

PhD Thesis Research Plan

**Multimodality as a tool for
boosting narrative and pragmatic abilities
in typical and non-typical language development**

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A handwritten signature in black ink, reading 'Júlia Florit'. The signature is written in a cursive style with a large, sweeping initial 'J'.

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ABSTRACT

Human communication is multimodal by nature, such that we do not only communicate through speech, but also through the use of prosody in speech and through body signals, including gesture, facial expressions and body movements, two pragmatics-related components. While there is evidence that hand and body movements can benefit children's structural language and cognitive abilities in typically developing (TD) children (see Hostetter, 2011; Hübscher & Prieto, 2019; Vilà-Giménez & Prieto, 2021, for reviews), less is known about multimodality and its interaction with other skills across development in non-TD children.

The current thesis aims to examine the effects of multimodality on preschool children's narrative and pragmatic abilities in both typical and non-typical development. Interestingly, children with Autism Spectrum Disorder (ASD) and with Developmental Language Disorder (DLD), albeit having differentiating diagnoses, present an area that might be of overlap, which concerns socio-communicative, narrative and pragmatic deficits. Both disorders face challenges with social relationships, intention understanding, perspective-taking and narrative abilities (see Fujiki & Brinton, 2017, for a review). Given the evidence about the positive effects of multimodality on children's language development, we hypothesize that the use of multimodal language that integrates prosodic and gestural cues will boost not only pragmatic development in TD, ASD and DLD children, but their oral narrative skills. To test this hypothesis, the present PhD thesis will include four empirical studies.

The first study will consist of a meta-analytic review which will analyze the results of previous studies on the relationship between multimodal language and linguistic abilities in ASD and DLD populations. The second study will be a correlational study that will investigate the relationship between multimodal abilities and narrative and pragmatic abilities in TD and non-TD (ASD and DLD) preschool children. Studies 3 and 4 will assess the effectiveness of a multi-tiered (i.e., with different levels of support) and naturalistic narrative-based intervention that will use multimodality to boost preschoolers' narrative and pragmatic abilities. The intervention will be designed to train narrative macrostructure (i.e., structure of the narrative in terms of story grammar elements) with a special focus on narrative perspective-taking (i.e., the ability to understand other characters' perspectives). The intervention will make use of multimodal language (body movements, hand gestures, facial expressions, prosodic cues) both by the interventionist and by the children themselves. Both Studies 3 and 4 will have a between-subjects design with pre- and post-intervention, and delayed post-intervention measures. The multimodal effects of the intervention will be tested with different multimodal and non-multimodal groups in the two studies. Importantly, participants in the multimodal condition will not only see the interventionist make use of multimodal language but also, they will be encouraged to use these multimodal cues when interacting with the interventionist and/or their classmates. Given that the intervention will be multi-tiered, Study 3 will test the effectiveness of this

multimodal treatment for children with ASD and DLD through an individualized and intensive delivery with a speech-language therapist, while Study 4 will explore the benefits of the treatment on TD, ASD and DLD populations in a preschool classroom context.

Overall, this PhD thesis will have practical implications for both preschool teachers and speech-language pathologists, which include a) theoretical and empirical advances about the role that multimodal learning plays in preschool children's language development; b) a broader knowledge about the narrative and pragmatic difficulties that ASD and DLD children face; and c) an improvement in multi-tiered and naturalistic narrative-based interventions focusing on perspective-taking in preschool education which can be implemented in both group and individual environments.

RESUM

La comunicació humana és multimodal per naturalesa, ja que no només ens comuniquem de manera oral, però també mitjançant la prosòdia i el nostre cos, el qual inclou els gestos, les expressions facials i els moviments corporals, dos components que estan relacionats pragmàticament. Mentre que tenim evidències dels beneficis que poden tenir els moviments del cos i de les mans en les habilitats lingüístiques i cognitives dels nens amb desenvolupament típic (vegeu Hostetter, 2011; Hübscher & Prieto, 2019; Vilà-Giménez & Prieto, 2021, per revisions), ens manca coneixement sobre com interactuen la multimodalitat i altres habilitats durant el desenvolupament dels nens amb desenvolupament atípic.

Aquesta tesi té per objectiu examinar els efectes de la multimodalitat en les habilitats narratives i pragmàtiques d'infants d'edat preescolar, tant en el desenvolupament típic com atípic. De fet, els nens amb Trastorn de l'Espectre Autista (TEA) i els nens amb Trastorn del Desenvolupament del Llenguatge (TDL), tot i tenir diagnòstics diferents, presenten una àrea que pot ser de solapament, la qual fa referència a dèficits sociocomunicatius, narratius i pragmàtics. Aquestes dificultats en aquestes patologies suposen un repte per a les relacions socials, les habilitats d'entendre les intencions, de saber-se posar en el lloc d'un altre i per a les habilitats narratives (vegeu Fujiki & Brinton, 2017, per a una revisió). Donades les evidències dels efectes positius de la multimodalitat en el desenvolupament del llenguatge, plantegem la hipòtesi que l'ús del llenguatge multimodal que integra el gest i la prosòdia ajudarà no només en el desenvolupament de les habilitats pragmàtiques, sinó també narratives en nens de desenvolupament típic i en nens amb TEA i TDL. Per tal de verificar aquesta hipòtesi, aquesta tesi doctoral inclourà quatre estudis empírics.

El primer estudi consistirà en una revisió meta-analítica amb la qual analitzarem els resultats dels estudis anteriors sobre la relació entre el llenguatge multimodal i les habilitats lingüístiques de la població amb TEA i TDL. L'Estudi 2 serà un estudi correlacional, amb el qual investigarem la relació entre les habilitats multimodals i les habilitats narratives i pragmàtiques en nens d'edat preescolar de desenvolupament típic i atípic (TEA i TDL). Els Estudis 3 i 4 avaluaran l'efectivitat d'una intervenció multinivell (amb diversos nivells de suport) i naturalista amb base narrativa que farà ús de la multimodalitat per impulsar les habilitats narratives i pragmàtiques dels nens d'educació infantil. La intervenció es dissenyarà per entrenar la macroestructura (l'estructura de la narració d'acord amb els elements de la història), però es focalitzarà especialment a entrenar les habilitats de posar-se al lloc d'un altre. La intervenció integrarà el llenguatge multimodal (moviments del cos, gestos manuals, expressions facials i prosòdia) tant per part de l'intervencionista com per part dels nens mateixos. Els Estudis 3 i 4 tindran un disseny inter-subjectes amb mesures de pre- i post-intervenció i mesures d'avaluació post-intervenció posterior. Els efectes multimodals es testejaran mitjançant grups multimodals i no-multimodals en els dos estudis. De fet, els participants que estiguin en el grup multimodal no només veuran l'intervencionista fer ús del llenguatge multimodal, sinó que també se'ls motivarà a utilitzar la multimodalitat quan interactuïn

amb l'intervencionista i/o amb els seus companys. Com que la intervenció serà multinivell, l'Estudi 3 examinarà l'efectivitat del tractament multimodal en nens amb TEA i TDL mitjançant una intervenció intensiva i individualitzada amb un logopeda, mentre que l'Estudi 4 explorarà els beneficis del tractament tant en la població típica com la població amb TEA i TDL en un context de classe d'educació infantil.

Així doncs, aquesta tesi doctoral tindrà implicacions pràctiques tant per a mestres d'educació infantil com per a logopedes, les quals inclouen a) avenços teòrics i empírics sobre el rol que juga la multimodalitat en el desenvolupament lingüístic dels nens, b) un coneixement més ampli sobre les dificultats narratives i pragmàtiques que presenten els nens amb TEA i TDL, i c) una millora en les intervencions multinivell i naturalistes que es poden implementar fàcilment tant en classes d'educació infantil com en el context logopèdic.

RESUMEN

La comunicación humana es multimodal por naturaleza, dado que no solo nos comunicamos de manera oral, sino también mediante la prosodia y nuestro cuerpo, incluyendo los gestos, las expresiones faciales y los movimientos corporales, dos componentes que están relacionados pragmáticamente. Pese a tener evidencias de los beneficios que puede tener el lenguaje multimodal en las habilidades lingüísticas y cognitivas de los niños con desarrollo típico (véase Hostetter, 2011; Hübscher & Prieto, 2019; Vilà-Giménez & Prieto, 2021, para revisiones), todavía nos falta conocimiento sobre cómo interactúan la multimodalidad y otras habilidades durante el desarrollo de los niños con desarrollo atípico.

Esta tesis tiene por objetivo examinar los efectos de la multimodalidad en las habilidades narrativas y pragmáticas de niños de edad preescolar, tanto en el desarrollo típico como atípico. De hecho, los niños con Trastorno del Espectro Autista (TEA) y los niños con Trastorno del Desarrollo del Lenguaje (TDL), incluso teniendo diagnósticos distintos, presentan un área que puede ser de solapamiento, la cual hace referencia a déficits socio-comunicativos, narrativos y pragmáticos. Estas dificultades suponen un reto para las relaciones sociales, las habilidades para entender las intenciones y para saber ponerse en el lugar de otro, y las habilidades narrativas (véase Fujiki & Brinton, 2017, para una revisión). Dadas las evidencias de los efectos positivos de la multimodalidad en el desarrollo del lenguaje, planteamos la hipótesis de que el uso del lenguaje multimodal integrando gesto y prosodia no solo ayudará en el desarrollo de las habilidades pragmáticas, sino también narrativas en niños con TEA i TDL. Para poder verificar esta hipótesis, esta tesis doctoral incluirá cuatro estudios empíricos.

El primer estudio consistirá en una revisión meta-analítica con la cual analizaremos los resultados de los estudios anteriores sobre la relación entre el lenguaje multimodal y las habilidades lingüísticas de la población con TEA y TDL. El segundo estudio será un estudio correlacional, con el cual investigaremos la relación entre las habilidades multimodales y las habilidades narrativas y pragmáticas en niños de edad preescolar de desarrollo típico y atípico (TEA y TDL). Los estudios 3 y 4 evaluarán la efectividad de una intervención multi-nivel (con distintos niveles de apoyo) y naturalista con base narrativa que usará la multimodalidad para impulsar las habilidades narrativas y pragmáticas de niños de edad preescolar. La intervención se diseñará para entrenar la macroestructura (la estructura de la narrativa en cuanto a los elementos de la historia), pero se focalizará especialmente en entrenar las habilidades de ponerse en el lugar del otro. La intervención integrará el lenguaje multimodal (movimientos del cuerpo, gestos manuales, expresiones faciales y prosodia) tanto por parte del intervencionista como por parte de los mismos niños. Los Estudios 3 y 4 tendrán un diseño inter-sujetos con medidas pre- y post-intervención y con medidas de evaluación post-intervención posterior. Los efectos multimodales se comprobarán con grupos multimodales y no multimodales en los dos estudios. De hecho, los participantes que reciban la intervención multimodal no solo verán al intervencionista utilizando el lenguaje multimodal, pero también

se los habrá motivado para que utilicen la multimodalidad mientras interactúen con el intervencionista y/o sus compañeros. Dado que la intervención será multi-nivel, el Estudio 3 evaluará la efectividad de este tratamiento en niños con TEA y TDL mediante una intervención individualizada e intensiva con un logopeda, mientras que el Estudio 4 explorará los beneficios de la intervención multimodal tanto en la población típica como en la población con TEA y TDL en un contexto de clase de educación infantil.

Así pues, esta tesis doctoral tendrá implicaciones prácticas tanto para maestros de educación infantil como para logopedas, las cuales incluyen a) avances teóricos y empíricos sobre el rol que juega la multimodalidad en el desarrollo lingüístico de los niños, b) un conocimiento más amplio sobre las dificultades narrativas y pragmáticas que afrontan los niños con TEA y TDL, y c) una mejora en las intervenciones multi-nivel y naturalistas que se pueden implementar fácilmente en clases de educación infantil y en el contexto logopédico.

1. INTRODUCTION

1.1. Object of analysis

Human communication is unique compared to other communication systems, as it is multimodal by nature. When we talk, we do not merely make use of our voice to express meaning, but also make use of our whole body. Therefore, we communicate dynamically integrating our speech —and specifically through the prosodic cues we use in our speech—, and our body signals —our hands, our facial expressions and our torso movements. For this reason, in this PhD thesis, we will expand Kendon’s (1980) definition of gesture and understand that all these communicative movements are “part of the speaker’s total expression” (Kendon, 1980, p. 207). Moreover, it is important to bear in mind that the thesis has a holistic view of multimodality, understood as a conjoint system that integrates gesture and prosodic patterns (see Hübscher & Prieto, 2019, for a review).

The present thesis focuses on how we can support preschool children’s oral narrative and pragmatic skills. It is well-known that strong narrative and pragmatic skills in the preschool years are crucial to further develop children’s later socio-communicative, linguistic and academic performance (e.g., Dickinson & McCabe, 2001). Specifically, children’s early milestones in narrative and pragmatic development have been found to be linked to the understanding and production of multimodal communication (see Goldin-Meadow, 2014; Prieto & Esteve-Gibert, 2018, for reviews).

While the link between multimodal communication and language development is well-established in typically developing (TD) children, less is known about this relationship in non-TD children. Importantly, the use of multimodal language in the preschool and school stages of acquisition has been shown to help improve TD children’s narrative and pragmatic abilities (see Hostetter, 2011; Vilà-Giménez & Prieto, 2021, for reviews). Given the importance of multimodal language in human communication and that its benefits have been proven on TD children, the present PhD thesis aims to show that multimodality can benefit both TD and non-TD children’s narrative and pragmatic development. Children with Autism Spectrum Disorder (ASD) and Developmental Language Disorder (DLD)¹ face challenges with the pragmatic area of language (e.g., the ability to appropriately use language in the communicative context, Andrés-Roqueta & Katsos, 2017) that interfere with their abilities to communicate with others. Even though some experimental interventions involving multimodal language have been designed to improve specific narrative and pragmatic areas (Corbett et al., 2017; Nicolopoulou et al., 2015; So et al., 2019, 2020a,b; see subsection 1.2.5 below), they have not fully considered the role of multimodality in more naturalistic educational environments. This PhD thesis will implement a multimodal training in which the

¹ Developmental Language Disorder has received different terms over the years, such as Specific Language Impairment (SLI), language impairment or language delay, among others. However, a group of researchers and clinicians arrived at a consensus to use the term DLD (Bishop et al., 2016, 2017; see also Andreu et al., 2021). This term, thus, will be used throughout this PhD Research Plan.

main idea is that the intervention will allow children to improve on their oral narrative and pragmatic skills. Specifically, they will learn about narrative macrostructure elements (e.g., structure of the narrative in terms of story grammar elements: characters, setting, attempt, goal), and about the perspective of the characters in the story, favoring perspective-taking abilities (e.g., being able to understand and retell a story from the perspectives of different characters) using multimodal language. Using multimodal language means that there is an active embodiment of the speaker by using gestural, prosodic, facial and bodily signals.

All in all, the goal of this PhD thesis is to explore the potential boosting role of multimodal language on TD and non-TD children's narrative and pragmatic development. The present thesis will be composed of four different experimental studies. These studies will explore a) the relationship between multimodality and linguistic abilities in ASD and DLD populations in previous research (Study 1); b) whether there is a correlation between multimodal abilities and narrative and pragmatic abilities in TD and non-TD populations (Study 2); c) whether multimodal language can be used in an individual intervention to improve ASD and DLD children's narrative and pragmatic skills (Study 3); and d) whether a multimodal group intervention can benefit not only ASD and DLD children's, but also TD children's narrative and pragmatic abilities (Study 4).

1.2. Literature review

1.2.1. Narrative and pragmatic abilities in development

Oral narrative skills and pragmatic skills have been argued to be tightly linked to children's linguistic, social and academic abilities. On the one hand, oral narrative abilities have been argued to serve as a valid and ecological measure to assess children's language development (e.g., Demir & Küntay, 2014; Duinmeijer et al., 2012; Stites & Özçalışkan, 2017). On the other hand, they have also been shown to have a long-term impact on children's reading abilities and academic performance, specifically in the preschool years, when these abilities act as predictors of later linguistic performance (e.g., Demir et al., 2014; Dickinson & McCabe, 2001; Griffin et al., 2004).

Given the complexity of narrative discourse —as linguistic, cognitive and social skills are involved—, the ability to narrate a story develops step by step during childhood ranging from basic retellings at the age of 3 with core macrostructure elements to the production of more complex narratives (e.g., macrostructure, microstructure, evaluative content) at the age of 9 (Berman & Slobin, 1994). Regarding narrative abilities in non-TD children, ASD and DLD children experience difficulties in its development. While autistic children tend to produce less coherent narratives and are more likely to introduce ambiguous referents and information that is not relevant for the story (Loveland & Tunali, 1993), children with DLD produce narratives that are poorer syntactically and that lack cohesion (Duinmeijer et al., 2012; Liles et al., 1995). Also, both populations tend to produce syntactic errors and show difficulties

identifying the macrostructure elements and organizing the narrative in a coherent and cohesive way (see e.g., Norbury & Bishop, 2003).

On the other hand, pragmatic development in the first years of life starts with children's use of verbal and non-verbal communicative intents, by making demands or asking questions, showing that they are learning about conversation (see Adamson & Dimitrova, 2014, Stephens & Mathews, 2014, for reviews). Existing research has documented that pragmatic abilities develop gradually between the first year of life and school-age years and adolescence (see Matthews, 2014, for an extensive review). At around the age of 9 months, children are already able to develop joint attention skills (e.g., eye gaze, pointing) while producing the first verbal vocalizations, and start understanding the intentions of other people (see Stephens & Matthews, 2014, for a review). Later on, over the school-age years, children start becoming pragmatically competent in terms of conversation, irony comprehension and narrative speech, which are also related to different abilities, such as core language (e.g., preliteracy skills, expressive and receptive language), Theory of Mind (ToM) abilities (i.e., the ability to attribute mental states to other people, Premack & Woodruff, 1978), emotion understanding and executive functions (e.g., working memory, inhibition) (see Matthews et al., 2018, for a review).

Non-typically developing children —specifically ASD and DLD children— show pragmatic difficulties that involve socio-communicative dimensions, such as empathy, irony understanding, intention understanding, perspective-taking, joint skills, and turn-taking in conversation (see Fujiki & Brinton, 2017, for a review). Importantly, autistic children tend to show greater difficulties with pragmatic tasks (which has been suggested to be related to ToM deficits, Baron-Cohen, 1995, 2000), while DLD children have been claimed to face difficulties with the linguistic part of pragmatics (e.g., requiring mainly structural language and pragmatic competence, as opposed to social pragmatics, which include ToM abilities apart from structural language and pragmatic competence²; Andrés-Roqueta & Katsos, 2020). An impaired use of pragmatic language has been documented to have a long-term impact in adulthood, regarding social relationships formation, employability and behavioral and emotional problems (e.g., Eaves & Ho, 2008; Lewis et al., 2008; St Claire et al., 2011; Whitehouse et al., 2009). Another key area in children's linguistic and cognitive development is the development of multimodal language as we will see in the following subsection.

1.2.2. Multimodality in development

When humans talk, they accompany their speech with visual information conveyed through multimodality, such as co-speech gestures, facial expressions and body movements. Interestingly, these movements we produce when talking are temporally and semantically aligned with our speech (see McNeill's (1992)

² We follow the CATALISE conceptualization (Bishop et al., 2016, 2017), in which different language components (phonology, lexis, semantics, pragmatics, syntax) are evaluated.

Phonological Synchrony Rule and Semantic-Pragmatic Synchrony Rule). In fact, this synchronization between speech and gesture develops smoothly in TD children, starting with the production of pointing gestures associated with first vocalizations before the first anniversary (e.g., Esteve-Gibert & Prieto, 2014), which have been shown to predict later lexical and grammatical development at 18 months (Igalada et al., 2015). At the ages of 2-3, iconic and non-referential gestures appear during spontaneous interactions (Özçalışkan & Goldin-Meadow, 2011; Nicoladis et al., 1999). These iconic (i.e., gestures that visually represent the semantic content in speech, McNeill, 1992) and non-referential gestures (i.e., gestures which do not visually represent any semantic content in speech, but rather highlight rhythmic, discursive and pragmatic elements in speech, Prieto et al., 2018) also appear when more complex discourses develop (e.g., narrative discourse), at the age of 4 to 5 (e.g., Colletta et al., 2010, 2015), with a significant increase of non-referential gesture use from the age of 5-6 to 7-9 (Florit-Pons et al., 2020). Importantly, these results have highlighted the importance of multimodal development, showing that co-speech gesture and language develop in parallel.

Importantly, multimodal developmental paths seem to be impaired in ASD and DLD children. One of the alerts for Autism Spectrum Disorder is a delayed use and comprehension of gesture and non-verbal communication. Specifically, between the ages of 18 to 24 months, children who are at high risk (HR) of language delay —because of having a sibling with ASD— already seem to produce fewer pointing and conventional gestures than non-risk TD children (e.g., Mastrogiuseppe et al., 2015; Sansavini et al., 2019; see LeBarton & Iverson, 2016; Mishra et al., 2020; and Ye et al., 2021, for similar results with 2- to 3-year-olds). These low rates of gesture production have also been documented to continue to develop in the school-age years and into adolescence, both in spontaneous speech (e.g., Braddock et al., 2016; So et al., 2015) and in more complex discourses, such as narrative discourse (e.g., de Marchena & Eigsti, 2014). Interestingly, some of these studies have provided evidence that the context is key when assessing ASD children's co-speech gesture production. De Marchena and Eigsti (2014) compared ASD adolescents' gesture use in narrative context and in an executive function task (the inhibition task from NEPSY-II), and showed that in narrative speech —in which gesture serves as a socio-communicative tool to engage the listener and to organize the discourse— adolescents with ASD produced fewer gestures than TDs, but that in the executive function task —in which gesture serves as a cognitive tool— the participants with ASD produced as much or even more gestures than their neurotypical peers. This thus shows that when in a context involving high communicative demands (e.g., narrative discourse), gesture use is impaired, as it is linked to socio-communicative impairments, while when the context is less communicative, fewer difficulties appear.

Autistic children's difficulties with multimodal language also extend to the comprehension of non-verbal and multimodal communication. Specifically, they tend to better comprehend iconic gestures as opposed to conventional gestures, given the fact that iconics visually depict some properties of the actual

object or action, while conventional gestures tend to be more abstract and less concrete (Dimitrova et al., 2017; Huang et al., 2020; Perrault et al., 2019). Also, the ASD population shows difficulties recognizing other people's facial expressions (e.g., Keating & Cook, 2020; see Black et al., 2017 and Harms et al., 2010, for reviews). Therefore, these results suggest that ASD children usually face challenges with both the production and comprehension of multimodal language (see Ramos-Cabo et al., 2020, for a review).

Even though fewer studies have been devoted to analyzing the multimodal development of DLD children, their challenges in the production of gestures have also been reported. For example, during the first two years of life, children with (or at risk of) language delay produced fewer and less defined pointing gestures than their TD peers (Lüke et al., 2017a; Lüke et al., 2017b). A bit later in development, the production of iconic gestures seems to increase in DLD children, and might even outnumber TD children's gesture rates (Lavelli et al., 2015; Mainela-Arnold et al., 2014), indicating that children with DLD tend to use gestures as a compensatory tool to express the meanings that they have difficulties expressing in speech. However, recent research has pointed out that there are no differences between neurotypical and DLD children in terms of the number of gestures produced but in the accuracy of these gestures in the context of gesture imitation and gesture elicitation (Wray et al., 2017). These results have extended the results by previous investigations assessing merely gesture use and have highlighted the importance of assessing gesture accuracy as well, and have been also confirmed with TD children, such that gesture frequency in preschool children is negatively correlated with narrative abilities (Grofulovic, 2019).

Prosody constitutes an essential part of multimodal language and is sometimes impaired in ASD and DLD populations (see Loveall et al., 2021; Peppé, 2018, for reviews). Prosodic impairment in autistic children involves an exaggerated use of pitch ranges and syllable length (e.g., Diehl & Paul, 2013; Filipe et al., 2014) as well as difficulties expressing and understanding emotions prosodically (e.g., Loveall et al., 2021; McCann & Peppé, 2003). Also, DLD children seem to face challenges in speech segmentation due to their atypical speech rhythm (e.g., Holliman et al., 2010). Despite these difficulties, DLD children are able to understand emotions from prosodic cues (e.g., Van der Meulen et al., 1997) and their prosodic patterns of cues such as syllable length and pitch range are similar to those of TD children (e.g., Snow, 2001).

The previous subsections have shown that narrative and pragmatic development and multimodal language are tightly intertwined and that thus develop in parallel in TD populations, less is known about this relation in non-TD children.

All in all, given the importance of studying multimodality as a key part of human communication (see e.g., Perniss, 2018), in the last decades, research has been devoted to analyzing how multimodal language (and specifically co-speech gesture) relates to children's linguistic and cognitive development, for TD and —to a lesser extent— for non-TD populations. However, less is known about the relationship between multimodal language and non-TD language development. To assess previous results on this area

comprehensively, the first study of the current PhD thesis will systematically review the relation between multimodal language and children's linguistic and cognitive development in non-TD populations, such as ASD and DLD (see section 3.1 below). This relation will also be investigated in the other studies of the thesis.

1.2.3. Benefits of multimodality on the development of structural language

1.2.3.1. Typically developing children

Recent research has shown that co-speech gesture plays a key role in typically developing children's linguistic and cognitive development. On the one hand, observing and producing referential gestures has been documented to benefit children's language development (see Colonna et al., 2010; Hostetter, 2011, for reviews). Specifically, several studies have found that observing referential gestures can benefit language learning and processing in terms of information recall (e.g., Kelly et al., 1999; So et al., 2012), word mapping (e.g., Mumford & Kita, 2014), comprehension of oral communication (e.g., Cocks et al., 2011; McNeil et al., 2000), and comprehension of complex syntax (e.g., Theakston et al., 2014). Producing referential gestures while taking part in different tasks can also have positive effects on children's linguistic and executive development, such as in memory recall (Cameron & Xu, 2011), and in resolving lexical and verbal ambiguities (e.g., Kidd & Holler, 2009). Other investigations have also been conducted to assess the role of non-referential gestures and have shown that observing non-referential gestures helped information recall and comprehension (Austin & Sweller, 2014; Igualada et al., 2017; Llanes-Coromina et al., 2018, see Vilà-Giménez & Prieto, 2021, for a recent review).

Concerning the prosodic part of multimodality, children are sensitive to prosodic patterns from the very beginning, and prosody helps word segmentation and word mapping (see Prieto & Esteve-Gibert, 2018, for a review, and the *prosodic bootstrapping hypothesis* by Gleitman & Wanner, 1982). Interestingly, investigations have shed light on the bootstrapping mechanism of prosody on syntax (see e.g., de Carvalho et al., 2018, for a review). Nevertheless, there is a lack of studies that analyze gesture and prosody as a conjoint multimodal system (see e.g., Hübscher & Prieto, 2019; Igualada et al., 2015).

1.2.3.2. Non-typically developing children

Even though not so extensively, research has also studied the role of multimodality on structural language development in ASD and DLD populations and has shown that children's early gesture production can predict later linguistic skills. For instance, Özçalışkan and colleagues (2016) documented that 18- and 30-month-old ASD infants' pointing gestures predicted their expressive vocabulary one year later, and that the referents they introduced through gesture at 18 and 30 months, were later introduced with speech (see also Özçalışkan et al., 2017). These results were also confirmed for older children (3- to 8-year-olds) by

Ökcün-Akçamuş et al. (2017). Also, Manwaring et al. (2017) pointed out that gesture use (both from parents' reports and from direct observation) were correlated with ASD children's expressive and receptive language at 12 to 48 months of age (see Manwaring et al., 2019, for similar results), and that the iconic and conventional gestures at this age predicted later receptive language 8 to 16 months later.

Fewer studies have analyzed the role of multimodal language in DLD children's language development. In a recent investigation, Lüke et al. (2020) have shown that the use of pointing gestures of both TD and DLD infants at the age of 12 months predicted productive and receptive language at the ages of 5 and 6, even though DLD infants showed lower linguistic skills. Also, Lüke and Ritterfeld (2014) reported that iconic gestures scaffolded the mapping of novel words in preschool DLD children. Importantly, a study by Wray et al. (2016) showed that 4- to 8-year-old DLD children had difficulties comprehending the semantic meaning of gesture when the referent was not produced orally at the same time, as opposed to TD age-matched peers who were able to understand the meaning of the gesture. These findings suggested that DLD children are more likely to understand gestures that are redundant (speech and gesture representations are the same), than extending gestures, which do not match gestural and speech meanings.

Research on atypical prosodic development (see Loveall et al., 2021; Peppé, 2018, for reviews) has shown that using melodic patterns (i.e., melodic therapy) can help autistic children improve their vocabulary and imitation skills (e.g., Sandiford et al., 2013), and that using interventions which train speech imitation (as well as gesture) can improve ASD children's language use (e.g., Ingersoll, 2008). Although the research on the link between prosody and language in DLD is scarce, a study by Corriveau and colleagues (2007) showed that DLD children had difficulties with auditory processing (e.g., amplitude rise time, duration), and that these deficits were linked to children's linguistic and phonological development in terms of word segmentation and impaired phonological representations.

1.2.4. The relationship between multimodality and narrative and pragmatic abilities in children

1.2.4.1. Typically developing children

Recent research in the field of gesture studies has emphasized the positive effects of using co-speech gesture on children's developing narrative skills. Specifically, both referential and non-referential gestures have been documented to serve as precursors (Stites & Özçalışkan, 2017) and predictors (Demir et al., 2015; Vilà-Giménez et al., 2020b; Vilà-Giménez et al., in press) of better narrative skills in later stages of children's language development. Moreover, other studies have shown that observing these gestures being produced can benefit narrative comprehension (e.g., Dargue & Sweller, 2020; Llanes-Coromina et al., 2018; Macoun & Sweller, 2016). Training studies have also shown that observing and encouraging them

to produce non-referential gestures can also help improve children's narrative abilities (Vilà-Giménez et al., 2019; Vilà-Giménez & Prieto, 2020a; see 1.2.5.2 for more details).

Interestingly, evidence has been provided to show that early multimodal imitation skills, which naturally occur in the first years of life, are related to socio-communicative skills. For instance, Heimann et al. (2006) showed that the deferred imitation abilities of 6-month-old babies, along with visual memory and communicative skills, were linked to more complex communicative skills (e.g., joint attention, gesture use) eight months later, at the age of 14 to 15 months (see also Hanika & Boyer, 2019). Interestingly, a more recent study by Castillo and colleagues (under review) analyzed the relationship between multimodal imitation abilities (in terms of gesture, prosody and lexical content) and narrative and pragmatic abilities in 3- and 4-year-olds. Their results indicated that narrative and pragmatic abilities were correlated with multimodal imitation performance, but not with object-based imitation, revealing that multimodal imitation abilities are key for children's socio-communicative development.

1.2.4.2. Non-typically developing children

Concerning non-typical populations, recent investigations have also demonstrated the effects of using co-speech gestures in pragmatic development, specifically in joint attention skills. For instance, So et al. (2015) showed that in a narrative context, the number of gestures produced was related with 6- to 12-year-old ASD children's socio-communicative symptoms, indicating that the participants who had severe impairments in social communication produced fewer gestures than those who had less severe symptoms. These results are in line with Braddock and colleagues (2016), who documented that ASD adolescents who gestured more were the ones who had better general communication abilities. In an experimental training study, Gulsrud and scholars (2014) longitudinally analyzed joint attention skills of ASD children who participated in a randomized controlled trial and showed that the children who were in the joint attention group increased their joint skills (coordinated joint looking and showing) and expressive language over time compared to the other experimental and control groups. Similarly, joint attention skills of 2;4- to 3;7-year-old autistic children, as well as language and pretend play, increased after they had received training on object imitation (Ingersoll & Schreibman, 2006).

Multimodal imitation skills have also been studied concerning social communication. For example, in a study with 34-month-old children with ASD, X Fragile Syndrome and other developmental disorders, Rogers and colleagues (2003) demonstrated that object and oral imitation skills of autistic children were linked to initiating joint attention and to the severity of autistic features. Also, they showed that manual, object and oral imitation was related to expressive language, while only manual imitation was linked to play behavior in children with other developmental disabilities. These findings are related to later results by Dohmen et al. (2016), who showed that body imitation skills at the age of 2 were associated with linguistic and socio-communicative difficulties at age 4.

Some interesting results have also been provided for children with language delays or DLD. For example, Dohmen et al. (2016) showed that early body movement imitation skills at the age of 2 were predictors of later social communication skills at the age of 4 in children with language delays. Also, in an individual training for preschool children, Vogt and Kauschke (2017) showed that observing iconic gestures improved word learning in TD and DLD children. However, they did not compare whether there were differences between these two groups and to our knowledge, there are no studies training multimodal abilities in DLD children.

All in all, the evidence presented in 1.2.4 has shown the key role of multimodality in not only TD children, but also in ASD and DLD children, even though it has been studied to a lesser extent. For this reason, we believe that more evidence is needed to establish a link between multimodal development and narrative and pragmatic abilities, in non-TD language development, an area which will be addressed by the second study of this PhD thesis. In addition, it is also necessary that intervention studies can test the value of multimodal interventions for improving both TD and non-TD children's linguistic abilities (see subsection below).

1.2.5. Multimodal and non-multimodal interventions for boosting narrative and pragmatic abilities

Given the importance of narrative and pragmatic skills in preschool and school-age children's language and social development, researchers and clinicians have developed interventions for improving these skills. The following two subsections, 1.2.5.1 and 1.2.5.2, will report on existing interventions that have been conducted both on TD and non-TD children, distinguishing between interventions that have made use of multimodality and those that have not.

1.2.5.1. Non-multimodal narrative and pragmatic interventions

Existing narrative and pragmatic intervention studies for TD and non-TD children have highlighted the importance of treating these abilities (see Walker et al., 2020, for a review). Importantly, trainings for TD children tend to focus on very specific areas of narrative discourse and pragmatics (e.g., narrative macro- and microstructure³, joint attention, ToM, irony comprehension, speech acts; see e.g., Spencer & Petersen, 2020). As this thesis will not only develop interventions for TD children, but for both TD and non-TD preschool children, we will discuss intervention studies designed for both TD and non-TD children or for non-TD children, that usually include TD peers as controls (see Binns & Cardy, 2019, and Parsons et al., 2017, for reviews on pragmatic interventions; and Camus Torres et al., 2021 and Favot et al., 2020, for recent reviews on oral narrative interventions).

³ Microstructure refers to the narrative complexity at sentence level in terms of number of words and syntax complexity. Please see section 1.1 for a definition of narrative macrostructure.

Validated and registered narrative interventions, such as Story Champs (Petersen & Spencer, 2012), Supporting Knowledge in Language and Literacy (SKILL; Gillam & Gillam, 2016), and Oral Narrative Intervention Programme (ONIP, Glisson et al., 2019), explicitly teach narrative macrostructure and microstructure using different activities and supports (e.g., storyboards, icon cards, images) in different settings (individual, small groups, classroom groups)⁴ and for different age ranges (school and adolescence). Research conducted with these intervention programmes on children with language impairments have reported improvements in narrative complexity, story grammar and narrative productivity in 5- to 10-year-old children (e.g., Gillam et al., 2018; Petersen et al., 2016) and have reported larger improvements for TD children (Petersen et al., 2016).

In addition, study-specific narrative interventions, which are the interventions that, in contrast to the interventions presented in the previous paragraph, are tailored to the study's goals and not further validated with other samples have designed interventions for school-aged children (e.g., 6- to 10-year-olds). These studies have also documented improvements in either narrative macrostructure (e.g., Favot et al., 2021) and microstructure (e.g., Miller et al., 2018; Swanson et al., 2005), or both (e.g., Peña et al., 2006; showing better pre- to post-test gains for TD children), mostly in fictional narratives, rather than personal narratives (e.g., Favot et al., 2021). Most of these studies, as well as the validated interventions, also make use of visual support (such as icons) to represent macrostructure elements (see Favot et al., 2020, for more details).

On the other hand, researchers have also implemented interventions for treating pragmatic difficulties, mostly addressed to autistic children (see e.g., Ornaghi et al., 2011, for a pragmatic intervention for TD children). A validated and well-known intervention in this area is the JASPER Intervention (Joint Attention, Symbolic Play, Engagement, and Regulation). This intervention programme addresses different areas of pragmatic language, such as joint attention skills, perspective-taking and empathy in both individual and group settings. Randomized controlled trials conducted with JASPER have shown improvements in 20- to 46-month-old ASD children's initiating joint attention, joint engagement, play behavior and gesture use (e.g., Kasari et al., 2010; Lawton & Kasari, 2012), and have reported a maintenance effect of these measures (e.g., Kasari et al., 2015).

Just like the narrative interventions, pragmatic study-specific interventions have also been designed, which target various subareas of pragmatic language⁵, such as conversation and turn-taking (e.g., Casenhiser et al., 2013), joint attention and engagement (e.g., Carter et al., 2011; Kaale et al., 2014), irony (e.g., Pexman et al., 2019), metaphors (e.g., Cortés et al., 2018) and other areas related to social cognition skills, such as emotion recognition and emotional regulation (e.g., Ryan & Charragáin, 2010; Wetherby et al., 2014). In general, these studies have reported improvements after the experimental groups have

⁴ While some interventions have been designed only for non-TD children (e.g., ONIP), others have been designed for both TD and non-TD populations (Story Champs, SKILL).

⁵ As opposed to narrative interventions, pragmatic interventions have not only been designed for school-age children, but also for preschoolers and thus the participants in these interventions range from 2- to 10 years of age.

received the intervention sessions (see Binns & Cardy, 2019, and Parsons et al., 2017, for more details). Importantly, most of these studies have used case or single-case designs with few participants receiving the intervention and sometimes even without having any control (rather a control with TD children receiving the intervention, or with groups that do not receive intervention).

All in all, evidence has been provided for either narrative or pragmatic development separately. To our knowledge, few studies have considered narrative and pragmatic abilities altogether, such as the study by Dodd et al. (2011). The authors analyzed the differences between a narrative-only intervention and an intervention that target perspective-taking abilities in a narrative-based context and found that school-aged ASD children who received the intervention with perspective-taking showed better narrative abilities and were able to better retell stories from the perspective of different characters. We believe that more naturalistic interventions are needed, such that they integrate narrative and pragmatic areas (as the intervention proposed by Dodd et al., 2011), along with more robust and multi-tiered (i.e., with different levels of support) designs and with bigger participant samples, rather than case studies or single-case studies (Favot et al., 2020).

1.2.5.2. Multimodal interventions

In subsection 1.2.4.1, empirical evidence was provided about the impact of short multimodal trainings on TD children's narrative abilities (e.g., Vilà-Giménez et al., 2019; Vilà-Giménez & Prieto, 2020a). Specifically, the studies by Vilà-Giménez and colleagues showed that after a short individual multimodal training session, the narrative abilities of 5- and 6-year-old children improved after they had observed non-referential gestures being produced by a storyteller (Vilà-Giménez et al., 2019) and after they had been encouraged to use them in their retellings (Vilà-Giménez et al., 2020a). Yet to our knowledge no previous investigation has tested the effects of a longer multimodal intervention for improving narrative skills in a real and naturalistic educational setting, in which multimodal language is used as an experimental condition, rather than a support in the training.

With respect to pragmatic abilities, to our knowledge, only one recent study has highlighted the benefits of an eight-session intervention using embodiment (in the same sense that we use multimodality in this thesis), such as including facial expressions, hand gestures, body movements and prosodic cues, rather than only using a specific type of gesture in training. In this classroom intervention by Pronina and colleagues (2021), the participants (3- to 4-year-old preschool TD children) watched different narratives enriched with emotional and mental states terms and then were asked to talk and embody these mental states (embodied condition) or to just talk about them (non-embodied condition). They found that the children who received the intervention (either in the embodied or in the non-embodied condition) improved their pragmatic abilities, as opposed to the children who did not receive the intervention. Even though these

results on the benefits of multimodal language seem quite promising, more evidence is still needed to prove the effectiveness of multimodality in intervention settings, specifically for non-TD populations.

Importantly, most of the available research has not directly assessed multimodality as an independent condition in narrative and pragmatic intervention contexts for non-typical populations. In fact, most studies have used different multimodal cues, such as facial expressions and hand gestures as a conversational strategy to support the participation of the children during intervention (e.g., Bunning et al., 2017; Justice et al., 2008, among many others). Other intervention studies have just assessed the number of gestures produced by the participants either through direct observation or through parent reports (Beaumont & Sofronoff, 2008; Fletcher-Watson et al., 2016; Solomon et al., 2014, among many others).

To our knowledge, five studies have considered multimodal language (only in theater contexts) as a main condition (Corbett et al., 2017; Nicolopoulou et al., 2015; So et al., 2019, 2020a, 2020b) for improving either oral narrative or pragmatic skills in ASD children and low-income preschoolers in group settings. For instance, in a treatment for 8- to 14-year-old autistic children, Corbett et al. (2017) implemented a 10-session theater intervention that made use of enactment and multimodal language (in a general sense, without emphasizing which features needed to be enacted). The authors found that children who received the theater-based intervention—as opposed to those in the wait-list control group—showed improvements in social abilities, memory for faces and for communication abilities, with the latter being still maintained at a 2-month follow-up. These results are related to Nicolopoulou et al. (2015) who used a narrative-based intervention enhancing story-acting to improve low-income 2- to 4-year-old children's language and social abilities in a classroom intervention lasting a school year (with two intervention sessions per week approximately). The children in the experimental condition, who were asked to compose and enact different stories, showed improvements in narrative comprehension, literacy skills and social competence, as opposed to the children in the non-experimental condition, who did not receive any interventions (e.g., they carried out their normal activities).

On the other hand, three studies involving a robot-based multimodal individual intervention have analyzed the effectiveness of watching robot dramas on ASD children's narrative and pragmatic abilities (So et al., 2019; 2020a, 2020b). While in the three studies, the children had to watch two robots enacting a story (e.g., body movements and manual gestures), only in the studies from 2019 and 2020a the children were then encouraged to enact the story. Specifically, in the first two studies the children were asked to watch the two robots perform a story, and once they had finished, they asked the child to act as if he/she was one of the main characters and to role-play with one of the two robots. After that, the child was asked to swap roles and to act as the other main character in the story and to interact with the other robot. Finally, the participant was asked to role-play the story with the researcher. In the 2020b study, however, once the robots had finished enacting the story, they did not ask the child to take part in the role-play, but rather during and after the drama the researcher asked the child to point to the images that the robots were talking

about in order to enhance eye gaze in conversation. Importantly, in the 2019 study, the results revealed that after receiving a 9-session intervention with the robots, autistic preschool children improved their narrative abilities (in terms of narrative length, narrative structure scores, syntactic complexity and cognitive inferences) and also that their gesture production per clause increased, and that these improvements were still maintained two weeks later. Similar benefits of the robot-drama interventions were documented for joint attention and play behavior. So et al. (2020a) showed in a pilot study with 23 autistic preschool children that those who received a 9-week intervention with robots improved their initiating joint attention skills (e.g., coordinated looking, pointing and showing) and functional play acts (e.g., self-directed play and other-directed play). Responses to joint attention were also found to improve after a robot drama-based 6-session intervention in 6- to 8-year-old ASD children (So et al., 2020b).

Even though the abovementioned studies have started providing evidence to the beneficial role of multimodal language, more research is still needed. First, studies examining the effects of multimodal language on TD and non-TD children's language development in naturalistic environments (as opposed to theater environments) are still missing. Second, the majority of training studies have relied on the exposure to multimodal language and the direct implication of role play and story acting, with less emphasis on the role of actual embodiment of multimodal features by the child. The present dissertation would like to reinforce the role of embodied cognition (see 1.3. below) as integrated with oral language, and ultimately show that our body helps our linguistic and cognitive development. Second, most interventions have focused on specific areas of narrative discourse (e.g., macrostructure or microstructure) or pragmatic skills (e.g., joint attention, empathy, social behavior) and have not considered studying these two dimensions in an integrated way, which is how we face it in day-to-day life. Therefore, to our knowledge, there is a lack of studies that are aimed at improving narrative and pragmatic skills in preschool children from a naturalistic perspective, such that integrate different areas of language, pragmatics and social communication, and that make use of natural communication means such as multimodal language. Third, interventions that offer different levels of support (e.g., intensive one-to-one in therapy contexts, and universal in classroom contexts) are still scarce. For this reason, the present PhD thesis will include two intervention studies that will address this research gap by testing the effectiveness of a naturalistic multimodal intervention for ASD and DLD preschool children in an intensive and individualized context (Study 3; see 3.4 below) and for TD, ASD and DLD preschool children in a classroom context (Study 4; see 3.5 below).

1.3. Theoretical framework: embodied cognition

The current PhD thesis is framed within the theory of embodied cognition (e.g., Adams, 2010; Foglia & Wilson, 2013; Ionescu & Vasc, 2014; Wilson et al., 2017). This theory refers to cognition as “dependent

upon features of the physical body” (Wilson et al., 2017). Specifically, the theory aims to understand cognition in a broad sense, such that our body impacts our perceptual, cognitive and motor capacities.

In some sense, the perspective stated by the embodied cognition paradigm can be regarded as partly opposite to the traditional cognitive science theory, which understands cognition in a narrower sense, such that mental capacities do not depend on physical properties nor on bodily features, but merely on the brain and mental processes, and that motor system and cognitive processing are totally independent. The theory of embodied cognition has postulated the embodiment thesis, which challenges the traditional view of cognitive science demonstrating that the body a) works as a constraint on cognition, b) is a distributor for cognitive processing, and c) helps regulate cognitive activity. Interestingly, the embodiment thesis relates to McNeill’s claim that when people talk, make use of the body, and this does not only affect human communication, but the speaker’s thinking as well (McNeill, 1992). Specifically for the scope of this thesis, we are interested in assessing how embodied cognition (e.g., the active involvement of the body in language tasks) impacts preschool children’s language development, specifically narrative and pragmatic learning. Given that most of the evidence comes from the field of adult’s cognition, in our view, it is also key to consider children’s cognition, as their motor systems and cognitive processes are in constant development (see Goldin-Meadow, 2014; Goldin-Meadow & Wagner, 2005; Loeffler et al., 2016; Wellsby et al., 2014, for reviews). As mentioned before, previous empirical evidence has shown how embodiment impacts children’s mathematical learning (e.g., Goldin-Meadow & Levine, 2014; Goldin-Meadow et al., 2009), working memory (Aussems & Kita, 2019; Stevanoni & Salmon, 2005) and other areas of language (see subsections 1.2.3 and 1.2.4 above).

Given the evidence on the close link between body and cognition and its role in children’s cognitive development, our goal is to expand our knowledge on the correlational (Study 2) and causal (Study 3 and 4) relationship between embodied training and narrative and pragmatic abilities. In fact, few studies have been able to trace the causal role of embodiment in the development of narrative and pragmatic skills (see Pronina et al., 2021; Vilà-Giménez et al., 2019, 2020; Corbett et al., 2017; Nicolopoulou et al., 2015; So et al., 2019, 2020a). For this reason, the studies of this PhD thesis are designed by taking this theory into account. While the first study will conduct a meta-analysis on the previous evidence to understand the relationship between multimodality and language, the second study will assess the correlation between multimodal performance and narrative and pragmatic abilities in preschool children. Finally, Studies 3 and 4 will directly assess the correlations to embodied cognition through two intervention studies which will test the causal effect of multimodality on children’s narrative and pragmatic abilities (see the following sections for more details).

1.4. Research gap and main motivation

All in all, the previous subsections have shown that narrative and pragmatic development, as well as multimodal language, are tightly intertwined and thus develop in parallel. Evidence has been provided to demonstrate that multimodality plays a pivotal role in children's narrative and pragmatic development, which has a long-term impact on later language skills, academic performance, and social relationships. Importantly, while benefits after receiving a multimodal treatment have been shown in few studies for TD children, the literature addressing this topic on non-TD children in a naturalistic environment has been less extensively investigated. Second, more studies are needed that treat narrative and pragmatic abilities as two areas that develop hand in hand in children's socio-communicative abilities. Finally, research that assesses different levels of support in intervention settings is also still missing.

For this reason, the present PhD thesis has the goal of providing a larger insight into the relationship between multimodal language and narrative and pragmatic skills in TD and non-TD children's language development. The thesis will aim to demonstrate a) the tight link between multimodality and language development (Studies 1 and 2) and b) that multimodal language interventions performed in a naturalistic and inclusive educational setting can scaffold preschoolers' oral narrative and pragmatic development (Studies 3 and 4).

2. RESEARCH QUESTIONS AND HYPOTHESES

As mentioned in subsection 1.4, the main underlying goal of the thesis is to evaluate how multimodal language can be used as a helping tool for boosting narrative and pragmatic abilities of TD, ASD and DLD children. To do this, this PhD thesis will include four different experimental studies which will provide complementary evidence to answer the general research question of the thesis. The following subsections explain in detail the specific research questions and hypotheses that will be addressed in each of the studies conducted in the PhD thesis.

2.1. Study 1: “The effects of multimodal language on ASD and DLD children’s language development: a meta-analysis”

The first study of the PhD thesis will be a meta-analytic review of the literature which will analyze the role of multimodality in linguistic and developmental patterns in ASD and DLD populations. The meta-analysis aims at answering the following research question: “Have previous studies motivated the relationship between multimodality and linguistic (e.g., structural language, narrative discourse and pragmatics) abilities in ASD and DLD populations?” This relationship will be studied in terms of gestural development, which is related to the gesture production in different developmental stages, and in terms of the effects of multimodal language on cognitive and linguistic abilities, such as a) correlational effects, referring to the strength of the relationship between multimodal abilities and cognitive and linguistic abilities, b) precursor and predictive effects, which refer to how multimodal abilities can precede in development or predict later linguistic and communicative abilities, and finally, c) causal effects, which relate to the direct effects of multimodality after a participant or group of participant has received a specific training or intervention that used multimodal language.

First of all, we hypothesize that most studies will analyze multimodal language development in terms of gesture production. We suspect that some studies will have analyzed the relationship between multimodal performance (in terms of gesture production and imitation abilities) and other linguistic abilities, showing both correlational and predictive and precursor effects, but not causal effects. We suspect that the studies will highlight the correlational, predictive, precursor, and causal role of multimodal communication on ASD and DLD children, by showing that multimodality is linked to children’s language development. Importantly, a first inspection of the materials reveals that there are several studies assessing these effects. However, the present meta-analytic review will help examine these effects and the value of multimodal language by comparing the effect sizes between different studies, and by comparing contradictory results, and will thus provide a comprehensive discussion of the relationship between multimodality and non-TD language development.

2.2. Study 2: “Which dimensions of multimodal abilities are related to narrative and pragmatic abilities? A correlational study with typically and non-typically developing preschool children”

The second study of the PhD thesis will be a correlational study that will analyze the relationship between TD, ASD and DLD preschool children’s multimodal abilities and narrative and pragmatic abilities. We would like to assess whether better expressive and comprehensive multimodal abilities are correlated with better narrative and pragmatic skills, or whether they act as independent components in children’s communicative development.

First, existing research has shown that gesture rate and multimodal perception expressive abilities are related to school-age and adolescent children’s linguistic and communicative skills (e.g., Braddock et al., 2016; So et al., 2015). Second, multimodal imitation abilities have also been shown to be related to narrative and pragmatic abilities (e.g., Castillo et al., under review; Dohmen et al., 2016; Rogers et al., 2003). Interestingly, recent research has highlighted the importance of considering gesture accuracy rather than gesture rate, as what distinguishes TD populations from non-TD populations is the accuracy of the gestures produced, such that the precision of the gesture helps the interlocutor understand what the gesturer wants to convey (Wray et al., 2017). These results along with the evidence that gesture is negatively correlated with narrative abilities (Grofulovic, 2019) show the importance of considering different measures of multimodal abilities.

Given this previous knowledge, the goal of Study 2 will be to carry out a multi-dimensional analysis of multimodal skills by assessing whether a set of multimodal abilities of preschool TD, ASD and DLD are related to narrative and pragmatic skills. We hypothesize that not all multimodal abilities of preschool children will be related to linguistic abilities in terms of narrative and pragmatic abilities, with pragmatically-related gesture accuracy patterns and patterns of semantic and temporal gesture-speech integrated being the most relevant. The multimodal abilities analyzed will include the following: a test of gesture rate in natural narrative productions, two tests of gesture accuracy (in terms of imitation and elicitation, see Castillo et al., under review, and Wray et al., 2017, respectively), a test gesture-speech semantic integration (a subtask in the PleaseApp pragmatic assessment tool by Andrés-Roqueta et al., 2020), two pragmatically-unrelated motor tasks (extracted from NEPSY-II), and a test of a non-pragmatically-relevant audiovisual integration task (Takehama et al., 2019). This set of different tasks will allow us to have a multi-dimensional view of multimodal abilities. We suspect that the tasks that relate to gesture accuracy, such as the imitation task and the elicitation task will be related to children’s narrative and pragmatic abilities, but also the gesture-speech semantic integration task, as it involves a mental understanding of what the gesture is referring to. We also expect that the correlations with motor-related abilities will be smaller than for meaningful multimodal abilities. Finally, given the existing knowledge that ASD and DLD children show an impaired use of multimodality in terms of gesture use and importantly,

gesture accuracy (see e.g., Wray et al., 2017; Ramos-Cabo et al., 2020, for a review), we hypothesize that the multimodal abilities from TD, ASD and DLD children might follow different paths and might impact differently on language development.

2.3. Studies 3 and 4: Multimodal interventions

The third and fourth studies of the thesis will be two intervention studies involving the same target multi-tiered multimodal intervention and the same target preschool-aged groups of children. While Study 3 will be carried out through an intensive and individualized setting with ASD and DLD children, Study 4 will be carried out in a group setting in a preschool classroom context (e.g., P5 level in the Catalan educational system). Crucially, the two interventions complement each other and can be considered multi-tiered, as they provide different levels of support for the participants, such that they can be intensive (individualized, Tier 1), secondary (small groups, Tier 2) and universal (majority of students, Tier 3) (check the Multi-Tiered Framework at <https://www.pbis.org/pbis/tiered-framework>). In our view, this multi-tiered intervention will enhance non-TD children's skills, as they will have received an intensive individualized intervention (in a clinical context) in Study 3, and a universal support intervention which will also benefit classmates (in a classroom context) in Study 4. This design will reinforce the goal of a broader view of inclusion, indicating that both levels of support are necessary to strengthen learning in both contexts. Importantly, the intervention studies in this thesis will be designed taking these differences into account and will be sensitive to the need of having multi-tiered treatments.

2.4. Study 3: “A multimodal intervention for boosting narrative and pragmatic abilities in ASD and DLD children in an intensive and individualized setting”

Study 3 will aim to explore whether a naturalistic multimodal intervention in a between-subjects design with some added features of a multiple-baseline design will improve ASD and DLD children's narrative and pragmatic abilities in a clinical setting with a speech-language therapist. With these added features of a multiple-baseline design, we aim to assess the individual support and the number of sessions that non-TD populations need to successfully improve narrative and pragmatic abilities, and therefore we will also analyze the individual learning curve of the participants in the two conditions (multimodal or non-multimodal).

We hypothesize that all children who receive the intervention in the multimodal condition will benefit more from the intervention than children in the non-multimodal condition for two main reasons. First, the use of multimodal language (understood as in the theory of embodied cognition) has potential benefits on cognition and language development. Second, shorter multimodal interventions have been documented to be effective for improving TD children's narrative (e.g., Dargue & Sweller, 2020; Macoun & Sweller, 2016; Vilà-Giménez & Prieto, 2020b) and pragmatic abilities (Pronina et al., 2021), and for

improving non-TD children's pragmatic abilities (Corbett et al., 2017; So et al., 2019, 2020a). Third, since the intervention will tightly integrate narrative and pragmatic as a conjoint system of communication, along with the use of multimodal language, this feature will create a naturalistic environment of how us humans communicate on a daily basis.

Importantly, the inspection of each child's learning curve together with attention to their specific needs in this individual intervention will help us frame the needs for Study 4 with universal support.

2.5. Study 4: “A multimodal intervention for boosting narrative and pragmatic abilities in TD, ASD and DLD children in a classroom setting”

Study 4 will examine the effectiveness of the same multimodal intervention as an universal support. Therefore, we would like to assess whether this intervention will benefit TD, ASD and DLD children's narrative and pragmatic abilities, and specifically whether the non-TD children will show greater improvements (concerning post-intervention maintenance results) after having been exposed to the intensive and individualized intervention (Study 3).

We believe that the intervention will boost the three population's narrative and pragmatic abilities because of the same reasons exposed in the previous subsection. Moreover, we hypothesize that there will be an effect of the multi-tiered design, indicating that ASD and DLD children will show further improvements thanks to the previous intensive and individualized intervention, and that will impact in a generalization of the abilities to a natural context of communication. Also, we suspect that a group effect might also be observable by showing the importance of children working with their classmates as a group.

3. EXPERIMENTAL STUDIES

3.1. Study 1: “The effects of multimodal language on ASD and DLD children’s language development: a meta-analysis”

The first study of the thesis will be a meta-analytic review that will assess the current state of the art on the relationship between multimodality and children’s linguistic skills in ASD and DLD populations.

3.1.1. Methods

To conduct this study, we will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA®), which is a system for reporting systematic reviews and meta-analyses. The PRISMA® Statement dictates different steps that need to be followed in terms of a) identification of studies, b) screening, c) eligibility and d) inclusion (see subsections below). Since this study is underway, we will report some preliminary results that have already been collected.

3.1.1.1. Identification of studies

The first step is to identify studies concerning the topic under research. According to our research question, we needed to find studies that were about ASD and DLD children and that included multimodality (i.e., gesture, facial expressions) in the study. For this reason, we run a boolean search (see Figure 1) in seven different databases: Scopus, PubMed, Web of Science, PsycInfo, ERIC, Cochrane CENTRAL and Epistemonikos.

((("ASD" OR "Autism Spectrum Disorder" OR "Autistic Spectrum Disorder" OR "Asperger" OR "Asperger syndrome")) OR ("DLD" OR "Developmental Language Disorder" OR "Developmental Language Impairment" OR "Developmental Delay" OR "SLI" OR "Specific Language Impairment" OR "Language Impairment" OR "Language disorders" OR "Severe Language Disorder")) AND ("Multimodality" OR "Multimodal" OR "Gesture" OR "Gestuality"))

Figure 1. Boolean search for the meta-analysis

The boolean search was applied to the title, abstract and keywords of the articles, and the database searches were limited to English-written works published in peer-reviewed journals between 1960 and 2021 and were conducted during the first week of February 2021. In this first step of identification, 1576 papers were retrieved from the seven databases, out of which 723 were considered for screening after the duplicates were removed.

3.1.1.2. Screening

Once the 723 articles were retrieved, their abstract was screened using Mendeley reference manager. In order to be included in the review, the papers needed to meet the following inclusion criteria:

- a. The article has been published in a peer-reviewed journal.
- b. The article is written in English.
- c. The article reports original research.
- d. The participants are children, aged 0 to 18.
- e. The participants or some of the participants have a diagnosis of ASD or DLD.
- f. The article evaluates a) language and communication and/or b) multimodal development.
- g. The article reports on multimodal language (gesture, head movements, body movements, facial expressions). Articles referring to multimodality as audiovisual data are excluded (as this term is used to refer to audio or visual support).
- h. The article reports on a) children's gesture and multimodality use and comprehension, b) the predictive and precursor role that multimodality has, c) the correlational effects that multimodality has, and/or c) the effects after trainings and interventions using multimodality. Studies about diagnosis and symptomatology are excluded.
- i. The article reports the effects using quantitative measures.
- j. The article is not a pilot study.
- k. The article does not include a pharmacological intervention.

Articles that warranted further examination were selected for full-text review. From the 727 papers, 160 were selected for eligibility.

3.1.1.3. Eligibility and inclusion

The 160 articles that meet the inclusion criteria will be read carefully and will be assessed according to the purposes of the study and to the inclusion criteria. If there is any study that does not meet the criteria, it will be excluded and the reasons will be detailed purposefully.

The literature that has been selected after the final full-text review, will be separated into four groups according to the main focus of the report: gestural development, correlational effects of multimodality, predictive and precursor effects of multimodality, and causal effects of multimodality. Also, their methodological quality will be assessed using Standard Quality Assessment Criteria for Evaluating Primary Research Papers from a Variety of Fields (Kmet et al., 2004). All the papers will finally be analyzed quantitatively.

3.1.2. Expected results

Given the evidence we have from the literature review and from the abstract screening, we suspect that most of the retrieved articles will focus on children's gestural development, such as their ability to produce gestures at different stages, or their ability to comprehend multimodal language since there is an impaired use of multimodality in ASD and DLD populations and research has aimed to describe it extensively. Second, we expect that fewer studies will be retrieved concerning the effects of multimodality, specifically the causal effects of interventions, as to our knowledge, most intervention studies do not consider multimodality as a main condition. Finally, we believe that most research will be on autistic children, given that an impairment in multimodal communication has long been used as a diagnostic criterion in ASD and a vast amount of research has focused on this population, although we expect fewer studies relating associated language difficulties in ASD to their multimodal abilities. On the opposite side, we suspect that we will retrieve less literature on DLD children, as their multimodal abilities are understudied. We also believe that the meta-analytic review will help us disentangle contradictory evidence provided by different studies and to provide closer insights into the differences between results. With this review, we will be able to assess in a more fine-grained fashion the effects that multimodal communication has on ASD and DLD children's language development.

3.2. Study 2: “Which dimensions of multimodal abilities are related to narrative and pragmatic abilities? A correlational study with typically and non-typically developing preschool children”

The second study of the thesis aims to analyze the relationship between multimodal abilities and narrative and pragmatic abilities, in both TD and non-TD children.

3.2.1. Methods

3.2.1.1. Participants

The participants of this study will be around 100 preschool children aged 4 to 6, that will be either typically developing or diagnosed with (or at risk of) ASD or DLD. On the one hand, the non-TD children will be recruited from Centers of Child Development and Early Care (CDIAPs for the name in Catalan) in Catalonia. These centers participate in the early diagnosis of preschool children (until 6 years of age) who show an atypical development (such as ASD and DLD children) or suffer from brain injuries, congenital defects or malformations of some kind. Non-TD participants will be eligible for the study if they (a) have a diagnosis of ASD or DLD by a speech-language pathologist (henceforth, SLP) working at the CDIAPs; (b) have Catalan as their primary language; (c) are able to speak using more than two-word utterances. On

the other hand, TD participants will be recruited from different schools and will be matched to the non-TD participants for age and non-verbal IQ.

Before conducting the data collection, the study will be presented to the Institutional Committee for Ethical Review of Projects at Universitat Pompeu Fabra so as to follow all legal and ethical standards. After that, the objectives and design of the study will be presented to both the SLPs working at CDIAPs and to the preschool teachers and coordinators of the participating schools, so that the study develops in conjunction with their support. Finally, families who want to participate in the study will fill out a questionnaire and will be asked to sign a consent form for accepting to participate in the study. Once the study has finished, the SLPs, teachers and families will be informed about the results of this investigation.

3.2.1.2. Materials and procedure

In order to assess the relationship between multimodal skills and, pragmatic and narrative abilities, all TD and non-TD preschool children participating in the study will perform a set of tasks that are aimed at assessing their multimodal, narrative and pragmatic skills. Table 1 below summarizes the tasks that will be used to assess pragmatic, narrative and multimodal tasks that will be delivered in the study. Even though the tasks will be piloted for the target population before testing, below we discuss the adequacy of the task for TD and non-TD preschool children.

First of all, concerning pragmatics, two different measures will be collected: the Audiovisual Pragmatic Test (APT) (Pronina et al., 2019) and the evaluation subtests in PleaseApp (Andrés-Roqueta et al., 2020). The APT is a test that has been designed to assess expressive pragmatics and pragmatic prosody from preschool to late childhood children. The test includes 47 items with illustrations that refer to different daily contexts that children live and include different pragmatic functions (e.g., basic interaction, speech-act, affective stance, focus and epistemic stance). The participants are asked about how they would react or respond in that situation (see the left panel in Figure 2 for an example). The responses are coded according to the appropriateness and the prosodic enactment of the answer. For the purposes of this study, only the first 35 items will be delivered to preschool participants (see Pronina et al., 2019). Even though this test was designed for TD children, it has also been successfully used with 7-year-old DLD children (Palomares Zafra, 2020).

Table 1. Summary of the tasks that will be conducted in Study 2 with the reference, timing and target population

	Name and reference	Target measure	Target population	Timing
Pragmatics	Audiovisual Pragmatic Test Pronina et al. (2019)	Expressive pragmatics	TD Age range: preschool - late childhood	20 min
	PleaseApp Andrés-Roqueta et al. (2020)	Receptive pragmatics	TD and non-TD Age range: 3 - 12	25 min
Narrative	Narrative retell task Adapted from Demir et al. (2014) and Dodd et al. (2011)	Narrative production	TD and non-TD Age range: 5 - 6 (Demir et al., 2014); 9 - 12 (Dodd et al., 2011)	5 min
Multimodality	Multimodal imitation task Castillo et al. (under review)	Gesture accuracy: imitation	TD Age range: 3 - 4	7 min
	Elicited single-gesture task Wray et al. (2017)	Gesture accuracy: production	Non-TD Age range: 6 - 8	5 min
	Gesture-speech semantic integration test Andrés-Roqueta et al. (2020)	Semantic integration: perception	TD and non-TD Age range: 3 - 12	-
	Manual motor sequences NEPSY-II (Korkman et al., 2007)	Hand movement imitation	TD and non-TD Age range: 3 - 12	Not specified
	Visuomotor precision NEPSY-II (Korkman et al., 2007)	Hand movement production	TD and non-TD Age range: 3 - 12	Not specified
	Audiovisual synchrony perception task Takehana et al. (2019)	Temporal integration: perception	TD Age range: tested on adults only	Not specified



Figure 2. Left: Example item in APT (Pronina et al., 2019); Right: Example from the indirect language subtest in PleaseApp. Free translation to English by myself

On the other hand, PleaseApp (Andrés-Roqueta et al., 2020) is an app that has been designed to evaluate and treat the pragmatic and socio-communicative skills of TD and non-TD children aged 3 to 12. For the purposes of this study, we will use the evaluation part, which consists of different contexts (i.e., subtests) where the participant's pragmatic competence is evaluated in terms of the use and comprehension of figurative language, referential expressions, disambiguation of lexic in context, narrative sequencing, metapragmatic abilities, humor and irony, politeness and gesture-speech integration (see the right panel in Figure 2 for an example). This task has been successfully evaluated with 5- to 12-year-old children.

Narrative abilities will be assessed through a narrative retelling task, adapted from Demir et al. (2014) and Dodd et al. (2011), which have been tested for TD children and children with language impairments. In the task, the children will watch a wordless cartoon featuring more than one character, and they will be asked to retell it to the experimenter, first from the perspective of the main character and then from a secondary character in the video. The narrative retells will be orthographically transcribed and coded in terms of narrative structure (0 to 6, Demir et al., 2014; see Appendix I) and in terms of perspective-taking appropriateness (0 to 5, Dodd et al., 2011; see Appendix II).

Finally, considering multimodality, it will be assessed using seven different measures, such that we can have a multi-dimensional view of the multimodal abilities. First, a multimodal imitation task (Castillo et al., under review, based on Ingersoll, 2012; Ingersoll & Lalonde, 2010) in which children watch twelve short videos where a professional actress interacts with a teddy bear. In these sequences, the actress addresses the teddy bear or the camera while producing a gesture (conventional, iconic or metaphoric), an accompanying facial expression and appropriate intonation (see the left panel in Figure 3 for an example). After each videorecording, the child will be asked to imitate what he/she has seen in the video and his/her performance will be coded in terms of gesture, prosody and lexical content (0 to 2, Castillo et al., under review; see Appendix III). This task has been designed for preschool TD children based on the intervention developed for autistic preschoolers (Ingersoll, 2012; Ingersoll & Lalonde, 2010). Second, for the elicited single-gesture task (Wray et al., 2017), children will be asked to represent eight different animals, objects, feelings and actions without speaking and using their body. The multimodal representations will be scored 0 to 3 in one-part items (e.g., *sad*, *painting*, *guitar*), and 0 to 6 in two-part items (e.g., *train*, *sleep walking*, *climbing a ladder*, *monkey* and *sword fight*). Third, the gesture-speech semantic integration subtest in the PleaseApp will be used as another multimodal measure. This subtest analyzes the participant's ability to appropriately integrate the gesture performed by the main character in the story with what he/she is saying and what he/she sees. For instance, in the right panel in Figure 3 the girl is saying that they went to the shop to buy something while visually representing the action of drinking and therefore the expected answer would be to select the can. It also provides information about the error type which could be led by a lack of semantic or gestural integration. The fourth and fifth tasks will be two motor tasks from NEPSY-II (Korkman et al., 2007). In the manual motor sequences task, the children will be asked to imitate different

pragmatically unrelated rhythmic movement sequences, while in the visuomotor precision test, the participants will be asked to draw lines inside tracks as quickly and as accurate as possible. We will also have a multimodal control task, which will be a pragmatically unrelated audiovisual integration task in which the participants need to decide whether the music they hear is temporally aligned with the body movements they are watching on the screen (Takehana et al., 2019). Even though this task was created originally for adults, it will be adapted for this study and will be piloted for 5-year-old TD and non-TD children before the data collection starts. In addition, in order to assess gesture rate patterns through a naturalistic task, the multimodal language (gestures, body movements and facial expressions) produced in the narrative retelling task will be annotated, following the MultiModal MultiDimensional (M3D) labeling scheme (Rohrer et al., 2020). With these annotations, we will be able to assess children's multimodal production in a semi-spontaneous discourse.



Metaphoric gesture

Hand rubbing stomach

Esmolet, per sopar menjarem una truita molt bona!

'Esmolet, for dinner we'll have a tasty omelette!'



Figure 3. Left panel: Example item in the multimodal imitation task (Castillo et al., under review); Right panel: Example from the gesture-speech integration subtest in PleaseApp. Free translation to English by myself

3.2.2. Data analysis

The data will be analyzed using R (R Core Team, 2019). We will conduct a Pearson correlational analysis, a regression analysis and a Structural Equation Modeling (SEM) analysis in order to determine the relationship between pragmatic and narrative skills and multimodal skills.

3.2.3. Expected results

Given the evidence that poorer gesture use is related to children's socio-communicative abilities (Braddock et al., 2016; Dohmen et al., 2016; So et al., 2015), and specifically, that gesture accuracy is more important than gesture frequency for assessing children's multimodal (Wray et al., 2017) and narrative abilities (Grofulovic, 2019), we expect that children's multimodal abilities (in terms of gesture accuracy in both imitation and elicitation tasks) will be correlated with their narrative and pragmatic abilities. Importantly, we also expect that pragmatic-based gesture-speech integration abilities (PleaseApp task) will also correlate with children's narrative and pragmatic abilities, such that the ability to integrate gesture and speech semantically and temporally is also directly related to gesture accuracy.

3.3. Studies 3 and 4: Multimodal interventions

The third and fourth studies of the PhD thesis will be two multi-tiered intervention studies that will follow the same multimodal treatment on a sequential basis, such that Study 4 will take place once Study 3 has finished. The two studies will have a between-subjects pre- and post-intervention design with a delayed post-intervention (see Figure 4 for a summary of the procedure of the two studies)⁶. While Study 3 will be conducted in an intensive and individualized support (Tier 1), Study 4 will be with universal support in a classroom context (Tier 3). These two studies will complement each other, as they will favor inclusion: ASD and DLD children will be able to benefit from the group and individual interventions. Figure 4 below shows the procedure of the two studies. The intervention will be multimodal and narrative-based and will put emphasis on perspective-taking abilities. The novelties of this treatment are threefold: a) multimodal language is enhanced and used as a main condition; b) narration and pragmatics are considered as a conjoint system, which allows for learning in a naturalistic environment; and c) the intervention is multi-tiered, allowing for different levels of support.

⁶ Importantly, Study 3 will be more flexible and adapt to the participants' needs (see more details below).

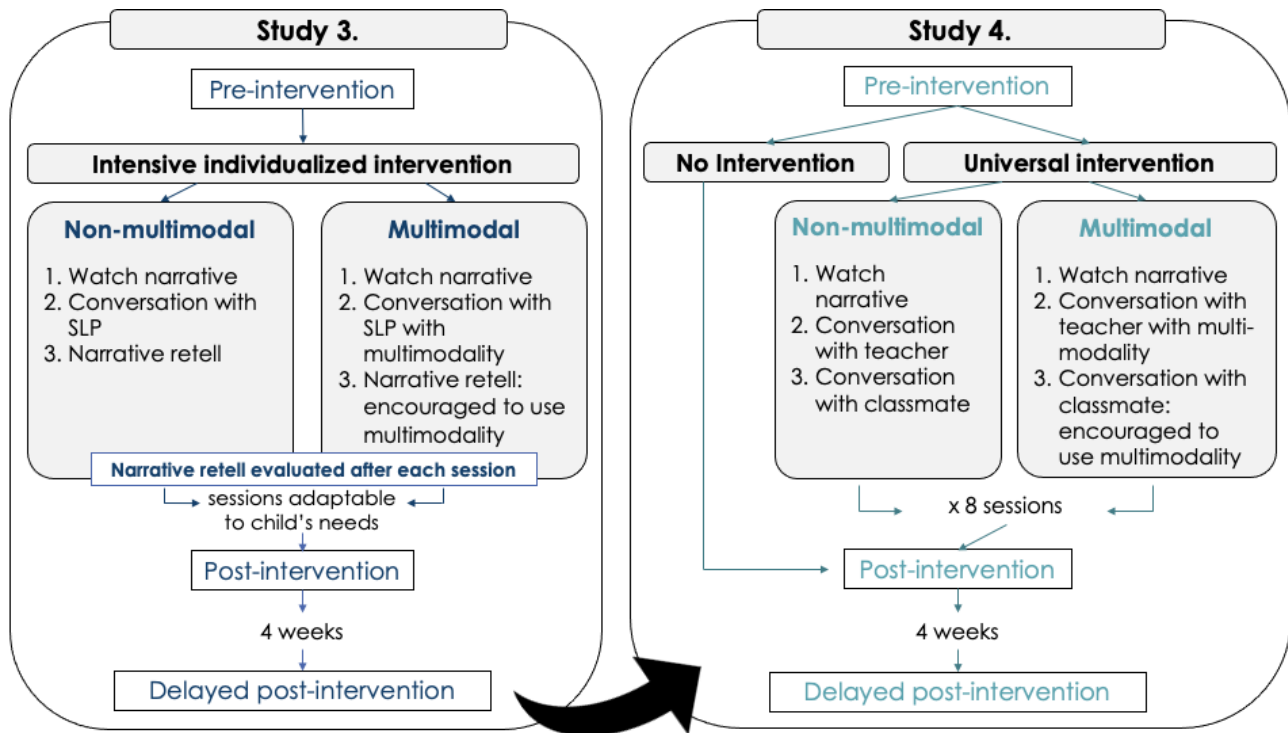


Figure 4. Procedure for Studies 3 and 4

3.4. Study 3: “A multimodal intervention for boosting narrative and pragmatic abilities in ASD and DLD children in an intensive and individualized setting”

Study 3 specifically aims a) to determine the effectiveness of a multimodal narrative-based intervention with a focus on perspective-taking for ASD and DLD children in a clinical context and b) to look at the individual learning curves of the participants, focusing on the support and sessions they need for improvement.

3.4.1. Methods

3.4.1.1. Participants

In Study 3 we will have around 50 participants, who will be the ASD and DLD participants in Study 2 (see 3.2.1.1 above).

3.4.1.2. Experimental design

Study 3 will have a between-subjects design with pre-, post-, and delayed post-intervention measures (see the left panel in Figure 4). This study will have some features of a multiple-baseline design, as it will be able to assess the learning curves (e.g., learning stability) of the participants by collecting a narrative retell task after each session. This task will help assess the individual learning patterns (e.g., number of sessions to reach learning stability) and the individual differences between participants. In this study, the

participants will receive an individualized intervention delivered by their SLP, who will have previously been trained. The study will contain two groups, the experimental group, who will receive the intervention enhanced with multimodal language, and the control group, who will receive the intervention without multimodality. In this study, the interventionist will be each child's SLP, who will receive previous training on how to deliver the intervention. The author of the thesis will check for treatment fidelity of the treatment administration (i.e., trained SLPs).

3.4.1.3. Pre-intervention, post-intervention and delayed post-intervention tasks

Table 2 summarizes the different tasks that will be conducted in this study with specific details about whether they are performed as control (only pre-intervention) or as target measures (pre- and post-intervention). Details about the tasks, such as reference and timing, are explained below.

Table 2. Summary of the tasks conducted in Study 3 with the reference, timing and target population

		Name and reference	Target measure	Target population	Timing
Control measures: Pre-intervention	Diagnosis	CELF Preschool 2 Wiig et al. (2009)	Receptive and expressive language	TD and non-TD Age range: 3 - 6;11	45 min
		K-BIT Matrices Kaufman (1990)	Non-verbal IQ	TD and non-TD Age range: 4 - 90	10 min
		CCC-2 Bishop (2003)	Core language Non-verbal communication Social communication	TD and non-TD Age range: 4 - 16;11	offline task
	Multimodality	Multimodal imitation task Castillo et al. (under review)	Gesture accuracy: imitation	TD Age range: 3 - 4	7 min
		Elicited single-gesture task Wray et al. (2017)	Gesture accuracy: production	Non-TD Age range: 6 - 8	5 min
Target measures: Pre- and post-intervention	Pragmatics	APT Pronina et al. (2019)	Expressive pragmatics	TD Age range: preschool - late childhood	20 min
		PleaseApp Andrés-Roqueta et al. (2020)	Receptive pragmatics	TD and non-TD Age range: 3 - 12	25 min
	Social cognition	1 st order false belief task Baron-Cohen (1985); Armstrong et al. (2018)	ToM	TD and non-TD Age range: not specified	2 min
		2 nd order false belief task Gopnik & Astington (1988)	ToM	TD and non-TD Age range: not specified	2 min

Table 3. Summary of the tasks conducted in Study 3 with the reference, timing and target population (contin.)

		<i>Name and reference</i>	<i>Target measure</i>	<i>Target population</i>	<i>Timing</i>
<i>Target measures: Pre- and post-intervention</i>	<i>Social cognition</i>	Expression-situation matching test Izard et al. (2003); Alonso-Alberca et al. (2012)	Emotion understanding	TD and non-TD Age range: 3-6	5 min
	<i>Narrative</i>	Narrative retell task Adapted from Demir et al. (2014) and Dodd et al. (2011)	Fictional narrative skills Perspective-taking skills	TD and non-TD Age range: 5 - 6 (Demir et al., 2014); 9 - 12 (Dodd et al., 2011)	5 min
		Personal narrative generation task Favot et al. (2021)	Personal narrative skills	Non-TD Age range: 6 - 7	5 min
<i>Delayed post-intervention</i>	<i>Pragmatics</i>	APT Pronina et al. (2019)	Expressive pragmatics	TD Age range: preschool - late childhood	15 min
	<i>Narrative</i>	Narrative retell task Adapted from Demir et al. (2014) and Dodd et al. (2011)	Fictional narrative skills Perspective-taking skills	TD and non-TD Age range: 5 - 6 (Demir et al., 2014); 9 - 12 (Dodd et al., 2011)	5 min
		Personal narrative generation task Favot et al. (2021)	Personal narrative skills	Non-TD Age range: 6 - 7	5 min

First, different measures will be used in order to control for differences and to assess the effectiveness of the treatment. First, some measures of control will be collected, such as diagnosis measures, which are the CELF Preschool-2 (Wiig et al., 2009) and the K-BIT Matrices for non-verbal IQ (Kaufman, 1990) and the Children's Communication Checklist (CCC-2; Bishop, 2003), which have been designed for both TD and non-TD children. While the first two will be collected directly with the participants, the latter will be filled in by the families. Even though children will already be attending CDIAPs and might already have a diagnosis, the participants might not have been diagnosed or treated with the same measures, and therefore we will use our own measures to have control across the sample. On the other hand, we will have some other control measures, such as language abilities (which will be collected from the subtests in CELF) and multimodal abilities in imitation and elicitation (see multimodal imitation task and multimodal elicitation

task in section 3.2.1.2). These control measures will be only collected at the pre-test and let us control for individual differences.

Apart from the control measures, some target measures will also be assessed: pragmatics, narrative abilities and social cognition. Following Pronina et al. (2021), we will adopt a multidimensional view of the testing of the intervention effects. First, for pragmatics, data will be collected using the APT and PleaseApp (see section 3.2.1.2 for more details). Social cognition abilities will also be collected, such as first- and second-order false belief tasks, an emotion understanding task, and a narrative retell task. The two ToM tasks will be the two classic ones: the Sally and Anne task (Baron & Cohen, 1985; adaptation to Catalan by Armstrong et al., 2018) and the Smarties task (Gopnik & Astington, 1988). For the emotion understanding task, we will deliver the expression-situation matching subtest from the Emotion Matching Test (Izard et al., 2003; adaptation to Spanish and Catalan by Alonso-Alberca et al., 2012). This subtest consists of twelve items in which the child is asked to decide which image expresses the emotion that fits into a specific context (see Figure 5 for an example). Children's responses are scored with 0 (incorrect) or 1 (correct).



Figure 5. Sample item from the expression-situation matching subtest

Also, gains in narrative skills pre- to post-intervention will be assessed with two tasks: the narrative retelling task presented in Study 2 (see section 3.2.1.2 for more details), and a personal narrative generalization task (Favot et al., 2021). This second task will only be collected in the post-intervention. In this task, the participant will be shown a picture of his/her weekend (previously sent by the family) and will be asked to explain what happened to him/her. The narrative retell will be coded according to the narrative structure score (Demir et al., 2014) and perspective-taking score (Dodd et al., 2011). This retelling will be used to assess generalization effects of the treatment, from fictional narratives to personal narratives. Importantly, we will be able to assess their abilities to integrate pragmatic abilities (e.g., social relationships, perspective-taking, emotion expression) into their personal lived experiences.

In order to assess whether the intervention effects are still maintained, and whether knowledge gained can be generalized (i.e., in the same narrative modality) and transferred (i.e., in other narrative modalities), a delayed post-test will be carried out after four weeks after the intervention and post-intervention data collection. Specifically, in the delayed post-test data collection, the participants will undertake the APT (for assessing expressive pragmatic skills) and the narrative tasks.

3.4.1.4. Intervention sessions and materials

The intervention sessions will start after the pre-intervention data collection. The intervention sessions have been adapted from Story Champs (Petersen & Spencer, 2012) and Pronina and colleagues (2021), and will integrate multimodality, narrative and pragmatic abilities, and a multi-tiered design. Specifically, the intervention in this study will be individualized and delivered by the child's usual SLP. Apart from the pre- and post-intervention, and delayed post-intervention tasks, after each intervention session the SLP will collect a generalization probe consisting of a narrative retell in order to assess children's learning curve more thoroughly.

Each intervention session will follow the same structure. First of all, the child is asked to watch a 2.30-minute cartoon about a capybara named Chigüiro (Ivar da Coll, s.d.⁷). Once the cartoon has finished, the participant interacts with the SLP by commenting on the narrative (e.g., who are the main characters, what has happened, how they felt, how would the child feel in a similar situation). After that, the interventionist asks the child to retell the story they had watched to a teddy bear that has not seen the story (see Figure 4 for the outline design). The SLP grades the narrative retell in terms of narrative structure (Demir et al., 2014; check Appendix I) and in terms of perspective-taking (Dodd et al., 2011; check Appendix II). On the other hand, for the participants in the experimental multimodal condition, in the second step, the interventionist will use multimodality (e.g., hand gestures, facial expressions, head nods, body movements and prosodic cues) to accompany the different key words, actions and feelings of the narrative and will tell the child not to only talk about the narrative, but also to enact the situation with multimodal cues. Finally, in the narrative retelling task, the interventionist will also encourage the participant to use multimodal cues while retelling the story to the teddy bear, as they have done in the previous step (see top panels in Figure 6 for the steps in the non-multimodal condition and the bottom panels for the multimodal condition). The use of multimodal language (e.g., on which targets will multimodal cues be placed) in each intervention session will first be piloted and then will be detailed in the materials for the SLPs conducting the sessions. Please go to the Appendix IV to see a full script of a sample intervention session in the two conditions.

⁷ This series of stories were initially illustrated by Ivar da Coll and were later adapted to audiovisual format by the Colombian Ministry of Culture for preschool children. Even though the original cartoons are wordless, for the studies in this PhD thesis we will add the voice of an actor narrating the story.



Figure 6. Top panels: Steps in each intervention session in the non- multimodal condition: Bottom panels: Steps in each intervention session in the multimodal condition. Images are examples.

The difficulty of the stories will be augmenting as the sessions go by, starting with the cartoons containing a single character (Chigüiro), and following to two characters (Chigüiro and an animal friend or a relative) and finally containing three or more characters (Chigüiro and two friends or relatives). The intervention sessions will last approximately 15 to 20 minutes and will take place twice a week in the CDIAPs. The number of sessions will be somewhat flexible and will correspond to each child's learning curve, with a minimum of 8 sessions.

3.4.2. Data analysis

The data for the current study will be analyzed using a Generalized Linear Mixed Model (GLMM) analysis with IBM SPSS Statistics (Version 26.0, IBM Corp., 2019). First, considering the improvement of the narrative retelling abilities in terms of the narrative structure and perspective-taking scores collected after each intervention session. We will analyze, first of all, individual improvements and then improvements in group (multimodal vs. non-multimodal) to see the specific learning curve session by session and to see whether multimodality has helped improve narrative retelling abilities during the intervention. While collecting the data, we will continuously assess the individual learning curves of children after each task. These learning curves will be analyzed after data collection and will help determine the specific needs and sessions that are needed in the universal intervention.

We will also analyze the effect of the intervention by comparing the results from the pre-intervention to the results from the post-intervention. With this analysis, we will be able to see a) whether there has

been an improvement after the intervention, b) whether there are differences between the multimodal and non-multimodal groups, c) on which areas (pragmatics, narrative abilities and social cognition) has the intervention been more effective, and d) whether children have transferred their narrative abilities on fictional stories to their own personal narratives.

Finally, we will analyze whether after four weeks pragmatic gains and narrative abilities are still maintained. Therefore, we will compare the results from the pre-intervention and post-intervention with delayed post-intervention to assess maintenance and generalization of narrative and pragmatic knowledge.

3.4.3. Expected results

All in all, given the existing evidence on the multimodal effects in short treatments both in TD (see Hostetter, 2011 and Vilà-Giménez & Prieto, 2021) and in ASD (Corbett et al., 2017; So et al., 2019, 2020a) children, and despite the fact that we expect that there is an improvement on narrative and pragmatic abilities in both conditions, we also hypothesize that the improvement from pre-intervention to post-intervention will be greater for the experimental multimodal group than the control non-multimodal group. Considering the delayed post-intervention measures, we also expect that there will be a significant improvement from the pre-intervention results and that children will maintain the gains from the post-intervention.

In addition, we expect that children's learning curves will be variable among participants and that ASD children will need more sessions than DLD children, as they tend to have greater difficulties with narrative and pragmatic abilities.

3.5. Study 4: “A multimodal intervention for boosting narrative and pragmatic abilities in TD, ASD and DLD children in a classroom setting”

The aim of Study 4 is to assess the effectiveness of the multimodal intervention in a classroom context and to see whether ASD and DLD children who have already received the individualized intervention, are able to improve more in the group setting.

3.5.1. Methods

3.5.1.1. Participants

The participants in Study 4 will be the same as in Study 2. Please see section 3.2.1.1.

3.5.1.2. Experimental design

This study will follow a between-subjects pre- and post-intervention with a delayed post-intervention design. As opposed to the two groups in Study 3, Study 4 will have three groups: the control, that receives

no intervention; the first experimental group, that receives the intervention with multimodality, and the second experimental group, that receives the intervention without multimodality (see Figure 4 in 3.3.). In this study, the interventionist will be each classroom teacher, who will receive previous training on how to deliver the intervention. Also, as in Study 3, the author of the thesis, will check for treatment fidelity.

3.5.1.3. Pre-intervention, post-intervention and delayed post-intervention tasks

The pre-intervention and post-intervention tasks in this study will be the same as in Study 3, with various control (diagnosis, language and multimodal skills) and target measures (pragmatics, narrative skills and social cognition). Please see subsection 3.4.1.3 and Table 2 for the details on the different tasks, references and timing. Importantly, the non-TD children who will have participated in Study 3 will not go over the pre-intervention tasks.

3.5.1.4. Intervention session materials

The intervention sessions will follow a similar procedure as in Study 3, with the main difference that in Study 3 the children interact individually with their SLP and will go through a narrative retell task after each intervention session, and in this study, they interact with the teacher and the classmates in a group setting and they will not undertake a narrative retelling task. Moreover, towards the end of each session, the children interact in pairs with a classmate (see below for more details). First of all, the children watch a 2.30-minute cartoon (*Chigüiro*, Ivar da Coll, s.d.). After that, in the non-multimodal condition, the whole group interacts with the interventionist: they will go over the different macrostructure elements of the narrative, will discuss how the different characters reacted and felt, and how the children would react and feel in a similar situation. Finally, the children will be separated into pairs and will be given different cards with images about the story and will have to talk about the different elements of the narrative. Specifically, in the multimodal condition, when the interventionist conversates with the children about the characters and the story, he/she will use multimodality by embodying the actions, reactions, and feelings, and he/she will tell the children not to only talk about the narrative, but also to enact the situation with multimodal cues (e.g., hand gestures, body movements, facial expressions, prosodic cues). Also, in the third step, the children will be encouraged to use these multimodal cues when talking to each other and conversating about the narrative, as they have done with the teacher (see Appendix V for a sample script of an intervention session). Figure 7 below shows the procedure of the intervention in both non-multimodal and multimodal conditions. The use of multimodal language (e.g., on which targets will multimodal cues be placed) in each intervention session will first be piloted and then will be detailed in the materials for the teachers conducting the sessions.



Figure 7. Top panels: Steps in each intervention session in the non-multimodal condition. Bottom panels: Steps in each intervention session in the multimodal condition. Images are examples.

The intervention sessions will last about 30 minutes, including 3 minutes to watch the narratives, 15 minutes of interaction with the teacher, and 12 minutes for the children to conversate in pairs. The whole intervention will consist of eight sessions, which will be twice a week, with at least a day without intervention in between. In the first four sessions, the participants will practice with stories with two main characters, while the last four will have three and four characters. Even though this is our initial target number of sessions, it can be susceptible to change following the results from Study 3.

3.5.2. Data analysis

In this study, we will conduct two different analyses using a Generalized Linear Mixed Model analysis with IBM SPSS Statistics (Version 26.0, IBM Corp., 2019). We will analyze a) the effectiveness of the treatment in the classroom context by comparing the results from the pre-intervention to the post-intervention of the three groups; b) the differences between the three groups, as well. We will also examine the impact of the intervention on the different areas (pragmatics, narrative skills and social cognition) measured pre-and post-intervention; c) the maintenance and transfer gains in the post-intervention; and d) whether the non-TD participants that will have received the individualized intervention (Study 3) show greater improvements according to the maintenance probes.

3.5.3. Expected results

First, we believe that there will be a significant difference pre- to post-intervention when comparing the two experimental (multimodal and non-multimodal) with the control (no intervention), showing that the groups who receive the intervention will improve their narrative and pragmatic abilities after the treatment, while the control group will not show any improvement. Particularly, we expect that the multimodal group will show larger gains than the non-multimodal condition. We expect that maintenance and transfer effects will be visible in the delayed post-intervention, in the two experimental groups, but with higher improvements for the multimodal group.

Also, we expect that ASD and DLD participants, which will have previously received the individual intervention one or two months before (see Study 3), will be able to attain further improvements. If this is the case, the present multi-tiered intervention will demonstrate the importance and the need for more inclusive and multi-tiered treatments, showing that atypical populations can benefit more from these treatments if they receive support from different settings.

4. WORK PLAN

This section describes the work that has been done during the course of this academic year (see 4.1) and the work that will be conducted in the following months and years until the defence of this PhD thesis (see □). Table 4 below shows a summary of the work plan for this PhD thesis.

4.1. Previous work

4.1.1. Academic year 2020-2021

- Attendance to online course “Intervención en la dimensión pragmática del lenguaje” organized by the Asociación Española de Logopedia, Foniatría y Audiología e Iberoamericana de Fonoaudiología (Spanish Association of Logopedics, Phoniatics and Audiology, and Ibero-American of Phonoaudiology)
- Organization of experimental design for **Studies 1, 2, 3 and 4**
- Data collection (selection of articles for the review) for **Study 1**
- Analysis of the data for **Study 1**
- Oral presentation at the conference *Gesture and Speech in Interaction (GeSpIn)*. Title: “The development and temporal integration of co-speech gesture in narrative speech: a longitudinal study”. Co-authors: Ingrid Vilà-Giménez, Patrick Louis Rohrer, Pilar Prieto
- Oral presentation at the *Gestures and Head Movements (GEHM)* plenary meeting. Title: “Crosslinguistic analysis of gesture development in narrative speech”. Co-authors: Maria Graziano, Ingrid Vilà-Giménez, Patrick Louis Rohrer, Pilar Prieto
- Oral presentation at the *Budapest CEU Conference on Cognitive Development (BCCCD21)*. Title: “The development of non-referential gestures and the ability to mark IS in narrative speech: A longitudinal study”. Co-authors: Ingrid Vilà-Giménez, Patrick Louis Rohrer, Pilar Prieto
- Oral presentation at the *18th World Old Conference on Phonology (OCPI8)*. Title: “Referent’s information status, pitch accentuation, and gestural marking in children’s narratives: a longitudinal perspective”. Co-authors: Ingrid Vilà-Giménez, Patrick Louis Rohrer, Pilar Prieto
- Writing of an article to a peer-reviewed journal. Title: “Multimodal development in children’s narrative speech: A longitudinal study of referential and temporal aspects of co-speech gesture”. Co-authors: Ingrid Vilà-Giménez, Patrick Louis Rohrer, Pilar Prieto.
- Writing and submission of an article to a peer-reviewed journal. Title: “Non-referential gestures mark discourse-new referents in children’s narrative speech”. Co-authors: Patrick Louis Rohrer, Ingrid Vilà-Giménez, Pilar Prieto. Journal: *Frontiers in Psychology*
- Writing and submission of **PhD Research Plan**

4.2. Following work

4.2.1. Academic year 2020-2021

May-July 2021

- Defense of **PhD Research Plan**
- Establish contact with CDIAPs and schools for conducting **Studies 2, 3 and 4**
- Carrying out of pilots for **Studies 2, 3 and 4**
- Analysis of the data for **Study 1**
- Begin writing for **Study 1**
- Attendance to online course “Atención temprana en el contexto del Trastorno del Espectro del Autismo (TEA)” organized by Hospital Sant Joan de Déu, June 1 - July 6
- Attendance to the Symposium on Research in Child Language Disorders (SRCLD), June 3-4
- Attendance to the Phonetics and Phonology in Europe (PaPE); Virtual conference, June 21-23
- Attendance to the XXXII Congreso Internacional de AELFA-IF; Virtual conference, July 1-3
- Attendance/Presentation to the XIIè Workshop sobre la prosòdia del català; Virtual workshop, July 15
- Attendance to the International Association for the Study of Child Language (IASCL) Conference; Virtual conference, July 15-25

4.2.2. Academic year 2021-2022

September-December 2021

- Writing for **Study 1**
- Preparation of the materials for **Studies 2, 3 and 4**
- Carrying out of pilots for **Studies 2, 3 and 4**
- Training to the speech-language therapists and kindergarten teachers carrying out the intervention sessions for **Studies 3 and 4**
- Attendance/Presentation to the 1st International Developmental Language Disorder Research Conference; Virtual conference, 20-22 September
- Attendance to the 46th Annual Boston University Conference on Language Development; Virtual conference, 4-7 November
- Attendance/Presentation to the 1st International Conference on Tone and Intonation; Sonderborg (Denmark), 6-9 December

January-April 2022

- Data collection for **Study 2** and pre-intervention data collection for **Study 3** at CDIAPs
- Intervention for **Study 3**

- Post-intervention data collection for **Study 3**

May-July 2022

- Delayed post-intervention data collection for **Study 3**
- Data collection for **Study 2** and pre-intervention data collection for **Study 4** at schools
- Post-intervention and delayed post-intervention data collection for **Study 4**
- Analysis of the data for **Study 3**
- Begin writing for **Study 3**
- Attendance/Presentation to Speech Prosody 2022; Lisbon (Portugal), 23-26 May
- Attendance/Presentation to the 9th Conference of the International Society for Gesture Studies. “Gesture: from description to application”; Chicago (United States), 13-15 July
- Attendance/Presentation to Child Language Symposium (CLS); Manchester (United Kingdom), Summer 2022 (dates to be confirmed)

4.2.3. Academic year 2022-2023⁸

September-December 2022

- Writing for **Study 3**
- Analysis of the data for **Study 4**
- Analysis of the data for **Study 2**

January-April 2023

- Begin writing for **Study 4**
- Analysis of the data for **Study 2**
- Begin writing for **Study 2**

May-July 2023

- Writing for **Studies 2** and **4**

4.2.4. Academic year 2023-2024

September-December 2023

- Writing for **Study 2**
- Begin writing **PhD thesis**

January-April 2024

- Writing and submission of **PhD thesis**
- Defense of **PhD thesis**

⁸ During this academic year, I will go on a **research stay** at the Literacy, Language & Communication Laboratory at the University College London under the supervision of Prof. Courtenay Norbury. However, the exact months have not yet been settled.

Table 4. Work plan for the PhD thesis

		2020-2021			2021-2022			2022-2023			2023-2024		
		Term 1	Term 2	Term 3	Term 1	Term 2	Term 3	Term 1	Term 2	Term 3	Term 1	Term 2	Term 3
Study 1	Selection of articles												
	Analysis of the data												
	Article writing												
Study 2	Pilot of the study												
	Data collection												
	Analysis of the data												
	Article writing												
Study 3	Pilot of the study												
	Data collection												
	Analysis of the data												
	Article writing												
Study 4	Pilot of the study												
	Data collection												
	Analysis of the data												
	Article writing												
PhD thesis	Design of studies 1-4												
	Writing of PhD Plan												
	Defense of PhD Plan												
	Writing of PhD Thesis												
	Defense of PhD Thesis												

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APPENDIX

I. Scoring criteria for narrative structure (Demir et al., 2014)

- 0 A narrative with no structure does not even contain a descriptive sequence.
 - 1 A descriptive sequence is a narrative that includes the physical and personality characteristics of an animate protagonist with no mention of a sequence of actions.
 - 2 An action sequence is a narrative with actions described in a temporal order (actions follow one another in time) but in which the actions are not causally organized.
 - 3 A reactive sequence contains actions that are causally organized but does not include the protagonist's goal, the intention of the protagonist to act to achieve a specific end.
 - 4 An incomplete goal-based narrative contains a goal statement and/or an attempt but no outcome following the goal.
 - 5 A complete goal-based narrative with one episode that includes not only temporal and causal structure but also a goal of the protagonist, an attempt to achieve the goal, and an outcome of these attempts.
 - 6 A complete goal-based narrative with multiple episodes includes multiple goal–attempt–outcome sequences.
-

III. Scoring criteria for perspective-taking (Dodd et al., 2011)

- 0 Participant failed to provide a story that was told from the perspective of the identified character (e.g., retells story using third person).
 - 1 Participant provided “some” reference to the character's perspective, such as using a quote.
 - 2 Participant demonstrated emerging role-taking as evidenced by his or her reference and correct use of personal pronouns.
 - 3 Participant referenced the target character's actions and perceptions or any two psychological terms: desire, perception, emotion, emotion-behavior, or cognition⁹.
 - 4 Participant used two or more psychological terms: desire, emotion-behavior, emotion, or cognition.
 - 5 Participant used a minimum of four psychological terms (e.g., desire, perception, emotion, emotion-behavior, cognition), two of which must have been from the cognition category.
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⁹ Psychological terms are the following (Dodd et al., 2011). Desire: *need, care, want, wish, crave, beg*; Perception: *see, hear, notice, watch, smell, spot, feel, look*; Emotion: *hungry, tired, love, sad, exhausted, worry, lonely, starving, surprised*; Emotion-behavior: *cry, kiss, smile, laugh, scream, giggle*; Cognition: *realize, believe, forget, wonder, remember, know, think*; Other: *like, hate*.

III. Scoring criteria for Multimodal Imitation task (Castillo et al., under review)

	<i>Gesture</i>	<i>Prosody</i>	<i>Lexical content</i>
0	The child does not imitate the gesture altogether or does something completely different from the model.	The child does not imitate the prosody altogether or does something completely different from the model.	The child does not imitate the lexical content altogether or does something completely different from the model.
1	The child reproduces the gesture only partially.	The child reproduces the prosody only partially.	The child reproduces the lexical content only partially.
2	The child accurately reproduces the gesture exactly as displayed in the video.	The child accurately reproduces the prosodic pattern exactly as displayed in the video.	The child accurately reproduces the lexical content exactly as displayed in the video.

IV. English transcription of an example script for intervention session, showing the variants corresponding to the two experimental conditions (Study 3)

Non-multimodal condition

Multimodal condition

1. Today we are going to talk about a capybara, named Chigüiro, and his friends the hen and the monkey. First, we will watch a video.

[Interventionist and child watch the cartoon]¹⁰

2. Do you remember what happened first to Chigüiro?

[Waiting for answer]

3. Indeed, he is waiting for the bus to arrive, but when the bus arrives, it passes by. How does Chigüiro feel when the bus passes by? What would you do if you were Chigüiro?

[Waiting for answer]

4. Very good! He is surprised and starts running to catch the monkey. What happened next? Who is waiting for the bus?

[Waiting for answer]

5. Yes, so the hen is waiting for the bus, as Chigüiro, but the monkey once again drives by! How does the hen react?

[Waiting for answer]

6. Indeed, she starts screaming because she is very angry! But then, the monkey stops the bus and the hen gets on the bus and the three of them ride happily on the bus. But then... What happened next?

[Waiting for answer]

7. Very good! How do they feel when they get a hole in the wheel? How would you feel if you were Chigüiro, the hen and the monkey?

3. Indeed, he is waiting for the bus to arrive, but when the bus arrives, it passes by [interventionist represents the action of the bus passing by]. How does Chigüiro feel when the bus passes by? Can you show me how he felt? What would you do if you were Chigüiro?

4. Very good! He is surprised and starts running to catch the monkey [interventionist represents the face of being surprised and the action of running to catch the bus]. What happened next? Who is waiting for the bus?

5. Yes, so the hen is waiting for the bus, as Chigüiro, but the monkey once again drives by! [interventionist represents the action of waiting and the bus passing by]. How does the hen react? Can you show me?

6. Indeed, she starts screaming because she is very angry! [interventionist imitates the voice of the hen screaming and puts an angry face]. But then, the monkey stops the bus and the hen gets on the bus and the three of them ride happily on the bus [interventionist represents the actions of stopping the bus and getting on it with a smiley face]. But then... What happened next?

7. Very good! How do they feel when they get a hole in the wheel? What would you do in this situation? Can you show me? How would you feel if you were Chigüiro, the hen and the monkey? Can you show me how they felt?

¹⁰ Link to the original video:

<https://www.youtube.com/watch?v=7XsVvOW5eJI&list=PLRdCllxNjSVZNqkQuBnXCWEUwIAkYQlxj&index=3>

[Waiting for answer]

8. Finally, how do they solve the problem?

9. Very good! Chigüiro has realized that he has brought a floatable wheel for the beach and that they can use it as a wheel for the bus. Finally, how do you think they felt once the bus starts riding again?

[Waiting for answer]

10. Well done! Now I want you to tell me on your own what happened in the story we have seen.

9. Very good! Chigüiro has realized that he has brought a floatable wheel for the beach and that they can use it as a wheel for the bus [interventionist represents the actions of thinking and then of changing the wheel]. Finally, how do you think they felt once the bus starts riding again? Can you show me how they felt?

10. Well done! Now I want you to tell me on your own what happened in the story we have seen using your body as we have just done.

V. English transcription of an example script for intervention session, showing the variants corresponding to the two experimental conditions (Study 4)

Non-multimodal condition

Multimodal condition

1. Today we are going to talk about a capybara, named Chigüiro, and his friends the hen and the monkey. First, we will watch a video.

[Interventionist and children watch the cartoon]¹¹

2. Do you remember what happened first to Chigüiro?

[Waiting for answers]

3. Indeed, he is waiting for the bus to arrive, but when the bus arrives, it passes by. How does Chigüiro feel when the bus passes by? What would you do if you were Chigüiro?

[Waiting for answers]

4. Very good! He is surprised and starts running to catch the monkey. What happened next? Who is waiting for the bus?

[Waiting for answers]

3. Indeed, he is waiting for the bus to arrive, but when the bus arrives, it passes by [interventionist represents the action of the bus passing by]. How does Chigüiro feel when the bus passes by? Can you show me how he felt? What would you do if you were Chigüiro?

4. Very good! He is surprised and starts running to catch the monkey [interventionist represents the face of being surprised and the action of running to catch the bus]. What happened next? Who is waiting for the bus?

¹¹ Link to the original video:

<https://www.youtube.com/watch?v=7XsVvOW5eJI&list=PLRdCllxNjSVZNqkQuBnXCWEUwIAkYQlxj&index=3>

5. Yes, so the hen is waiting for the bus, as Chigüiro, but the monkey once again drives by! How does the hen react?

[Waiting for answers]

6. Indeed, she starts screaming because she is very angry! But then, the monkey stops the bus and the hen gets on the bus and the three of them ride happily on the bus. But then... What happened next?

[Waiting for answers]

7. Very good! How do they feel when they get a hole in the wheel? How would you feel if you were Chigüiro, the hen and the monkey?

[Waiting for answers]

8. Finally, how do they solve the problem?

9. Very good! Chigüiro has realized that he has brought a floatable wheel for the beach and that they can use it as a wheel for the bus. Finally, how do you think they felt once the bus starts riding again?

[Waiting for answers]

10. Well done! Now, get in pairs. You need to talk about the story of Chigüiro, the hen and the monkey, and you need to talk as if you were one of the characters.

5. Yes, so the hen is waiting for the bus, as Chigüiro, but the monkey once again drives by! [interventionist represents the action of waiting and the bus passing by]. How does the hen react? Can you show me?

6. Indeed, she starts screaming because she is very angry! [interventionist imitates the voice of the hen screaming and puts an angry face]. But then, the monkey stops the bus and the hen gets on the bus and the three of them ride happily on the bus [interventionist represents the actions of stopping the bus and getting on it with a smiley face]. But then... What happened next?

7. Very good! How do they feel when they get a hole in the wheel? What would you do in this situation? Can you show me? How would you feel if you were Chigüiro, the hen and the monkey? Can you show me how they felt?

9. Very good! Chigüiro has realized that he has brought a floatable wheel for the beach and that they can use it as a wheel for the bus [interventionist represents the actions of thinking and then of changing the wheel]. Finally, how do you think they felt once the bus starts riding again? Can you show me how they felt?

10. Well done! Now, get in pairs. You need to talk about the story of Chigüiro, the hen and the monkey, and you need to talk as if you were one of the characters. And remember, use your body as we have just done.