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Neurocognitive Benefits of Assistive Technology on English Language Learners with Special Learning Needs

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Abstract: *This research paper investigates the neurocognitive effects of assistive technology (AT) on English Language Leaners (ELL) with specific learning difficulties. Neurodevelopmental disorders bring major learning difficulties for students in conventional educational settings and may hinder comprehension, spelling, retention, time management and decoding abilities which impact their academic performance. AT offers innovative solutions to bridge the gap between limitations and learning and emerges as an essential intervention for learning by providing students with text-to-speech-to-text software (TTS and STT) and apps together with audiobooks, note-taking apps and lecture recordings. The researcher seeks to examine how specific AT interventions modulate cognitive functions such as attention, memory, and executive control in students with diverse learning needs by investigating the effects of multiple AT tools on thinking patterns together with their impact on reading, understanding and educational performance outcomes. The researcher designed this exploratory research that analyzes a series of observational data through observational methods. The study adds value to current research about inclusive classrooms and technological tools that help students with learning difficulties.*

Keywords: assistive technology, neurocognitive processing, learning difficulties, inclusive education, educational equity

INTRODUCTION

Specific Learning Disability (SLD):

Learning is a natural human process which leads to the acquisition of new knowledge and abilities. However, for students having Specific Learning difficulty (SLD), this process may be different and they may face challenges with their reading, writing or mathematical abilities (Rufus, Liman, Abubakar & Kwalzoom, 2015). After standard instruction and adequate intelligence, the SLD condition continues to cause persistent issues with word recognition and decoding, and spelling challenges. SLD produces brain differences that affect how the brain processes sounds and forms visual associations for words. Traditional instruction methods for reading that ignore neurocognitive variation create academic difficulty, together with self-esteem reduction for students with SLD.

SLD Neural Patterns:
Investigations utilizing neuroimaging methodologies - functional magnetic resonance imaging and diffusion tensor imaging have identified distinctions in cerebral architecture and functional dynamics when comparing individuals diagnosed with SLDs to those without such diagnoses. According to Shaywitz (2008) differences in the left temporal-parietal cortex and the occipital-temporal cortex lead to phonological processing (understanding and manipulating sounds in language) and word recognition. Individuals with SLD often show reduced activation and altered connectivity within these regions. Recent research emphasizes that learning difficulties may not solely reside in specific brain regions but also in the connectivity between different brain areas.

Inclusive Education:
The framework of inclusive education is to make sure that all students from different backgrounds and varying abilities study together (UNESCO, 2009). Inclusive education makes sure that all students have the rights to a great learning experience by understanding and supporting each student's needs in a regular classroom. Students with special needs learn alongside their classmates in mainstream settings in a respectful and supportive manner.

Assistive Technology:
Assistive technology is integral to special education and is designed to support student who learn differently. It is an essential part of the planning and creating student-centered learning experiences for students with learning difficulties. Assistive technology offers several advantages yet contains specific restrictions that affect the enhancement of reading comprehension and academic results (Foorman, et al., 2021). Assistive technology consists of various computer and software applications that can support students to understand and improve their academic ability based on their potential. The combination of assistive tools, including text-to-speech-to-text applications, audiobooks, and specialized readable fonts, provides learning benefits for students. Students benefit from assistive technologies because they reduce mental stress, improve information absorption, and gain better control over their educational development.

Rationale for the Study :
Although many research studies have explored how Assistive Technologies address the educational experiences of SLD students, the neurocognitive aspect of these interventions require further research. (Rufus et al., 2015 & Wood et al., 2017). Research studies on how well assistive technologies address educational obstacles that SLD students experience suggests an investigation into the neurocognitive elements to deliver evidence-supported methods for maximizing assistive technology usage in educational institutions. Further investigation is needed regarding AT tools because their levels of effectiveness differ from one another, and researchers must understand both neurocognitive processing and academic outcomes resulting from these tools. Consequently, the current investigation offers a systematic review of the neurological viewpoints examining the influence of a range of assistive technologies on enhancing the academic outcomes of students with specific learning disabilities (SLDs).

Research Question:
Outlined below is the research question which is specifically developed to tackle the problem highlighted in this study.
How do different forms of AT, specifically note-taking, spaced repetition, and organizational tools, influence cognitive processes related to information retrieval, memory enhancement, and cognitive flexibility?

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LITERATURE REVIEW

Learning involves acquisition of new information. Children in their initial phase of development, learn the basic skills of reading and writing in accordance to their age and cognitive ability. However, despite having normal or above normal intellectual abilities, which means that they are not struggling with low intelligence, some children encounter challenges during the learning process that make them unable to acquire language skills (Dhanda & Jagawat, 2013 and Kumar & Raja, 2010). Learning difficulties consists of a diverse set of traits. Students with SLD might struggle across various academic subjects as significant challenges are most frequently observed in foundational educational skills like reading and writing. The 2006 United Nations Convention on the Rights of Persons with Disabilities (UNCRPD) stresses on the rights of individuals with SLD to procure different modes of learning throughout all phases of their lives without facing discrimination and with the same opportunities as everyone else. It also stresses that they should not be excluded from enrolling into the regular education systems because of their learning disabilities. The primary aim of education for children with SLD is to offer the appropriate support in a welcoming environment for all such students, with the goal of maximizing their educational attainment within mainstream settings (Felicia, et.al, 2014). However, Keetam and Alkahtani's research demonstrates that, "the learning development of children with learning difficulties in a general education classroom depends on the skilful application of teaching techniques and materials to facilitate the learning of these children".

As SLD students find it challenging to be on par with regular students in a classroom setting, it is imperative that the Teacher's instructional in-class activities be aligned to SLD student's needs. Activities such as incorporation of assistive technology, peer tutoring and teaching cognitive strategies have been proven in enhancing the acquisition of language skills with SLD students (Lindeblad, et.al, 2016). In their 2021 work, Arias Gundín and García Llamazares examined the Response to Intervention (RTI) model to understand how early intervention strategies contribute to improved literacy development in students with SLD. The research demonstrates how structured, purpose-driven technological solutions help struggling readers receive much-needed support. According to Foorman et al. (2021), technology plays an essential role in helping students with reading difficulties benefit from a personalized learning approach under early intervention programs. Assistive technology serves as an essential tool to customize educational approaches, especially when teaching students with dyslexia, according to their research findings. Handler (2024) studied dyslexia treatment while emphasizing that reading support for students with challenges can be achieved through text-to-speech digital tools. The research study demonstrates how children need interventions that utilize multiple teaching approaches to learn literacy skills. The research by Smythe et al. (2021) presented findings about early intermediation methods for children with SLD in lower and average income countries. Assistive technology demonstrates the potential to transform educational disparities according to study results but faces issues with accessibility and implementation challenges. The article by Snow (2021) examined the scientific aspects of language development and reading alongside necessary evidence-based interventions for students. This research demonstrates how digital technology and structured educational systems should be used together within special education classrooms. Studies on assistive technology (AT) have generated important findings, yet literature research still contains several unaddressed areas about AT practice efficiency. Researchers have not performed adequate longitudinal research to understand how AT usage influences academic results as well as mental development over extended periods. Most research shows how assistive technology brings immediate reading comprehension and writing skill achievements, but no widespread studies examine sustained achievements across different educational stages (Foorman et al., 2021). The evaluation of AT utilization would strengthen if researchers study literacy maintenance rates among students together with their progress in independent learning and career readiness skills. Research data demonstrates that

assistive technology generates substantial benefits for dyslexic students by enhancing their reading comprehension alongside writing skills and educational dedication. Students who utilize TTS software demonstrate better reading precision, as per research findings (Smythe et al., 2021). Students demonstrate better word recognition skills together with improved comprehension when they read digital text that has accompanying audio support. The reading education benefits most profoundly appear in students whose phonemic awareness and decoding skills required improvement. STT applications generate favorable results when used. STT tools provide students dealing with spelling and sentence structures by enabling them to express themselves verbally without the associated manual writing challenges. Students use STT tools to transform their thoughts into proper sentences with ease, which reduces their assignment-related frustration. The ability of students to construct coherent essays together with longer written responses improves with repeated usage of TTS tools.

The main advantage observed is how AT tools support students in developing independent learning capabilities. Teachers who depended on their students begin to discover that their students can now operate AT tools without assistance to access course materials independently. Audiobooks enable students to access academic content on par with their peers who do not experience challenges with reading speed. The wider availability of educational content through AT decreases the academic difference in academic performance between students with dyslexia and their non-dyslexic peers (Arias-Gundín & García Llamazares, 2021). AT tools provide customizable options where students can alter settings such as velocimetry speed in TTS software and text font dimensions to create their unique, personalized educational experiences.

Some educational institutions offer AT tools to students, yet many academic facilities face budget difficulties, preventing their learners from using essential technological resources. The way teachers implement AT in classrooms depends heavily on their training level because differences in professional preparation lead to varying results. The lack of AT tools training among teachers presents a barrier to their effective implementation, thus lowering the benefits students experience from SLD (Handler, 2024). Students who need maximum benefit from assistive technologies must receive extra training, but some students maintain comprehension issues even with technological support. The research demonstrates why customized AT should be deployed according to individual student cognition because each person requires specialized tools for their cognitive needs.

The evolution of SLD domain along with the integration of assistive technology (AT) is a beacon of hope offering transformative potential for students grappling with diverse learning challenges. Beyond the conventional understanding of AT as mere tools for accommodation, one seeks to unravel the intricate neurocognitive mechanisms through which these technologies exert their influence.

This exploration necessitates a paradigm shift, moving beyond surface-level observations of behavioral outcomes to a deeper understanding of the neural underpinnings that govern learning and cognition in students with special needs. AT encompasses of a lot modern tools, and systems designed to enhance the learning capabilities of students with SL difficulties. These technologies span a broad spectrum, from average technological solutions like adapted pencils and visual timers to above average technological innovations like speech-generating apps, eye-tracking systems, and virtual reality platforms. The common thread that unites these diverse tools is their capacity to empower students, enabling them to overcome barriers to learning and participate more fully in academic and social environments. According to Alkahtani (2013), assistive technology not only facilitates curriculum access for students with specific learning difficulties but also enhances the quality of their learning experiences. The research by Starcic & Istenic (2010) indicates that assistive technological devices can help teachers enhance students' cognitive capabilities by promoting their engagement in learning opportunities, such as peer tutoring and activities. The study provides essential insights about assistive

technology because it helps researchers understand its role in helping SLD students eliminate educational challenges. A substantial number of students with SLD exist, while traditional educational methods regularly neglect their learning requirements. The study evaluates assistive tools notably text-to-speech and speech-to-text applications to generate evidence that enhances inclusive education strategies. The study of AT technology effects on SLD student learning supports general knowledge development within special education research. Educational findings will assist teachers, together with public administrators and technology developers, to develop better and inclusive learning environments. The study demonstrates the necessity of thorough training together with appropriate financial allocations to allow proper implementation of AT tools.

This exploration into the neurocognitive impact of AT on SLD students is a journey into the heart of learning and cognition. By combining the insights of neuroscience, cognitive psychology, and educational technology, we can unlock the transformative potential of AT, empowering SLD students to overcome their challenges and unlock their academic potential. This paper will explore the specific categories of AT, review the current state of research, analyze case studies, and discuss the future directions of this important and evolving field, all with the goal of illuminating how assistive technologies can reshape the cognitive feature of students, leading to a more nuanced understanding of their potential to empower and transform the lives of diverse learners.

From the various literatures reviewed, it can be seen that the various technologies play significant roles in the education of SLD students and that they apply to the various disabling conditions of SLD students. And so, the choice of the type of technology to adopt in the education of a special need students greatly depends on the feature of the student's learning disability. SLD students can choose to implement audio technologies, visual technologies, or audio-visual technologies, as these represent the three available technology categories. However, the various literatures do not offer strong empirical evidence about the responsibility of technological tools in educating SLD students, hence, there is need for this study

METHODOLOGY

The methodology for this exploratory research focuses on a systematic examination of existing research on the neurocognitive benefits of Assistive Technology (AT) for English Language Learners (ELLs) with special learning needs. This review involves a comprehensive search of academic databases in SLD education, language acquisition, and cognitive neuroscience. The selection criteria for inclusion prioritized studies that investigated the intersection of AT use, cognitive processes (such as attention, memory, executive functions), and English language learning outcomes for SLD students. The analysis involved a synthesis of the findings from these studies, identifying reported neurocognitive enhancements or supports facilitated by various AT tools. This exploratory review aimed to map the current understanding of how AT may impact the cognitive mechanisms underlying English language acquisition for SLD students, highlighting potential benefits, limitations identified in the literature, and areas requiring further empirical investigation.

FINDINGS/RESULTS

Assistive technology serves two key roles. Firstly, it can enhance an SLD students' existing abilities to offset the impact of the disability. Secondly, it can offer alternative ways to complete a task, effectively working around or eliminating the issues imposed by the disabilities (Lewis, 1998). A range of students' learning difficulties and the Assistive Technologies that can be used to minimize learning obstacles in classrooms are outlined by the Australian Disability Clearinghouse on Education and Training (ADCET):

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Language Aspect of the Cognitive Ability

Listening and Speaking

Challenges encountered with auditory processing can hinder a student's ability to distinguish subtle variations in sounds, which in turn can affect their pronunciation. Receptive language difficulties impair the comprehension of spoken language and also make it harder to organize thoughts and communicate them effectively. Furthermore, language-based speech difficulties can lead to problems expressing ideas, recalling the correct vocabulary, and acquiring new terms.

Reading and Comprehension

Students with reading disability typically experience difficulties in accurately identifying words recognition. This core challenge negatively affects a students' ability to read accurately, fluently. Due to their reading difficulties, students frequently experience reading as a arduous and lengthy activity, which hinders their ability to retain the information they read. Some SLD students may read the material effortlessly, but may encounter little to no retention of the reading material due to deficits in their working memory.

Writing and Spelling

The writing process, particularly the organization of ideas, can be hampered for individuals with SLD due to difficulties in accessing information stored in their short-term or long-term memory. Furthermore, SLD students may also struggle to transcribe their ideas into words onto paper. Their spelling abilities are also affected by their weak phonemic awareness (understanding the connection between letters and sounds) and decoding skills. This may also lead to hindrances in linking spoken sounds to written letters and due to working memory limitations their ability to retain and recall words is restricted.

Organisation and Time Management

SLD students find it challenging to plan, organize things and manage time efficiently. Due to this deficit they find it difficult to adhere to time lines as a result setting priorities, creating a plan, and working methodically is a problematic task. This reduced ability to organize academic work may result in missed deadlines and a feeling of being overwhelmed.

Recommendation:

Implementing appropriate assistive technologies, individuals with SLD can overcome hurdles they face to achieve academic success. Some Assistive Technology to Enhance SLD are:

- Recorders to record and re-listen to the lectures.
- Alternative options to use voice recording to develop presentations for students who experience communication apprehension.
- Digital note-taking device that allow audio recording of lectures with simultaneous notes.
- Electronic dictionaries with audio pronunciation.
- Digital books with audio to enhance comprehension by providing both visual and auditory input.
- Graphic organisers to enhance recall and minimises stress on working memory.
- Software that reads text aloud from Word or PDF formats, email and web content.
- Software that transcribes spoken words into text through dictation given to the device.
- Spell checkers to check spelling of words.
- Outline software to create writing structure
- Digital calendars to schedule tasks and appointment

- Reminder applications to set alerts for task and deadlines
- AI planning tools to create structured checklist for reminders

CONCLUSION

The development of assistive technology has proved to be an essential instrument that enhances receptive and productive skills of SLD students with learning difficulties through improved understanding while simultaneously decreasing mental workload and promoting self-directed learning. AT supports literacy development through different approaches for students to access and participate with text-based educational material according to the research. Although students benefit from AT integration, many issues exist regarding its successful deployment. The problem of accessibility divides exists strongly because certain students cannot afford AT tools or face institutional restrictions when seeking them. The role of artificial intelligence in improving AT applications requires further study to develop more tailored and flexible learning capabilities for SLD students. Educational gaps experienced by SLD students will benefit from continuous advances in AT development, which requires sustained research work as well as innovative funding for inclusive educational system improvements.

Implications and Future Studies:
This exploratory research has provided valuable initial insights into how students interact with a range of AT tools within real-time educational settings. However, the cross-sectional nature of this study limits our understanding of how these interactions evolve over time. To address this limitation and gain a deeper understanding of the longitudinal patterns of AT tool use, future research will involve a longitudinal in-class study spanning one academic year. This study will follow the same group of students to examine how their interactions with AT tools change, adapt, and potentially impact their learning outcomes over an extended period. This longitudinal approach will allow for a more comprehensive understanding of the long-term integration of AT tools in educational environments.

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