Language Optionality and Variation
Festschrift in Honor of Anna Cardinaletti
edited by Chiara Branchini, Gianluca Lebani,
Lara Mantovan, Francesca Volpato

Treatment of Movement Derived Sentences Using an Educational Game: The Case of a Boy with Cornelia de Lange Syndrome

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Abstract The study explores language variation in a 13-year-old Italian-speaking boy with Cornelia de Lange Syndrome in the production and the comprehension of restrictive relative clauses and the production of *wh*-questions. Assessments were conducted before and after a linguistic training intervention based on the explicit teaching of verb argument structure, Theta criterion, and *wh*-movement in object relative clauses. The participant's performance was compared with that of four typically developing controls. Post-intervention results indicate an improvement in the participant's performance, which nevertheless remained significantly lower than that of the control group. Follow-up data suggest that the training effects were sustained only in the production of subject *wh*-questions.

Keywords Cornelia de Lange Syndrome. Linguistic training intervention. Relative clauses. wh-questions.

Summary 1 Introduction. – 2 Materials and Methods. – 3 Results. – 4 Discussion.

Edizioni Ca'Foscari

LiVVaL 9
e-ISSN 2974-6574 | ISSN 2974-6981
ISBN [ebook] 979-12-5742-086-4 | ISBN [print] 979-12-5742-121-2

Peer review | Open access **377**
Submitted 2025-11-07 | Accepted 2026-05-09 | Published 2026-11-17
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DOI 10.30687/979-12-5742-086-4/023

1 Introduction

This paper describes a linguistic training intervention administered to a 13-year-old Italian-speaking boy with Cornelia de Lange syndrome (CdLS) presenting with significant morphosyntactic impairments. This study investigates whether the intervention improves the production and comprehension of movement-derived structures, specifically relative clauses and *wh*-questions, and whether these effects generalize to untrained structures or persist after a three-months follow-up.

CdLS is a heterogeneous congenital condition characterized by distinctive facial features, growth delays, and intellectual disability, often accompanied by specific deficit in language development (Kline et al. 2007; 2019; Ajmone et al. 2013). Based on linguistic abilities, individuals with CdLS are categorized into four groups: *Talkers* exhibit language development within the typical range, though they reach milestones slightly later than their typically developing peers; *Late talkers* produce their first words at 30 months and first sentences at 6 years, but fail to reach typical syntactic proficiency; *Limited talkers* initiate language production around age 7 but never achieve adequate linguistic competence; *Guarded talkers* do not reach verbal expression beyond the isolated production of two or three words (Goodban 1993). Their linguistic output typically features short sentences (Mean Length of Utterances (MLU) under 10 words) and ungrammatical, atypical structures (Vizziello et al. 2010; Ajmone et al. 2014; Kline et al. 2019).

Regarding complex syntax, previous research has primarily analyzed *wh*-questions in English-speaking individuals, finding a tendency to produce ungrammatical *in-situ* interrogatives where the auxiliary is omitted (Goodban 1993). Similar impairments are observed in patients with aphasia (Thompson et al. 1998; 2003; Stadie et al. 2008), children and adolescents with Developmental language disorder (DLD, Levy, Friedmann 2009), and deaf children with cochlear implants (D'Ortenzio, Volpato 2020). These structures, along with relative clauses, involve syntactic movement from a base position to the sentence's beginning (Chomsky 1977; 1981). Such sentences exhibit a subject-object asymmetry (Utzeri 2007; Volpato, Adani 2009; Volpato 2012): subject-movement structures are easier to process, while object-movement structures suffer from intervention effects caused by the embedded subject (Rizzi 1990), particularly in clinical populations (Grillo 2008).

Extensive research indicates that focused training on syntactic rules, such as verb argument structure (Chomsky 1981), Theta criterion (Chomsky 1981), and syntactic movement (Chomsky 1977), can improve performance. This methodology has proven effective across diverse populations, including English-speaking children with

DLD (Ebbels 2014), English speaking adults with aphasia (Thompson, Shapiro 2005), Italian speaking deaf children with cochlear implants (D'Ortenzio 2023), L2 learners (Volpato, Bozzolan 2017; Volpato, De Nichilo 2020), and Italian-speaking individuals with dyslexia (Cardinaletti et al. 2022). This methodology was found to be effective also for supporting the teaching of grammatical rules in the school context (Lupo, Campanella 2024). Furthermore, training on relative clauses may induce generalization effects to *wh*-questions (Thompson, Shapiro 2005), as both structures are derived by the same movement, though the latter is easier to process. Stadie et al. (2008) found that also passive sentences can be improved following training on relative clauses, given their comparatively simpler syntactic structure.

These findings encouraged the development of a teaching tool called *Il mio GIGI – Gioco Interattivo di Grammatica Inclusiva* "Interactive Game for Inclusive Grammar" (Albiero 2020) which was previously used as complementary tool for teaching relative clauses in Primary School (Lupo, Campanella 2024). This tool was selected for this case study and it is described in section 2.3.

2 Materials and Methods

2.1 Participants

The participant is a 13;10-year-old Italian-speaking boy with a mild Cornelia de Lange Syndrome (CdLS) phenotype, classified as a *Late talker*. Since the age of 2, his linguistic development has been supported by Augmentative and Alternative Communication (AAC) combining graphic symbols and signs from the Italian Sign Language (LIS), alongside speech therapy until age 8; he acquired reading skills at age 7. His current production assessed with the tests described in section 2.2 is characterized by short sentences (MLU = 4), morphosyntactic agreement impairments, and frequent omission of function words. Cognitive assessment via WISC-IV (Wechsler Intelligence Scale for Children-IV Edition; Wechsler 2012) revealed a general IQ of 40, indicating moderate intellectual disability, and a moderate deficit in the area of communication (Verbal Comprehension Index: 52).

A control group of four typically developing Italian-speaking adolescents (age range 11;10-14;5; mean: 13;2) was included for comparison in the experimental tasks.

2.2 Assessment's Procedure

The participant was assessed with standardized and experimental tests. Experimental tests were administered before training (T0), immediately after (T1), and at a three-month follow-up (T2). Tests were administered by one of the authors (M.C.M.) during regular speech therapy sessions. Controls were assessed only once. Responses were audio-recorded and lately transcribed on Excel for later analysis.

Standardized tests were used to assess the participant's lexical production (Boston Naming Test; Kaplan et al. 2001)[1] and comprehension (Peabody Picture Vocabulary Test – PPVT; Dunn, Dunn 2000), as well as morphosyntactic comprehension (Test for Reception of Grammar – TROG-2; Bishop 2009).

Experimental tests evaluated the participant's production and comprehension of relative clauses (Volpato 2010; 2012; 2019) and the production of *wh*-questions (Guasti et al. 2012; 2015).

The production of subject relative (SR) and object relative (OR) clauses was assessed through a shortened version of the elicited production task developed by Volpato (2010; 2012; 2019). Each trial is supported by two pictures depicting different scenarios. Figure 1 and (1) illustrate an item to elicit an SR.

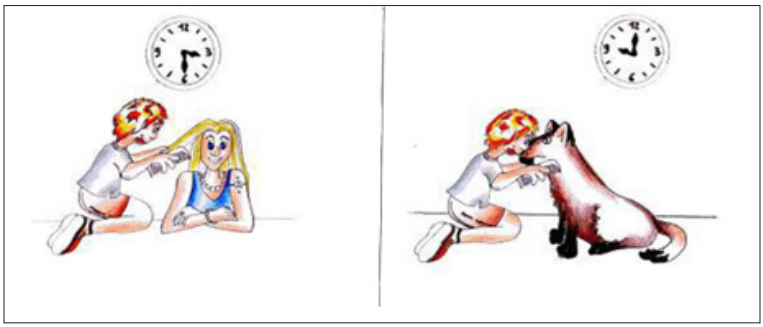


Figure 1 Item eliciting a SR

(1) Experimenter: "There are two pictures. In the first, the child combs the mother; in the second, the child combs the dog. Which child do you prefer? Start the sentence with "I like the child…"
Target: "I like the child that combs the mother/the dog".

1 The Boston Naming Test was selected for verbal production because other instruments commonly used with children, such as the *Batteria per la Valutazione del Linguaggio 4-12* (BVL 4-12; Marini et al. 2015), are specifically designed for children under 13 years of age.

Comprehension of relative clauses was assessed via a referent selection task (Volpato 2010; 2012; 2019). Each trial featured two pictures, each involving two types of referents (singular or plural), as shown by Figure 2. The participant was required to select the correct answer among four potential referents. Example (2) shows the assessment of the comprehension of an SR, while (3) shows the procedure for an OR.



Figure 2 item for the comprehension of a SR or an OR

(2) Experimenter: "Show me the bear that greets the turtles".
Correct answer: A

(3) Experimenter: "Show me the turtles that the bear greets".
Correct answer: B

Items consisted of semantically reversible sentences with present-tense verbs to avoid auxiliary-related confounding variables (Chesi 2006). Additionally, both tasks controlled for number features.

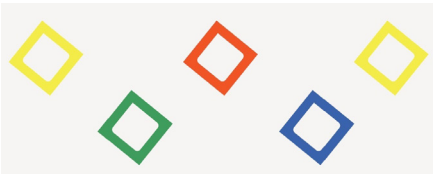
Subject and object questions introduced by *chi* 'who' or *quale*+NP 'which+NP' were assessed using an elicited production task presented via PowerPoint (Guasti et al. 2012; 2015). Depending on whether a subject or object question was being elicited, one of the characters involved in the action was covered by a geometric shape.

2.3 Training

The training consisted of ten 60-minute sessions over two and a half months, adapting the protocol by D'Ortenzio (2023). We utilized

Il mio GIGI – Gioco Interattivo di Grammatica Inclusiva (Albiero 2020), an educational tool that employs physical tiles to represent sentence constituents. This tool was developed based on the previous experiments involving Italian-speaking deaf or dyslexic children and adolescents (D'Ortenzio et al. 2020; Cardinaletti et al. 2022). The different types of tiles are described in Table 1.

Table 1 Description of the tile types used in the intervention

Tile type	Description	Example / Features
Name-tiles	Square tiles featuring the printed word and its corresponding picture	 Proper names or common nouns
Verb-tiles	Rectangular-shape	 3rd person verbs singular and plural
Function-tiles	Small tiles for grammatical markers	Complementizers (e.g., *che*), articles, and auxiliaries
Theta-frames	Color-coded frames representing Theta roles	 Agent (e.g., blue), Theme (e.g., red)
Trace-tile	Circular tiles marking the original position of a moved constituent	 Visual placeholder for the syntactic gap

The intervention followed three phases: (i) instruction on verb argument structure and Theta Criterion using AAC symbols for clarity; (ii) explicit teaching and practice of *wh*-movement in object relatives (ORs); and (iii) a final review. In phase (ii), the participant constructed simple sentences, joined them using the complementizer *che* 'that', and was guided to move the relevant argument while leaving a trace as shown by Figure 3.

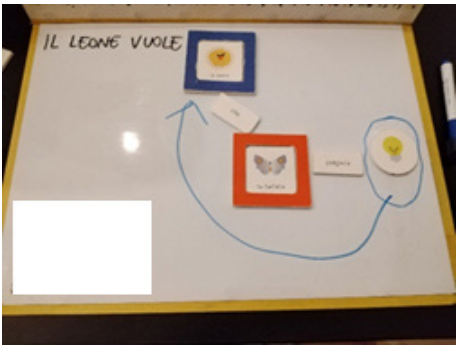


Figure 3 Explicit explanation of A' syntactic movement using Il mio GIGI

2.4 Statistical Analyses

To evaluate the training effects across the three assessment sessions (T0, T1, T2), we conducted a series of one-way repeated-measures ANOVAs with the assessment sessions as the within-subjects factors. Given the single-case nature of the study, we also considered the results of the Friedman's test for non-parametric comparison. Statistical analyses were performed using JASP (2024).

Following Levy and Friedmann (2009), we compared the participant's performance at each time point to the mean performance of the four control participants using the Crawford t-test (Crawford, Garthwaite 2007). This procedure is specifically designed to compare a single-case score against a small control sample. These analyses were conducted in RStudio (Version 2024.04.2; Posit Team 2024).

3 Results

Both the PPVT (Dunn, Dunn 2000) and the Boston Naming Test (Kaplan et al. 2001) show participant's impaired lexical abilities, since the participant scored less than -2 standard deviation.

Performance on the TROG-2 (Bishop 2009) placed his morphosyntactic comprehension within the clinical range (1st percentile). Error analysis

indicated persistent difficulties with reversible constructions (e.g., in/on reversals, subject–verb reversals, reversible passives). Items containing a postponed main clause were consistently misinterpreted as object relative clauses. In some cases, responses suggested a strategy of attributing modifiers to the nearest noun, resulting in a canonical SVO interpretation of the stimulus sentences.

As for the experimental tasks, the participant shows a measurable improvement immediately following the intervention. Table 3 shows the participant's longitudinal scores compared to the control group.

Table 3 Data showing means and standard deviations of the participant's assessment at T0, T1, and T2. SR: subject relatives, OR: object relatives with preverbal subject; S-wh: subject wh questions; O-wh: object wh questions

	CdLS T0 M(SD)	CdLS T1 M(SD)	CdLS T2 M(SD)	Control participants M(SD)
SR production	0.17 (0.41)	0.83 (0.41)	0.17 (0.41)	0.92 (0.28)
OR production	0.17 (0.41)	0.17 (0.41)	0.17 (0.41)	0.08 (0.41)
SR comprehension	0.92 (0.29)	0.92 (0.29)	0.58 (0.51)	0.96 (0.20)
OR comprehension	0.22 (0.42)	0.45 (0.50)	0.25 (0.44)	0.97 (0.18)
S-*wh* production	0.50 (0.52)	0.75 (0.45)	0.92 (0.29)	0.98 (0.14)
O-*wh* production	0.50 (0.52)	0.67 (0.49)	0.50 (0.52)	0.98 (0.14)

Considering the participant's whole performance, the Friedman test showed a significant effect ($X^2_F[2] = 10.792$, $p < .005$, Kendall's $W = .057$) with a quadratic trend ($p < .002$) as shown by Figure 4

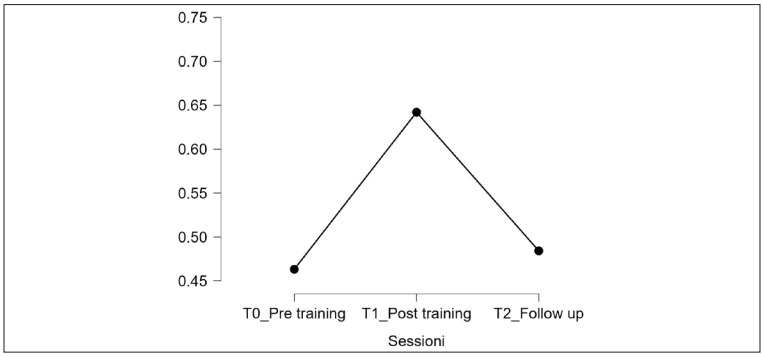


Figure 4 Participant's total number of correct answers given during the three tests across the three sessions

A Bayesian test for single-case assessment (Crawford, Garthwaite 2007) was used to compare the participant's performance at T0 to that of the control participants. The participant's score (Raw =

44.00, Z = -58.79, percentile = 0.00) was significantly lower than that of the control sample (M = 92.00, SD = 0.82; p_p =.001). The analysis indicated that the participant scored below 100% of the control population (95% CI [0.00, 0.00]). The same test was used also to compare the participant's performance at T1 to that of the control participants. The participant's score (Raw = 61.00, Z = -37.97, percentile = $1.01 * 10^{-313}$) was significantly lower than that of the control sample (M = 92.00, SD = 0.82; p_p =.001). The analysis indicated that the participant scored below 100% of the control population (95% CI [0.00, 0.00]). Finally, the same analysis was performed also at T2. The participant's score (Raw = 46.00, Z = -56.34, percentile = 0.00) was significantly lower than that of the control sample (M = 92.00, SD = 0.82; p_p =.001). The analysis indicated that the participant scored below 100.00% of the control population (95% CI [0.00, 0.00]).

4 Discussion

This study investigated language variation in a 13-year-old Italian-speaking boy with Cornelia de Lange syndrome (CdLS) following explicit syntactic training targeting object relative clauses (ORs). We hypothesized generalization to subject relatives (SRs) and *wh*-questions, with maintenance at three-month follow-up. These predictions were only partially confirmed.

Regarding the production of relative clauses, the participant exhibited significant impairment in both SRs and ORs at baseline (T0), frequently producing ungrammatical sentences lacking the complementizer *che* 'that' or sentences with altered semantic meaning. At T1, SR production improved, whereas ORs remained problematic, often replaced by structures with inverted thematic roles. These gains were not sustained at T2, as performance returned to baseline levels. Notably, unlike typically developing peers who avoid ORs by producing passive alternatives, reflecting age-appropriate linguistic ability (Belletti 2014), the participant relied on ungrammatical structures.

In comprehension, SRs were better preserved than ORs. Errors with ORs comprehension involved either inversion of the relative head or reversal of thematic roles, suggesting profound difficulty in processing marked word order. While comprehension improved immediately post-training, the effects vanished at follow-up, where accuracy fell significantly below that of controls.

In the production of *wh*-questions, the participant initially performed better on subject-*who* questions (0.83) than on other structures analyzed (subject-*which*: 0.17; object-*who*: 0.50; object-*which*: 0.50). By T1, performance remained stable for subject- and

object-*who* questions, but improved for both subject-*which* (0.67) and object-*which* (0.83) questions. Interestingly, at T2, a further improvement was observed in subject-*who* (1.00) and -*which* questions (0.83), while object *wh*-questions declined. Despite this improvement, the participant's performance remained significantly lower than that of the control participants. The continued improvement in subject *wh*-questions during the follow-up may be interpreted as a generalization effect of the OR-based training. As noted by Thompson and Shapiro (1995; 2005) and Stadie et al. (2008) it is possible to achieve generalization on structures that are syntactically less complex than the training targets.

The participant showed higher accuracy in the production of subject *who*-questions than subject *which*-questions consistent with previous research (Guasti et al. 2012; 2015; Belletti, Guasti 2015), attributing this to the greater complexity of the *which*+NP element. Specifically, *which*-questions involve the movement of a *wh*-element with pied-piping of the nominal restriction and require complex agreement relations (Belletti, Guasti 2015).

Interestingly, the participant performed better on object *which*-questions. In light of previous research on children with intellectual disabilities (Koizumi et al. 2019), this result may be explained by the structure of the experimental stimuli: each referent was introduced on a separate slide, which may have facilitated the participant's comprehension of the visual context and, consequently, the interpretation of the target sentence.

The observed subject-object asymmetry across all tasks, with better performance on subject-derived sentences, aligns with the intervention effects framework (Rizzi 1990). In Italian, subject-derived sentences preserve the canonical SVO word order, facilitating processing (Volpato, Vernice 2014). Conversely, object-movement structures suffer from the intervention of the embedded subject (Utzeri 2007; Volpato, Adani 2009; Volpato 2012).

The lack of long-term maintenance for relative clauses may be attributed to the limited duration of the training. While ten sessions were sufficient for populations in previous studies, this participant's significant lexical and morphosyntactic deficits, evident in his initial struggles with verb argument structure, suggest that a more intensive and prolonged application of the GIGI tool is necessary. Given that individuals with CdLS often require extensive repetition, a longer training period might better consolidate these grammatical rules.

Despite these limitations, our findings are promising. This study fills a critical gap in the literature, as, to our knowledge, no previous research has provided such an in-depth investigation of morphosyntactic abilities in Italian-speaking individuals with CdLS.

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