THE ISSUE OF AI-BASED SUPPORT FOR STRUGGLING READERS THROUGH THE LENS OF UDL PRINCIPLES

IL SUPPORTO BASATO SULL'INTELLIGENZA ARTIFICIALE PER LETTORI SVANTAGGIATI ATTRAVERSO LA LENTE DEI PRINCIPI DELL'UDL

Andrea Mangiatordi
University of Milano-Bicocca, Italy
andrea.mangiatordi@unimib.it

Diego Joseph Villalón
University of Milano-Bicocca, Italy
diego.villalon@unimib.it

Cristina Liviana Caldiroli
University of Milano-Bicocca, Italy
cristina.caldiroli@unimib.it

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ABSTRACT
One of Universal Design for Learning principles suggests to "design multiple means of representation" (CAST, 2024) and it can be applied to text accessibility by granting 1) readability and legibility, 2) disambiguation of terms and symbols, and 3) support to comprehension through various means. Text simplification is often mentioned as a possibility offered by AI for struggling readers. In this contribution we argue that it can efficiently be combined with intelligent tutoring systems in order to achieve better results that are in line with UDL guidelines.

Uno dei principi dell'Universal Design for Learning suggerisce di "progettare molteplici mezzi di rappresentazione" (CAST, 2024) e può essere applicato all'accessibilità dei testi garantendo 1) leggibilità e comprensibilità, 2) disambiguazione di termini e simboli e 3) supporto alla comprensione attraverso vari mezzi e modalità. La semplificazione dei testi è spesso citata come una possibilità offerta dall'IA per i lettori in difficoltà. In questo contributo sosteniamo che essa può essere efficacemente combinata con sistemi di tutoraggio intelligente al fine di ottenere risultati migliori in linea con le linee guida UDL.

KEYWORDS
Inglese: Text simplification; Struggling readers; Recognition network
Italiano: Semplificazione del testo; Lettori in difficoltà; Network di riconoscimento.

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Introduction

Universal Design for Learning (UDL) offers a powerful framework to address accessibility issues in learning content by promoting flexible and inclusive instructional practices, including the design of "multiple means of representation". This is one of the three main principles of the UDL framework, together with "design multiple means of engagement" and "design multiple means of expression" (CAST, 2024). According to UDL, in order to provide multiple means of representation it is necessary to take into consideration at least three aspects, that are reflected in UDL guidelines n. 1, 2 and 3:

1. Design Options for Perception
2. Design Options for Language & Symbols
3. Design Options for Building Knowledge

These three guidelines reflect three dimensions of reading comprehension: a reader must be able to perceive text; it must then be able to decode all symbols, words and expressions efficiently; finally, it must be able to understand the meaning of the text, which largely depends on the style it is written in and on its complexity. Digital technology offers many ways to address the mentioned dimensions. In the case of simple perception, for example, we know that digital text offers many ways to customize fonts and overall pagination to allow for better text readability. Then there is the possibility to facilitate decoding of text by providing additional information through dictionary and web searches. Text comprehension is a little less straightforward, but there is actual abundance of calculators for ease of reading that can be incorporated also in writing tools.

The main hypothesis behind this work is based on the idea that newer technological solutions, like virtual tutors powered by Generative AI based on Large Language Models (LLMs), can be effectively used to implement solutions that are in line with the above-mentioned needs and that provide even better support compared to more "traditional" solutions. The focus is on the way an interface can be built to sustain such an effort.

AI technologies offer promising tools for tailoring textual content to diverse learner needs. Text simplification using AI (Hedlin et al., 2025; Padovani et al., 2024), automated question generation (Liu et al., 2024), and dialog-based tutoring systems (McCarthy & Yan, 2024). All these solutions represent innovative strategies for enhancing readability, promoting engagement, and supporting deeper understanding. However, these approaches are often investigated in isolation.

This paper proposes the exploration of a design concept for a set of AI virtual tutors that would allow to apply multiple strategies to the integration of these techniques to scaffold reading comprehension for struggling readers. Grounded in UDL principles and informed by recent advancements in educational technology, this work seeks to examine how a set of AI chatbots can serve as an effective, scalable, and accessible reading aid by streamlining the user experience of readers. The ultimate goal is to bridge a gap identified in existing research and communication papers about the use of AI assistants based on LLMs to provide more accessible text to struggling readers: this possibility is mentioned by many researchers, but it is often unclear how better readability could be achieved. Practitioners and users could greatly benefit of a unified model based on learning design theory - such as UDL - that would be able to provide clear directions on how to achieve such simplification.

1. State of the art in AI-based text simplification

Recent studies in AI-based text simplification have employed a range of methodologies. In some cases hybrid approaches have been employed, combining rule-based techniques with neural networks (Bahrainian, Dou, & Eickhoff, 2024; Maddela, Alva-Manchego, & Xu, 2021; Narayan & Gardent, 2014; Štajner & Glavaš, 2017; Truică, Stan, & Apostol, 2023); in some other cases, sequence-to-sequence models were adopted (Martin, Sagot, Clergerie, & Bordes, 2019; Nisioi, Štajner, Ponzetto, & Dinu, 2017); other techniques that were used include neural machine translation (Alissa & Wald, 2023), edit-based methods (Omelianchuk, Raheja, & Skurzhanskyi, 2021), and phrase-based machine translation (Wubben, Bosch, & Krahmer, 2012a).

Text simplification effectiveness is evaluated through several key measurement approaches. Automated Metrics like SARI (System output Against References and against the Input sentence) is specifically designed for text simplification and appears frequently across studies (Kumar, Mou, Golab, & Vechtomova, 2020; Phatak, Savage, Ohle, Smith, & Mago, 2022). BLEU (Bilingual Evaluation Understudy) is commonly used to measure similarity between model output and reference simplifications (Alissa & Wald, 2023; Campillos-Llanos et al., 2024). Flesch-Kincaid Grade Level (FKGL) is frequently used to assess text complexity (Wubben, Bosch, & Krahmer, 2012b; Zhang & Lapata, 2017).

Another commonly used approach is human assessment, which can be used to evaluate many different aspects, such as: fluency and adequacy (Kumar et al., 2020), simplicity and meaning preservation (Woodsend & Lapata, 2011), and grammaticality (Štajner, 2015).

While automated metrics provide quantifiable results, the combination of both automated and human evaluation methods offers the most reliable assessment of simplification effectiveness, as different metrics capture different aspects of the simplification quality.

The utilisation of generative AI in text simplification research has yielded findings that suggest the efficacy of methodologies integrating user control with adaptive, context-aware processing in enhancing text access for groups of disadvantaged readers. For example, research on individuals with dyslexia showed that lexical simplification with on-demand synonym displays enhanced readability and comprehension, and transfer learning applied to produce dyslexia-friendly text improved the reading experience by 27% (Madjidi & Crick, 2023). Research focused on non-native speakers demonstrated that resource-light neural models and context-aware word embeddings reduced errors by up to 25% and performed as effectively as systems based on manually simplified corpora (Paetzold, 2016). In language learners, gaze-driven systems that integrate GPT-3.5 improved sentence-level comprehension, while BERT-driven applications increased accessibility for readers with low literacy or cognitive disabilities (Higasa, Tanaka, Feng, & Morishima, 2023; Jin, Sun, & Li, 2024). Studies indicate that balancing automated text modification with user-directed features – such as on-demand lexical substitution and adaptive simplification – offers promising benefits for non-native speakers, individuals with learning disabilities, and low-education populations (Alonzo, Seita, Glasser, & Huenerfauth, 2020; Higasa et al., 2023; Rello, Baeza-Yates, Bott, & Saggion, 2013).

The evidence collated from academic literature appears to support the hypothesis that the utilisation of generative AI is a favourable option for the simplification of text, particularly in the context of addressing disadvantaged readers. In the next section we will explore the possibilities that open up when this approach is combined with a comprehensive theory, like the UDL framework, to obtain dynamic results that can be adapted to a variety of populations and needs.

2. Methods and Materials

The present study concentrated on UDL guidelines 1, 2 and 3. It is asserted that Guideline 1, "Design Options for Perception", can be addressed by applying various types of typographical adjustments to text, without recourse to generative AI (Caldiroli et al., 2017; Mangiatordi & Sareen, 2011).

This preliminary supposition enabled us to concentrate on formulating particular prompts for two chatbots, which were designed to address guidelines n. 2 and 3. We proceeded to the creation of two very simple chatbots, each one connected with the requirements set by these two guidelines.

For guideline n. 2, “Design Options for Language & Symbols”, we envisioned that the main support that could come from a chatbot, also based on what was discussed in the previous section, would be an automated provider of word definitions. We created this basic prompt:

- You are an AI chatbot. You are a little robot eager to help a primary school child discover the meaning of words. Every time you receive a word, you try to give a definition. When asked for the definition of a vulgar word, refer the user to an adult or teacher.

The main advantage of a chatbot based on this simple directive is that it does not require the user to explain what they want to achieve, speeding up the process of discovering the meaning of difficult words to such an extent that it is possible to imagine a reading interface in which the selection of a single word immediately activates this solution. Symbols and special characters are supported natively, leveraging the ability to recognise characters such as π and ß available to the underlying LLM (using the gpt-3.5-turbo model from OpenAI).

To address the requirements of UDL guideline n. 3, “Design Options for Building Knowledge”, we emphasized the aspect of reading ease by instructing a second chatbot with the following fixed prompt:

- You are a teacher and your main role is to disambiguate references in complex sentences for children who need to read simpler sentences consisting of a subject, predicate and as few complements as possible. Your main goal is to construct simple sentences that can be used to better understand the text, necessarily returning a bulleted list. It doesn't matter if you have to repeat the same words many times, you must always return a list of minimal, meaningful sentences.

The main aspect that is visible here is the stress on “simple sentences”, including just the minimum required to express simple and linear ideas. The chatbot expects a chunk of text, which means that for future implementations it should be connected with the selection of sentences or entire paragraphs. The phrases generated in this way can be easily reused as a basis for constructing concept maps, advanced information organisers whose usefulness is well known, especially for people with specific learning disorders (Novak, Gowin, & Johansen, 1983).

Testing the generative AI system revealed that it effectively simplified complex texts into clear, concise sentences while maintaining the core meaning. The system consistently produced grammatically correct output and demonstrated a strong ability to identify and preserve key information. However, in some cases, subtle nuances or technical details were lost during simplification, highlighting the trade-off between readability and depth. Overall, the results suggest the system performs reliably for general summarization tasks but may require further tuning for domain-specific content. As an example, we provide here some of the outputs obtained by feeding the chatbot a paragraph about French Revolution that was taken from the English Wikipedia, which scored 13.6 on the Flesch-Kincaid Grade Level and 39.2 on the Flesch Reading Ease Score, meaning its level is “College” (Difficult to read):

- The French Revolution was a period of political and societal change in France.
- It began with the Estates General of 1789 and ended with the Coup of 18 Brumaire in 1799.
- The revolution's ideas are considered fundamental principles of liberal democracy.
- Its values remain central to modern French political discourse.
- The causes of the revolution include social, political, and economic factors.
- A financial crisis and social distress led to the convocation of the Estates General in May 1789.
- The representatives of the Third Estate broke away and formed a National Assembly in June.
- The Storming of the Bastille in Paris on July 14 was followed by radical measures by the Assembly.

The integration of tools that facilitate typographical modifications to text, in conjunction with the utilisation of two chatbots like the ones described here, constitutes a cost-effective approach to achieving the implementation of the selected Universal Design for Learning (UDL) guidelines.

We anticipate that the combination of the two chatbots described here will demonstrate measurable improvements in reading comprehension for struggling readers when compared to performance without AI support.

These outcomes will support our hypothesis that newer technological solutions, like virtual tutors powered by Generative AI based on LLMs, can be effectively used to implement solutions that are in line with the above mentioned needs and that provide even better support compared to more “traditional” solutions. This also aligns with UDL principles and allows to implement the variated degrees of support that the framework so strongly emphasizes.

3. Discussion

The experience collected from this study has implications for both research and practice in inclusive education and educational technology. AI chatbots could exemplify how multiple AI-supported strategies - namely word definitions and text simplification - can be meaningfully integrated to address the needs of struggling readers. Such integration reflects the spirit of UDL, which emphasizes the proactive design of learning environments to accommodate learner variability.

From a theoretical perspective, the work conducted thus far contributes to a growing body of literature that seeks to operationalise UDL principles using cutting-edge technologies. The present study extends prior research by demonstrating how generative AI can not only adapt text content but also provide metacognitive and interactive supports that promote agency and comprehension.

Practically, the use of multiple, specialized virtual tutors like the ones discussed here offers a promising model for scaling individualized support in mainstream classrooms, potentially reducing dependence on one-to-one human intervention. This is especially relevant in contexts where educators face high student-to-teacher ratios and limited resources for differentiated instruction.

Nonetheless, several challenges must be acknowledged. The accuracy and appropriateness of AI-generated content, particularly in sensitive educational contexts, must be rigorously monitored. Ensuring that the tutor’s feedback remains developmentally appropriate and culturally responsive will be critical. Additionally, long-term studies will be required to assess whether these tools foster durable comprehension improvements or only short-term gains.

Future research should investigate how learners with different profiles (e.g., dyslexia, multilingual backgrounds, ADHD) interact with and benefit from different combinations of AI strategies, and how such systems can be optimized through learner feedback loops.

Conclusions

The objective of this proposed study is to establish a connection between AI-powered reading tools and inclusive educational frameworks by integrating and aligning multiple virtual tutors with the fundamental principles of Universal Design for Learning. The integration of specific responses to UDL guidelines 1, 2 and 3 is expected to provide a scalable and personalised approach to supporting struggling readers, as facilitated by the AI tutor.

The anticipated benefits span improved comprehension outcomes, greater learner autonomy, and reduced instructional burden — all of which are vital in increasingly diverse and resource-constrained classrooms. Furthermore, this research contributes to the growing discourse on responsible and pedagogically informed applications of generative AI in education.

Ultimately, the project seeks to demonstrate that when AI tools are carefully designed with learner variability in mind, they can offer not just accessibility, but true equity in reading and learning opportunities.

Author contributions

All authors have participated in the ideation and in the planning of the paper, in a collaborative effort. Diego Villalon wrote the introduction and the state of the art, Andrea Mangiatordi wrote the “methods and materials” section, Cristina Caldiroli wrote the discussion. All three authors participated in writing the conclusions.

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