# Supporting Children with Linguistic Vulnerabilities Through Advanced, Theory-Driven Technological Solutions: The TELMÌ Approach for Italian children with DLD and Children with Italian as L2

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#### **ABSTRACT (ENGLISH)**

This paper presents the early stages of a research project employing advanced technological solutions to improve language skills in two groups of 5- to 8-year-old children with linguistic vulnerabilities: those with Developmental Language Disorder (DLD) and those with Italian as a second language (L2). Although both groups may exhibit similar linguistic difficulties, the underlying causes are distinct, necessitating tailored interventions. Currently, the lack of appropriate linguistic support interventions and normative data for L2 learners underscore the urgent need to investigate how learning processes differ between the two groups to develop more targeted training programs. Another major challenge in conventional speech therapy is the reliance on traditional, paper-based methods, often perceived as stressful and unengaging by children. These methods frequently overlook the broader cognitive, social, and emotional context of language, and can be costly and logistically demanding for many families. To address these limitations, this study introduces a multi-week training program delivered through an innovative technological platform called TELMI, which is grounded in solid theoretical principles from speech therapy and psycholinguistics. TELMI aims to foster children's morphosyntactic skills through interactive storytelling deliverable through two distinct modalities: a tablet-based web application and an immersive, interactive multisensory system known as the Magic Room. This study has two main objectives: (1) to assess whether children in the DLD and L2 groups show improvements in their linguistic skills and, if so, to examine the gualitative and quantitative differences in their learning; (2) to explore whether the delivery format (tablet vs. Magic Room) yields distinct outcomes. Findings will inform the design of specialized, context-aware interventions for each population and shed light on the potential benefits of integrating technology into speech therapy. **Keywords:** Developmental Language Disorders (DLD); L2 Italian Learners; Technology in speech therapy; smart spaces; interactive storytelling.

#### **ABSTRACT (ITALIANO)**

Offrire un supporto ai bambini con vulnerabilità linguistiche attraverso soluzioni tecnologiche avanzate e teoricamente motivate: l'approccio TELMÌ per i bambini italiani con DPL e per quelli con italiano come L2. Questo articolo presenta le fasi iniziali di un progetto di ricerca che impiega soluzioni tecnologiche avanzate per migliorare le competenze linguistiche in due gruppi di bambini di età compresa tra i 5 e gli 8 anni con vulnerabilità linguistiche: quelli con Disturbo Primario del Linguaggio (DPL) e quelli che usano l'italiano come seconda lingua (L2). Nonostante i due gruppi possano presentare difficoltà linguistiche simili, le cause sottostanti le fragilità linguistiche nei due gruppi sono diverse, richiedendo pertanto interventi mirati. Al momento, la mancanza di interventi adeguati di supporto linguistico e di dati normativi per i bambini con italiano L2 evidenzia l'urgente necessità di indagare come i processi di apprendimento differiscano tra questi due gruppi, al fine di sviluppare programmi di supporto più specifici. Un'ulteriore sfida nelle terapie logopediche convenzionali è rappresentata dall'uso di strumenti cartacei spesso percepiti dai bambini come stressanti e poco coinvolgenti. Tali metodi trascurano di frequente il più ampio contesto cognitivo, sociale ed emotivo del linguaggio e possono risultare costosi e impegnativi dal punto di vista

logistico per molte famiglie. Per superare tali limitazioni, questo studio introduce un programma di training linguistico, basato su solidi principi teorici della logopedia e della psicolinguistica, della durata di alcune settimane, erogato attraverso una piattaforma tecnologica innovativa chiamata TELMÌ. TELMÌ mira a potenziare le abilità morfosintattiche dei bambini attraverso la narrazione interattiva, proposta in due modalità: un'applicazione web su tablet e un sistema immersivo e multisensoriale chiamato "Magic Room". Lo studio ha due obiettivi principali: (1) valutare se i bambini italiani con DPL e quelli con italiano L2 mostrino miglioramenti nelle loro competenze linguistiche e, in caso affermativo, esaminare le differenze qualitative e quantitative nei processi di apprendimento tra i due gruppi; (2) indagare se diverse modalità di erogazione (tablet vs. Magic Room) producano esiti differenti. I risultati forniranno indicazioni utili alla progettazione di interventi specializzati e sensibili al contesto per ciascuna popolazione, facendo luce sui potenziali benefici dell'integrazione tecnologica nella terapia logopedica.

**Parole chiave:** Disturbo Primario del Linguaggio (DPL); bambini con Italiano L2; Soluzioni tecnologiche in logopedia; spazi intelligenti; narrazione interattiva.

#### 1. INTRODUCTION

Possessing solid language skills is fundamental for social integration and for individuals to fully realize their potential in both educational and professional arenas, as well as in maintaining a fulfilling social life. Effective linguistic abilities are paramount, serving as the cornerstone for interacting with others and navigating various social contexts. Indeed, language is a transversal skill that significantly influences a wide range of other competencies, including cognitive development, academic achievement, and emotional well-being. However, when these abilities are compromised—as in the case of children with Developmental Language Disorder (DLD), a disorder that specifically affects language acquisition and use-such challenges can hinder not only academic performance, but also social and emotional development<sup>1</sup>. Children learning Italian as a second language (L2) may also experience language difficulties, especially when compared to typically developing peers who speak Italian as their first (L1) language<sup>2</sup>. Interestingly, it has been found that children with DLD and those learning Italian as a L2 may share common difficulties, at least superficially, especially during the early years of L2 acquisition<sup>3</sup>. Despite this, while Italian L2 children may initially appear similar to those with DLD, a detailed examination reveals that their language profiles differ significantly in both quality and quantity (Vender et al., 2016). Indeed, it is important to emphasize that the linguistic difficulties experienced by children with DLD and those learning Italian as L2 have different causes and origins—DLD is believed to result from various factors, including genetic, neurological, and environmental influences, while the challenges faced by children learning Italian as an L2 are associated with limited language exposure. Because their language difficulties arise from different sources, both populations need tailored support and training programs. Providing targeted support to both groups is essential to ensure their effective integration and overall development (Guasti, 2017). Currently, there are substantial issues concerning both the support for L2 children with language fragilities and the language rehabilitation of children with DLD. Children with Italian as L2 do not always receive the necessary or adequate attention because their need for support is frequently underestimated. On the other hand, they are sometimes treated as if they have DLD, due to the lack of specific tools to differentiate deficiencies caused by insufficient exposure from those originating from a

<sup>1</sup> DLD is a highly heterogeneous disorder and includes various cases. In general, children with DLD start speaking later than their peers and exhibit slow language development (Guasti, 2017). Their difficulties can selectively affect different linguistic areas. They often show phonological challenges (Bortolini et al., 2006), a vocabulary below the typical range, difficulties in the correct use of morphosyntactic structures, and challenges with functional morphemes such as third person plural inflection (Bortolini et al., 2006) and clitics (Arosio et al., 2014; Bortolini et al., 2006), among others. However, some researchers argue that these language disorders can co-occur with non-purely linguistic disorders. Sometimes, difficulties are also observed in non-linguistic areas such as verbal memory (Gathercole, 2006) and fine motor skills (Adi-Japha et al., 2011; Hill, 2001).

<sup>2</sup> The proficiency of Italian L2 children is strongly influenced by the timing of their first exposure to the L2 language. The literature distinguishes different types of bilingualism based on the period of language exposure (Abdelilah-Bauer, 2008; Contento, 2010; Guasti, 2017). In general, bilingualism is categorized as simultaneous or sequential, depending on whether exposure to L2 occurs from birth or begins after birth, respectively.

<sup>3</sup> Children with Italian as L2 may have a more limited vocabulary and perform worse in lexical comprehension compared to their monolingual peers (Bialystok et al., 2010; Guasti, 2017; Oller et al., 2007). Additionally, they may exhibit reduced average sentence length (Guasti, 2017) and face challenges in using morphosyntactic elements and functional words (Paradis et al., 2008; Paradis & Crago, 2000; Vender et al., 2016).

linguistic problem, as well as the absence of normative data on L2 acquisition (Bedore & Peña, 2008; Guasti, 2017). Therefore, there is an urgent need to clearly distinguish between the two conditions in order to develop tailored training approaches for each distinct group of children. As for the conventional speech-language therapy for DLD children, it commonly relies on paper-based materials. While these materials successfully target some of the most challenging linguistic skills for these children, the methods of their administration present several drawbacks (Spitale et al., 2021). Firstly, therapy is often perceived by children as stressful and frustrating. These exercises are typically administered in a setting where the child is required to respond directly to the therapist, which can cause pressure and anxiety for some children. Another issue is the lack of engagement and appeal in these exercises, which children often perceive as boring, leading to limited effectiveness for training. Lack of engagement can lower children's motivation and participation. When activities seem monotonous or irrelevant to their everyday lives, their willingness to participate and practice declines, reducing the overall effectiveness of the intervention. Moreover, many of these exercises are overly artificial, straying from the way in which language acquisition naturally occurs, involving multiple aspects of communication, including social and relational elements. The artificial nature of conventional speech-language therapy can lead to negative outcomes: by concentrating narrowly on isolated markers, these sessions often fail to support the holistic language development children need. Because language is inherently tied to cognitive, social, and emotional domains, ignoring its broader context hinders children's ability to integrate language skills into everyday communication, ultimately limiting both their overall proficiency and practical use of language. Another important aspect of conventional therapy to consider is cost and accessibility. Therapy sessions come with expenses that, unfortunately, many families find difficult to afford, especially considering those children who come from low socio-economic backgrounds. Additionally, therapy often requires traveling to the therapist's location and organizing schedules. As a result, the process is frequently demanding in terms of both cost and time. Furthermore, extending interventions to environments beyond the clinical setting, such as homes and schools, presents significant difficulties (Spitale et al., 2021). As emphasized by Spitale and colleagues (2021), a more holistic and ecological approach is necessary. This would foster children's motivation, which appears to mediate the cognitive factors involved in learning (Moreno & Mayer, 2007). Higher motivation would in turn lead to better performance and lower dropout rates during training. This is where technology can address emerging needs. Technology can be leveraged to promote inclusivity by providing accessible, personalized, and engaging tools that cater to the needs of children with linguistic fragilities.

#### 2. TECHNOLOGY IN SPEECH THERAPY

Recent studies have explored the integration of interactive technologies into speech-language therapy to address some of the previously mentioned challenges (Spitale et al., 2021). Technological solutions providing game immersion experiences have proven effective in engaging and captivating children more successfully than traditional intervention methods (Cheng et al., 2015). Moreover, the use of technology in training solutions appears to enhance the acquisition of language skills more rapidly and support longer retention of these skills (Durrleman et al., 2019; Edwards & Dukhovny, 2017). There are several technological solutions that can be adopted for this purpose, including computer devices (Adrian et al., 2003; Clendon et al., 2003; Engwall et al., 2006; Hair et al., 2020; Nanavati et al., 2018; Saz et al., 2009; Spitale et al., 2021; Stark & Warburton, 2018), robots (Buchwald et al., 2018; Charron et al., 2017; Robles-Bykbaev, Lopez-Nores, Pazos-Arias, et al., 2015; Robles-Bykbaev, Lopez-Nores, Ochoa-Zambrano, et al., 2015; Robles-Bykbaev et al., 2016; Spitale et al., 2021, 2023) and smart spaces created with augmented reality (AR) (Da Silva et al., 2015; Wanti et al., 2024) or virtual reality (VR) (Cappadona et al., 2023; Devane et al., 2023; Giachero et al., 2020; Vaezipour et al., 2022, 2023). By integrating these technologies into speech-language training interventions, it is possible to develop more dynamic, engaging, and personalized intervention strategies, ultimately enhancing the overall effectiveness of the training. Each of these technological solutions offers its own advantages. The affordability and widespread availability of computer devices make therapy accessible to more children in need and provide content beyond the therapist's office, allowing sessions to be undertaken at more convenient times while reducing financial and logistical obstacles. Robotic systems can engage children through interactive activities that promote skills important for language, such as turn-taking, eye contact, attention and executive functions (Spitale et al., 2023). Additionally, interacting with a robot might make children feel more comfortable, encouraging them to participate more freely without fear of being judged compared to interacting with a speech therapist. Augmented reality (AR) and virtual reality (VR) provide immersive experiences that

blend digital content with the physical world, making learning more engaging and effective by replicating and simulating real-life learning situations. According to the theoretical foundations of Embodied Cognition, the development of all human cognitive functions is related to our sensorimotor experiences (Wilson & Golonka, 2013). These theories have gained significant traction in the field of language acquisition and processing (Kontra et al., 2012). It appears that sensorimotor interactions with the environment help children process linguistic rules and acquire concepts (Gibbs, 2005). There has long been evidence supporting the beneficial effects of multisensory procedures on language development (Ayres & Mailloux, 1981). The benefits are not limited to strictly language-specific abilities but also include improved academic performance and greater ease of interaction in social contexts (Mauer, 1999).

# 3. CASE STUDY

The objective of this study is to adopt an innovative methodology that employs an advanced technological solution to overcome the limitations of traditional therapy in providing linguistic training and support to two populations with language fragilities: children aged between 5 and 8 years diagnosed with DLD and those with Italian as a second language (Italian L2). The training program aims to enhance the morphosyntactic skills of the two groups of children effectively. The training activities consist of interactive stories featuring selected morphosyntactic structures which are delivered in two formats: through tablet (web app) and by utilizing a more sophisticated immersive system: a multisensory room called the *Magic Room* (Garzotto & Gelsomini, 2018). With this study we aim to evaluate the effectiveness of training based on these technological solutions by assessing whether participants show improvements in their linguistic skills after the training and whether there are learning differences between the two modalities (tablet vs. Magic Room) and between the two populations (Italian children with DLD vs. children with Italian as L2). With this study, we aim to build upon and extend the work of Garzotto and Gelsomini (2018) by addressing some of the limitations identified in their previous research.

#### 4. METHODOLOGY

The study will involve approximately 120 children aged 5 to 8, divided into two main groups: 60 native Italian-speaking children with DLD and 60 typically developing children with Italian as L2. Each main group will be further divided into three subgroups of 20 children each, with the following participation modalities: one group will carry out the training in the Magic Room, a second group will train using the tablet, a third group will passively listen to the stories without performing specific activities during the narration. This group will serve as the control group: although exposed to the same stories as the other groups, they will not actively participate. The presence of this group is crucial to demonstrating the effectiveness of the active training. The study comprises three primary phases: an initial assessment of linguistic abilities prior to training (pre-training), the training intervention itself (conducted either in the multisensory room or via tablet), and a subsequent assessment of linguistic abilities following the training (post-training). For both the pre-training and post-training assessments, standardized tests from the BVL battery (Marini et al., 2015) will be administered to evaluate language production and comprehension. Additionally, during the pre-training assessment, the standardized Raven's Progressive Matrices (Raven, 1956) will be administered to evaluate non-verbal intelligence. The training phase consists of ten sessions, each lasting approximately one hour. In each session, children are presented with interactive stories that incorporate target sentences designed to train morphosyntactic abilities in comprehension. These include: passive constructions (Reggiani, 2010; Leonard et al., 2003, 2006; Riches, 2013; Robertson & Joanisse, 2010); relative clauses (Arosio et al., 2017, 2024; Contemori & Garraffa, 2010; Håkansson & Hansson, 2000; Novogrodsky & Friedmann, 2006; Rakhlin et al., 2016; Riches et al., 2010; Stavrakaki, 2002; Wada et al., 2020; Wang & Yu, 2021, 2022); clitic pronouns (Arosio et al., 2014; Guasti, 2017); inflectional morphology, including the pluralization of both real words and non-words, and subject-verb agreement with auxiliaries in compound tenses (Chondrogianni & John, 2018; Deevy & Leonard, 2018; Devane et al., 2023; Hadley & Rice, 1996; Leonard, 2014; Niemi, 1999; Oetting & Rice, 1993; Rice & Wexler, 1996). The interactive stories have been designed to be engaging, stimulating, instructive, enjoyable, and appropriate for the target age group of the children. We adopted the storytelling format, as in Spitale and colleagues (2021), since extensive research has shown that storytelling can effectively boost and improves children's language skills and their syntactic comprehension (Isbell et al., 2004). The stories were designed to be scalable and maintain a consistent structure. The entire development process, encompassing both the UX design of activities and the coding process, leverages an innovative pattern-oriented approach with

multiple levels of abstraction, which supports the reuse and scalability, both at the level of UX design and implementation phase (Borchers, 2001; Schmidt et al., 2000; Pree & Sikora, 1997; Spitale et al., 2021; Van Welie et al., 2001). The interactive stories are delivered through a web app called TELML, which supports language training activities in two formats: through tablet (web app) (Figure 1B) and by utilizing a more sophisticated immersive system: a multisensory room called the Magic Room (Figure 1A). The Magic Room employs innovative software and hardware technologies to transform indoor spaces into interactive, multisensory, and highly ecological environments. Users can be exposed to a variety of visual and auditory stimuli that can be integrated and controlled through gestures and movements, thereby facilitating the use of language by recreating everyday situations. The two versions of TELMI (tablet and Magic Room) work in the same way, with a difference only in how participants interact with the systems. In both versions, each segment of the story is accompanied by three different images (a target, a competitor, and a distractor), following the principle of the picture-matching task. Only one of these three images (i.e., the target image) accurately reflects the content described by the pre-recorded narration. The child's task is to select the image that they believe correctly corresponds to the heard sentence. In the web app the participants interact by clicking on the image on the tablet (Figure 2B), while in the Magic Room users must physically move, by either touching the projected image on the wall, stepping onto it, or placing an object on the image if it is projected on the floor (Figure 2A).



Figure 1A: The Magic Room and its components.

Figure 1B: TELMÌ tablet application.



Figure 2: A story segment featuring three different images, with only one image accurately reflecting the content presented by the pre-recorded narration. Figure 2A represents the Magic Room version. In this case, the child has to step onto the image projected on the floor which corresponds to the heard sentence.

# Figure 2B: The tablet version. The child's task is to select the image that they believe correctly corresponds to the heard sentence by touching it.

In the Magic Room responses are recorded via sensors – a Kinect device to track participants' movements and positions – and no video recordings are made. In both the tablet and Magic Room versions, if a child selects an incorrect image, they receive immediate feedback and the opportunity to attempt the response again. The response time and the number of attempts are recorded for each trial.

Consistent with findings in the literature on the use of technology in language therapy, we expect both types of training to yield positive effects. Furthermore, we hypothesize that the Magic Room may be more engaging than the tablet, leading to greater improvements in performance. Indeed, the greater sensorimotor engagement provided by the multisensory room could address the issue of "non-ecological" approaches typical of traditional clinical protocols and training methods. This in turn would foster higher motivation, which mediates the cognitive factors involved in learning (Moreno & Mayer, 2007), thus promoting better performance and reducing the risk of dropouts during training. Another objective of our study is to examine whether there are differences in training between the two groups of children and, if so, to identify what those differences are. As previously explained, the origins and causes of linguistic difficulties differ between the two populations; therefore, we expect to observe differences in their learning

processes. Specifically, we hypothesize that the two groups will exhibit distinct linguistic behaviors and that their learning pace (measured in terms of training benefits) will differ. More precisely, we anticipate that children with Italian L2 will demonstrate a faster learning pace during the sessions compared to Italian children with DLD.

## 5. CONCLUSIONS

We presented the design of an experimental study that harnesses cutting-edge technology to enhance language abilities in two populations with fragilities: children with DLD and those with Italian as a second language. Our research has the potential to guide future studies, drive the development of targeted and tailored linguistic training interventions for the two groups, and illuminate both the benefits and possible limitations of using technology in speech therapy.

#### ACKNOWLEDGEMENTS

This work was supported by the Italian National Recovery and Resilience Plan (PNRR), Mission 4, Component 2, Investment 1.1, funded by the European Union – NextGenerationEU, under the PRIN 2022 project "A Technology-driven linguistic intervention for children with language and literacy weaknesses", CUP: B53D23014380006.

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