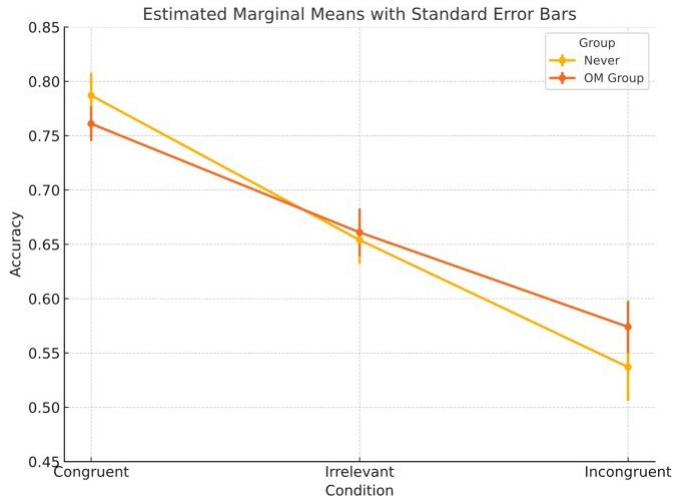
Therefore, there was no significant difference in the accuracy of responses between individuals with or without a history of otitis media infections in childhood. The congruency

affects the accuracy of all participants' responses, but there are no apparent residual effects of childhood otitis media infections in young adults. The lack of significance for the between-subjects factor suggests that any potential differences in the accuracy of responses are unrelated to the history of otitis media in childhood.

These results indicate no significant difference in phonological processing between the two groups. Consistent with Zumach et al. (2010), the findings do not provide evidence that phonological deficits arising from recurrent otitis media persist into adulthood.

Figure 4.

Estimated Marginal Means



Note. Condition ✻ otitis media (OM) in childhood group.

Discussion

The results of this study reinforce the importance of phonological congruency in word recognition. The significant main effect observed for congruency suggests that phonological activation is integral to visual word recognition, a finding compatible with core principles from

both dual-route and connectionist models of reading (Coltheart, 2006; Seidenberg et al., 2022). These results align with prior research indicating that phonological information is activated automatically, even in silent reading (Perfetti & Helder, 2022). However, the findings do not provide strong evidence for the lingering effects of childhood otitis media on phonological processing in young adulthood. These findings suggest that either compensatory mechanisms have effectively mitigated the impact of early auditory disruptions or that the current sample size lacked the statistical power to detect more subtle, lingering effects.

Stanovich's (1980) interactive-compensatory model provides a compelling theoretical lens to interpret this possibility. This model posits that reading is not governed by a rigid hierarchy of processes, but rather by a flexible and interactive system in which weaknesses in one domain (e.g., phonological processing) can be offset by strengths in others (e.g., orthographic or semantic processing). Accordingly, individuals with early phonological deficits, such as those resulting from recurrent otitis media, may still attain reading fluency by relying more heavily on higher-level contextual or visual cues.

In a related framework, Stanovich's (2009) Matthew Effect framework highlights the cumulative and self-reinforcing nature of reading development. Early proficiency in phonological processing can lead to greater print exposure, vocabulary acquisition, and general cognitive growth. In contrast, early difficulties may initiate a downward spiral characterized by reduced reading engagement and slower linguistic development. Nevertheless, the absence of significant long-term deficits in this study may reflect successful compensation or access to enriched learning environments that helped interrupt this negative trajectory. Together, these models underscore the importance of both foundational skills and ongoing reading experience in shaping literacy outcomes across development.

While previous studies, such as Owen and Borowsky (2003), have demonstrated a quadratic function in the graphical depiction of their results, our replication did not yield the same pattern. In the present study, we observed a linear function. The differences in the pattern of results could indicate a change in cognitive mapping for facilitation dominance to bias (i.e., equal facilitation and inhibition) or differences in methodological and contextual factors, such as differences in participant demographics, stimulus presentation, and environmental conditions that may have influenced word processing outcomes. For instance, the original study was conducted in a dimly lit laboratory, whereas our study took place in a well-lit environment, which may have subtly affected participants' visual processing or attentional focus. Additionally, procedural differences, such as software updates or display characteristics, could have played a role in shaping response patterns.

Despite these variations, the results align with previous research on phonological processing, showing that congruency plays a significant role in word recognition accuracy. The study further supports the view that phonological activation occurs even in silent reading, which challenges traditional assumptions about post-lexical phonological processing (Seidenberg et al., 2022). Additionally, it underscores the broader significance of phonological awareness in both early and skilled reading, reinforcing its role in cognitive models of literacy.

These findings also align with the notion that phonological processing is not isolated but interwoven with other reading components. The interactive-compensatory model further supports the idea that readers flexibly engage available cognitive resources depending on their individual strengths and weaknesses. This view accommodates the developmental plasticity that is suggested by the findings of this study.

Furthermore, practical applications of these findings suggest that individual expertise, such as stenographers' ability to engage in phonetic transcription, may alter the functional relationship between phonological and orthographic processing. Fowler and Dekle (1991) provided evidence that both visual and tactile modalities can influence speech perception, suggesting that multiple sensory inputs may contribute to phonological processing. Although their study focused primarily on speech perception, it raises questions about whether similar cross-modal interactions exist in written word recognition, particularly for individuals with specialized training.

Limitations of the Study

While the study provides meaningful insights, certain limitations must be acknowledged. First, the sample consisted exclusively of young adults, limiting generalizability to other age groups. Since phonological processing evolves across the lifespan, future research should examine whether similar patterns are observed in children and older adults.

Second, the reliance on self-reported histories of otitis media introduces potential recall bias. Future studies could incorporate audiological assessments or medical records to classify participants based on early auditory health history more accurately.

Third, environmental factors such as laboratory conditions and stimulus presentation methods may have influenced participant responses. Although these variables were controlled to the extent possible, future research should explore how subtle differences in testing environments impact phonological processing outcomes.

Future Directions

Several promising avenues for future research emerge from this study. Future research should aim to address the limitations outlined above by incorporating more controlled

experimental conditions and objective measures of otitis media history. Longitudinal studies could track individuals from early childhood into adulthood to better understand how phonological processing develops over time. Such research would clarify whether compensatory mechanisms emerge gradually and how they interact with literacy development.

Neuroimaging studies may also offer valuable contributions by identifying the neural correlates of phonological and orthographic processing in individuals with a history of otitis media. Researchers can explore how early auditory disruptions impact brain activation patterns during reading tasks by utilizing techniques such as functional MRI and ERPs.

Additionally, further investigation into specialized populations, such as stenographers and interpreters, could provide a deeper understanding of how phoneme-to-grapheme mapping expertise influences cognitive processing. Research in this area could help refine models of word recognition and contribute to educational strategies for training individuals in phoneme-based transcription.

Conclusions

This chapter has explored the cognitive mechanisms involved in single-word processing, highlighting the interaction between orthographic and phonological systems. The dual-route and connectionist models offer valuable theoretical perspectives on how readers recognize words and extract meaning from text, highlighting both rule-based decoding and distributed, interactive processing.

While prior research has raised concerns about the potential long-term effects of early auditory disruptions, especially recurrent otitis media, on phonological awareness and reading development, the present study did not find evidence of enduring deficits in young adulthood. Accuracy in phonological discrimination tasks did not significantly differ between participants

with and without a childhood history of otitis media. These findings suggest that early phonological impairments, if present, may have resolved over time or been mitigated through compensatory processes.

The significant main effect of phonological congruency reinforces its essential role in visual word recognition, indicating that readers benefit from consistent orthographic and phonological cues. However, the absence of group differences implies that the impact of early auditory deficits may diminish with age, potentially due to the brain's cognitive plasticity or external supports such as early intervention and enriched learning environments.

These results appear inconsistent with Stanovich's (2009) Matthew Effect framework, which posits that early disadvantages in phonological processing can trigger a cumulative cycle of reduced reading exposure and weaker literacy development. Instead, the findings suggest that some individuals may have avoided this downward trajectory, possibly due to unmeasured protective factors. Although this study did not directly evaluate those influences, the pattern of results is consistent with successful remediation or resilience.

Conversely, the findings align with Stanovich's (1980) interactive-compensatory model, which emphasizes the flexible coordination of orthographic, phonological, and semantic systems in reading. According to this model, when one domain is underdeveloped, other components of the reading system can adaptively compensate. This compensatory mechanism may help explain the observed reading proficiency despite early auditory disruption and underscores the variability in reading development across individuals.

Overall, these findings underscore the importance of developmental timing, environmental context, and cognitive flexibility in shaping long-term reading outcomes. A deeper understanding of these factors is essential for designing effective early interventions and

educational practices that support resilience in individuals with a history of auditory or phonological challenges.

Looking beyond the mechanisms of word recognition, the next chapter broadens the focus from language processing to cognitive strategies that support effective learning more generally. While this chapter emphasized how foundational skills like phonological and orthographic processing contribute to reading, Chapter 3 explores how learners can actively shape their educational outcomes through deliberate practice techniques. Drawing on insights from cognitive psychology and educational research, it examines evidence-based strategies, such as active recall, spaced repetition, and elaborative encoding, that enhance retention and support long-term academic success. This transition marks a shift from understanding the cognitive underpinnings of reading to applying cognitive principles to optimize how we learn.

3. Optimizing Postsecondary Learning Outcomes with Flashcard-Based Strategies

The importance of effective study strategies in higher education cannot be overstated, particularly as students contend with growing academic demands and constrained preparation time. Within this context, cognitive psychology offers a strong theoretical basis for understanding how learning can be optimized through evidence-based strategies such as active recall, spaced practice, and elaborative encoding (Dunlosky et al., 2013; Roediger & Butler, 2011). These strategies draw on key cognitive principles, including memory consolidation, retrieval-induced reconsolidation, and the spacing effect, all of which support durable, transferable learning (Carpenter et al., 2022; Roediger & Karpicke, 2006; Cepeda et al., 2006).

Flashcards represent a uniquely effective medium for operationalizing these principles across both traditional and digital modalities. While conventional flashcards often emphasize rote memorization, structured approaches such as the Flashcards-Plus strategy promote deeper cognitive engagement through paraphrasing and the generation of personal examples (Appleby, 2013; Senzaki et al., 2017). While conventional flashcards often emphasize rote memorization, structured approaches such as the Flashcards-Plus strategy aim to deepen cognitive processing by incorporating elaborative encoding techniques. This method encourages students not only to review definitions but to actively paraphrase the content in their own words and generate personally meaningful examples (Appleby, 2013; Senzaki et al., 2017). These elaborative prompts are designed to link new information to existing knowledge, which enhances comprehension and supports long-term retention. Originally developed for use in university-level psychology courses, the Flashcards-Plus method has been associated with improved metacognitive monitoring and deeper conceptual understanding in learners (Appleby, 2013). This method exemplifies elaborative encoding and aligns with the Levels of Processing

framework (Craik & Tulving, 1975), which suggests that memory retention improves when information is processed at a deeper, semantic level rather than through shallow, surface-level features such as appearance or sound.

Although the Levels of Processing framework has been influential in cognitive psychology, it is not without criticism. Some scholars have noted that the theory suffers from conceptual circularity — defining "depth" by its effects on memory performance — and lacks clear operational definitions that can be consistently applied across studies or contexts (Lockhart, 2002; Baddeley, 2007). To address these limitations, the present research operationalizes elaborative encoding using clearly defined instructional prompts, such as paraphrasing definitions and generating personalized examples. These prompts move beyond abstract notions of "depth" by providing concrete, measurable study behaviours that can be consistently evaluated across learners. In doing so, Flashcards-Plus draws on the foundational insights of the Levels of Processing framework while addressing its theoretical ambiguities through a structured, empirically grounded design.

The study described here evaluates these strategies in both digital and traditional formats, offering actionable insights into improving student engagement, retention, and academic success across diverse educational contexts. A particular focus is placed on how flashcard-based techniques function in real-world settings, especially as students increasingly rely on digital platforms like Quizlet, Cram, and Anki. Quizlet is a widely used web-based study tool that allows users to create and study custom flashcard sets using various modes such as Flashcards, Learn, and Test formats (Quizlet, n.d.-a; Quizlet, n.d.-b). Cram also offers user-generated flashcards and supports spaced repetition through the Leitner system, which adjusts review frequency based on user performance (Cram.com, n.d.-b). Anki is an advanced flashcard

application that emphasizes long-term retention through algorithmic spaced repetition, allowing learners to prioritize and customize study schedules (AnkiWeb, n.d.). The comparative benefits of retrieval practice and spaced repetition — two well-established cognitive strategies — are examined to determine their relative impact on long-term memory and performance.

Additionally, the Flashcards-Plus strategy is assessed across multiple interventions to evaluate how structured elaboration and personalization support comprehension, application, and conceptual understanding (Appleby, 2013). By analyzing both paper-based and digital applications, this study provides a nuanced exploration of how learners can optimize study habits through structured, evidence-based strategies.

This research also explores the role of self-regulated learning and learner autonomy in implementing these strategies effectively (Zimmerman, 2002; Deci & Ryan, 1985). According to research, active recall and spaced repetition require consistent engagement and goal-directed behaviour — skills that are central to self-regulated and independent learning (Karpicke & Aue, 2015; Carpenter et al., 2022). Incorporating Flashcards-Plus may support metacognitive monitoring by encouraging learners to reflect on their understanding and personalize their encoding processes, a possibility supported by prior research demonstrating that elaborative encoding strategies enhance metacognitive accuracy (Appleby, 2013; Senzaki et al., 2017).

Key theoretical constructs, such as judgements of learning (JOLs) and cognitive engagement, are woven into the study as foundational frameworks. Research shows that JOLs play a critical role in guiding study behaviour, yet students often misjudge the effectiveness of strategies like retrieval and spacing (Koriat, 1997; Nelson & Dunlosky, 1991). This work also addresses test anxiety, examining how structured study tools can help reduce stress and increase confidence through predictable, mastery-oriented preparation methods (Rana et al., 2020).

The findings presented in this chapter are drawn from three experiments that collectively investigate how retrieval practice, spaced repetition, and elaborative encoding impact retention, metacognitive accuracy, and academic performance. These experiments compare different flashcard-based learning strategies across modality and structure, providing empirical data on what works, for whom, and under what conditions.

Together, the three experiments offer a nuanced and theoretically grounded understanding of how flashcard-based learning can be adapted to enhance academic outcomes in postsecondary education. This multi-faceted approach bridges cognitive psychology and educational practice, ensuring that findings are both practically applicable and theoretically informative. By integrating core strategies — retrieval practice, spaced repetition, and elaborative encoding — structured flashcard use has the potential to foster deeper learning, support metacognitive development, and improve test performance (Dunlosky et al., 2013; Brown-Kramer, 2022).

Ultimately, flashcards serve as a powerful self-testing tool, capitalizing on core cognitive mechanisms to support learning. By reinforcing recall through repeated retrieval, spacing reviews to enhance memory consolidation, and encouraging elaboration through personalization, these techniques offer students both efficiency and depth in their learning, whether delivered via digital platforms or traditional materials (Roediger & Butler, 2011; McDaniel, 2023).

Retrieval Practice, Spaced Practice, and Their Digital Applications

Retrieval practice and spaced practice are two foundational learning techniques in cognitive psychology, both of which have been consistently shown to improve long-term retention and knowledge transfer. A central element of retrieval practice is active recall, the deliberate retrieval of information from memory without external cues, a process that strengthens

memory traces and makes information more durable and accessible over time (Roediger & Butler, 2011).

At the cognitive level, retrieval practice reinforces retrieval pathways, making recall more automatic and resistant to forgetting (Carpenter et al., 2022). Neuroscientific evidence suggests that repeated retrieval engages memory reconsolidation processes, strengthening memory networks through hippocampal and dopaminergic interactions (Roediger & Butler, 2011).

The spacing effect, first documented by Ebbinghaus in 1885 (as cited from Ebbinghaus, 2013), demonstrates that distributing learning sessions over time significantly improves retention. “Spaced practice” refers to the general distribution of study sessions over time, whereas “spaced repetition” typically involves algorithm-driven reviews, such as those employed in platforms like Anki (Carpenter et al., 2022; AnkiWeb, n.d.). Spaced repetition optimizes memory consolidation by timing reviews just before forgetting occurs (Cepeda et al., 2006). This approach reduces forgetting while strengthening memory, improving knowledge application across domains. Research has found that spacing benefits learners across various educational levels, from early childhood education to professional training programs (Carpenter et al., 2022).

Despite their shared effectiveness, retrieval and spacing strategies are underused by students, who often rely on passive techniques such as rereading and highlighting — methods that foster a false sense of fluency rather than lasting learning (Brown-Kramer, 2022). Karpicke et al. (2009) suggest that this tendency may be driven by overconfidence in these passive methods. To help close this gap, digital platforms like Quizlet and Cram offer scalable solutions for implementing evidence-based study techniques.

Although both Quizlet and Cram support flashcard-based retrieval practice, the platforms differ in how they prioritize cognitive strategies. Quizlet emphasizes retrieval through active recall features like flashcards, tests, and matching games, while Cram focuses on spaced repetition through the Leitner system, which schedules reviews based on recall performance. Therefore, the comparison presented in Experiment 1 reflects differences in algorithmic design and user experience, not mutually exclusive learning methods. However, it is important to note that both platforms incorporate elements of both retrieval and spacing, and the results should be interpreted in light of this overlap.

Quizlet is a versatile and widely adopted platform designed to facilitate vocabulary acquisition and conceptual learning through a range of interactive study modes. The platform supports retrieval-based learning via its "Flashcards" mode, which prompts users to actively recall definitions, paired concepts, or categorical relationships (Özdemir & Seçkin, 2024). Additionally, it incorporates adaptive learning sequences, meaning the software adjusts to user performance and provides increased exposure to terms that require further reinforcement (Quizlet, n.d.-b).

Beyond flashcards, Quizlet integrates multiple study modes, including "learn mode" that uses adaptive sequencing to present material in spaced intervals, reinforcing long-term retention, "test mode" that allows users to self-assess knowledge using automatically generated quizzes with multiple-choice, true/false, and written-response questions, and "match mode" that encourages rapid association between terms and definitions through gamified matching tasks.

In the present study, Quizlet flashcards were customized to align with experimental learning conditions. Each flashcard consisted of a key concept on one side and its definition on the other. For instance, a sample flashcard used in this study displayed the term "abstract

thinking" on one side and its definition, "capacity to understand theoretical concepts", on the flip side. Engaging with these materials across multiple study sessions encouraged students to leverage retrieval-based learning and spaced reinforcement to optimize knowledge retention.

Cram, in contrast, specializes in spaced repetition through its implementation of the Leitner system. This widely used algorithm organizes flashcards into increasingly larger intervals based on user recall accuracy and study time to weaker material, thereby optimizing memory consolidation (Cram, n.d.-b). This method systematically sorts flashcards into levels, ensuring that frequently recalled material is reviewed less often, while incorrectly recalled items remain in lower tiers for more frequent review (Serfaty & Serrano, 2020). The Leitner system has been empirically validated as an effective spaced learning approach, particularly in second language acquisition and factual recall learning (Serfaty & Serrano, 2020).

Unlike traditional study methods that rely on massed repetition, Cram's platform optimizes spaced learning by increasing the intervals between successful recall attempts (Cram, n.d.-a). This approach ensures that learners spend more time reviewing difficult concepts while reinforcing stronger knowledge at optimal intervals, reducing cognitive overload and enhancing long-term retention (Yuan, 2022). Additionally, its "Memorize" mode follows an adaptive review schedule, gradually increasing the time between exposures for correctly answered items to prevent premature forgetting (Serfaty & Serrano, 2020).

From a cognitive perspective, retrieval practice and spaced practice represent two distinct yet complementary mechanisms for enhancing long-term memory. Retrieval practice strengthens memory through active recall, reinforcing neural pathways associated with learning. In contrast, spaced practice reduces forgetting by distributing learning over time, thereby facilitating memory consolidation. Neuroscientific evidence supports both mechanisms, showing that each engages

critical brain regions such as the hippocampus and prefrontal cortex — areas implicated in memory formation, retrieval, and cognitive control (Roediger & Butler, 2011; Yuan, 2022).

Despite their shared theoretical foundations, the relative benefits of retrieval versus spacing remain underexplored in digital contexts, where learners rely on platforms like Quizlet and Cram. These tools differ in how they emphasize each strategy: Quizlet primarily promotes retrieval through active recall features like flashcards, tests, and matching games, whereas Cram emphasizes spacing via the Leitner system, an algorithm that schedules review intervals based on user performance. Such design differences offer a unique opportunity to examine how each cognitive strategy functions when embedded in real-world learning tools.

The effectiveness of these approaches may depend on user engagement, interface usability, and individual differences in motivation and self-regulation (Zimmerman, 2002; Deci & Ryan, 1985). Accordingly, the present experiment evaluates the learning outcomes associated with each platform, seeking to isolate the relative contributions of spaced repetition and retrieval practice as distinct cognitive strategies. By comparing these approaches in a controlled setting, this study aims to clarify their differential impact on retention and provide evidence-based recommendations for optimizing digital study interventions.

Elaborative Encoding and the Flashcards-Plus Strategy

Elaborative encoding involves integrating new information with prior knowledge by creating meaningful associations, such as paraphrasing or generating examples (Craik & Tulving, 1975). The Flashcards-Plus strategy exemplifies this approach by requiring students to personalize definitions and generate examples, promoting deeper cognitive engagement and aligning with self-regulated learning theories (Zimmerman, 2002). By fostering active learning,

this method can enhance comprehension, retention, and application of information (Dunlosky et al., 2013).

The effectiveness of elaborative encoding is further explained by the Encoding Specificity Principle (Tulving & Thomson, 1973), which states that retrieval success is maximized when encoding and retrieval cues align. Research supports that elaborative encoding enhances retrieval practice by strengthening memory recall through the generation of multiple retrieval pathways (McDaniel, 2023). Additionally, deep semantic processing leads to greater memory durability compared to shallow processing (Craik, 2002), reinforcing the Levels of Processing framework. This principle suggests that learning is most effective when information is meaningfully structured and actively reconstructed.

The Flashcards-Plus strategy integrates both retrieval practice and spaced repetition to maximize long-term retention. Unlike rote memorization, it encourages students to engage with material at increasing intervals (progressively more extended periods between review sessions), reinforcing memory consolidation and retrieval strength (Roediger & Butler, 2011). By incorporating verbatim definitions (retention), paraphrased explanations (comprehension), and personal examples (application), Flashcards-Plus fosters deeper encoding and conceptual understanding (Appleby, 2013; Senzaki et al., 2017). Furthermore, it helps students navigate different types of multiple-choice questions by strengthening self-explanation and problem-solving skills.

The efficacy of this method is supported by studies showing that elaborative encoding combined with retrieval practice enhances retention beyond either strategy alone (McDaniel, 2023). By implementing strategies that promote meaningful learning connections, students can improve both memory retention and conceptual understanding. As research suggests, combining

elaborative encoding, retrieval practice, and structured self-regulated learning tools leads to higher academic performance and improved metacognitive accuracy, making Flashcards-Plus a powerful and versatile learning strategy.

Modality Effects

The format in which flashcards are delivered may influence learning efficacy, as different modalities engage cognitive processes in unique ways (Yuan, 2022). Traditional paper flashcards provide a unique tactile experience, unlike digital-based flashcards. In this regard, embodied cognition frameworks suggest that the physical act of handling and flipping paper flashcards engages sensorimotor pathways, reinforcing learning through active interaction with the material (Wilson, 2002). This process may strengthen memory retention by offloading cognitive work onto the environment, reducing cognitive load, and fostering deeper conceptual understanding.

In contrast, digital flashcards leverage gamification, progress tracking, and multimodal features that may increase motivation and engagement (Quizlet, n.d.; Cram, n.d.-a; Zeitlin & Sadhak, 2023). Empirical research supports the motivational value of these design elements: Sailer et al. (2017) found that specific gamification components, such as points, badges, and leaderboards, enhanced learners' intrinsic motivation by satisfying key psychological needs for competence, autonomy, and relatedness. For instance, recent studies have provided empirical evidence of Quizlet's effectiveness in various educational contexts. Fursenko et al. (2021) demonstrated that Quizlet significantly improved vocabulary retention and speaking proficiency in an aviation English course, with students in the Quizlet-based learning group outperforming traditional learners by 22.4%. Similarly, Özdemir and Seçkin's (2024) meta-analysis of 23 studies found that Quizlet had a moderate-to-large positive effect on vocabulary retention (Hedges' $g = 0.74$) and a moderate effect on overall learning outcomes (Hedges' $g = 0.62$).

Additionally, digital tools like Anki can help automate spaced repetition, optimizing review schedules based on retrieval performance (Rana et al., 2020). However, while digital flashcards enhance efficiency and accessibility, their effectiveness may be influenced by a learner's ability to manage potential distractions and the absence of tactile engagement, which could impact cognitive encoding and recall.

JOLs

JOLs refer to learners' ability to evaluate their mastery of material, which plays a critical role in guiding effective study strategies. Accurate JOLs help students allocate study time efficiently, whereas overconfidence or inaccurate judgments can lead to ineffective preparation and poor retention (Nelson & Dunlosky, 1991).

Koriat's (1997) cue-utilization framework explains that JOLs are influenced by three primary cues: intrinsic (item difficulty), extrinsic (study conditions), and mnemonic (internal retrieval fluency). Research suggests that while intrinsic and mnemonic cues strongly affect JOLs, extrinsic factors, such as study repetition, are often discounted, leading students to misjudge the effectiveness of spaced practice and retrieval-based learning (Koriat, 1997). This bias contributes to students' preference for passive techniques, such as rereading, over more effortful but effective strategies like retrieval practice (Carpenter et al., 2022).

Retrieval practice and spaced repetition improve JOL accuracy by reinforcing memory traces and revealing knowledge gaps through feedback (Koriat, 1997; Nelson & Dunlosky, 1991). The delayed-JOL effect, where JOLs made after a time delay are significantly more predictive of actual recall, demonstrates how retrieval-based strategies enhance metacognitive monitoring and self-regulated learning (Nelson & Dunlosky, 1991). Furthermore, delayed JOLs

reduce the impact of short-term memory interference, making them more reliable indicators of retention over time (Tiwari, 2015).

Digital learning tools that incorporate spaced retrieval algorithms can further improve JOL accuracy by offering immediate feedback on retention performance, helping learners prioritize study efforts effectively (Yuan, 2022). However, overconfidence in unstructured study environments remains a challenge (Higgins, Frankland, & Rathner, 2021). The presence of multimodal information, such as text combined with images or audio, can also introduce a cognitive load, sometimes leading to overestimated JOLs and increased overconfidence in digital learning environments (Chen & Fu, 2003).

Misconceptions about learning, particularly the belief that passive strategies like rereading are more effective, contribute to inaccurate JOLs (Anstead, 2022). These misjudgments cause students to allocate study time inefficiently, underestimating the benefits of retrieval-based learning and spaced repetition, ultimately hindering metacognitive accuracy and long-term retention (Carpenter et al., 2022). To improve learning outcomes, interventions should focus on enhancing students' metacognitive awareness of effective study techniques while promoting structured, feedback-driven learning environments that support retention, comprehension, and application of knowledge.

Test Anxiety

Test anxiety significantly affects academic performance by increasing stress and impairing cognitive functions (Hembree, 1988). In many post-secondary courses, students face the challenge of comprehending, retaining, and integrating substantial volumes of information across multiple courses each semester. This demanding academic context, often complicated by overlapping test and assignment due dates, creates an environment conducive to heightened test

anxiety (Rana & Mahmood, 2010; see also Gerwing et al., 2015). Rana and Mahmood (2010) reported a significant negative correlation between students' achievement scores and their levels of test anxiety, underscoring the importance of cognitive factors, particularly worry, in contrast to affective factors such as emotional distress. Their research posited test anxiety as a contributing factor to suboptimal performance and academic underachievement, emphasizing the potential of targeted interventions to provide students with effective coping strategies.

Structured study tools like flashcards may help mitigate anxiety by promoting a sense of control and systematic preparation (Rana et al., 2020). Research suggests that flashcard-based strategies, particularly those incorporating spaced repetition and retrieval practice, can enhance students' confidence in their ability to recall information under pressure, ultimately reducing anxiety levels. Empirical evidence supports this connection, with studies showing that structured flashcard use is linked to lower test anxiety, particularly among first-year university students — for instance, 60.3% of first-year medical students reported reduced anxiety after incorporating flashcards into their study routine (Rana et al., 2020).

Accurate JOLs, reinforced through retrieval practice, may also play a crucial role in reducing test anxiety by helping students better assess their preparedness and allocate study time effectively. Instructors can further contribute to alleviating test anxiety by implementing explicit test orientations, encouraging positive thinking, fostering peer support networks, and recommending relaxation training (Rana & Mahmood, 2010). Gerwing et al. (2015) additionally suggested informing students about the commonality of test anxiety as a strategy to reduce associated stigma, potentially enhancing students' ability to seek and utilize available supports.

Taken together, these findings accentuate the imperative for examining and developing additional structured interventions, such as flashcard strategies, that bolster students' capacity to

achieve intended learning outcomes and support efforts to manage test anxiety, particularly in high-stakes academic settings where retrieval fluency and stress regulation are important.

Given the impact of test anxiety on academic performance, it is essential to explore structured study interventions that not only enhance learning outcomes but also help manage stress. Flashcard-based strategies, particularly those incorporating retrieval practice and spaced repetition, have been shown to foster confidence, improve retention, and provide students with a sense of control over their study process (Rana et al., 2020). However, while existing research highlights the benefits of flashcards in reducing anxiety, questions remain about the optimal ways to implement these strategies across different learning modalities, whether through traditional paper-based methods or digital platforms.

To address this gap, the current research investigates how various flashcard-based learning techniques influence retention, metacognitive accuracy, and test performance in postsecondary students. By systematically examining retrieval practice, spaced repetition, and elaborative encoding across different formats, these experiments aim to identify the most effective approaches for optimizing learning, self-regulated study behaviours, and anxiety reduction.

Research Objectives

This chapter presents findings from three interconnected experiments examining the effectiveness of flashcard-based learning strategies in postsecondary education. Specifically, the study explores (1) spaced versus retrieval practice in digital flashcards, investigating which method yields superior retention and exam performance; (2) the effectiveness of the Flashcards-Plus strategy in paper-based flashcards, assessing whether elaborative encoding enhances retention beyond traditional flashcard use; and (3) the integration of Flashcards-Plus with spaced

practice in digital learning, exploring whether combining these techniques optimizes learning outcomes, enhances metacognitive accuracy through JOLs, and reduces test anxiety.

Experiment 1 examines the relative benefits of spaced and retrieval practice within digital flashcard platforms, with the primary objective of determining which method leads to better retention and higher exam performance. Additionally, this experiment evaluates whether students' self-reported cramming behaviours (massed practice) negatively impact learning outcomes. Although not its central focus, Experiment 1 also explores preliminary associations between flashcard use and self-reported test anxiety, offering a baseline for comparisons in later experiments.

Experiment 2 builds on these findings by evaluating the Flashcards-Plus strategy in a traditional paper-based format. This method incorporates elaborative encoding through paraphrasing and personalized examples and is expected to promote deeper cognitive engagement and improve retention. Crucially, this experiment also measures students' JOLs to assess the accuracy of their metacognitive monitoring and whether enhanced encoding strategies align perceived and actual performance.

Experiment 3 investigates whether students perceive benefits from using Flashcards-Plus in combination with algorithmic spaced repetition, as implemented in Anki. Rather than directly comparing flashcard types, the study focuses on the relationship between students' perceived helpfulness of flashcards and their academic performance, while assessing test anxiety and judgment-of-learning (JOL) accuracy. The experiment aims to determine whether students who report greater perceived usefulness of structured flashcard strategies also report lower anxiety and perform better academically, thereby informing the potential value of adaptive digital tools for supporting metacognitive monitoring and self-regulated learning in postsecondary settings.

Findings from these experiments will contribute to a deeper understanding of how evidence-based learning strategies interact with cognitive and neural mechanisms to optimize student performance. However, their effectiveness is highly dependent on implementation strategies. Structured approaches, such as the Flashcards-Plus strategy, offer an efficient way to integrate retrieval practice and spaced repetition into study routines, maximizing long-term retention and academic success.

Together, these experiments provide a comprehensive understanding of how retrieval practice, spaced repetition, and elaborative encoding interact across different learning modalities. While Experiment 2 focuses on traditional learning environments, Experiment 3 examines how technology-assisted flashcards optimize learning through adaptive scheduling (Roediger & Butler, 2011; Cepeda et al., 2006). By systematically evaluating these strategies, this research bridges cognitive psychology with educational practice, offering actionable insights for educators seeking to enhance student retention, metacognitive self-awareness, and academic success (Dunlosky et al., 2013; Brown-Kramer, 2022). Addressing these research objectives sequentially ensures a logical progression of insights, allowing each experiment to build on prior findings and contribute to a cohesive framework for effective study strategies. Although referred to as experiments, they are better understood as quasi-experimental investigations due to the absence of fully randomized control groups and limited control over study conditions. This classification reflects the naturalistic educational contexts in which they were conducted and acknowledges the pragmatic constraints of classroom-based research.

Ethics Approvals

All three studies were conducted in line with the ethical principles of research. Research ethics approvals were obtained from both UNBC (approval number 6009020 – Appendix 2) and

CNC (approval number EO-2024-0508-102 – Appendix 3) in accordance with the Panel on Research Ethics guidelines (2023). The students in both institutions were informed about the nature and the purpose of the research after their final exam and provided with a data release consent form with the possibility to opt out of their data being used for the study. Students who gave their consent were provided with a paper-based survey in UNBC and a web-based survey in CNC that assessed their study habits and post-test anxiety levels using the Westside Test Anxiety Scale.

To ensure that participation did not influence grading outcomes, data analysis was postponed until two weeks after students' final grades had been submitted. Confidentiality and anonymity have been maintained for all participants by anonymizing all responses after the student grades were associated with survey responses. Data confidentiality was strictly maintained in accordance with institutional and ethical guidelines. Identifiable information was not collected, and all data were stored securely.

Additionally, several safeguards were implemented to mitigate any potential conflict of interest arising from the Principal Investigator's dual role as both researcher and course instructor. Teaching Assistants, rather than the instructor, assessed all flashcard assignments throughout the semester. Furthermore, following the final exam, research assistants, not the course instructor, distributed and collected the research surveys. These measures ensured the researcher's non-involvement in grading and data collection processes, thereby maintaining the integrity and impartiality of the research outcomes.

Experiment 1: Spaced Practice vs. Retrieval Practice

Method

Participants. A total of 144 students enrolled in PSYC 102 Introduction to Psychology course at UNBC in the winter semester of 2023 were randomly assigned to one of the experimental conditions: 1) retrieval practice group (n = 72) where the students were instructed to use Quizlet flashcards to prepare for their exams, and 2) spaced practice group (n = 72) where the students were instructed to use Cram flashcards to prepare for their exams. Among the students, 107 participants provided their consent for their data to be used for the study. To ensure completeness, students with missing exam scores, whether from one of the midterms or the final exam, were excluded from the analysis, resulting in the removal of nine participants from the dataset. The resulting course performance data from 98 students (Quizlet group: n = 47; Cram group: n = 51) were analyzed. Table 2 provides an overview of the demographic characteristics of the study participants.

Table 2

Experiment 1 Demographics

Demographic Variable	Description
Sample Size (N)	98
Mean Age (years)	20.18 (SD = 3.75)
Age Range (years)	17 - 46
Sex Distribution	Female = 73, Male = 25
Gender Distribution	Female = 71, Male = 25, Non-Binary = 1, Gender Fluid = 1
Degree Programs	Bachelor of Science (n = 52), Bachelor of Health Sciences (n = 30), Other (n = 11)
Most Common Major	Psychology (n = 40)
Experimental Conditions	Cram (n = 51), Quizlet (n = 47)

Note. Experiment 1 Demographics.

Procedures. Quizlet (quizlet.com) and Cram (cram.com) were selected as the digital platforms for this study, representing two distinct self-testing approaches: retrieval practice and spaced practice. Both tools are well-established for supporting learning through flashcards, leveraging key cognitive strategies such as active recall and spaced repetition to enhance memory retention and conceptual understanding (Özdemir & Seçkin, 2024; Fursenko et al., 2021). While Quizlet and Cram were selected to represent retrieval and spacing, respectively, both platforms incorporate elements of each strategy. Quizlet includes adaptive features that space review, and Cram still involves active recall through its flashcard interface. Thus, the comparison reflects differences in design emphasis rather than pure strategy implementation.

To maintain consistency across experimental conditions, identical flashcard content was used on both platforms. For instance, a Cram flashcard in this study featured the term “affective

forecasting" on one side and its definition, "ability to predict our own and others' happiness," on the reverse. By leveraging spaced repetition principles, Cram provides an efficient, structured learning tool that integrates evidence-based cognitive strategies for long-term retention (Cram, n.d.-a; Serfaty & Serrano, 2020).

The flashcards for both platforms were pre-designed by the course instructor to align with the textbook chapters and lecture materials. These flashcards included key terms and definitions deemed critical for understanding the course content and succeeding on the exams (Appendix 4).

The PSYC 102 Introduction to Psychology course included four equally weighted examinations: three midterms and one final exam. Each exam comprised four matching questions and 36 multiple-choice questions, all directly assessing terminology and definitions that students practiced using flashcards. The exams each covered two textbook chapters, focusing on the following topics: (1) the history of intelligence testing and the definition of intelligence, (2) developmental psychology, (3) theories of emotion and motivation, (4) stress and health, (5) social psychology, (6) personality theories, (7) psychological disorders, and (8) psychological and biological therapies (Lilienfeld et al., 2022). These topics, drawn from Chapters 9–16 of the course textbook, were reinforced through lectures that closely followed the assigned readings. To ensure consistency, identical flashcard content, aligned with the textbook chapters and lecture material, was used across both the Quizlet and Cram platforms.

Students were randomly assigned to one of two groups: the Quizlet group (n = 72) or the Cram group (n = 72). Before each exam, both groups received a link to pre-made flashcards on their respective platforms. These flashcards contained instructor-selected key terms and definitions from the relevant textbook chapters and were intended to support exam preparation. Students were instructed to use the flashcards to practice and were required to submit screenshots

of their practice sessions as part of their class participation grade, which accounted for 5% of the total course grade. Students received full participation marks for submitting the screenshots, regardless of the frequency or duration of practice.

After completing the final exam, students were informed about the research study and provided with a data release consent form. Those who consented participated in a paper-based survey that assessed their perceptions of the flashcard assignments, study habits, and test anxiety levels using the Westside Test Anxiety Scale (Driscoll, 2007). Nine participants with missing exam scores (either one of the midterms or the final exam) were removed from the analysis. The resulting course performance data from 98 students (Quizlet group: n = 47; Cram group: n = 51) were included in the analysis. These data were exported from the Learning Management System (LMS) Moodle, while a research assistant entered survey responses into an Excel spreadsheet. Both datasets were then processed in R and statistically analyzed using R and Jamovi to evaluate the efficacy of the self-testing strategies and the effect of other factors. Only a small minority of students, ranging from 6 to 8, indicated they had not used flashcards to prepare for a particular exam. At the same time, the overwhelming majority reported using them consistently across all four assessments.

Results

Test Scores. A Multivariate Analysis of Variance (MANOVA) was conducted to examine whether the flashcard condition (Quizlet vs. Cram) significantly affected students' exam performance across multiple assessments, including Midterm 1, Midterm 2, Midterm 3, and the Final Exam. Results indicated a statistically significant multivariate effect of flashcard condition on exam performance, Wilks' $\Lambda = 0.51$, $F(4, 94) = 22.61$, $p < .001$, partial $\eta^2 = .49$, suggesting that the type of study method (Quizlet vs. Cram) significantly influenced students' exam

performance across multiple assessments, confirming a meaningful multivariate effect. MSE is not being reported for the MANOVA because it is not commonly used in multivariate tests like Wilks' Λ, which focus on overall differences across several dependent variables rather than analyzing each one separately, like in ANOVA.

Table 3

Means, standard deviations, and results of MANOVA models for Quizlet and Cram groups

	Total (N = 98)	Quizlet Group (n = 47)	Cram Group (n = 51)	p-value	Partial η^2
Midterm 1 grade	74.39 (12.11)	75.96 (11.34)	72.94 (12.72)	.220	.016
Midterm 2 grade	68.65 (12.81)	68.88 (13.8)	68.43 (11.97)	.863	< .001
Midterm 3 grade	68.37 (14.88)	68.72 (14.93)	68.04 (14.97)	.821	< .001
Final Exam grade	65.99 (14.61)	66.44 (13.98)	65.59 (15.29)	.776	< .001

Note. Descriptive statistics and MANOVA results for exam performance across flashcard conditions. Both p-values and partial η^2 are reported in this table in accordance with APA recommendations to convey the statistical significance and the magnitude of the effect.

A follow-up one-way Analysis of Variance (ANOVA) was conducted to determine whether the flashcard condition (Quizlet vs. Cram) had a significant effect on students' exam performance, averaging across all three midterms and the final exam. Results revealed no statistically significant difference between the Quizlet group (M = 70.00, SD = 11.91) and the Cram group (M = 68.75, SD = 10.98) in terms of their overall exam performance, $F(1, 96)$ = 0.29, MSE = 3642.10, p = .59. These findings suggest that, while the MANOVA revealed a significant multivariate effect across individual exams, there was no significant difference when considering the overall average exam performance between the two groups.

To further explore differences in individual exams, a Mann-Whitney U test was conducted instead of a standard independent-samples t-test due to the substantial imbalance in sample sizes between groups. Specifically, the number of students who reported not using flashcards to prepare for any of the four exams was consistently much smaller than that of students who reported using flashcards, leading to unequal variances across exams. Unlike the standard t-test, the Mann-Whitney U test is a non-parametric alternative that does not assume normality, making it the most appropriate statistical approach for this analysis.

For Midterm 1, students who used flashcards ($M = 74.58$, $SD = 12.25$) had slightly higher scores than those who did not ($M = 72.19$, $SD = 10.89$); however, this difference was not statistically significant, $U = 412.5$, $p = .498$. A similar pattern was observed for Midterm 2, where students who used flashcards ($M = 68.83$, $SD = 12.39$) scored slightly higher than non-users ($M = 65.83$, $SD = 19.54$), but the difference remained non-significant, $U = 294.5$, $p = .789$. Likewise, Midterm 3 scores were nearly identical between flashcard users ($M = 68.37$, $SD = 14.93$) and non-users ($M = 68.33$, $SD = 15.38$), with no significant difference, $U = 276.0$, $p = 1.000$. However, for the Final Exam, students who used flashcards ($M = 67.25$, $SD = 14.00$) scored significantly higher than those who did not ($M = 51.88$, $SD = 14.68$), $U = 560.0$, $p = .009$, indicating a significant advantage for flashcard users.

Table 4

Mann-Whitney U Test Results with Medians and Interquartile Range (IQR) for flashcard users and non-users

	Mdn (users)	IQR (users)	Mdn (non-users)	IQR (non-users)	U-statistic	p-value
Midterm 1	77.50	16.88	72.50	11.88	412.5	.498
Midterm 2	70.00	17.50	67.50	27.50	294.5	.789
Midterm 3	68.75	21.25	68.75	21.25	276.0	1.000
Final Exam	67.50	20.00	52.50	17.50	560.0	.009

Note. Medians and interquartile ranges (IQRs) are reported for each group to reflect central tendency and variability. The Mann-Whitney U-statistic and corresponding p-values are included to indicate the significance of group differences.

Therefore, flashcard use did not significantly impact performance on the first three midterms, but a significant benefit emerged for the Final Exam. These findings suggest that flashcards may facilitate long-term retention rather than providing an immediate advantage for short-term exam preparation. The extended time frame for preparing for the Final Exam may have allowed students to fully benefit from spaced repetition and retrieval practice, which are key cognitive mechanisms underlying the effectiveness of flashcard-based studying.

Test Anxiety. A Spearman's rank-order correlation analysis was conducted to examine the relationship between students' test anxiety levels and their final course grades. The Westside Test Anxiety Scale scores were compared with students' actual final grades to assess the strength and direction of the association.

The analysis yielded a non-significant correlation, $r_s = 0.002$, $p = .98$, indicating no meaningful relationship between test anxiety levels and final course grades. These findings

suggest that students with higher test anxiety scores did not systematically achieve lower academic performance compared to their peers.

This finding aligns with prior research, which highlights that mild to moderate levels of anxiety may not substantially impair performance (Driscoll, 2007; Connor et al., 2016). Given the negligible effect size, test anxiety does not appear to be a strong predictor of academic outcomes in this experiment.

JOL Accuracy. Descriptive analysis revealed that students' expected final course grades (M = 73.03, SD = 14.24) were very close to their actual final course grades (M = 73.57, SD = 11.87). Expected grades ranged from 2.90% to 100.00%, while actual final grades ranged from 33.28% to 96.06%.

A Spearman's rank-order correlation was conducted to examine the relationship between students' self-reported expected grades and their actual final grades. The analysis yielded a weak positive correlation, r_s = 0.17, p = .09. This result was not statistically significant.

These findings are partially consistent with prior research, which highlights that while optimistic self-assessments may align with academic success in some cases, other factors, such as study strategies, motivation, and anxiety, play a critical role in shaping actual performance (Zimmerman, 2002; Koriat & Bjork, 2005). Students with more accurately calibrated JOLs may demonstrate better self-regulation and academic outcomes. However, given the non-significant correlation observed in this dataset, other influences beyond students' initial expectations may have contributed to their final performance.

Cramming Tendencies. Students' self-reported cramming behaviour, measured on a scale from 1 ("never") to 5 ("all the time"), had a mean of 3.66 (SD = 1.10), suggesting that most students reported cramming behaviour "quite often" or "50% of the time." Final course grades

averaged 73.51% (*SD* = 11.94), while test anxiety scores, assessed on a scale from 1 to 5, had a mean of 3.22 (*SD* = 0.74), indicating moderate levels of test anxiety among participants.

A Spearman's rank-order correlation analysis was conducted to explore the relationships among cramming behaviour, final grades, and test anxiety. The results revealed a non-significant correlation between cramming and final grades, $r_s = 0.18$, $p = .09$. Similarly, a non-significant correlation was found between cramming and test anxiety, $r_s = 0.12$, $p = .23$.

None of the correlations between cramming behaviour, test anxiety, and final course grades reached statistical significance. These findings align with prior research suggesting that cramming may not inherently harm or improve academic outcomes but may contribute to short-term stress (Hartwig & Dunlosky, 2012). Given that none of these correlations reached statistical significance, future research could explore alternative study habits, such as distributed practice, and investigate whether structured interventions targeting test anxiety and study strategies could enhance academic performance.

The findings from the first experiment provided insights into the effectiveness of different digital flashcard platforms (Quizlet vs. Cram) in enhancing student learning. While both methods facilitated final exam performance, no significant differences emerged between the two, suggesting that the overall benefit of flashcards may stem from their active recall and repetition components rather than the specific platform used. This outcome implies that while both retrieval practice and spaced repetition are effective, neither strategy appeared to outperform the other when implemented through standard platform settings, possibly due to overlapping features or inconsistent engagement with the intended algorithms. Additionally, the role of study habits, cramming behaviours, and test anxiety did not strongly predict final course grades, indicating

that other factors, such as the structure of the study materials, may play a crucial role in learning outcomes.

Building upon these results, Experiment 2 was designed to test the hypothesis that an enhanced flashcard method, Flashcards-Plus, would improve retention and metacognitive accuracy compared to traditional paper-based flashcards. The Flashcards-Plus condition introduces additional metacognitive prompts, such as paraphrasing and generating personal examples, designed to improve self-regulated learning by enhancing metacognitive monitoring and control over encoding strategies. In contrast, the Traditional Flashcards condition reflects conventional study practices that emphasize rote memorization, which may support basic recall but offer limited benefits for higher-order cognitive processes like metacognitive awareness, elaborative encoding, and strategic self-regulation. This experiment aimed to determine whether modifying flashcard structure and encouraging deeper engagement with study materials can lead to greater retention and academic success.

Experiment 2: Flashcards-Plus vs Traditional Flashcards in Paper-Based Format

Method

Participants. Participants in Experiment 2 included 40 students enrolled in PSYC 319 Philosophy of Mind course at UNBC during the winter semester of 2023. Among these, 28 students consented to participate in the research by signing the data release consent form. The sample had a mean age of approximately 21.3 years (*SD* = 3.8), with ages ranging from 18 to 42 years. Gender distribution included primarily female participants (n = 18) and male participants (n = 10). Most participants were pursuing Bachelor of Arts degrees with a major in Psychology (n = 17), while others were enrolled in interdisciplinary programs or related fields.

This sample was selected to explore the impact of different flashcard-based study methods on academic performance, with students engaging in both traditional and Flashcards-Plus strategies as part of the course curriculum. Demographic data and survey responses were collected to provide insights into the role of study habits, anxiety, and test performance across the study population.

Materials. The PSYC 319 Philosophy of Mind course utilized Ravenscroft's (2005) textbook as the required reading. Course lectures closely followed the textbook and covered four main topics: (1) Mental States (chapters 1–5), (2) Mind as Machine (chapters 6 and 7), (3) Mind in a Physical World (chapters 8–10), and (4) Consciousness (chapters 11 and 12). These topics provided a comprehensive foundation for understanding contemporary debates in philosophy of mind.

To support their learning, students were supplied with 3x5-inch white index cards to create their flashcards. For example, a typical flashcard demonstrated by the instructor in the PowerPoint presentation might have had the term "Epiphenomenalism" written on one side, with the definition "a version of property dualism that insists that mental properties do not causally impact upon the brain" on the reverse. This approach ensured uniformity in the materials while allowing for individual content customization.

Procedures. The course assessments comprised three equally weighted "knowledge tests" (15% each), analogous to two midterms and one final exam. Each test was a closed-book, in-class assessment that covered approximately one-third of the course material. All assessments were designed to evaluate students' conceptual understanding, factual recall, and ability to articulate philosophical arguments in written form.

Knowledge Test I assessed chapters 1–4 and consisted of 40 questions: 30 multiple-choice questions (1 point each), five fill-in-the-blank items (1 point each), three true/false items (1 point each), and two short-answer questions (6 points each). Knowledge Test II covered chapters 5–8 and included 30 questions: 26 multiple-choice items (1 point each) and four short-answer questions (6 points each). Knowledge Test III examined chapters 9–12 and included 30 questions: 26 multiple-choice items (1 point each), one true/false question (1 point), and three short-answer questions (5 points each).

Before the first test, all students were given a list of instructor-selected key terms and definitions, along with blank index cards. Students created paper-based flashcards using the provided materials as part of the lecture. The terms and definitions on the list were derived from the textbook and lecture content, focusing on critical concepts necessary for understanding and exam success. This ensured consistency in the flashcards produced by the students, providing a uniform study aid for the first midterm exam.

For the second test, the same process was followed with one critical difference: students were instructed to use the Flashcards-Plus strategy. This method required students to paraphrase the provided definitions in their own words and generate personalized examples for each key term. These tasks were completed during class time, and students were encouraged to use their custom flashcards for exam preparation. The Flashcards-Plus strategy aimed to deepen cognitive engagement and promote active learning by requiring students to process the material at a more personalized and meaningful level.

No specific instructions or pre-defined lists of terms were provided for the final exam. Students were instead encouraged to develop their flashcards independently using their preferred methods. Paper-based index cards remained available for students to use, but the approach to

flashcard creation was left to their discretion. Subsequently, 17 students reported using flashcards to prepare for the final knowledge test, while 11 students indicated they did not use them.

After completing the final test, students were informed about the study by a research assistant and invited to participate by signing a data release consent form. Similarly to the first experiment, this was done by a research assistant in the absence of the course instructor, who was also the Principal Investigator in the study, in order to mitigate any potential conflict of interest and ensure the integrity and impartiality of the research outcomes.

Students who agreed to participate completed a paper-based survey that gathered information on their perceptions of the flashcard assignments, study habits, and levels of test anxiety, assessed using the Westside Test Anxiety Scale (Driscoll, 2007). Data analysis was delayed for two weeks until after students' final course grades were entered into the system and made available to them before the analysis began.

The resulting course data from 28 consenting students were included in the analysis. Performance data were exported from the LMS (Moodle) into Excel, while a research assistant manually entered survey responses into an Excel spreadsheet. Both datasets were subsequently imported into R for preprocessing and analyzed statistically using Jamovi. These analyses examined the effectiveness of the flashcard assignments and explored their relationships to students' academic performance, study strategies, and perceptions of the learning process.

Planned statistical analyses included nonparametric methods such as Friedman's test to compare repeated exam scores across flashcard conditions (traditional vs. Flashcards-Plus) among consistent users, as well as Spearman's rank-order correlations to assess the relationships between metacognitive measures (JOLs), test anxiety scores, and academic performance. The

primary dependent variables were knowledge test scores, test anxiety (Westside Scale), and self-reported study behaviours. The independent variables included flashcard strategy (traditional vs. Flashcards-Plus) and flashcard usage (yes/no), as defined by student condition and self-report. These analyses were designed to address the study's broader purpose of evaluating how elaborative encoding and metacognitive scaffolding influence learning outcomes, particularly in relation to self-regulation, retention, and anxiety in high-stakes assessment contexts.

Results

Test Scores. The analysis focused on students who consistently reported using flashcards for all three assessments (n = 14) to evaluate the impact of flashcard-based study strategies on academic performance. This selection reduced variability from inconsistent study habits and allowed for a clearer examination of whether regular flashcard use influenced test performance over time.

The mean score for Knowledge Test 1, which was prepared using instructor-provided definitions and paper-based flashcards, was $M = 74.86\%$ ($SD = 9.31$). For Knowledge Test 2, which incorporated the Flashcards-Plus strategy, the mean score was $M = 75.10\%$ ($SD = 7.38$), suggesting minimal change despite a strategy shift that encouraged deeper cognitive engagement and personalized learning. By Knowledge Test 3, the mean score decreased to $M = 71.77\%$ ($SD = 10.05$), reflecting a slight decline in performance over time.

A Friedman's test was conducted to determine whether there were significant differences in exam scores across Knowledge Test 1, Knowledge Test 2, and Knowledge Test 3 among students who consistently used flashcards for all three tests ($n = 14$). Due to the small sample size and potential violations of normality, Friedman's test was chosen as a non-parametric alternative to repeated-measures ANOVA. While *MSE* is not typically required in APA-style

MANOVA reporting, its inclusion follows the recommendations of Tabachnick and Fidell (2007), who emphasize its value in understanding model error and precision. Including *MSE* helps enrich the interpretation of the multivariate results by offering insight into the residual variance associated with each dependent variable. Specifically, the *MSE* values for Knowledge Test 1, Knowledge Test 2, and Knowledge Test 3 were 140.29, 66.39, and 201.00, respectively, reflecting varying levels of residual error across the three assessments.

The results of Friedman's test did not indicate a statistically significant difference in performance across the three tests, $\chi^2(2) = 1.00$, $p = .607$, suggesting that students' scores remained relatively stable despite consistent flashcard use. To further assess the robustness of these findings, a bootstrapped Friedman's test (10,000 resamples) was conducted. The bootstrapped mean Friedman statistic was 2.98, with a 95% confidence interval ranging from 0.14 to 10.43. The wide confidence interval suggests high variability in the resampled distributions, likely due to the small sample size, which may have limited the statistical power to detect meaningful differences.

The findings indicate that consistent flashcard use did not lead to significant improvements or declines in test performance over time. While flashcards are widely recognized as an effective study tool, their impact may depend on additional factors such as study duration, test format, or complementary learning strategies. The bootstrapped results further confirm that the observed differences in test scores were small and inconclusive, suggesting that a larger sample size may be necessary to determine the actual effects of flashcard-based study strategies.

Test Anxiety. A Spearman's rank-order correlation analysis was conducted to examine the relationship between students' test anxiety levels and their final course grades. The Westside

Test Anxiety Scale scores were compared with students' actual final grades to determine the strength and direction of the association.

The analysis yielded a Spearman's correlation coefficient of -0.12 (p = .45), indicating a non-significant negative relationship between test anxiety levels and final grades. These findings suggest that students with higher test anxiety scores did not exhibit significantly lower academic performance compared to their peers, consistent with prior research indicating that mild to moderate levels of anxiety may not necessarily impair performance (Driscoll, 2007; Connor et al., 2016).

JOLs. To examine students' JOLs, the analysis focused on the relationship between their self-reported expected final course grades and their actual final grades. Descriptive statistics revealed that students' mean anticipated grades (M = 74.54, SD = 7.61) were slightly lower than their actual final grades (M = 76.36, SD = 6.98). This pattern of underestimation suggests a slight tendency toward conservative estimates, contrasting with the common trend of overestimation found in prior studies (Koriat & Bjork, 2005; Son & Metcalfe, 2005).

To investigate this relationship further, Spearman's rank-order correlation assessed the association between students' expectations and their actual performance. The analysis yielded a strong, positive correlation (r_s = 0.686, p < .001), indicating that students with higher expectations tended to achieve higher final grades compared to their peers. This finding aligns with prior research emphasizing the link between optimistic self-assessments and academic performance (Zimmerman, 2002).

In addition, students who accurately calibrated their judgments (i.e., those with smaller discrepancies between expected and actual grades) exhibited better overall performance, consistent with theories of self-regulated learning. Future research should explore whether

interventions targeting metacognitive awareness might further align students' JOLs with their actual outcomes, potentially enhancing academic success.

The findings from Experiment 2 suggest that modifying flashcard design to include metacognitive prompts (Flashcards-Plus) may support students in monitoring their learning. However, without structured guidance, the long-term impact on retention and performance remains unclear. Notably, students in this study exhibited a conservative bias in their JOLs, underestimating their actual performance, a pattern that contrasts with prior research suggesting a tendency toward overestimation. Furthermore, the strong positive correlation between expected and actual grades suggests that students with higher self-expectations generally achieve better academic outcomes, reinforcing the link between self-assessment accuracy and performance. However, the results also indicate that additional factors, such as study strategies and test anxiety, may contribute to learning outcomes beyond self-expectations alone.

Building on these findings, Experiment 3 explores whether integrating Flashcards-Plus features into a digital format can enhance learning outcomes and self-regulation. Although the third experiment does not directly compare Flashcards-Plus with traditional flashcards through statistical testing, it investigates whether incorporating elaborative encoding techniques within digital tools aligns with students' performance, metacognitive awareness, and anxiety. The aim is to evaluate how specific design features in digital flashcards influence academic outcomes and study behaviours.

Experiment 3: Flashcards-Plus in Digital Format

Method

Participants. The third experiment was conducted at two post-secondary institutions: UNBC and CNC (the participants are the same participants who took part in the study described

in Chapter 4 of this dissertation). The sample consisted of 40 participants (12 male and 28 female; mean age = 23) enrolled in introductory psychology courses at these institutions. Of these, 14 participants were native speakers of English, while the remaining participants spoke one of India's official languages or dialects.

At UNBC, the study involved 18 participants who attended face-to-face courses. The gender distribution at UNBC included 14 females and four males. Participants' ages ranged from 18 to 30 years, with an average age of approximately 20.6 years (*SD* = 3.07). Table 5 details the participants' first and second languages by institution. At CNC, the study included 22 participants who attended an online course. The gender distribution included 16 females and six males. Participants' ages ranged from 19 to 44 years, with an average age of approximately 22.5 years (*SD* = 4.84).

Table 5

L1 and L2 by Institution

Institution 1				Institution 2			
L1	n spoken	L2	n spoken	L1	n spoken	L2	n spoken
English	7	English	9	Punjabi	15	English	12
Hindi	3	Hindi	3	English	7	Hindi	4
Gujarati	2	Urdu	3			Punjabi	1
Punjabi	1	Malaydam	2			None	7
Shina	1	Punjabi	2				
Sindhi	1	Arabic	1				
Tagalog	1	Burushaski	1				
Urdu	1	Italian	1				
		Yoruba	1				
		None	4				

Note. L1 and L2 by Institution.

Materials. At UNBC, the PSYC 101 Introduction to Psychology course included two equally weighted in-class exams (midterm and final), each worth 30% of the final grade. These closed-book assessments covered different portions of the course material and could include multiple-choice and short-answer questions. In addition to exams, students completed weekly quizzes and assignments (20%), which were typically open-book and could be delivered during class as pop quizzes. These included essay-style and fill-in-the-blank questions based on lecture content and textbook readings. A creative group project (20%) allowed students to present a psychological concept using a format of their choice (e.g., video, podcast, cartoon, or debate). Projects were evaluated on accuracy, clarity, creativity, and peer feedback. Students could also earn up to 4% bonus credit through participation in departmental research studies.

During Weeks 2 and 3, students received lists of instructor-selected key terms and definitions aligned with the textbook and lecture content, focusing on essential concepts for understanding and exam success. Following instructor guidance, students used these to create their first set of Anki flashcards during class. In Weeks 3 and 4, students were introduced to the Flashcards-Plus strategy, which required them to paraphrase definitions in their own words and generate personal examples. A second set of flashcards was created in class, with guidance on how to use them in preparation for the final exam.

At CNC, the PSYC 101 course was delivered asynchronously online, with assessments including weekly quizzes and assignments (40%), a final exam (30%), and an individual concept presentation (30%). Similar to UNBC, quizzes and assignments included open-book short-answer and fill-in-the-blank questions, and could be based on textbook or lecture materials not explicitly covered in both. For the final exam, students were tested on cumulative knowledge using a mix of multiple choice, true/false, matching, fill-in-the-blanks, or essay-type questions. The concept presentation allowed students to select and explore a major psychological concept using a creative format, individually or with a partner. Presentations were assessed based on clarity, conceptual accuracy, and presentation style.

The required textbook for both sections was the NOBA Psychology Collection (Biswas-Diener & Diener, 2016). The flashcard content was aligned closely with the textbook and lecture materials.

Procedures. This quasi-experimental design explored the relationship between perceived flashcard helpfulness and academic outcomes in two postsecondary psychology courses. Students at two institutions, UNBC and CNC, used Anki digital flashcards throughout the semester, first in a traditional format and later with the Flashcards-Plus strategy. This design

allowed for an investigation into whether students who engaged with elaborative encoding perceived benefits in retention and test performance, although no direct statistical comparison was made between the two strategies.

Unlike Experiments 1 and 2, which investigated the effects of structured flashcard strategies on exam performance, Experiment 3 focused on students' perceived usefulness of flashcards as the key variable of interest. Evaluating students' attitudes provided insight into how learners engage with self-regulated learning tools in real-world academic settings. These metacognitive evaluations are critical for understanding not only whether a strategy is effective, but whether students recognize its value and are likely to adopt it independently—factors that strongly influence long-term learning outcomes and strategy sustainability.

At UNBC, during weeks 2 and 3, students created Anki flashcards based on instructor-provided key terms and definitions, using the standard format of a concept on one side and its definition on the reverse. The Flashcards-Plus strategy was introduced in weeks 3 and 4, prompting students to paraphrase definitions and generate personalized examples. Students used these flashcards throughout the course for weekly quizzes, midterms, and the final exam. At CNC, students created flashcards using video instructions in weeks 1 to 5, employing the traditional method. In weeks 6 to 10, they implemented the Flashcards-Plus strategy, again using personalized flashcards for ongoing assessments.

At CNC, during weeks 1 to 5, students created Anki flashcards following video instructions. They adopted the Flashcards-Plus strategy from weeks 6 to 10, using personalized flashcards for quizzes, assignments, and the final exam.

The primary dependent variable was academic performance (quiz, assignment, and final exam scores). The main independent variable was students' perceived helpfulness of flashcards,

as reported in the end-of-course survey. Planned statistical analyses included Spearman's rank-order correlations to assess the relationship between perceived flashcard helpfulness and academic performance outcomes. Analyses were conducted separately for each institution due to differing instructional conditions. Consistent with previous experiments, data analysis was delayed for two weeks following grade finalization to protect student confidentiality and reduce bias.

Results

The collected data were analyzed to examine whether students who reported that flashcard assignments helped them remember information better also performed better academically. Spearman's rank-order correlations were computed between students' perceived flashcard usefulness and their scores on quizzes and assignments, final exams, and overall course performance.

For the CNC class, the Spearman correlation between flashcard helpfulness ratings and students' quizzes and assignment scores was not significant, $r_s(20) = -0.31$, $p = .16$. The correlation between flashcard helpfulness ratings and overall course performance was also not significant, $r_s\ (20) = -0.06$, $p = .79$. Additionally, the correlation between flashcard helpfulness ratings and final quiz scores was not significant, $r_s(20) = 0.41$, $p = .058$.

For the UNBC class, the correlation between flashcard helpfulness ratings and students' quizzes and assignment scores was not significant, $r_s(16) = 0.35$, $p = .16$. The correlation between flashcard helpfulness ratings and final exam scores was not significant, $r_s(16) = -0.22$, $p = .38$, and the correlation with overall course performance was also not significant, $r_s(16) = 0.06$, $p = .81$.

These results indicate no statistically significant relationships between students' perceived flashcard usefulness and their academic performance in either class. The lack of significant relationships suggests that external factors, such as study habits, test-taking strategies, and metacognitive awareness, may play a greater role in determining academic success than students' perceptions of study tool effectiveness.

Conclusions

This research investigated the effectiveness of flashcard-based learning strategies by examining the role of active recall, spaced repetition, and elaborative encoding in improving academic performance, self-regulated learning, and test-related anxiety in postsecondary education. Three interconnected experiments explored these cognitive techniques across digital and paper-based modalities to assess their impact on exam performance, perceptions of learning, and metacognitive accuracy.

Experiment 1 evaluated retrieval practice and spaced repetition using Quizlet and Cram flashcards in a digital learning environment. While MANOVA results suggested a statistically significant multivariate effect of flashcard condition on exam performance, further analysis revealed no significant difference in overall exam performance between the two groups. However, students who consistently used flashcards showed significantly higher final exam scores, suggesting that flashcards may be particularly beneficial for long-term retention rather than short-term exam preparation. Additionally, neither test anxiety nor cramming tendencies strongly predicted final course grades, highlighting the need for structured interventions that promote effective study habits.

Experiment 2 examined the effectiveness of the Flashcards-Plus strategy, which incorporates elaborative encoding through paraphrasing and personalized examples, in a

traditional paper-based format. The results indicated that while test performance remained stable across different study methods, students exhibited a strong positive correlation between their expected and actual final grades. This finding suggests that metacognitive awareness, rather than specific flashcard techniques, may play a crucial role in academic performance. Additionally, students in this study tended to underestimate their performance, contrasting with previous research on overconfidence in self-assessments.

Experiment 3 assessed the Flashcards-Plus strategy in a digital format combined with spaced repetition algorithms. The results were mixed, with no statistically significant correlation between students' perceived usefulness of flashcards and their academic performance at either CNC or UNBC. This suggests that external factors such as study consistency, instructional guidance, and course structure may influence the effectiveness of digital flashcard tools more than students' subjective perceptions of their utility.

Notably, test anxiety did not significantly correlate with academic outcomes in any experiment, suggesting that mild to moderate anxiety may not impair performance. In contrast, metacognitive awareness, as demonstrated by a strong positive correlation between expected and actual grades in Experiment 2, was more predictive of academic success. However, this relationship was not replicated in Experiment 3, where students' perceived flashcard helpfulness did not align with performance.

Across all three experiments, this research provides nuanced insights into the role of retrieval practice, spaced repetition, and elaborative encoding in optimizing learning outcomes. While flashcards facilitate long-term retention, their effectiveness appears to depend on structured implementation, student engagement, and contextual factors such as study duration and modality. The findings emphasize the importance of metacognitive awareness in self-

regulated learning. They also highlight the need for further research on integrating digital learning tools with structured instructional support to maximize their benefits in postsecondary education.

Discussion

The current research offers both theoretical and practical insights into how flashcard-based learning strategies influence academic performance, self-regulated learning, and metacognition in postsecondary education. By evaluating retrieval practice, spaced repetition, and the Flashcards-Plus strategy across multiple learning modalities, this study provides a nuanced understanding of how these cognitive techniques interact with different instructional formats and study behaviours.

The findings from Experiment 1 reinforce the well-established cognitive benefits of retrieval practice and spaced repetition (Roediger & Butler, 2011; Dunlosky et al., 2013). Although the MANOVA revealed a significant multivariate effect of flashcard condition on exam performance, follow-up analyses showed no significant difference in overall performance between the Quizlet (retrieval) and Cram (spaced) groups. This may suggest that both platforms offer overlapping cognitive benefits, possibly due to participants' unintentional use of both strategies or limited adherence to each platform’s distinctive algorithms.

However, students who consistently used flashcards performed significantly better on the final exam, suggesting that these techniques may be more beneficial for long-term retention rather than short-term gains. This pattern may reflect the naturally extended preparation timeline for final exams, which could amplify spacing effects regardless of the assigned platform (Cepeda et al., 2006). Moreover, unmeasured individual differences, such as intrinsic motivation or

conscientiousness, may have influenced both flashcard use and final outcomes, introducing potential confounds (Deci & Ryan, 1985).

Experiment 2 emphasized the potential of elaborative encoding to enhance metacognitive monitoring. However, despite strong correlations between students' expected and actual grades, there were no significant differences in test scores across the Flashcards-Plus and traditional flashcard phases. This may suggest that elaborative prompts alone are insufficient without ongoing guidance. Prior work suggests that elaboration benefits are maximized when paired with immediate feedback or retrieval attempts (McDaniel, 2023). The decline in performance on the third test could also reflect cognitive fatigue or increased difficulty of content, rather than diminished effectiveness of elaborative encoding.

Moreover, the high JOL accuracy observed may reflect students' prior academic experience or domain familiarity rather than improved metacognitive calibration due to flashcard type. Learners with greater topic familiarity tend to make more accurate JOLs, independent of the strategies used (Koriat & Bjork, 2005). Thus, differences in students' baseline knowledge or self-efficacy may have contributed to observed outcomes.

Experiment 3 yielded no statistically significant correlation between students' perceived flashcard helpfulness and their academic performance; nevertheless, the findings provide valuable insights into the complexities of digital learning environments. While this could imply a disconnect between perceived and actual learning benefits, several alternative explanations merit consideration. One possibility is that digital learning contexts impose distinct cognitive demands, such as multitasking and susceptibility to distractions, which may reduce the efficacy of otherwise well-designed tools (Chen & Fu, 2003). It is also plausible that external factors, such as study habits, test-taking strategies, and metacognitive awareness, exert greater influence on

academic success than students' subjective perceptions of tool effectiveness. Additionally, retrospective bias may have influenced students' self-ratings, such as hindsight bias following grade feedback or social desirability during post-course surveys (Tversky & Kahneman, 1974).

Across all three experiments, test anxiety did not significantly predict academic performance. While structured tools like flashcards have been proposed to reduce anxiety by enhancing perceived preparedness (Rana et al., 2020), the null findings in this study may reflect a restricted range of anxiety levels, particularly given the moderate average anxiety scores observed. Moreover, contextual factors such as grading policies, exam format, or instructor support may have mitigated test anxiety across groups, reducing its predictive value.

Lastly, metacognitive calibration was strongly associated with academic performance in Experiment 2. The strong correlation between students' grade expectations and their performance underscores the importance of accurate self-assessment in learning (Koriat & Bjork, 2005; Zimmerman, 2002). However, this relationship may be bidirectional: students who performed well might have retrospectively aligned their expectations with their results, rather than demonstrating accurate foresight. Because the study did not include pretest JOLs, it remains unclear whether improved calibration resulted from strategy use or simply a reaction to performance feedback.

In sum, these findings support the cognitive value of flashcards and metacognitive scaffolding but also underscore the importance of sustained engagement, contextual factors, and learner variability. Together, these findings contribute to a deeper understanding of how retrieval practice, spaced repetition, and elaborative encoding interact with different educational contexts. While flashcards remain a highly effective learning tool, their success depends on consistent engagement, structured implementation, and metacognitive support mechanisms.

Implications and Future Directions

The present findings offer several implications for improving learning outcomes and guiding future research on flashcard-based study strategies in postsecondary education. First, retrieval-based learning strategies should be systematically integrated into curricula through structured digital tools like Quizlet and Anki or through instructor-facilitated exercises, as the findings across all three experiments demonstrated that consistent flashcard use, particularly strategies emphasizing active recall, was associated with higher exam performance and stronger metacognitive calibration, even when no single platform or technique consistently outperformed others.

However, the results from Experiment 3 highlight that students' perceptions of flashcard effectiveness do not necessarily predict academic performance. This disconnect may reflect the influence of retrospective bias, e.g., hindsight or social desirability effects (Tversky & Kahneman, 1974) and contextual factors that shape students' evaluations after assessment rather than during the learning process. This suggests that external factors, such as study habits, test-taking strategies, and metacognitive awareness, may play a more significant role in learning outcomes than the perceived usefulness of digital study tools.

Second, the study underscores the importance of consistent guidance and scaffolding in sustaining effective study habits over time. Experiment 2 showed that without structured support, students may revert to passive learning behaviours, reducing the long-term benefits of elaborative encoding, as evidenced by the lack of significant improvement in test performance between the traditional and Flashcards-Plus phases, despite the latter involving deeper processing through paraphrasing and example generation. This plateau in performance suggests that simply

introducing elaborative prompts may not be sufficient unless reinforced through continued instructional scaffolding and feedback.

To maximize learning outcomes, educators should incorporate explicit instructional strategies that encourage active engagement with retrieval practice, spaced repetition, and elaborative encoding. Providing structured guidance in implementing flashcard-based techniques, especially those incorporating elaborative encoding, may help students maintain effective study strategies over time and maximize long-term learning outcomes.

Third, these findings support the integration of elaborative encoding into self-testing strategies, as it promotes not just memorization but also deeper comprehension and knowledge application. The Flashcards-Plus strategy, which requires paraphrasing and personalized examples, was associated with improvements in metacognitive calibration. Future studies may also explore whether elaborative encoding within digital flashcard formats, such as Flashcards-Plus, yields measurable performance benefits compared to traditional digital flashcards, as this distinction was not explicitly examined in the current experiment.

However, this relationship may be bidirectional: students who performed well might have retroactively aligned their expectations with their actual outcomes rather than predicting them accurately from the outset. Given that many students struggle with metacognitive accuracy, future interventions could focus on enhancing self-monitoring strategies, such as immediate feedback, reflection prompts, and adaptive learning technologies, to promote more precise JOLs. Future studies should also include both pre- and post-test JOLs to distinguish between genuine calibration and post hoc rationalization.

Additionally, the moderate test anxiety levels observed in this study, along with the lack of significant predictive value, suggest that contextual or instructional variables may buffer

students from the negative effects of test anxiety. Future research could examine whether structured tools like flashcards are more effective in reducing anxiety under conditions of high-stakes pressure, minimal support, or greater baseline anxiety.

Future research should explore how the combination of retrieval practice, spaced repetition, and elaborative encoding can be optimized for diverse learning populations, particularly among students with varying levels of metacognitive awareness. Additionally, investigating how study frequency, structured retrieval practice, and instructional guidance mediate the relationship between perceived effectiveness and actual learning outcomes would further refine our understanding of these strategies' impact on knowledge retention and transfer.

Given the variability in digital learning outcomes observed in Experiment 3, future studies should examine how different instructional formats and scaffolding methods affect engagement with digital flashcards. Adaptive learning technologies that personalize study schedules based on individual performance may offer new insights into optimizing learning efficiency in digital environments. Research should also consider the role of cognitive load, working memory capacity, and retrieval difficulty in shaping the effectiveness of different study techniques.

Finally, future studies should track platform-specific usage patterns more closely to determine whether students engage with flashcard software as intended. Previous work has shown that learners may bypass the core features of retrieval or spacing when using digital tools, limiting their effectiveness (Karpicke et al., 2009). To improve internal validity, future studies should incorporate more direct measures of engagement, such as log file tracking or usage diaries, to determine how closely participants follow the intended study schedules and to better

isolate the effects of spaced repetition. This highlights the need for better alignment between tool design, instructional context, and student behaviour.

Future research should adopt more consistent measurement approaches to improve comparability across experiments. In particular, combining perceived effectiveness ratings with behavioural usage data, such as usage logs or structured study diaries, would offer a more comprehensive view of student engagement. The methodological divergence in Experiment 3, while necessary due to cross-institutional constraints, limited the ability to track flashcard use directly and compare findings with Experiments 1 and 2. Greater alignment in data collection would strengthen future interpretations of strategy effectiveness.

Although this study did not impose external controls on the timing or frequency of flashcard use, students provided self-reported data on how often they practiced with each card set. These usage data were not included in the main analyses to preserve the clarity and statistical focus on platform-based comparisons. However, they offer a valuable avenue for future secondary analyses. Investigating whether students who reported more frequent or distributed practice achieved better performance could help clarify the influence of self-directed spacing behaviour on learning outcomes.

Overall, this research provides empirical support for the potential effectiveness of structured flashcard-based strategies in postsecondary education, particularly when combined with instructional support. By integrating retrieval practice, spaced repetition, and elaborative encoding, structured flashcard techniques can enhance memory retention and metacognitive accuracy. The results emphasize the need for consistent instructional support and self-regulated learning strategies to maximize their benefits. These findings contribute to the growing body of

literature on evidence-based study strategies and highlight important considerations for educators and learners when implementing flashcard-based learning techniques.

4. Exploring the Efficacy of GenAI Tools in Post-Secondary Education

At all educational levels, the demand for students to comprehend, retain, and integrate vast amounts of information often leads to significant test anxiety (Connon et al., 2016). Common student behaviours consistent with assignment and test anxiety include procrastination, ineffective study habits, distraction, cramming to complete an assignment or study for a test, and mental "freezing," to name a few (Trifoni & Shahini, 2011). Several studies have suggested that test anxiety amongst university students can have deleterious impacts, including poor academic performance, negative self-image, failing courses and dropout rates (Cassady & Johnson, 2002; Gerwing et al., 2015; Hembree, 1988; Megivern et al., 2003). Nevertheless, in post-secondary education institutions, where innovative technologies continually reshape research and pedagogical approaches, the integration of generative artificial intelligence tools presents avenues for enhancing student learning experiences.

Artificial intelligence (AI) and GenAI tools like chatbots have emerged as promising avenues to improve learning outcomes related to critical thinking, writing proficiencies, and study skills (Chiu, 2024). AI is the science of using computers, algorithms, and datasets to achieve human-like problem-solving by analyzing a specific environment and acting toward a defined goal (Sheik, 2023). GenAI is a set of technological tools that can produce new and unique outputs, including text, images, computer coding, and videos, in response to input commands (Chiu, 2024). Chatbots are a type of GenAI designed to simulate human conversation or writing, with ChatGPT being a common example of such an application. ChatGPT, developed by OpenAI, is based on a Generative Pre-trained Transformer architecture that uses deep learning techniques to generate human-like text based on the input it receives (OpenAI, 2023).

While previous research (e.g., seminal work by Beck, Stern, & Haugsjaa, 1996 and Woolf, 1991; or a more recent systematic literature review on the topic by Tahiru, 2021) has explored the application of AI within educational milieus, an examination of the potential for chatbots to enhance student learning outcomes necessitates further empirical scrutiny. For example, it is unclear if such learning aids ameliorate academic learning and test anxiety. This chapter explored whether student learning and general test anxiety can be improved by purposefully integrating GenAI tools into students' approaches to course assignments. Specifically, the research investigated how students engage with chatbots as 'study confidantes' to support content learning and how students use AI-generated essays to develop their academic writing skills by critically evaluating their structure and content. As Chiu (2024) emphasized, it is critical that students, the most important stakeholders in education, are involved in research that explores the impact of GenAI.

The implications of this study serve to understand how educators' learning outcomes can be more easily achieved with well-designed assignments incorporating GenAI tools. Understanding the efficacy of GenAI tools in a learning context will enable instructors to design assignments and learning activities that maximize student engagement and learning outcomes. Similar to Sana et al. (2020), this research examined efficacy in terms of optimizing learning. The study also contributes to the growing body of literature on AI in education, providing empirical data on the benefits and limitations of GenAI tools. As research continues to emerge, post-secondary institutions will be better able to utilize this body of literature to inform policy decisions regarding the integration of advanced technologies in the curriculum.

Test Anxiety

In many post-secondary courses, students are tasked with comprehending, retaining, and integrating substantial volumes of information across multiple courses each semester. This situation, compounded by similar test and assignment due dates, creates a challenging overall learning environment due to the need to synthesize extensive content that may lead to pronounced test anxiety. Rana and Mahmood (2010; see also Gerwing et al., 2015) reported a significant negative correlation between students' achievement scores and their levels of test anxiety, highlighting the salience of cognitive factors, particularly worry, over affective factors such as emotional distress. Their investigation posited that test anxiety constitutes a contributing element to students' suboptimal performance and academic underachievement. Importantly, their study emphasized the potential for mitigating test anxiety through targeted interventions aimed at equipping students with coping mechanisms to address the underlying stressors. Instructors can strive to mitigate some test anxiety by providing explicit assignment and test orientations and preparation, encouraging positive thinking, seeking peer support, and recommending relaxation training, to name a few interventions (Rana & Mahmood, 2010). Gerwing et al. (2015) further concluded that educators should inform students of the prevalence of test anxiety as a potential method to reduce the stigma of test anxiety.

Taken together, these suggestions related to students' academic stress accentuate the imperative for examining further interventions designed to bolster students' capacity to achieve the intended learning outcomes and ameliorate test anxiety. GenAI may offer some promise through purposefully designed critical analysis assignments, self-instructional training, or the preparation of exam notes to enhance study skills and thereby increase confidence and reduce the negative impact of test anxiety.

Cognitive Load, Active and Authentic Learning

Cognitive load theory, introduced by Sweller (1988), posits that learning is hindered when cognitive resources are overloaded. This theory identifies three types of cognitive load: intrinsic, extraneous, and germane (Sweller, 2010). Intrinsic load refers to the inherent difficulty associated with a specific task; extraneous load is related to how information is presented; and germane load pertains to the mental effort used to create schemas. Effective instructional design aims to reduce extraneous load and optimize germane load, thereby facilitating efficient learning processes.

Active learning, a core principle of constructivist theory, is also supported by GenAI tools. Constructivist learning theories, championed by Piaget (1952) and Vygotsky (1978), emphasize the active role of learners in constructing knowledge through interaction with their environment. These theories advocate for learning environments that promote exploration, problem-solving, and the application of knowledge in various contexts. Constructivist approaches encourage learners to actively engage with the material, fostering deeper understanding and retention.

Seeking new learning opportunities is important for all students to achieve the intended learning outcomes, which is well-supported in educational research. Another concept, authentic learning, emphasizes that students are more motivated and better prepared for success when their education mirrors real-life contexts and addresses topics relevant to their lives outside of school. This approach encourages students to actively seek out and engage in new learning experiences, thereby enhancing their understanding and retention of knowledge (Lombardi & Oblinger, 2007; Nachtigall et al., 2022).

These educational approaches highlight the critical role of students proactively engaging in new learning opportunities to achieve their intended educational goals. By fostering a mindset of curiosity and continuous improvement, students not only enhance their academic performance but also develop essential skills that prepare them for real-world problem-solving and lifelong learning.

Educational use of GenAI

Instructors have been creatively adapting the use of GenAI to enhance critical thinking, digital literacy, writing, and study skills (Kee et al., 2024; Muthmainna, 2022; Zawacki-Richter, Marín et al., 2019) and potentially contribute to reducing academic anxiety. Chatbots can assist students in learning a particular concept through the use of text prompts and conversational responses. One of the chatbots that has received widespread attention from the academic field due to both the opportunities it affords and concerns related to academic integrity is ChatGPT, where GPT stands for "generative pre-trained transformer." Language-processing chatbots undergo pre-training on extensive language model databases, characterized by multiple stages. Typically, the initial phase involves supervised learning, wherein a specific prompt is chosen from a corpus, followed by the provision of a desired response by a human agent. Subsequently, the neural network fine-tunes its outputs based on this input. In the subsequent phase, the network is presented with a prompt, generating several responses that are subsequently assessed for quality by human evaluators. These evaluations serve to enhance the reward model employed by the network. Moreover, the model's efficacy can be further refined by integrating "policies" designed to impose constraints on specific types of outputs. For instance, given a prompt such as "Describe Chomsky's perspectives regarding ChatGPT," the chatbot processes the input and generates a written response.

Researchers and practitioners are beginning to explore the potential of chatbots for enhancing learning processes and reducing test anxiety. Empirical evidence suggests that affording students self-testing opportunities, such as practice quizzing, can significantly enhance their retention of course material while also fostering metacognitive awareness of their comprehension levels (Stewart et al., 2014). This set of conclusions aligns with the constructivist view that self-regulation and active engagement in learning activities are crucial for effective learning (Zimmerman, 2002). The question arises: can GenAI tools, such as chatbots, serve as facilitators for heightened learning retention and bolstered confidence in assignment submissions, thereby mitigating academic anxiety?

Building upon the current research context, this study investigated two emerging lines of inquiry: (1) How effective are GenAI tools in enhancing post-secondary students' learning outcomes? and (2) To what extent can GenAI tools mitigate test anxiety? The first question was delimited by contextual factors encompassing the academic discipline and the course level. Specifically, this research explored how first-year college and university students in psychology could use a chatbot as a "study confidante" to assist with self-testing for difficult course materials before a midterm. Furthermore, a secondary assignment was devised to afford students an opportunity to learn the intricacies of crafting an academic essay. In this secondary task, students selected a chatbot of their preference to generate an academic essay, subsequently appraising the content and structure based on a rubric provided by the instructor for this assignment in advance.

Based on emerging research disseminated at conferences and in scholarly journals (e.g., Li et al., 2021; Mon et al., 2023), this study posed two hypotheses. Hypothesis 1 posits that students can elevate their learning and effectively attain specified course learning objectives

through purposefully designed assignments integrating GenAI. In addition, empirical investigations have revealed that test anxiety exerts a negligible influence on exam performance when adjusted for preceding levels of knowledge (Theobald et al., 2022). Theobald et al. also identified a correlation between lower levels of knowledge and heightened test anxiety. Consequently, hypothesis 2 posits that implementing assignments incorporating GenAI to augment students' knowledge levels will concomitantly mitigate test anxiety levels. This study includes students' JOLs, which are metacognitive self-assessments of how well a person has learned particular information (e.g., Koriat & Bjork, 2005; Koriat & Shitzer-Reichert, 2002; Son & Metcalfe, 2005), to assess the efficacy of learning using assignments that integrate GenAI.

Method

The primary objectives of our investigation were to assess the efficacy of (1) self-testing facilitated by chatbots in enhancing learning processes and, thus, potentially conferring cognitive advantages to students and (2) using written material produced by chatbots to learn about the structure of academic writing. In the context of this research, the efficacy of GenAI in learning environments refers to students' self-assessment of enhanced learning towards specific learning outcomes and mitigated test anxiety. Efficacy is measured by the extent to which these tools improve students' self-assessment of improved learning outcomes such as comprehension, retention, critical thinking, and writing skills. This study comprehensively examined the viability of integrating chatbots within the instructional assignments for an Introduction to Psychology course offered at UNBC and CNC during the Spring Intersession of 2023. Central to our inquiry was the exploration of the extent to which chatbots could augment student learning outcomes and foster deeper comprehension of course content. A mixed methods (i.e., qualitative and quantitative) methodological approach was taken following Creswell and Creswell (2017).

Research Site and Participants

This study was conducted at two post-secondary institutions in British Columbia, Canada: the University of Northern British Columbia (UNBC) and the College of New Caledonia (CNC). The sample consisted of 40 participants (12 male and 28 female; mean age = 23) enrolled in introductory psychology courses at these institutions. Of these, 14 participants were native speakers of English, while the remaining participants spoke one of India's official languages or dialects.

At the UNBC, the study involved 18 participants who attended face-to-face courses. The gender distribution at UNBC included 14 females and four males. Participants' ages ranged from 18 to 30 years, with an average age of approximately 20.6 years (SD = 3.07). Table 5 details the participants' first and second languages by institution. The CNC study included 22 participants who attended an online course. The gender distribution included 16 females and six males. Participants' ages ranged from 19 to 44 years, with an average age of approximately 22.5 years (SD = 4.84).

Data Collection Procedures

Two assignments involving GenAI were incorporated into the course curriculum. These assignments were developed to align with two specific learning outcomes. In the first assignment, the students were required to ask a chatbot of their choice to explain a difficult concept related to the course material. In this assignment, the students used GenAI as a "study confidante" to help prepare for their midterm exam. This assignment was aligned with the following learning outcome: students will be able to demonstrate a comprehensive understanding of key psychological theories, concepts, and terminology across major domains of psychology and to critically evaluate relevant information from different sources.

In the second assignment, the students asked a chatbot to write an academic essay and then graded it based on the instructor-provided marking rubric. This second assignment was aligned with the following learning outcome: students will be able to critically evaluate writing examples and will demonstrate proficiency in identifying and analyzing the coherence, clarity, and organization of written arguments, as well as the effectiveness of evidence and support used to bolster claims.

The assignment instructions provided to the students were as follows: for the first assignment, students were tasked with engaging a chatbot of their choice (e.g., ChatGPT) to explain a concept they found challenging while preparing for their midterm examination. Emphasis was placed on carefully formulating questions/prompts, with students being encouraged to refine their queries based on the chatbot's responses. Subsequently, students were required to document their interactions by taking a screenshot of the conversation and submitting it as part of the assignment. The course instructor allocated participation marks for formulating their prompt in a way that would allow the chatbot to generate a detailed and accurate response. If the answer generated by the chatbot seemed insufficient or off-topic, the students were required to ask follow-up questions. In their comments that constituted the second part of the assignment, the students were asked to reflect on how the information provided by the chatbot compared to the course textbook and/or the lecture material. In the subsequent class discussion, the instructor selected a few examples of how the information generated by the chatbot appeared to be incorrect or outdated and discussed with the class the importance of cross-referencing AI-generated responses with peer-reviewed scientific research or, at minimum, with the textbook.

For the essay analysis assignment, students were tasked with providing instructions to a chatbot of their choice to compose an essay on a topic covered in the course curriculum. Once

again, students were told to craft their questions/prompts carefully and to refine their inquiries based on the chatbot's response. Utilizing a grading rubric supplied by the instructor, students were tasked to evaluate the essay as if they were instructors assessing a student's academic submission. During a class session, the instructor explained the rubric's categories and scale to ensure students' understanding. On the rubric, students were prompted to justify the mark they assigned, reflecting on the purpose of the assignment and contemplating how the integration of GenAI could be incorporated with traditional classroom assignments.

Additionally, students were encouraged to consider potential implications and caveats associated with utilizing GenAI. Upon completion, students were required to submit both the completed rubric with their comments and the essay generated by the chatbot. The goal of this assignment was to encourage critical thinking by tasking the students with evaluating someone else's written work based on detailed and clear criteria contained in the rubric and familiarizing students with the elements and the structure of an academic essay. The instructor reviewed each submission for sufficient, precise, and well-worded instructions provided to the chatbot, as well as the clarity of the assigned mark's justification.

At the onset of the semester, students completed a pre-test measure using the Westside Test Anxiety Scale (Driscoll, 2007). Following their final exam, students were briefed about the study's objectives and its association with two specific assignments. They were then presented with a data release consent form, affording them the option to opt out of their data being utilized for the study. Students who provided consent were administered either a paper-based survey (for the in-person course at the university) or an online survey link (for the online course at the college).

The survey collected: (1) basic demographic information (e.g., age, sex, gender identity, first language, multilingualism, and learning disorder history); (2) ratings of study strategies used, including frequency of cramming, and self-reported usefulness of flashcards and AI-based assignments; (3) perceived effectiveness of chatbot-assisted assignments for concept understanding and academic writing; (4) likelihood of future use of flashcards and AI tools; (5) open-ended responses on study strategies and course experience; and (6) a post-test administration of the Westside Test Anxiety Scale. In addition, participants were asked to provide a JOL by estimating their expected final course grade on a scale from 0 to 100%.

To ensure impartiality and minimize potential biases, survey data were collected independently by a research assistant, distinct from the course instructor who served as the first author. These data were securely housed in a designated laboratory until final grades were submitted and approved for both courses.

Ethics Approvals

Research ethics approvals were obtained from both UNBC (approval number 6009020 – Appendix 5) and CNC (approval number EO-2024-0508-102 – Appendix 3) in accordance with the Panel on Research Ethics guidelines (2023). The students in both institutions were informed about the study after their final exam and provided with a data release consent form with the possibility to opt out of their data being used for the study. Students who gave their consent were provided with a paper-based survey in UNBC and an identical web-based survey in CNC that assessed their study habits and post-test anxiety levels using the Westside Test Anxiety Scale.

To ensure that participation did not influence grading outcomes, data analysis was postponed until two weeks after students' final grades had been submitted. Confidentiality and anonymity have been maintained for all participants by anonymizing all responses after the

student grades were associated with survey responses. Data confidentiality was strictly maintained in accordance with institutional and ethical guidelines. Identifiable information was not collected, and all data were stored securely.

Additionally, to mitigate any potential conflict of interest arising from the Principal Investigator's dual role as both researcher and course instructor, it was research assistants who distributed and collected the research surveys following the final exam. These safeguards ensured the researcher's non-involvement in grading and data collection processes, thereby maintaining the integrity and impartiality of the research outcomes.

Data Analysis

Data from surveys and assignments were entered into a single .csv file and imported into R for preprocessing, analysis, and visualization. Descriptive analytics were used to identify trends and relationships in the survey response data. A dependent measures t-test examined any differences between pre- and post-test anxiety scores. Given the similarities between the response profiles of both the university and the college students, the analysis collapsed the data and provided descriptive analytics on the aggregate data.

Spearman's rank-order correlation was conducted to evaluate the relationship between students' expectations (i.e., JOLs) and their actual performance. JOLs refer to individuals' predictions of their future performance on a task based on their current understanding or knowledge (Koriat & Bjork, 2005; Son & Metcalfe, 2005). Additionally, correlations between post-test anxiety scores and both expected and actual final grades were assessed. This analysis examined whether students' self-reported anxiety levels at the end of the course were related to their expected grades (i.e., JOLs) and their actual academic performance.

To ensure the validity and reliability of the findings, data screening procedures were implemented to check for missing values, outliers, and assumptions of normality. The use of Spearman's rank-order correlation was particularly beneficial in this context as it is less sensitive to outliers compared to Pearson's correlation and is suitable for data that do not necessarily follow a normal distribution.

Results

Efficacy of Learning

The post-course survey findings reveal positive perceptions of chatbot assistance in understanding course material and constructing academic papers. The majority of students (86%) stated that using a chatbot as a "study confidante" helped them better understand/remember specific course information for an exam. For the essay grading assignment, 61% of university students expressed that the process of reviewing and analyzing an AI-generated essay helped them understand the structure of an academic essay, and 83% of college students reported that the essay grading assignment helped them understand the information better. A small minority (12.5%) expressed that they disagreed that this assignment helped them understand the structure of an academic essay. It was noted that 60% of the students who disagreed that the assignment helped them understand the structure of an academic essay (i.e., 3 out of 5 students) had English as their first language (EFL). In contrast, only 4% of the total number of non-English as a first language (non-EFL) students expressed disagreement. Prior experience with essay writing at the post-secondary level may explain the difference between EFL and non-EFL students.

The post-course survey also explored students' likelihood of using GenAI tools like chatbots in future classes. Most students (70%) stated that they would likely use chatbots in future classes. Based on the feedback provided by the students during the class discussions, the

intended learning outcome for the first GenAI assignment was achieved: in addition to major psychological concepts, the students understood that as helpful as the AI-generated information may be, it is not always reliable and, therefore, necessitates careful scrutiny. It is also worth noting that ChatGPT was the most common, but not the only GenAI tool that students chose to use for the two assignments. Some other chatbots of choice were Tiimo Vercel, My AI, essaywriters.ai, and Microsoft Bing.

Qualitatively, some of the feedback provided by the students within their submissions included the following comment:

> I feel that Al can be incorporated into traditional classrooms as it is a highly useful source of information, that is available at any time with access to all the information you would ever need to know. I would say that students using Al need to be made aware that they must do a bit of fact-checking with some of the information before assuming it is all correct. As well as ask the Al a question a few different ways before just going off the first bit of info they receive to make sure it is true and all answers they are getting are relatively the same.

Other comments included: “Although there was a level of understanding on the topics, using information without proper sources is plagiarism” (the student assigned the “F” grade to the essay generated by the chatbot); and “The essay shows a partial understanding of the material, but lacks depth and thoroughness in discussing sensation and perception.” In the subsequent class discussion, the instructor selected some examples of fake references generated by chatbots (a commonly known limitation) to emphasize the importance of information cross-checking once again and sought students’ feedback on the ethical considerations of incorporating GenAI into contemporary post-secondary education. The students expressed the importance of

having clear guidelines to follow on the institution's and instructors' part regarding the acceptable use of GenAI technology and the transparency on the student's part when it is being used. Some students shared that it is often unclear whether instructors find using such tools acceptable to use, which leads to either fear of utilizing any AI tools or withholding the fact when they are being used. This feedback underscores the need for thorough examination when using AI tools for academic purposes.

Examining Test Anxiety and JOLs

The students' average anxiety score remained relatively stable from the pre-test to the post-test at "high normal test anxiety" (Driscoll, 2007). The average pre-test anxiety score was 2.82, which corresponds to high normal test anxiety, while the average post-test anxiety score was 2.97, which was still at high normal test anxiety. A dependent samples t-test illustrated no difference between pre- and post-test anxiety scores, $t(35) = 0.36$, $SEM = 0.203$, $p > 0.72$, indicating that the difference between the pre-test and post-test anxiety scores is not statistically significant at conventional significance levels. The four students who did not complete the pre-test anxiety measure at the beginning of the semester were excluded from this analysis.

In addition to analyzing survey data concerning student perceptions of GenAI assignments, this study examined JOLs (Koriat & Bjork, 2005; Son & Metcalfe, 2005) by assessing students' self-reported expected final course grades and their correlation with the actual final course marks they received. The students' mean anticipated grades, that is, their JOL for the course ($\overline{x} = 78.65$), exceeded their actual final grades ($\overline{x} = 64.37$) by approximately 14 percentage points. This disparity suggests a tendency towards inflated JOLs, which may have arisen due to a fundamental difference between learning and testing conditions (Koriat & Bjork, 2005; Koriat & Shitzer-Reichert, 2002). In addition, Spearman's rank-order correlation was used

to evaluate the relationship between students' expectations and their actual performance. The statistical analysis yielded a moderate, positive correlation ($r_s = 0.413$, $p < .05$), indicating that students with higher expectations tended to achieve higher grades than their peers. However, the moderate correlation underscores the limited predictability of actual performance based solely on students' expectations. Despite some alignment between expectations and academic outcomes, the correlation suggests that other factors also influence students' final grades.

Spearman's correlation was also conducted to assess the relationship between the post-test Westside Test Anxiety scores and the self-reported expected final grades. The correlation coefficient was 0.016, $p = 0.92$, indicating no significant relationship between the two variables. Finally, Spearman's correlation was performed between the post-test Westside Test Anxiety scale scores and the actual final grades, revealing no significant relationship between anxiety levels and final grades, $r_s = –0.103$, $p = 0.53$, which is consistent with past research (Connon et al., 2016).

Discussion

This study has demonstrated the potential of GenAI tools in enhancing learning experiences in post-secondary settings. The integration of chatbots as "study confidantes" and essay writers was perceived by students to positively influence comprehension and retention of course material. While the anticipated reduction in test anxiety was not observed, the findings underscore the potential of chatbots in improving learners' perceived understanding of writing an academic essay. The present research contributes to the scholarship of teaching and learning by examining the utility and effectiveness of GenAI tools in supporting student learning outcomes and aiding their test anxiety. The stability of test anxiety scores suggests that further

investigation is needed to explore the relationship between test anxiety and learning interventions.

Overall, the results provided partial support for the hypotheses. Hypothesis 1, which posited that students could elevate their learning and effectively attain specified course learning objectives through purposefully designed assignments integrating GenAI, was supported by the positive perceptions and improved understanding reported by students. However, hypothesis 2, which proposed that the implementation of assignments incorporating GenAI would mitigate test anxiety levels, was not supported as the difference between pre-test and post-test anxiety scores was not statistically significant.

Even though the two assignments involving GenAI, as designed and implemented in the two courses, did not lead to a statistically significant reduction in test anxiety among participants, the present descriptive research provides a valuable exploration of students' perspectives regarding the integration of chatbots as learning aids and the potential ramifications for future teaching and learning methodologies. As underscored by Chiu (2024), pedagogical inquiries aimed at integrating technology to enhance learning outcomes necessitate consideration of student perspectives. Our study engaged students in self-reflection regarding their experiences with GenAI-enabled learning activities, encompassing tasks to demonstrate a comprehensive understanding of key psychological concepts and critically evaluate writing examples. Overall, the findings indicate that students held positive perceptions of assignments incorporating GenAI, noting its beneficial impact on their learning endeavours. As Ertmer and Newby (2013) remark while reflecting on their seminal work from 20 years ago, the widespread availability of the Internet and Web 2.0 tools, the emergence of a new generation of learners with distinct preferences and capabilities, and the evolution of teaching methods that predominantly align

with the tenets of constructivism are the three major forces shaping today's learning processes. Ertmer and Newby (2013) stress the imperative of adapting instructional design to meet the evolving needs of today's learners, advocating for contextualized, personalized, and collaborative learning experiences. These findings hold significant implications for educators seeking innovative strategies to enrich student learning outcomes.

Building upon Ertmer and Newby's (2013) contention that instructional designers should prioritize the efficacy of learning theories in facilitating mastery of specific skills rather than adhering to a one-size-fits-all approach, this principle extrapolates to the realm of individual assignments. This extension prompts us to explore how assignments can be meticulously crafted to foster targeted learning outcomes tailored to the unique needs of learners. In the ever-evolving landscape of education, characterized by the advent of new and innovative technologies, the integration of GenAI tools emerges as a promising avenue for enhancing student learning experiences. Instructors can create dynamic learning environments that resonate with contemporary learners by intentionally designing learning assessments that leverage GenAI to align with course objectives. Moreover, soliciting ongoing formative feedback from students regarding the efficacy and relevance of these assignments enables educators to fine-tune assignments for future use, fostering a culture of continuous improvement in pedagogical practices within higher education.

Students' positive reception of chatbots points towards a promising direction for integrating AI in post-secondary education. These findings align with the hypothesis that GenAI tools can serve as effective pedagogical aids. However, the lack of a significant decrease in test anxiety from pre- to post-test highlights the complexity of test anxiety as an affective state, which may not be easily ameliorated through academic assignments. The discrepancy between

students' expected and actual grades also reveals an overconfidence bias, which GenAI tools did not affect. These results suggest that while GenAI can enhance content comprehension and academic skills, its role in fostering realistic self-assessment and mitigating psychological aspects of learning demands further exploration.

Purposefully designed assignments using GenAI chatbots can minimize the extraneous cognitive load (Sweller, 2010) by providing information in a clear, concise manner and allowing the opportunity for immediate revisions based on the prompts generated by the students themselves. This immediate feedback helps prevent learners from becoming overwhelmed by irrelevant or inadequately structured information. A lack of prompt feedback from the instructor was found to cause confusion, anxiety and frustration in students (Hara, 2000). By offering scaffolding and adaptive support, chatbots can enhance germane cognitive load, encouraging learners to invest mental effort in meaningful learning activities, such as critical thinking (e.g., evaluating whether the generated response is appropriate) and problem-solving.

GenAI assignments can also facilitate active learning by engaging students in interactive dialogues, posing questions, prompting reflections, and providing opportunities for self-assessment. These interactions can stimulate learners' cognitive processes, encouraging them to actively apply and consolidate their knowledge. For example, a chatbot might simulate a real-world scenario related to the course content, requiring students to apply their understanding in a practical context. The benefits of active learning were found to lead to increases in examination performance and decreases in failure rates compared with traditional lectures (Freeman et al., 2014).

Therefore, the integration of GenAI tools, such as chatbots, can support cognitive load theory by optimizing the balance of intrinsic, extraneous, and germane cognitive load and align

with constructivist principles by fostering active and personalized learning experiences. By leveraging these theoretical frameworks, GenAI tools can enhance the effectiveness of instructional design, ultimately improving student learning outcomes.

Limitations of the Study

Although the two assignments involving GenAI as designed and implemented in the two courses did not lead to a statistically significant reduction in test anxiety among participants, the present descriptive research provides a valuable exploration of students' perspectives regarding the integration of chatbots as learning aids and the potential ramifications for future teaching and learning methodologies. The sample size was relatively small and limited to two smaller institutions, which may not be representative of broader post-secondary student populations. Additionally, the reliance on self-reported data may introduce bias, as students' perceptions and reported behaviours may not fully align with their actual experiences and outcomes. However, this diverse group of participants provided a broad range of perspectives and experiences among post-secondary students, enriching the study's findings. The linguistic and cultural diversity within the sample is an important consideration in understanding the varied impacts and perceptions of GenAI tools in today's post-secondary educational settings.

Future Directions

Future research should focus on developing a more nuanced understanding of how different types of GenAI tools can be optimized for various learning contexts and student needs. Additionally, exploring the integration of GenAI tools with other interventions to reduce test anxiety could offer a more comprehensive approach to improving educational outcomes. As this study has shown, GenAI holds considerable promise for enhancing post-secondary education, but its full potential needs continued investigation and innovative pedagogical practices.

Finally, in the context of integrating GenAI tools within academic settings, it is imperative to consider the reflections and feedback provided by students. As observed in the two courses where GenAI tools were employed for assignments, students exhibited a significant level of maturity and critical thinking. In their written feedback and during class discussions that followed the assignments, students articulated insightful views concerning the limitations of GenAI tools, particularly the issues related to accuracy and ethical considerations. This engagement indicates a deeper understanding and a critical perspective on the role and implications of GenAI in academic environments.

The articulation of concerns and perspectives by students regarding GenAI underscores the necessity for their active participation in dialogues surrounding institutional policies and the future role of GenAI in academia. It is paramount that educational institutions recognize the value of incorporating student voices into these discussions. Including students in the conversation ensures that policies and practices surrounding the use of GenAI in academic settings reflect not only technological and pedagogical considerations but also the ethical and practical concerns of those directly impacted by these technologies.

The active involvement of students in evaluating GenAI tools within academia is essential for fostering critical thinking and ethical reasoning. Discussion should extend beyond technological capabilities to include ethical considerations such as academic integrity and the impact of AI on learning. Among the various concerns related to post-secondary students' use of GenAI, ethical issues are most prominent (Mahmud, 2024; Luo, 2024). However, as Eaton (2023) argues, in the era when AI and neurotechnology are integrated into daily life, ethics and integrity become crucial as these technologies become inseparable from everyday life, impacting how we teach, learn, and interact. The ineffectiveness of trying to police the use of cutting-edge

technologies for academic honesty suggests the need for transdisciplinary research to understand the ethical implications of such technologies in education. The approach the present work advocates for advances a technologically proficient learning environment and promotes ethical responsibility and intellectual development (Reich & Ito, 2017).

Conclusions

Incorporating student perspectives and student-informed research into the discourse on GenAI reflects democratic principles in educational policymaking, ensuring decisions are informed by the stakeholders most affected by them — students themselves (Biesta, 2015; Chiu, 2024). This participatory process may allow for GenAI's integration into curricula in a manner that is both educationally effective and ethically sound, supporting broader educational objectives of critical engagement and informed citizenship. In conclusion, GenAI allows us to creatively adapt the instructional design and well-articulated learning outcomes (e.g., Sana et al., 2020) to provide today's learners with contextualized, personalized, and collaborative learning experiences.

5. Conclusion: Advancing Learning Through Cognitive Research, Established Practices, and AI Tools

How do we optimize learning in an era of rapid technological advancement while maintaining a foundation in cognitive science and established educational strategies? The dissertation addressed this overarching question by integrating insights from cognitive mechanisms, retrieval-based learning, and AI-driven tools to enhance knowledge acquisition and application. Through three distinct yet interconnected chapters, this research examined single-word processing, explored the efficacy of structured learning techniques, and evaluated the role of GenAI in higher education. Together, these studies contribute to the evolving discourse on cognitive mechanisms of learning, effective teaching methodologies, and their implications for the SoTL.

Chapter 2 investigated the cognitive underpinnings of single-word processing, emphasizing the role of orthographic and phonological mechanisms in reading and language acquisition. Building on the theoretical frameworks outlined in the introduction, particularly Stanovich's (1980) interactive-compensatory model and the Reading Systems Framework (Perfetti & Helder, 2022), this chapter explored how readers recognize words and extract meaning from text, even in the presence of early sensory disruptions.

Word recognition is a highly interactive and adaptive process, involving the automatic activation of phonological, orthographic, and semantic representations, even during silent reading (Seidenberg et al., 2022). Theories such as the dual-route model and connectionist frameworks offer distinct perspectives on how reading occurs. The dual-route model posits that skilled readers can recognize words through either a lexical route (direct word recognition) or a phonological route (sublexical decoding based on sound-symbol correspondence) (Coltheart,

2006). In contrast, connectionist models propose that reading is a probabilistic, distributed process, where word recognition emerges from repeated exposure to linguistic input, continuously strengthening the links between orthographic patterns, phonology, and semantics (Seidenberg et al., 2022).

These frameworks align with Stanovich's (1980) view that weaknesses in one component of the reading system may be compensated for by strengths in another, such that individuals with reduced phonological input may increasingly rely on orthographic or semantic information. The findings of this study reinforce the importance of phonological activation in visual word recognition, supporting both dual-route and connectionist models. Masked priming studies have shown that phonological information is accessed automatically, even when reading tasks do not require overt pronunciation, challenging traditional assumptions that phonology plays a post-lexical role. Instead, phonological activation occurs in parallel with orthographic and semantic processing, dynamically shaping how words are recognized and understood (Perfetti & Helder, 2022).

A critical component of the research in Chapter 2 was evaluating whether early auditory disruptions, such as recurrent otitis media, have lasting effects on phonological processing. Given that phonological awareness is foundational to reading development (Carroll & Breadmore, 2018), previous research has suggested that children who experience fluctuating hearing loss due to otitis media may struggle with phoneme discrimination, potentially leading to long-term difficulties in reading (Winskel, 2006; Mody et al., 1999). However, the results of this study demonstrated no significant differences in phonological processing between young adults with a history of recurrent otitis media and those without. While phonological congruency had a clear impact on word recognition accuracy, reinforcing its role in reading, the absence of

significant between-group differences suggests that compensatory mechanisms may have enabled affected individuals to achieve normative reading proficiency over time (Stanovich, 1980).

This finding is particularly relevant in light of Stanovich's (2009) Matthew Effect, which suggests that early phonological deficits can lead to cumulative academic disadvantages when unaddressed. The current results, however, imply that not all early disadvantages result in long-term impairment, and that cognitive plasticity or enriched literacy environments may support recovery or adaptation.

Methodological factors and environmental conditions may have influenced the results, as differences in participant demographics, stimulus presentation, and testing environments have been shown to affect phonological processing outcomes. For instance, previous studies, such as Owen and Borowsky (2003), reported a quadratic function in their results, while this study did not replicate that specific pattern. Discrepancies in stimulus conditions, lighting environments, or other procedural variations may have contributed to response differences, highlighting the complexity of phonological-orthographic interactions in reading research.

Despite these variations, this study supported prior findings that phonological activation plays a critical role in word recognition. Phonological awareness remains central to skilled reading, reinforcing its significance in cognitive models of literacy. Furthermore, the results highlighted potential applications beyond basic reading research. For instance, expertise in phoneme-to-grapheme mappings, such as that developed by stenographers and interpreters, may influence phonological-orthographic interactions, warranting further research into specialized populations. Such populations merit further investigation, as prior studies on cross-modal interactions suggest that phonological processing can be influenced by visual and even tactile

inputs (McGurk & MacDonald, 1976; Millar, 2003), raising questions about how different sensory modalities contribute to word recognition.

Given these findings, several avenues for future research emerge. Longitudinal studies tracking individuals from childhood through adulthood could clarify whether phonological processing deficits from early auditory disruptions fade naturally or are actively compensated for through learning and literacy exposure. Additionally, neuroimaging research using fMRI or ERPs could explore whether individuals with a history of otitis media exhibit different neural activation patterns during reading tasks, shedding light on potential adaptive mechanisms in the brain.

Aside from implications for phonological processing, the research in Chapter 2 informs the development of AI-driven literacy tools that support reading acquisition. Since phonological activation is integral to word recognition, AI-based reading interventions should incorporate phoneme-grapheme mapping exercises and adaptive feedback mechanisms to reinforce phonological awareness. By integrating insights from cognitive psychology, AI-driven reading support can be tailored to individuals with phonological processing difficulties, helping optimize learning experiences.

Therefore, this study reinforces the essential role of phonological and orthographic interactions in word recognition, supporting theoretical frameworks such as the dual-route and connectionist models. While recurrent otitis media has been associated with phonological processing challenges in earlier research, the present findings did not reveal significant differences in phonological discrimination among young adults with or without a childhood history of otitis media. This finding suggests that, in the current sample, any early phonological deficits may have been mitigated over time, potentially through compensatory mechanisms or

enriched literacy experiences — an interpretation consistent with Stanovich's (1980) interactive-compensatory model. Although these findings do not support a persistent deficit, they contribute to a more nuanced understanding of developmental plasticity and its role in reading outcomes. As such, they carry tentative implications for literacy interventions and technology-based reading support, particularly for learners with histories of early auditory disruptions.

Beyond word recognition, effective learning depends not only on cognitive mechanisms but also on the strategies learners employ to reinforce and retain information. Just as phonological and orthographic processing interact dynamically to support reading fluency, structured study techniques such as retrieval practice and spaced repetition leverage similar cognitive principles to enhance knowledge retention and metacognition. The ability to retrieve information, reinforce conceptual connections, and regulate study behaviours plays a critical role in academic success.

As such, Chapter 3 shifted focus to applied educational strategies, examining the impact of retrieval-based learning (via Quizlet), spaced repetition (via Cram), and elaborative encoding (via Flashcards-Plus) on student performance. Through a series of experimental studies, this research explored how different flashcard-based learning strategies, both digital and traditional, affect knowledge retention, metacognitive accuracy, and self-regulated learning. The findings suggest that active engagement in learning, while not always leading to immediate performance gains, contributes to improved metacognitive calibration and student confidence.

Retrieval practice and spaced practice are two foundational learning techniques that enhance retention and knowledge transfer (Dunlosky et al., 2013). Active recall, a key component of retrieval practice, strengthens neural pathways associated with memory, leading to long-term retention and improved application of knowledge. The study described in Chapter 3

confirmed that flashcards inherently promote retrieval practice, particularly when used for self-testing, fostering deeper cognitive engagement. Experiment 1 compared retrieval practice through Quizlet flashcards and spaced repetition via Cram flashcards. While both methods were effective, no significant performance difference was observed between the Quizlet and Cram groups, but students who used flashcards consistently outperformed non-users on the final exam, suggesting that these techniques particularly benefit long-term retention rather than short-term exam performance.

Students often underestimate the effectiveness of retrieval-based learning, favouring passive study techniques such as rereading and highlighting. This misjudgment is linked to inaccurate JOLs, where students overestimate their comprehension and retention abilities (Koriat, 1997; Dunlosky et al., 2013). Experiment 2 revealed that students who engaged in retrieval practice exhibited better calibration in their self-assessments, improving their ability to allocate study time effectively. However, test scores remained stable across different study methods, indicating that additional instructional support may be necessary to help students sustain effective study habits and translate metacognitive gains into performance improvements.

A key innovation explored in this study was the Flashcards-Plus strategy (Appleby, 2013; Senzaki et al., 2017), which integrates elaborative encoding by requiring students to paraphrase definitions and generate personalized examples. Unlike traditional flashcards that primarily support rote memorization, Flashcards-Plus encourages deeper cognitive processing by linking new information to prior knowledge. Although this study did not include a control group using traditional flashcards, findings suggest a potential link between elaborative encoding and improved metacognitive accuracy. Specifically, students using the Flashcards-Plus method demonstrated a strong correlation between their expected and actual performance, even though

overall test scores did not significantly differ across groups. These results are consistent with the hypothesis that deeper encoding strategies may support more accurate self-assessment, but further controlled comparisons are needed to draw firm conclusions about causality.

The study examined how flashcard-based strategies function across digital and paper-based modalities. While platforms such as Quizlet and Cram incorporate features like spaced repetition and adaptive learning, the research did not find significant performance differences between them. Experiment 2 used traditional paper-based flashcards and incorporated the Flashcards-Plus strategy to promote elaborative encoding, though performance remained stable across study phases. Although the study did not systematically assess student preferences, the lack of significant performance advantage for paper or digital formats suggests that contextual factors, such as study environment, consistency, and instructional support, may influence learning outcomes more than modality alone.

Beyond improving retention, structured flashcard strategies also played a role in reducing test anxiety and enhancing students' confidence. Flashcards were found to provide a structured approach to studying, helping students feel more prepared and reducing last-minute cramming behaviours. However, despite students reporting decreased anxiety levels after using flashcards, the research found no statistically significant correlation between test anxiety and final course grades. This suggests that while structured study techniques can mitigate stress, additional factors, such as metacognitive awareness, prior knowledge, and exam-taking strategies, may influence overall academic performance.

Despite the effectiveness of retrieval practice and spaced repetition, a significant challenge remains: ensuring students adopt and maintain these strategies over time. The study revealed that while students initially engaged with flashcards effectively, their final exam

performance declined, suggesting possible inconsistencies in strategy use during the latter part of the course. However, because the study did not track study methods during the final exam period, it is unclear whether students reverted to passive strategies or continued to use active retrieval ineffectively. Moreover, students' perceived usefulness of flashcards was not significantly associated with their exam performance, highlighting a disconnect between strategy preference and actual effectiveness. These findings point to the importance of instructional interventions that not only introduce evidence-based techniques but also support sustained, effective implementation throughout the academic term.

Finally, the findings of Chapter 3 research have broader implications for the design of AI-powered study tools. As GenAI becomes increasingly integrated into education, there is a growing opportunity to develop AI-enhanced flashcards that incorporate retrieval-based learning, spaced repetition, and elaborative encoding. Adaptive learning technologies that personalize study schedules based on students' individual performance could further optimize retention and engagement. However, ensuring that students actively interact with AI-generated content, rather than passively relying on automated responses, remains a critical challenge. Future research should examine how AI-driven flashcard tools can be designed to promote active learning, improve metacognitive accuracy, and reduce cognitive overload while maintaining ethical considerations in their implementation.

Together, these findings emphasize the importance of structured, evidence-based study strategies in higher education. By combining retrieval practice, spaced repetition, and elaborative encoding, flashcard-based learning methods offer an effective framework for enhancing retention, metacognitive awareness, and academic performance. However, to maximize their impact, educators must provide ongoing guidance, helping students develop self-regulated

learning habits that extend beyond short-term exam preparation. Additionally, the format through which these strategies are delivered may play a subtle but meaningful role in learning efficacy. As discussed in earlier sections, embodied cognition frameworks suggest that paper-based flashcards may reinforce memory by engaging sensorimotor pathways (Wilson, 2002), highlighting the potential value of tactile interaction in reducing cognitive load and supporting deeper conceptual understanding. Future research should further explore how modality influences the effectiveness of structured study strategies in real-world contexts. This research underscores the need for continued investigation into optimizing digital and traditional learning tools, ensuring that students have access to effective, engaging, and adaptable study strategies that support long-term knowledge acquisition and academic success.

As educational landscapes continue to evolve, integrating technology into learning environments presents new opportunities and challenges. While retrieval-based study strategies and structured learning methods have long been established as effective, the increasing prevalence of AI in education introduces a paradigm shift in how students engage with learning materials. AI-powered tools have the potential to personalize instruction, enhance cognitive engagement, and streamline study processes, but they also raise important questions about academic integrity, student autonomy, and the depth of learning.

Chapter 4 explored the integration of GenAI in education, assessing its potential to support personalized learning, critical thinking, and academic writing. Student feedback indicated that AI tools were generally well-received, particularly in enhancing comprehension and essay-writing skills. Many students viewed AI chatbots as valuable study aids but also recognized the risks of misinformation, emphasizing the need for content verification. While most expressed interest in using AI in future coursework, uncertainty surrounding institutional

guidelines led to hesitation or undisclosed AI use, highlighting the importance of clear policies on responsible AI integration.

Despite AI's ability to support learning, its impact on test anxiety was negligible. Students' JOLs tended to be inflated, with expected grades often exceeding actual performance. This suggests that AI-assisted study tools can create an illusion of understanding, reinforcing surface-level familiarity rather than deep mastery of concepts. To maximize AI's potential while mitigating its limitations, structured assignments should pair AI feedback with active engagement, critical analysis, and source verification. For example, the essay evaluation task required students to critique AI-generated essays using a rubric, which helped them learn academic essay structure but also recognize concerns about plagiarism, fabricated references, and AI's lack of depth, reinforced the need for human oversight.

By bridging traditional and AI-enhanced learning methods, this dissertation underscores the benefits of a holistic approach to education that integrates cognitive science, evidence-based study techniques, and technological advancements. This integrative perspective acknowledges that effective learning is not the product of a single method or tool but instead emerges from the interplay between foundational cognitive-based-base principles (such as retrieval practice and elaborative encoding), learner agency and metacognition, and adaptive technologies that personalize and scaffold the learning experience. In doing so, this research highlights the importance of designing educational environments that are both scientifically grounded and responsive to the evolving digital landscape, ensuring that students are equipped not only to acquire knowledge but also to transfer, apply, and regulate that knowledge in dynamic, real-world contexts.

AI should ultimately be harnessed as a cognitive augmentation tool rather than a replacement for human intellectual effort (De Cremer & Kasparov, 2021). When GenAI applications are aligned with evidence-based learning principles, they can support the development of engaging, effective, and ethically responsible curricula that enhance student learning while preserving academic integrity (Reich & Ito, 2017). Rather than supplanting human cognition, AI has the potential to empower students by fostering critical thinking, self-regulation, and strategic study habits, leading to deeper and more meaningful engagement with knowledge (Chiu, 2024; Zawacki-Richter et al., 2019).

While AI presents opportunities for personalized instruction, it also raises critical questions about ethical AI use and the preservation of deep learning. Future research should investigate the long-term effects of AI-driven study tools on knowledge retention, student autonomy, and academic integrity. This study found that while GenAI tools helped students comprehend and remember content, they did not significantly reduce test anxiety or improve metacognitive accuracy, indicating that such tools must be embedded within broader interventions to support psychological outcomes (Theobald et al., 2022).

To ensure responsible AI engagement, institutions must develop comprehensive best practices that encourage students to use AI as a tool for cognitive augmentation rather than a substitute for intellectual effort. This involves not only clarifying policies around acceptable AI use but also embedding AI literacy into curricula across disciplines. The assignments examined in this study emphasized careful prompt formulation, source verification, and reflection, which were perceived by students as helpful in fostering deeper engagement and ethical reasoning around AI use (Chiu, 2024).

By embedding AI literacy within broader digital literacy and academic integrity frameworks, educators can empower students to use AI tools thoughtfully and transparently. This also includes teaching students about the limitations of current AI systems, such as biases, hallucinations, and a lack of contextual understanding. Promoting ethical AI use requires creating a culture of reflection and accountability, where students view AI not as a shortcut, but as a partner in their cognitive development.

Moreover, the design of AI-enhanced assignments should consider cognitive load theory (Sweller, 2010), ensuring that extraneous load is minimized and germane load is optimized. Chatbots, when used as interactive "study confidantes," provided just-in-time explanations, allowed for follow-up clarification, and enabled active content revision — all of which helped reduce confusion and cognitive overload (Chiu, 2024). These practices align with constructivist learning theory, which emphasizes active engagement, problem-solving, and authentic learning experiences (Vygotsky, 1978; Piaget, 1952).

Ultimately, fostering metacognitive awareness and ethical engagement with AI can help institutions create learning environments where technology serves as an adaptive support system, enhancing student learning while preserving academic integrity and intellectual rigour. This includes acknowledging that while GenAI may aid performance on specific tasks, it does not replace the need for effortful learning or personal accountability. Students in the study recognized this nuance, often emphasizing the need to cross-check AI responses and to use the tools critically and reflectively (Chiu, 2024).

Overall, this study underscores the potential of GenAI as a cognitive tool that can enhance learning, but only when used critically and with clear instructional guidance. While AI chatbots were perceived as helpful in improving comprehension and writing skills, their impact

on test anxiety was negligible, and they did not improve students' accuracy in judging their own learning. These findings highlight the importance of structured AI integration, where AI tools support — but do not replace — critical thinking, self-assessment, and academic integrity.

The discrepancy between students' anticipated and actual grades reflects overconfidence bias, a common metacognitive issue not resolved by AI integration (Koriat & Bjork, 2005). This gap reinforces the need for scaffolding tools that promote self-testing, spaced practice, and reflective self-evaluation.

Moving forward, educators must carefully design AI-based assignments that encourage active learning, reinforce self-regulation, and align with ethical academic practices. By fostering AI literacy and clear institutional guidelines, higher education can harness AI's strengths while safeguarding against its potential pitfalls, ensuring that AI serves as a tool for cognitive enhancement rather than a shortcut to learning. The integration of AI into education represents just one dimension of a broader effort to optimize learning outcomes. Understanding how students acquire, retain, and apply knowledge requires a multifaceted approach that draws from cognitive science, traditional learning techniques, and technological innovations.

Together, the three chapters showcase a range of research methodologies, from cognitive experiments to applied educational interventions and technology-driven innovations. This dissertation underscores the value of using diverse methodological approaches to address the multifaceted nature of learning and education. By examining how learners recognize and process language, engage with structured study techniques, and interact with GenAI in academic contexts, this research provides a broad view of the cognitive, behavioural, and technological factors that shape educational outcomes.

This dissertation emphasizes the importance of interdisciplinary research in optimizing educational strategies by combining insights from cognitive psychology, instructional design, and AI-enhanced learning environments. It demonstrates that meaningful learning occurs at the intersection of evidence-based practices and adaptable tools, and that addressing complex educational challenges requires both theoretical depth and practical application. Across its three chapters, this work advocates for a multifaceted approach to learning that acknowledges individual differences, supports learner autonomy, and leverages emerging technologies without losing sight of foundational cognitive principles.

Looking ahead, the findings presented here suggest several promising directions for future research. Continued investigation is needed into how cognitive mechanisms interact with technological tools across different learner populations, including those with diverse linguistic, cognitive, and accessibility needs. Longitudinal studies could further explore how sustained engagement with strategies like elaborative encoding or adaptive AI tools shapes learning trajectories over time. In addition, future work should consider how instructors can be best supported in facilitating evidence-based learning strategies and guiding students to use AI ethically and effectively within academic contexts.

Ultimately, this dissertation contributes to an evolving conversation about how best to support learning in an age of rapid technological advancement. It calls for educational practices that are both cognitively grounded and technologically responsive practices that empower learners not just to retain information, but to think critically, reflect deeply, and engage actively with their learning environments. This research lays the groundwork for a more informed, adaptable, and inclusive vision of education in the digital age by integrating cognitive science, pedagogical innovation, and emerging AI tools.

This dissertation has explored how students learn through cognitive processing, deliberate practice, and the evolving affordances of AI. At the heart of this inquiry lies a fundamental tension: how can the science of learning be upheld while responsibly incorporating emerging educational technologies? Rather than privileging one method over others, this research illuminates how diverse learning pathways — whether rooted in phonological awareness, spaced or retrieval practice, or AI-facilitated scaffolding — can support meaningful learning. Learning is not a linear progression but a dynamic interplay of memory, attention, strategic regulation, and context. In an era saturated with tools and information, the challenge is no longer access to knowledge but developing the skills necessary for effective, adaptive learning.

Across the three empirical studies, this research supports the view that effective learning is active, cognitively effortful, and anchored in metacognitive awareness. Cognitive flexibility enables learners to recover from early disruptions; structured techniques such as retrieval practice and elaboration enhance both long-term retention and metacognition; and AI systems, when integrated with pedagogical intent, can supplement — but not substitute — critical thinking. These findings extend beyond theory and offer direct implications for educators, instructional designers, and learners navigating increasingly complex academic environments.

Looking forward, the imperative is clear: educators must foster adaptable, critically aware learners who are equipped not only with content knowledge but also with the skills to evaluate, integrate, and apply what they know. As Huey (1908) anticipated more than a century ago, the ultimate goal of educational science is not only to understand how learning occurs but to shape the conditions in which it can thrive. We can better prepare learners for a future that

demands intellectual rigour and thoughtful adaptability by grounding instruction in cognitive principles while thoughtfully embracing technological innovation.

References

Aarhus, L., Tambs, K., Kvestad, E., & Engdahl, B. (2015). Childhood otitis media: A cohort study with 30-year follow-up of hearing (The HUNT study). *Ear and Hearing, 36*(3), 302–308. https://doi.org/10.1097/AUD.0000000000000118

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Addison Wesley Longman. https://eduq.info/xmlui/handle/11515/18824

AnkiWeb. (n.d.). *Anki* [Computer software]. https://apps.ankiweb.net

Anstead, N. (2022). Judgments of Learning in the Context of Worked Mathematics Questions in College Students.

Appleby, D. C. (2013). *A flashcard strategy to help students prepare for three types of multiple-choice questions commonly found on introductory psychology tests*. Society for the Teaching of Psychology's Office of Teaching Resources. https://www.teachpsych.org/Resources/Documents/otrp/resources/appleby13flashcard.pdf

Baddeley, A. (2007). *Working memory, thought, and action* (Vol. 45). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198528012.001.0001

Beck, J., Stern, M., & Haugsjaa, E. (1996). Applications of AI in education. *XRDS: Crossroads, The ACM Magazine for Students, 3*(1), 11–15. https://doi.org/10.1145/332148.332153

Berti, L. C., Guilherme, J., Esperandino, C., & de Oliveira, A. M. (2020). Relationship between speech production and perception in children with Speech Sound Disorders. *Journal of Portuguese Linguistics*, *19*(1). https://doi.org/10.5334/jpl.244

Biesta, G. J. (2015). *Beyond learning: Democratic education for a human future*. Routledge.

Biswas-Diener, R., & Diener, E. (2016). *Introduction to psychology: The full Noba collection*. DEF Publishers. https://nobaproject.com/textbooks/introduction-to-psychology-the-full-noba-collection

Borowsky, R., Owen, W. J., & Fonos, N. (1999). Reading speech and hearing print: Constraining models of visual word recognition by exploring connections with speech perception. *Canadian Journal of Experimental Psychology / Revue canadienne de psychologie expérimentale, 53*(4), 294–301. https://doi.org/10.1037/h0087317

Brady, S., & Calcus, A. (2021). Speech Perception and Reading Ability: What Has Been Learned from Studies of Categorical Perception, Nonword Repetition, and Speech in Noise?. *The Handbook of Speech Perception*, 656-696. https://doi.org/10.1002/9781119184096.ch24

Brown-Kramer, C. R. (2022). Teaching students to learn better in introductory psychology: A replication and extension study. *Teaching of Psychology*, *49*(2), 108-117. https://doi.org/10.1177/0098628321997137

Brysbaert, M. (2022). Word recognition II: phonological coding in reading. *The science of reading: A handbook*, 79-101. https://doi.org/10.1002/9781119705116.ch4

Cai, T., & McPherson, B. (2016). Hearing loss in children with otitis media with effusion: a systematic review. *International Journal of Audiology*, *56*(2), 65–76. https://doi.org/10.1080/14992027.2016.1250960

Cai, T., McPherson, B., Li, C., & Yang, F. (2018). Hearing loss in children with otitis media with effusion: Actual and simulated effects on speech perception. *Ear and Hearing*, *39*(4), 645-655. http://dx.doi.org/10.1080/14992027.2016.1250960

Carpenter, S. K., Pan, S. C., & Butler, A. C. (2022). The science of effective learning with spacing and retrieval practice. *Nature Reviews Psychology*, *1*(9), 496-511. https://doi.org/10.1038/s44159-022-00089-1

Carroll, J. M., & Breadmore, H. L. (2018). Not all phonological awareness deficits are created equal: Evidence from a comparison between children with otitis media and poor readers. *Developmental Science, 21*(3), Article e12588. https://doi.org/10.1111/desc.12588

Cassady, J. C., & Johnson, R. E. (2002). Cognitive test anxiety and academic performance. *Contemporary educational psychology*, *27*(2), 270-295. https://doi.org/10.1006/ceps.2001.1094

Cattell, J. M. (1886). The time it takes to see and name objects. *Mind, 11*(41), 63–65. http://www.jstor.org/stable/2247157

Cepeda, N. J., Pashler, H., Vul, E., Wixted, J. T., & Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin, 132*(3), 354–380. https://doi.org/10.1037/0033-2909.132.3.354

Chen, G., & Fu, X. (2003). Effects of multimodal information on learning performance and judgment of learning. *Journal of Educational Computing Research*, *29*(3), 349-362. https://doi.org/10.2190/J54F-B24D-THN7-H9PH

Chiu, T.K.F. (2024). Future research recommendations for transforming higher education with generative AI. *Computers and Education: Artificial Intelligence, 6,* 1-9, 100197. https://doi.org/10.1016/j.caeai.2023.100197

Connon, H. A., Rash, J. A., Allen Gerwing, A. M., Bramble, B., Landine, J., & Gerwing, T. G. (2016). Post-Secondary Educators' Perceptions of Students' Test Anxiety. *Canadian*

Journal for the Scholarship of Teaching and Learning, *7*(1), 9. https://doi.org/10.5206/cjsotl-rcacea.2016.1.9

Coltheart, M. (2006). Dual route and connectionist models of reading: An overview. *London Review of Education, 4*(1), 5–17. https://doi.org/10.1080/13603110600574322

Craik, F. I. (2002). Levels of processing: Past, present... and future?. *Memory*, *10*(5-6), 305-318. https://doi.org/10.1080/09658210244000135

Craik, F. I., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General, 104*(3), 268–294. https://doi.org/10.1037/0096-3445.104.3.268

Cram.com. (n.d.-a). *Cram* [Website]. Retrieved May 23, 2025, from https://www.cram.com

Cram.com. (n.d.-b). *Cram mode: Spaced repetition with the Leitner System*. Retrieved from https://www.cram.com/docs/help

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage Publications.

Deci, E. L., & Ryan, R. M. (1985). Conceptualizations of intrinsic motivation and self-determination. In *Intrinsic motivation and self-determination in human behavior* (pp. 11–40). Springer. https://doi.org/10.1007/978-1-4899-2271-7_2

De Cremer, D., & Kasparov, G. (2021, March 18). *AI should augment human intelligence, not replace it*. Harvard Business Review. https://hbr.org/2021/03/ai-should-augment-human-intelligence-not-replace-it

Dehaene, S., & Cohen, L. (2011). The unique role of the visual word form area in reading. *Trends in Cognitive Sciences, 15*(6), 254–262. https://doi.org/10.1016/j.tics.2011.04.003

Delage, H., & Tuller, L. (2007). Language development and mild-to-moderate hearing loss: Does language normalize with age? *Journal of Speech, Language, and Hearing Research, 50*(5), 1300–1313. https://doi.org/10.1044/1092-4388(2007/091)

Driscoll, R. (2007). *Westside test anxiety scale validation*. Distributed by ERIC Clearinghouse. https://eric.ed.gov/?id=ED495968

Duke, N. K., & Cartwright, K. B. (2021). The science of reading progresses: Communicating advances beyond the simple view of reading. *Reading Research Quarterly*, *56*, S25-S44. https://doi.org/10.1002/rrq.411

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest, 14*(1), 4–58. https://doi.org/10.1177/1529100612453266

Eaton, S. E. (2023). Postplagiarism: transdisciplinary ethics and integrity in the age of artificial intelligence and neurotechnology. *International Journal for Educational Integrity*, *19*(1), 23. https://doi.org/10.1007/s40979-023-00144-1

Ebbinghaus, H. (2013). *Memory: A contribution to experimental psychology* (Original work published 1885). *Annals of Neurosciences, 20*(4), 155–156. https://doi.org/10.5214/ans.0972.7531.200408

Ertmer, P. A., & Newby, T. J. (2013). Article update: Behaviorism, cognitivism, and constructivism: Connecting "yesterday's" theories to today's contexts. *Performance Improvement Quarterly, 26*(2), 65–71. https://doi.org/10.1002/piq.21143Wiley Online Library+2SCIRP+2caitlinmeyer.github.io+2

Fowler, C. A., & Dekle, D. J. (1991). Listening with eye and hand: Cross-modal contributions to speech perception. *Journal of Experimental Psychology: Human Perception and Performance, 17*(3), 816–828. https://doi.org/10.1037/0096-1523.17.3.816

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Fursenko, T., Bystrova, B., & Druz, Y. (2021). Integrating Quizlet into aviation English course. *Advanced Education, 8*(17), 118–127. https://doi.org/10.20535/2410-8286.217990

Gerwing, T. G., Rash, J. A., Allen Gerwing, A. M., Bramble, B., & Landine, J. (2015). Perceptions and incidence of test anxiety. *The Canadian Journal for the Scholarship of Teaching and Learning, 6*(3), Article 3. https://doi.org/10.5206/cjsotl-rcacea.2015.3.3

Gillon, G. T. (2017). *Phonological awareness: From research to practice* (2nd ed.). Guilford Press. https://www.guilford.com/books/Phonological-Awareness/Gail-Gillon/9781462532889

Grainger, J. (2018). Orthographic processing: A 'mid-level' vision of reading. *Quarterly Journal of Experimental Psychology, 71*(1), 246–250. https://doi.org/10.1080/17470218.2017.1314515

Grainger, J. (2022). Word recognition I: Visual and orthographic processing. In M. J. Snowling, C. Hulme, & K. Nation (Eds.), *The science of reading: A handbook* (2nd ed., pp. 60–78). Wiley. https://doi.org/10.1002/9781119705116.ch3

Gough, P. B. (1972). One second of reading. In J. F. Kavanagh & I. G. Mattingly (Eds.), *Language by ear and by eye* (pp. 331–358). MIT Press.

Gough, P. B., & Hillinger, M. L. (1980). Learning to read: An unnatural act. *Bulletin of the Orton Society, 30*, 179–196. https://doi.org/10.1007/BF02653717

Hara, N. (2000). Student distress in a web-based distance education course. Information, Communication & Society , 3 (4), 557-579. https://doi.org/10.1080/13691180010002297

Hartwig, M. K., & Dunlosky, J. (2012). Study strategies of college students: Are self-testing and scheduling related to achievement? *Psychonomic Bulletin & Review, 19*(1), 126–134. https://doi.org/10.3758/s13423-011-0181-y

Hembree, R. (1988). Correlates, causes, effects, and treatment of test anxiety. *Review of Educational Research, 58*(1), 47–77. https://doi.org/10.3102/00346543058001047

Higgins, N., Frankland, S., & Rathner, J. (2021). Self-regulated learning in undergraduate science. *International Journal of Innovation in Science and Mathematics Education*, *29*(1). https://doi.org/10.30722/IJISME.29.01.005

Huey, E. B. (1908/2003). *The psychology and pedagogy of reading: With a review of the history of reading and writing and of methods, texts, and hygiene in reading*. MIT Press. https://mitpress.mit.edu/9780262580106/the-psychology-and-pedagogy-of-reading/

Jamal, A., Alsabea, A., & Tarakmeh, M. (2022). Effect of ear infections on hearing ability: a narrative review on the complications of otitis media. *Cureus*, *14*(7). https://doi.org/10.7759/cureus.27400

James, W. (1890). *The principles of psychology* (Vol. 1). Henry Holt and Company. https://www.gutenberg.org/files/57628/57628-h/57628-h.htm

Karpicke, J. D., & Aue, W. R. (2015). The testing effect is alive and well with complex materials. *Educational Psychology Review*, *27*, 317-326. https://doi.org/10.1007/s10648-015-9309-3

Karpicke, J. D., Butler, A. C., & Roediger III, H. L. (2009). Metacognitive strategies in student learning: do students practise retrieval when they study on their own?. *Memory*, *17*(4), 471-479. https://doi.org/10.1080/09658210802647009

Kee, T., Kuys, B., & King, R. (2024). Generative artificial intelligence to enhance architecture education to develop digital literacy and holistic competency. *Journal of Artificial Intelligence in Architecture, 3*(1), 24–41. https://doi.org/10.24002/jarina.v3i1.8347

Koriat, A. (1997). Monitoring one's own knowledge during study: A cue-utilization approach to judgments of learning. *Journal of Experimental Psychology: General, 126*(4), 349–370. https://doi.org/10.1037/0096-3445.126.4.349

Koriat, A., & Bjork, R. A. (2005). Illusions of competence in monitoring one's knowledge during study. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(2), 187–194. https://doi.org/10.1037/0278-7393.31.2.187

Koriat, A., & Shitzer-Reichert, R. (2002). Metacognitive judgments and their accuracy: Insights from the processes underlying judgments of learning in children. In P. Chambres, M. Izaute, & P.-J. Marescaux (Eds.), *Metacognition: Process, function and use* (pp. 1–17). Springer US. https://doi.org/10.1007/978-1-4615-1099-4_1

Krakau, M., Dagöö, B. R., Hellström, S., & Granath, A. (2017). Long-term hearing outcomes after recurrent acute otitis media during early childhood. *Acta Oto-Laryngologica, 137*(12), 1238–1243. https://doi.org/10.1080/00016489.2017.1362111

Li, X., Ma, Z., Tu, Y., & Du, Y. (2021, November). Study on the application of artificial intelligence technology in empowering education: Taking "Intelligent Learning Partner" as an example. In *2021 2nd International Conference on Information Science and Education (ICISE-IE)* (pp. 1449–1453). IEEE. https://doi.org/10.1109/ICISE-IE53922.2021.00323

Liberman, I. Y., Shankweiler, D., Liberman, A. M., Fowler, C., & Fisher, F. W. (1977). Phonetic segmentation and recoding in the beginning reader. In A. S. Reber & D. L. Scarborough (Eds.), *Toward a psychology of reading: The proceedings of the CUNY conference* (pp. 207–225). Erlbaum.

Lilienfeld, S. O., Lynn, S. J., Namy, L. L., Cramer, K. M., & Schmaltz, R. (2022). *Psychology: From inquiry to understanding* (5th Canadian ed.). Pearson Canada.

Lockhart, R. S. (2002). Levels of processing, transfer-appropriate processing, and the concept of robust encoding. *Memory*, *10*(5-6), 397-403. https://doi.org/10.1080/09658210244000225

Lombardi, M. M., & Oblinger, D. G. (2007). *Authentic learning for the 21st century: An overview* (ELI Paper 1: 2007). EDUCAUSE Learning Initiative. https://library.educause.edu/resources/2007/1/authentic-learning-for-the-21st-century-an-overview

Luo, J. (2024). A critical review of GenAI policies in higher education assessment: a call to reconsider the “originality” of students’ work. *Assessment & Evaluation in Higher Education*, 1-14. https://doi.org/10.1080/02602938.2024.2309963

Mahmud, S. (Ed.). (2024). *Academic integrity in the age of artificial intelligence*. IGI Global. https://doi.org/10.4018/979-8-3693-0240-8

McCandliss, B. D., Cohen, L., & Dehaene, S. (2003). The visual word form area: Expertise for reading in the fusiform gyrus. *Trends in Cognitive Sciences, 7*(7), 293–299. https://doi.org/10.1016/S1364-6613(03)00134-7

McDaniel, M. A. (2023). Combining retrieval practice with elaborative encoding: Complementary or redundant?. *Educational Psychology Review*, *35*(3), 75. https://doi.org/10.1007/s10648-023-09784-8

McGurk, H., & MacDonald, J. (1976). Hearing lips and seeing voices. *Nature*, *264*(5588), 746-748. https://doi.org/10.1038/264746a0

Megivern, D., Pellerito, S., & Mowbray, C. (2003). Barriers to higher education for individuals with psychiatric disabilities. *Psychiatric Rehabilitation Journal, 26*(3), 217–231. https://doi.org/10.2975/26.2003.217.231

Millar, S. (2003). *Reading by touch*. Routledge. https://doi.org/10.4324/9780203359440

Mody, M., Schwartz, R. G., Gravel, J. S., & Ruben, R. J. (1999). Speech perception and verbal memory in children with and without histories of otitis media. *Journal of Speech, Language, and Hearing Research, 42*(5), 1069–1079. https://doi.org/10.1044/jslhr.4205.1069

Mon, B. F., Wasfi, A., Hayajneh, M., & Slim, A. (2023, August). A study on role of Artificial Intelligence in education. In *2023 International Conference on Computing, Electronics & Communications Engineering (iCCECE)* (pp. 133-138). IEEE. https://doi.org/10.1109/iCCECE59400.2023.10238613

Murray, M. S. (2016). Word recognition skills: One of two essential components of reading comprehension. In K. A. Munger (Ed.), *Steps to success: Crossing the bridge between literacy research and practice* (pp. 27–42). Open SUNY Textbooks.

Muthmainnah, Ibna Seraj, P. M., & Oteir, I. (2022). Playing with AI to investigate human-computer interaction technology and improving critical thinking skills to pursue 21st century age. *Education Research International, 2022*, Article 6468995. https://doi.org/10.1155/2022/6468995

Nachtigall, V., Shaffer, D. W., & Rummel, N. (2022). Stirring a secret sauce: A literature review on the conditions and effects of authentic learning. *Educational Psychology Review*, *34*(3), 1479-1516. https://doi.org/10.1007/s10648-022-09676-3

Nelson, T. O., & Dunlosky, J. (1991). When people's judgments of learning (JOLs) are extremely accurate at predicting subsequent recall: The "delayed-JOL effect". *Psychological Science*, *2*(4), 267-271. https://doi.org/10.1111/j.1467-9280.1991.tb00147.x

Owen, W. J., & Borowsky, R. (2003). Examining the interactivity of lexical orthographic and phonological processing. *Canadian Journal of Experimental Psychology / Revue canadienne de psychologie expérimentale, 57*(4), 290–303. https://doi.org/10.1037/h0087432

OpenAI. (2023). *ChatGPT: Optimizing language models for dialogue*. https://openai.com/chatgpt

Owen, W. J., & Borowsky, R. (2003). Examining the Interactivity of Lexical Orthographic and Phonological Processing. *Canadian Journal of Experimental Psychology/Revue canadienne de psychologie expérimentale*, *57*(4), 290. https://doi.org/10.1037/h0087432

Özdemir, O., & Seçkin, H. (2024). Quantifying cognitive and affective impacts of Quizlet on learning outcomes: A systematic review and comprehensive meta-analysis. *Frontiers in Psychology, 15*, 1349835. https://doi.org/10.3389/fpsyg.2024.1349835

Panel on Research Ethics. (2023). *TCPS 2: CORE—Course on Research Ethics*. http://tcps2core.ca/welcome

Pattamadilok, C., Chanoine, V., Pallier, C., Anton, J., Nazarian, B., Belin, P., & Ziegler, J. C. (2017). Automaticity of phonological and semantic processing during visual word recognition. *Neuroimage, 149*, 244-255. https://doi.org/10.1016/j.neuroimage.2017.02.003

Perfetti, C., & Helder, A. (2022). Progress in reading science: Word identification, comprehension, and universal perspectives. In M. J. Snowling, C. Hulme, & K. Nation (Eds.), *The science of reading: A handbook* (2nd ed., pp. 5–35). Wiley. https://doi.org/10.1002/9781119705116.ch1

Petersen, S. E., Fox, P. T., Snyder, A. Z., & Raichle, M. E. (1990). Activation of extrastriate and frontal cortical areas by visual words and word-like stimuli. *Science, 249*(4972), 1041–1044. https://doi.org/10.1126/science.2396097

Petinou, C., Richard, G., Schwartz, J., Gravel, L., & Raphael, K. (2001). A preliminary account of phonological and morphophonological perception in young children with and without otitis media. *International Journal of Language & Communication Disorders, 36*(1), 21–42. https://doi.org/10.1080/13682820010020689

Piaget, J. (1952). *The origins of intelligence in children*. International Universities Press. https://doi.org/10.1037/11494-000

Price, C. J. (2012). A review and synthesis of the first 20 years of PET and fMRI studies of heard speech, spoken language and reading. *NeuroImage, 62*(2), 816–847. https://doi.org/10.1016/j.neuroimage.2012.04.062

Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patterson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review, 103*(1), 56–115. https://doi.org/10.1037/0033-295X.103.1.56

Quizlet. (n.d.-a). *Quizlet* [Website]. Retrieved May 23, 2025, from https://quizlet.com

Quizlet. (n.d.-b). *Studying with Flashcards mode*. Retrieved from https://help.quizlet.com/hc/en-us/articles/360030988091-Studying-with-Flashcards-mode.

Rana, R., & Mahmood, N. (2010). The relationship between test anxiety and academic achievement. *Bulletin of Education and Research*, *32*(2), 63-74.

Rana, T., Laoteppitaks, C., Zhang, G., Troutman, G., & Chandra, S. (2020). An investigation of Anki Flashcards as a study tool among first year medical students learning anatomy. *The FASEB journal*, *34*(S1), 1-1. https://doi.org/10.1096/fasebj.2020.34.s1.09736

Ravenscroft, I. (2005). *Philosophy of mind: A beginner's guide*. Oxford University Press, USA.

Reich, J., & Ito, M. (2017). *From good intentions to real outcomes: Equity by design in learning technologies*. Digital Media and Learning Research Hub. https://clalliance.org/publications/good-intentions-real-outcomes-equity-design-learning-technologies/

Reicher, G. M. (1969). Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology, 81*(2), 275–280. https://doi.org/10.1037/h0027768PubMed+2

Risko, E. F., & Gilbert, S. J. (2016). Cognitive offloading. *Trends in cognitive sciences*, *20*(9), 676-688. https://doi.org/10.1016/j.tics.2016.07.002

Roediger, H. L., III, & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences, 15*(1), 20–27. https://doi.org/10.1016/j.tics.2010.09.003

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science, 17*(3), 249–255. https://doi.org/10.1111/j.1467-9280.2006.01693.x

Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior, 69*, 371–380. https://doi.org/10.1016/j.chb.2016.12.033

Sana, F., Forrin, N. D., Sharma, M., Dubljevic, T., Ho, P., Jalil, E., & Kim, J. A. (2020). Optimizing the efficacy of learning objectives through pretests. *CBE—Life Sciences Education, 19*(3), Article ar43. https://doi.org/10.1187/cbe.19-11-0257

Seidenberg, M. S. (1987). Sublexical structures in visual word recognition: Access units or orthographic redundancy? In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 245–263). Lawrence Erlbaum Associates. https://doi.org/10.4324/9781315630427-14

Seidenberg, M. S., Farry-Thorn, M., & Zevin, J. D. (2022). Models of word reading: What have we learned? In M. J. Snowling, C. Hulme, & K. Nation (Eds.), *The science of reading: A handbook* (2nd ed., pp. 36–59). Wiley-Blackwell. https://doi.org/10.1002/9781119705116.ch2

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review, 96*(4), 523–568. https://doi.org/10.1037/0033-295X.96.4.523

Senzaki, S., Hackathorn, J., Appleby, D. C., & Gurung, R. A. (2017). Reinventing flashcards to increase student learning. *Psychology Learning & Teaching*, *16*(3), 353-368. https://doi.org/10.1177/1475725717719771

Serfaty, J., & Serrano, R. (2020). Examining the potential of digital flashcards to facilitate independent grammar learning. *System*, *94*, 102342. https://doi.org/10.1016/j.system.2020.102342

Sheikh, H., Prins, C., & Schrijvers, E. (2023). Artificial intelligence: Definition and background. In E. Schrijvers (Ed.), *Mission AI: The new system technology* (pp. 15–41). Springer International Publishing. https://doi.org/10.1007/978-3-031-21448-6_2

Snowling, M. J., Hulme, C., & Nation, K. (Eds.). (2022). *The science of reading: A handbook* (2nd ed.). John Wiley & Sons. https://doi.org/10.1002/9781119705116

Son, L. K., & Metcalfe, J. (2005). Judgments of learning: Evidence for a two-stage process. *Memory & Cognition*, *33*, 1116-1129. https://doi.org/10.3758/BF03193217

Stålnacke, H. (2022). Phonological development in children with otitis proneness. A longitudinal study for ages 3.6 to 5.6 years. *Journal of Hearing Science, 12*(1).

Stanovich, K. E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly, 16*(1), 32–71. https://doi.org/10.2307/747348

Stanovich, K. E. (2009). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Journal of Education, 189*(1–2), 23–55. https://doi.org/10.1177/0022057409189001-204

Stewart, D., Panus, P., Hagemeier, N., Thigpen, J., & Brooks, L. (2014). Pharmacy student self-testing as a predictor of examination performance. *American Journal of Pharmaceutical Education, 78*(2), Article 32. https://doi.org/10.5688/ajpe78232

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257–285. https://doi.org/10.1207/s15516709cog1202_4

Sweller, J. (2010). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational Psychology Review, 22*, 123–138. https://doi.org/10.1007/s10648-010-9128-5

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics* (5th ed.). Pearson.

Tahiru, F. (2021). AI in education: A systematic literature review. *Journal of Cases on Information Technology (JCIT)*, *23*(1), 1-20. https://doi.org/10.4018/jcit.2021010101

Tiwari, G. K. (2015). Does judgement of learning predict accuracy of recall during emotional arousal. *Madhya Bharati*, *68*(1), 175-190.

Theobald, M., Breitwieser, J., & Brod, G. (2022). Test anxiety does not predict exam performance when knowledge is controlled for: Strong evidence against the interference hypothesis of test anxiety. *Psychological Science*, *33*(12), 2073-2083. https://doi.org/10.1177/09567976221119391

Trifoni, A., & Shahini, M. (2011). How does exam anxiety affect the performance of university students? *Mediterranean Journal of Social Sciences, 2*(2), 93–100.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80*(5), 352–373.

Tversky, A., & Kahneman, D. (1974). Judgment under Uncertainty: Heuristics and Biases: Biases in judgments reveal some heuristics of thinking under uncertainty. *science*, *185*(4157), 1124-1131. https://doi.org/10.1126/science.185.4157.1124

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wheeler, D. D. (1970). Processes in word recognition. *Cognitive Psychology*, *1*(1), 59-85. https://doi.org/10.1016/0010-0285(70)90005-8

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*(4), 625–636. https://doi.org/10.3758/BF03196322

Winskel, H. (2006). The effects of early otitis media on phonological awareness and reading ability. *British Journal of Educational Psychology, 76*(4), 727–744. https://doi.org/10.1348/000709905X68312

Woolf, B. P. (1991). *AI in education* (Technical Report No. 91-37). Department of Computer and Information Science, University of Massachusetts Amherst. https://web.cs.umass.edu/publication/docs/1991/UM-CS-1991-037.pdf

Yuan, X. (2022). Evidence of the spacing effect and influences on perceptions of learning and science curricula. *Cureus, 14*(1), e21201. https://doi.org/10.7759/cureus.21201

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education - where are the

educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 1–27. https://doi.org/10.1186/s41239-019-0171-0

Zeitlin, B. D., & Sadhak, N. D. (2023). Attitudes of an international student cohort to the Quizlet study system employed in an advanced clinical health care review course. *Education and Information Technologies*, *28*(4), 3833-3857. https://doi.org/10.1007/s10639-022-11371-3

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice, 41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

Zumach, A., Gerrits, E., Chenault, M., & Anteunis, L. (2010). Long-term effects of early-life otitis media on language development. *Journal of Speech, Language, and Hearing Research, 53*(1), 34–43. https://doi.org/10.1044/1092-4388(2009/08-025)

Appendix 1. Ethics Approval E2022.0107.001.01

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

RESEARCH ETHICS BOARD

MEMORANDUM

To: Leah Chambers
CC: William Owen

From: Chelsea Pelletier, Vice-Chair,
Research Ethics Board

Date: January 16, 2023

Re: **E2022.0107.001.01(a)**
Assessing the Potential Long-term Effects of Otitis Media on Language Skills

Thank you for submitting a request for renewal and amendments to the Research Ethics Board (REB) regarding the above-noted proposal. Your requests have been approved.

We are pleased to issue renewal approval for the above-named study for a period of 12 months from the date of this letter. Continuation beyond that date will require further review and renewal of REB approval. Any further changes or amendments to the protocol or consent form must be approved by the REB.

Please refer to the Chair Bulletins found on the REB webpage for updates on *in-person* interactions with participants during the COVID-19 pandemic. If questions remain, please do not hesitate to email reb@unbc.ca.

Good luck with continuation of your research.

Sincerely,

C. Pelletier

Dr. Chelsea Pelletier,
Vice-Chair, Research Ethics Board

3333 University Way, Prince George, BC, V2N 4Z9, Telephone (250) 960-6735

Appendix 2. Ethics Approval 6009020

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

March 06, 2023

Leah Chambers
c/o University of Northern British Columbia
Faculty of Human and Health Sciences\Psychology

Dear Chambers,

File No: 6009020
Project Title: Flashcards as Form of Self-Testing in First and Third-Year Psychology Courses
Approval Date: March 06, 2023
Expiry Date: March 05, 2024

Thank you for submitting the above-noted proposal to the Research Ethics Board ("REB"). Your project has been approved.

We are pleased to issue approval for a period of twelve months from the date of this letter. To continue your proposed research beyond March 05, 2024, you must submit a Renewal Form prior to that date. If your research has been completed before a Renewal Form is due, please submit a Final Report Form in order to close the REB file.

Throughout the duration of this REB approval, all requests for modifications, renewals and serious adverse event reports must be submitted to the REB via the Romeo Research Portal. If you encounter any issues when working in the Research Portal, please contact our system administrator by email to researchportal@unbc.ca.

Please refer to the Chair Bulletins found on the REB webpage for updates on *in-person* interactions with participants during the COVID-19 pandemic. If questions remain, please do not hesitate to email reb@unbc.ca.

Good luck with your research.

Sincerely,

Dr. Davina Banner-Lukaris, Chair,
Research Ethics Board

Appendix 3. Ethics Approval EO-2024-0508-102.

College of New Caledonia
CNC

RESEARCH ETHICS BOARD

July 27, 2023

Leah Chambers

Re: Application for CNC Ethics Approval
'The Efficacy of Various Self-Testing Methods'

Dear Leah,

Thank you for your recent application for Ethics Approval from the CNC Research Ethics Board (REB). I **am delighted** to inform you that your application has been **APPROVED**.

The Approval Number for your research project is **EO-2024-0508-102.**

Should you have any questions, please contact the REB Administrative Assistant, Robyn O'Donnell. She can be reached by email at reb@cnc.bc.ca or by phone at (250) 562-2131 ext. 5676. Please be sure to quote your Approval Number in any correspondence. Please notify the REB once your research is completed.

On behalf of the REB, I would like to extend our congratulations! We look forward to the results of your research.

Sincerely,

Paula Hayden, EdD
Chair, Research Ethics Board

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3330 – 22nd Avenue, Prince George, BC V2N 1P8

Appendix 4. Flashcards

Chapter 9: Intelligence

abstract thinking	capacity to understand hypothetical concepts
bell curve	distribution of scores in which the bulk of the scores falls toward the middle, with progressively fewer scores toward the “tails” or extremes
between–group heritability	extent to which the difference in a trait between groups is genetically influenced
convergent thinking	capacity to generate the single best solution to a problem
crystallized intelligence	accumulated knowledge of the world acquired over time
culture–fair IQ test	abstract reasoning measure that doesn’t depend on language and is often believed to be less influenced by cultural factors than other IQ tests
deviation IQ	expression of a person’s IQ relative to his or her same–aged peers
divergent thinking	capacity to generate many different solutions to a problem
emotional intelligence	ability to understand our own emotions and those of others, and to apply this information to our daily lives
eugenics	movement in the early twentieth century to improve a population’s genetic stock by encouraging those with good genes to reproduce, discouraging those with bad genes from reproducing, or both
fluid intelligence	capacity to learn new ways of solving problems
Flynn effect	finding that average IQ scores have been rising at a rate of approximately three points per decade
g (general intelligence)	hypothetical factor that accounts for overall differences in intellect among peo
ideological immune system	our psychological defences against evidence that contradicts our views
intellectual disability	condition characterized by an onset prior to adulthood, an IQ below about 70, and an inability to engage in adequate daily functioning
intelligence quotient (IQ)	systematic means of quantifying differences among people in their intelligence
intelligence test	diagnostic tool designed to measure overall thinking ability
mental age	age corresponding to the average individual’s performance on an intelligence multiple intelligences; idea that people vary in their ability levels across different domains of intellectual skills

reliability	consistency of measurement (test–retest reliability refers to the extent to which scores on a measure remain stable over time)
s (specific abilities)	particular ability level in a narrow domain
Stanford–Binet IQ test	intelligence test based on the measure developed by Binet and Simon, adapted by Lewis Terman of Stanford University
stereotype threat	fear that we may confirm a negative group stereotype
test bias	tendency of a test to predict outcomes better in one group than another
triarchic model	model of intelligence proposed by Robert Sternberg positing three distinct types of intelligence– analytical, practical, and creative
validity	the extent to which a test measures what it purports to measure
Wechsler Adult Intelligence Scale (WAIS)	most widely used intelligence test for adults today, consisting of 15 subtests to assess different types of mental abilities
wisdom	application of intelligence toward a common good
within–group heritability	extent to which the variability of a trait within a group is genetically influenced

Chapter 10: Human Development

accommodation	Piagetian process of altering a belief to make it more compatible with experience
adolescence	the transition between childhood and adulthood commonly associated with the teenage years
assimilation	Piagetian process of absorbing new experience into current knowledge structures
attachment	the strong emotional connection we share with those to whom we feel closest
average expectable environment	environment that provides children with basic needs for affection and discipline
blastocyst	ball of identical cells early in pregnancy that haven’t yet begun to take on any specific function in a body part
cognitive development	study of how children acquire the ability to learn, think, reason, communicate, and remember
cohort effect	effect observed in a sample of participants that results from individuals in the sample growing up at the same time
concrete operations stage	stage in Piaget’s theory characterized by the ability to perform mental operations on physical events only

conservation	Piagetian task requiring children to understand that despite a transformation in the physical presentation of an amount, the amount remains the same

Chapter 11: Emotion & Motivation

affective forecasting	ability to predict our own and others' happiness
anorexia nervosa	eating disorder associated with excessive weight loss and the irrational perception that one is overweight
broaden and build theory	theory proposing that happiness predisposes us to think more openly
bulimia nervosa	eating disorder associated with a pattern of bingeing and purging in an effort to lose or maintain weight
Cannon–Bard theory	theory proposing that an emotion–provoking event leads simultaneously to an emotion and to bodily reactions
cognitive theories of emotion	theories proposing that emotions are products of thinking
companionate love	love marked by a sense of deep friendship and fondness for one's partner
defensive pessimism	strategy of anticipating failure and compensating for this expectation by mentally overpreparing for negative outcomes
discrete emotions theory	theory that humans experience a small number of distinct emotions that are rooted in our biology
display rules	cross–cultural guidelines for how and when to express emotions
drive reduction theory	theory proposing that certain drives, like hunger, thirst, and sexual frustration, motivate us to act in ways that minimize aversive states
durability bias	belief that both our good and our bad moods will last longer than they do
emotion	mental state or feeling associated with our evaluation of our experiences
excitement phase	phase in human sexual response in which people experience sexual pleasure and notice physiological changes associated with it
facial feedback hypothesis	theory that blood vessels in the face feed back temperature information in the brain, altering our experience of emotions
glucostatic theory	theory that when our blood glucose levels drop, hunger creates a drive to eat to restore the proper level of glucose
guilty knowledge test (GKT)	alternative to the polygraph test that relies on the premise that criminals harbour concealed knowledge about the crime that innocent people don't
hedonic treadmill	tendency for our moods to adapt to external circumstances

hierarchy of needs	model, developed by Abraham Maslow, proposing that we must satisfy physiological needs and needs for safety and security before progressing to more complex needs
homeostasis	equilibrium
incentive theories	theories proposing that we're often motivated by positive goals
integrity test	questionnaire that presumably assesses workers' tendency to steal or cheat
internal–external theory	theory holding that obese people are motivated to eat more by external cues than internal cues
James–Lange theory of emotion	theory proposing that emotions result from our interpretations of our bodily reactions to stimuli
leptin	hormone that signals the hypothalamus and brain stem to reduce appetite and increase the amount of energy used
motivation	psychological drives that propel us in a specific direction
nonverbal leakage	unconscious spillover of emotions into nonverbal behaviour
orgasm (climax) phase	phase in human sexual response marked by involuntary rhythmic contractions in the muscles of genitals in both men and women
passionate love	love marked by powerful, even overwhelming, longing for one's partner
Pinocchio response	supposedly perfect physiological or behavioural indicator of lying
plateau phase	phase in human sexual response in which sexual tension builds
positive psychology	discipline that has sought to emphasize human strengths
primary emotions	small number of emotions (perhaps seven) believed by some theorists to be cross–culturally universal
proxemics	study of personal space
proximity	physical nearness, a predictor of attraction
reciprocity	rule of give and take, a predictor of attraction
resolution phase	phase in human sexual response following orgasm, in which people report relaxation and a sense of well–being
set point	value that establishes a range of body and muscle mass we tend to maintain
similarity	extent to which we have things in common with others, a predictor of attraction
somatic marker theory	theory proposing that we use our "gut reactions" to help us determine how we should act

two–factor theory	theory proposing that emotions are produced by an undifferentiated state of arousal along with an attribution (explanation) of that arousal
Yerkes–Dodson law	inverted U–shaped relation between arousal on the one hand and mood and performance on the other hand

Chapter12: Stress, Coping, & Health

acquired immune deficiency syndrome (AIDS)	a life–threatening, incurable, yet treatable condition in which the human immunodeficiency virus (HIV) attacks and damages the immune system
acupuncture	ancient Chinese practice of inserting thin needles into more than 2,000 points in the body to alter energy forces believed to run through the body
aerobic exercise	exercise that promotes the use of oxygen in the body
alternative medicine	health care practices and products used in place of conventional medicine
biofeedback	feedback by a device that provides almost an immediate output of a biological function, such as heart rate or skin temperature
biopsychosocial perspective	the view that an illness or medical condition is the product of the interplay of biological, psychological, and social factors
complementary medicine	health care practices and products used together with conventional medicine
coronary heart disease (CHD)	damage to the heart from the complete or partial blockage of the arteries that provide oxygen to the heart
corticosteroid	stress hormone that activates the body and prepares us to respond to stressful circumstances
emotion–focused coping	coping strategy that features a positive out– look on feelings or situations accompanied by behaviors that reduce painful emotions
fight–or–flight response	physical and psychological reaction that mobilizes people and animals to either defend themselves (fight) or escape (flee) a threaten– ing situation
hardiness	set of attitudes marked by a sense of control over events, commitment to life and work, and courage and motivation to confront stressful events
health psychology	field of psychology, also called behavioral medicine, that integrates the behavioral sciences with the practice of medicine

homeopathic medicine	remedies that feature a small dose of an illness–inducing substance to activate the body's own natural defenses
immune system	our body's defense system against invading bacteria, viruses, and other potentially illness-producing organisms and substances
meditation	a variety of practices that train attention and awareness
peptic ulcer	inflamed area in the gastrointestinal tract that can cause pain, nausea, and loss of appetite
primary appraisal	initial decision regarding whether an event is harmful
proactive coping	anticipation of problems and stressful situations that promotes effective coping
problem–focused coping	coping strategy by which we problem solve and tackle life's challenges head–on
psychoneuroimmunology	study of the relationship between the immune system and central nervous system
psychophysiological	illnesses such as asthma and ulcers in which emotions and stress contribute to, maintain, or aggravate the physical condition
secondary appraisal	perceptions regarding our ability to cope with an event that follows primary appraisal
social support	relationships with people and groups that can provide us with emotional comfort and personal and financial resources
spirituality	search for the sacred, which may or may not extend to belief in God
stress	the tension, discomfort, or physical symptoms that arise when a situation, called a stressor— a type of stimulus—strains our ability to cope effectively
tend and befriend	reaction that mobilizes people to nurture (tend) or seek social support (befriend) under stress

Chapter 13: Social Psychology

adaptive conservatism	evolutionary principle that creates a predisposition towards distrusting anything or anyone unfamiliar or different
aggression	behaviour intended to harm others, either verbally or physically
altruism	helping others for unselfish reasons
attitude	belief that includes an emotional component
attribution	process of assigning causes to behaviour

belief	conclusion regarding factual evidence
cognitive dissonance	unpleasant mental experience of tension resulting from two conflicting thoughts or beliefs
conformity	tendency of people to alter their behaviour as a result of group pressure
cults	groups of individuals who exhibit intense and unquestioning devotion to a single cause
deindividuation	tendency of people to engage in uncharacteristic behaviour when they are stripped of their usual identities
diffusion of responsibility	reduction in feelings of personal responsibility in the presence of others
diffusion of responsibility	reduction in feelings of personal responsibility in the presence of others
discrimination	negative behaviour towards members of out–groups
door–in–the–face technique	persuasive technique involving making an unreasonably large request before making the small request we are hoping to have granted
enlightenment effect	learning about psychological research can change real–world behaviour for the better
explicit prejudice	unfounded negative belief of which we are aware regarding the characteristics of an out–group
foot–in–the–door technique	persuasive technique involving making a small request before making a bigger one
fundamental attribution error	tendency to overestimate the impact of dispositional influences on other people's behaviour
group polarisation	tendency of group discussion to strengthen the dominant positions held by individual group members
groupthink	emphasis on group unanimity at the expense of critical thinking and sound decision–making
implicit prejudice	unfounded negative belief of which we are unaware regarding the characteristics of an out–group
impression management theory	theory that we do not really change our attitudes, but report that we have so that our behaviours appear consistent with our attitudes
inoculation effect	approach to convincing people to change their minds about something by first introducing reasons why the perspective might be correct and then debunking it
in–group bias	tendency to favour individuals within our group over those from outside our group

jigsaw classroom	educational approach designed to minimise prejudice by requiring all children to make independent contributions to a shared project
just–world hypothesis	claim that our attributions and behaviours are shaped by a deep–seated assumption that the world is fair and all things happen for a reason
low–ball technique	persuasive technique in which the seller of a product starts by quoting a low sale price, and then mentions all of the add–on costs once the customer has agreed to purchase the product
mass hysteria	outbreak of irrational behaviour that is spread by social contagion
obedience	adherence to instructions from those of higher authority
out–group homogeneity	tendency to view all individuals outside our group as highly similar
paramedic studies	studies in which an experimenter systematically manipulates the independent variable to observe its effects on the dependent variable
pluralistic ignorance	error of assuming that no one in a group perceives things as we do
prejudice	drawing conclusions about a person, a group of people or a situation prior to evaluating the evidence
relational aggression	form of indirect aggression, prevalent in girls, involving spreading rumours, gossiping and nonverbal putdowns for the purpose of social manipulation
scapegoat hypothesis	claim that prejudice arises from a need to blame other groups for our misfortunes
self–monitoring	personality trait that assess the extent to which people's behaviour reflects their true feelings and attitudes
self–perception theory	theory that we acquire our attitudes by observing our behaviours
social comparison theory	theory that we seek to evaluate our beliefs, attitudes and abilities by comparing our reactions with those of others
social facilitation	enhancement of performance brought about by the presence of others
social loafing	phenomenon whereby individuals become less productive in groups
social psychology	study of how people influence others' behaviour, beliefs and attitudes
stereotype	a belief, positive or negative, about the characteristics of members of a group that is applied generally to most members of the group
ultimate attribution error	assumptions that behaviours among individual members of a group are due to their initial dispositions

Chapter 14: Personality

anal stage	psychosexual stage that focuses on toilet training
archetype	cross–culturally universal symbols
Big Five	five traits that have surfaced repeatedly in factor analyses of personality
collective unconscious	according to Jung, our shared storehouse of memories that ancestors have passed down to us across generations
conditions of worth	according to Rogers, expectations we place on ourselves for appropriate and inappropriate behavior
defense mechanisms	unconscious maneuvers intended to minimize anxiety
denial	motivated forgetting of distressing external experiences
displacement	directing an impulse from a socially unacceptable target onto a safer and more socially acceptable target
ego	psyche's executive and principal decision maker
Electra complex	conflict during phallic stage in which girls supposedly love their fathers romantically and want to eliminate their mothers as rivals
empirical method of test construction	approach to building tests in which researchers begin with two or more criterion groups, and examine which items best distinguish them
erogenous zone	sexually arousing zone of the body
face validity	extent to which respondents can tell what the items are measuring
factor analysis	statistical technique that analyzes the correlations among responses on personality inventories and other measures
genital stage	psychosexual stage in which sexual impulses awaken and typically begin to mature into romantic attraction toward others
graphology	psychological interpretation of handwriting
id	reservoir of our most primitive impulses, including sex and aggression– completely unconscious
identification with the aggressor	process of adopting the characteristics of individuals we find threatening
idiographic approach	approach to personality that focuses on identifying the unique configuration of characteristics and life history experiences within a person
incongruence	inconsistency between our personalities and innate dispositions

incremental validity	extent to which a test contributes into beyond other, more easily collected, measures
inferiority complex	feelings of low self–esteem that can lead to overcompensation for such feelings
latency stage	psychosexual stage in which sexual impulses are submerged into the unconscious
lexical approach	approach proposing that the most crucial features of personality are embedded in our language
locus of control	extent to which people believe that reinforcers and punishers lie inside or outside of their control (internals– life events are due to own efforts, externals– life events are product of fate)
MMPI	The Minnesota Multiphasic Personality Inventory – widely used structured personality test designed to assess symptoms of mental disorders
molecular genetic study	investigation that allows researchers to pinpoint genes associated with specific personality traits
Neo–Freudian theories	theories derived from Freud's model, but that placed less emphasis on sexuality as a driving force in personality and were more optimistic regarding the prospects for long–term personality growth
nomothetic approach	approach to personality that focuses on identifying general laws that govern the behavior of all individuals
Oedipus complex	conflict during phallic stage in which boys supposedly love their mothers romantically and want to eliminate their fathers as rivals
oral stage	psychosexual stage that focuses on the mouth
P.T. Barnum effect	tendency of people to accept high base rate descriptions as accurate
peak experience	transcendent moment of intense excitement and tranquility marked by a profound sense of connection to the world
personality	people's typical ways of thinking, feeling, and behaving
phallic stage	psychosexual stage that focuses on the genitals
pleasure principle	tendency of the id to strive for immediate gratification
projection	unconscious attribution of our negative characteristics to others
projective hypothesis	hypothesis that in the process of interpreting ambiguous stimuli, examinees project aspects of their personality onto the stimulus
projective test	test consisting of ambiguous stimuli that examinees must interpret or make sense of
psychic determinism	the assumption that all psychological events have a cause

rational/theoretical method of test construction	approach to building tests that requires test developers to begin with a clear–cut conceptualization of a trait and then write items to assess that conceptualization
rationalization	providing a reasonable–sounding explanation for unreasonable behaviors or for failures
reaction–formation	transformation of an anxiety–provoking emotion into its opposite
reality principle	tendency of the ego to postpone gratification until it can find an appropriate outlet
reciprocal determinism	tendency for people to mutually influence each other's behaviors
regression	the act of returning psychologically to a younger, and typically simpler and safer, age
repression	motivated forgetting of emotionally threatening memories or impulses
Rorschach Inkblot test	projective test consisting of ten symmetrical inkblocks
self–actualization	drive to develop our innate potential to the fullest possible extent
social learning theorists	theorists who emphasize thinking as a cause of personality
structured personality test	paper/pencil test consisting of questions that respondents answer in one of a few fixed ways
style of life	according to Adler, each person's distinctive way of achieving superiority
sublimation	transforming a socially unacceptable impulse into an admired goal
superego	our sense of morality
TAT	Thematic Apperception Test – projective test requiring examinees to tell a story in response to ambiguous pictures
trait	relatively enduring predisposition that influences our behavior across many situations

Chapter 15: Psychological Disorders

ADHD	childhood condition marked by excessive inattention, impulsivity, and activity
agoraphobia	fear of being in a place or situation from which escape is difficult or embarrassing, or in which help is unavailable in the event of a panic attack
antisocial personality disorder	condition marked by a lengthy history of irresponsible and/or illegal actions

anxiety sensitivity	fear of anxiety–related sensations
asylum	institution for people with mental illnesses created in the 15th century
autistic disorder	disorder marked by severe deficits in language, social bonding, and imagination, usually accompanied by mental retardation
axis	dimension of functioning
bipolar disorder	condition marked by a history of at least one manic episode
borderline personality disorder	condition marked by extreme instability in mood, identity, and impulse control
catatonic symptom	motor problem, including extreme resistance to complying with simple suggestions, holding the body in bizarre or rigid postures, or curling up in a fetal position
categorical model	model in which a mental disorder differs from normal functioning in kind rather than degree
cognitive model of depression	theory that depression is caused by negative beliefs and expectations
comorbidity	co–occurrence of two or more diagnoses within the same person
compulsion	repetitive behavior or mental act performed to reduce or prevent stress
deinstitutionalization	governmental policy that focused on releasing hospitalized psychiatric patients into the community and closing mental hospitals
delusion	strong held, fixed belief that has no basis in reality
demonic model	view of mental illness in which odd behavior, hearing voices, or talking to oneself was attributed to evil spirits infesting the body
depersonalization disorder	condition marked by multiple episodes od depersonalization
diathesis–stress model	perspective proposing that mental disorders are a joint product of a genetic vulnerability, called a diathesis, and stressors that trigger this vulnerability
dimensional model	model in which a mental disorder differs from normal functioning in degree rather than kind
dissociative amnesia	cant recall important personal info
dissociative disorder	condition involving disruptions in consciousness, memory, identity, or perception
dissociative fugue	drop everything and flee stressful circumstance
dissociative identity disorder	multiple personalities

DSM	diagnostic system containing the American Psychiatric Association criteria for mental disorders
generalized anxiety disorder	continual feelings of worry, anxiety, physical tension, and irritability across many areas of life functioning
hallucination	sensory perception that occurs in the absence of an external stimulus
hypochondriasis	an individuals continual preoccupation with the notion that he has a serious physical disease
insanity defense	legal defense proposing that people shouldn't be help legally responsible for their actions if they weren't of sound mind" when committing them"
involuntary commitment	procedure of placing some people with mental illnesses in a psychiatric hospital or other facility based on their potential danger to themselves or others, or their inability to care for themselves
labeling theorists	scholars who argues that psychiatric diagnoses exert powerful negative effects on people's perceptions and behaviors
learned helplessness	tendency to feel helpless in the face of events we can't control
major depressive episode	state in which a person experiences a lingering depressed mood or diminished interest in pleasurable activities, along with symptoms that include weight loss and sleep difficulties
manic episode	experience marked by dramatically elevated mood, decreased need for sleep, increased energy, inflated self–esteem, increased talkativeness, and irresponsible behavior
medical model	view of mental illness as due to a physical disorder requiring medical treatment
moral treatment	approach to mental illness calling for dignity, kindness, and respect for those with mental illness
obsession	persistent idea, thought, or impulse that is unwanted and inappropriate, causing marked distress
OCD	condition marked by repeated and lengthy immersion in obsessions, compulsions, or both
panic attack	brief, intense episode of extreme fear characterized by sweating, dizziness, light–headedness, racing heartbeat, and feelings of impending death or going crazy
panic disorder	repeated and unexpected panic attacks, along with either persistent concerns about future attacks or a change in personal behavior in an attempt to avoid them
personality disorder	condition in which personality traits, appearing in adolescence, are inflexible, stable, expressed in a wide variety of situations, and lead to distress or impairment

phobia	intense fear of an object or situation that's greatly out of proportion to its actual threat
prevalence	percentage of people within a population who have a specific mental disorder
psychopathic personality	condition marked by superficial charm, dishonesty, manipulativeness, self–centeredness, and risk taking
psychotic symptom	psychological problem reflecting serious disortions in reality
PTSD	marked emotional disturbance after experiencing or witnessing a severely stressful event
schizophrenia	severe disorder of thought and emotion associated with a loss of contact with reality
social phobia	marked fear of public appearances in which embarrassment or humiliation seems likely
somatoform disorder	condition marked by physical symptoms that suggest an underlying medical illness, but that are actually psychological in orgin
specific phobia	intense fear of objects, places, or situations that is greatly out of proportion to their actual threat

Chapter 16: Psychological and Biological Treatments

Alcoholics anonymous	Twelve–step self–help program that provides social support for achieving sobriety
Aversion therapy	Treatment that uses punishment to decrease the frequency of undesirable behaviors
Behavior therapist	Therapist who focuses on specific problem behaviors and current variables that maintain problematic thoughts, feelings, and behavior
Cognitive–Behavioral therapy	Treatment that attempts to replace irrational cognitions and maladaptive behaviors with more rational cognitions and adaptive behaviors
Dismantling	Research procedure for examining the effectiveness of isolated components of a larger treatment
Ecological momentary assessment	Assessment of thoughts, emotions, and behaviors that arise in the moment in situations in which they occur in everyday life
Electroconvulsive therapy (ECT)	Treatment for serious psychological problems in which patients receive brief electrical pulses to the brain that produce a seizure
Empirically supported treatment (EST)	Intervention for specific disorders supported by high–quality scientific evidence

Exposure therapy	Therapy that confronts clients with what they fear with the goal of reducing the fear
Free association	Technique in which clients express themselves without censorship of any sort
Gestalt therapy	Therapy that aims to integrate different and sometimes opposing aspects of personality into a unified sense of self
Group therapy	Therapy that treats more than one person at a time
Humanistic therapies	Therapies that emphasize the development of human potential and the belief that human nature is basically positive
Insight therapies	Psychotherapies, including psychodynamic, humanistic, existential, and group approaches, with the goal of expanding awareness or insight
Interpersonal therapy (IPT)	Treatment that strengthens social skills and targets interpersonal problems, conflicts, and life transition
Meta–analysis	Statistical method that helps researchers interpret large bodies of psychological literature
Paraprofessional	Person with no professional training who provides mental health services
Participant modeling	Technique in which the therapist first models a problematic situation and then guides the client through steps to cope with it unassisted
Personalized medicine	Medical practice that customizes interventions to maximize success in treating patients with specific psychological or medical disorders and conditions
Person–centered therapy	Nondirective therapy centering on the client's goals and ways of solving problems
Psychopharmacotherapy	Use of medications to treat psychological problems
Psychosurgery	Brain surgery to treat psychological problems
Psychotherapy	Psychological intervention designed to help people resolve emotional, behavioral, and interpersonal problems and improve the quality of their lives
Resistance	Attempts to avoid confrontation and anxiety associated with uncovering previously repressed thoughts, emotions, and impulses
Response prevention	Technique in which therapist prevent clients from performing their typical avoidance behaviors
Strategic family intervention	Family therapy approach designed to remove barriers to effective communication

Structural family therapy	Treatment in which therapists deeply involve themselves in family activities to change how family members arrange and organize interactions
Systematic desensitization	Clients are taught to relax as they are gradually exposed to what they fear in a stepwise manner
Token economy	Method in which desirable behaviors are rewarded with tokens that clients can exchange for tangible rewards
Transference	Act of projecting intense, unrealistic feelings and expectations from the past onto the therapist

Appendix 5. Ethics Approval 6009220 (2)

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

August 13, 2023

Leah Chambers (Principal Investigator)
Dr. Bill Owen (Co-Investigator)
Ms. Ami Hagiwara (Co-Investigator)
c/o University of Northern British Columbia
Faculty of Human and Health Sciences\Psychology

Dear Ms. Chambers, Dr. Bill Owen & Ms.Hagiwara,
File No: 6009220
Project Title: The Efficacy of Various Self-Testing Tools in Higher Education Research
Approval Date: August 13, 2023
Expiry Date: August 12, 2024

Thank you for submitting the above-noted proposal to the Research Ethics Board ("REB"). Your project has been approved.

We are pleased to issue approval for a period of twelve months from the date of this letter. To continue your proposed research beyond August 12, 2024, you must submit a Renewal Form prior to that date. If your research has been completed before a Renewal Form is due, please submit a Final Report Form in order to close the REB file.

Throughout the duration of this REB approval, all requests for modifications, renewals and serious adverse event reports must be submitted to the REB via the Romeo Research Portal. If you encounter any issues when working in the Research Portal, please contact our system administrator by email to researchportal@unbc.ca.

Please refer to the Chair Bulletins found on the REB webpage for updates on in-person interactions with participants during the COVID-19 pandemic. If questions remain, please do not hesitate to email reb@unbc.ca.

Good luck with your research.

Sincerely,

Dr. Neil Hanlon, Chair,
Research Ethics Board