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Communication development from an intersubjective perspective: Exploring the use of a layered communication model to describe communication development in students with congenital deafblindness

Kirsten Wolthuis^{a,*}, Gerard W. Bol^b, Alexander Minnaert^a, Marleen J. Janssen^a

^a Faculty of Behavioral and Social Sciences, University of Groningen, Department of Special Needs Education and Youth Care, Grote Rozenstraat 38, 9712 TJ, Groningen, the Netherlands

^b Faculty of Arts, University of Groningen, Neurolinguistics and Language Development, Oude Kijk in 't Jatstraat 26, 9712 EK, Groningen, the Netherlands

A B S T R A C T

This exploratory study conducts a quantitative investigation on the communication development of students with congenital deafblindness (CDB). First, a layered communication model (LCM) is introduced, describing communicative behaviors based on three layers of intersubjective development for typically developing children (Bråten & Trevarthen, 2007). Subsequently, an analysis is made of how applicable the LCM is for children with CDB. Video recordings of four dyads of students with CDB with varying developmental ages and their teachers are coded using ten-second partial interval coding. The presence of LCM behaviors, the student and teacher contributions to communication, and the development over a half-year period are described and compared between dyads. The results reflected the developmental differences between dyads. At the primary layer, all behaviors occurred a comparable number of times between dyads, which confirms that this is a basic communication layer. Quantitative differences between dyads were encountered between and within the secondary and tertiary layers. Teacher contribution was higher for students with lower developmental ages compared to students with higher developmental ages. Also, teacher contribution was higher for the secondary and tertiary layer behaviors of the LCM compared to the primary layer behaviors. No increase was found in the behaviors over the half-year period. Results suggest that the LCM can be used to gain insight into the communication level of a dyad, hereby paving the way for intervention studies to improve communication development.

1. Introduction

Deafblindness is a term used to describe people with varying degrees of hearing and vision impairments. It is a very heterogeneous population that is defined in this study according to the Nordic definition which states that “*deafblindness is a distinct disability. Deafblindness is a combined vision and hearing disability. It limits activities of a person and restricts full participation in society to such a degree that society is required to facilitate specific services, environmental alterations and/or technology*” (Dammeyer, 2010, p. 76). This functional definition focuses both on the impact of the double sensory impairment on daily life (e.g. communication) and on the medical assessment of vision and hearing.

Scientifically, the area of deafblind education is still at an early stage. In recent review studies about communication and literacy in students with deafness, blindness, hearing impairments, and deafblindness, several methods and approaches for deafblind education are described (Bruce, Nelson, Perez, Stutzman, & Barnhill, 2016; Luckner, Bruce, & Ferrell, 2015). Most approaches build on

* Corresponding author.

E-mail addresses: k.wolthuis@rug.nl (K. Wolthuis), g.w.bol@rug.nl (G.W. Bol), a.e.m.g.minnaert@rug.nl (A. Minnaert), h.j.m.janssen@rug.nl (M.J. Janssen).

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the view that interaction between the environment and the child has considerable impact on communication and language development (Bronfenbrenner, 1979; Sameroff, 2009).

A distinction can be made between ‘systematic instructional approaches’ and ‘child-guided approaches’ (Bruce et al., 2016). The ‘systematic instructional approaches’ are grounded in the principles of behavioral theory applied in different augmentative and alternative communication interventions and proved to be useful in improving the abilities of people with deafblindness in three main areas of communication: rate of expressive communication, range of communicative functions, and vocabulary across forms (Brady & Bashinski, 2008; Heller, Ware, Allgood, & Castelle, 1994; Schweigert & Rowland, 1992; Sigafos et al., 2008). These approaches focus directly on the abilities and skills of the child with deafblindness.

The child-guided approaches are characterized by strategies of communication partners which are attuned to the child. Examples of important partner strategies are establishing trust, responding to the child’s interests, and responding to attempts at communication using the child’s expressive forms (see for more examples Bruce et al., 2016; Damen, Janssen, Ruijsenaars, & Schuengel, 2015; Janssen, Riksen-Walraven, & Van Dijk, 2003a, 2003b; Janssen, Riksen-Walraven, Van Dijk, & Ruijsenaars, 2011; Nelson, Van Dijk, McDonnell, & Thompson, 2002). Some child-guided approaches are based on attachment theory and other developmental psychological theories, emphasizing the importance of the affective relationship shared by the child with deafblindness and the hearing and sighted communication partner (Janssen et al., 2003a; Stern, 1998; Trevarthen & Hubley, 1978; Trevarthen, 1993).

Communication is viewed and defined as a form of mutual interaction in which meaning is transmitted and shared by the use of utterances that are perceived, interpreted, and elaborated by the communication partner (Bjerkman, 1996; Janssen et al., 2003a). In this communication approach, the sensitive and responsive competences of the communication partners are seen as crucial for the child’s learning and motivation (Trevarthen & Aitken, 2001).

As Bruce et al. (2016) stated, individualized programming and intervention should reflect an understanding of the levels of communicative development and the process of symbolization. In some existing models, this development towards symbolization has already been embedded (Bashinski, 2011; Bruce, 2005a, 2005b; Hartmann, 2013; MacFarland, 1995; Rowland, 2011; Van Dijk, 1967). However, no intervention studies have looked at training communication partners of people with deafblindness to understand the developmental stages so they can determine the next aim or goal in communication interventions or monitor communication development. Since it is mandatory that student development be monitored and documented (UNESCO, 1994), a model is needed that can monitor communication development in students with congenital deafblindness (CDB). Teachers must know a student’s current communication level to be able to set appropriate goals. Also, when students make the transition from a school situation to a working or care situation, people in the new environment need to know their current communication level.

The intersubjectivity theory of Trevarthen (Trevarthen & Hubley, 1978; Trevarthen, 1993) was chosen in earlier intervention studies because of its focus on interpersonal communication development and its strong focus on child-guided partner strategies. This theoretical perspective was first used in several *practice-based* studies on deafblindness (Daelman, Nafstad, Rødbroe, Souriau, & Visser, 1999; Janssen & Rødbroe, 2007; Rødbroe & Souriau, 1999), and was used more recently to develop *evidence-based* interventions in deafblind studies (Boers, 2015; Bloeming-Wolbrink, Janssen, Ruijsenaars, Menk, & Riksen-Walraven, 2015; Bloeming-Wolbrink, Janssen, Ruijsenaars, & Riksen-Walraven, 2018; Damen, Janssen, Huisman, Ruijsenaars, & Schuengel, 2014, 2015; Janssen, Riksen-Walraven, van Dijk, Ruijsenaars, & Vlaskamp, 2007; Janssen, Riksen-Walraven, van Dijk, & Ruijsenaars, 2010; Janssen et al., 2011; Martens, Janssen, Ruijsenaars, Huisman, & Riksen-Walraven, 2014). It provides researchers and clinical support staff and parents who approach deafblindness from developmental and socio-cognitive perspectives with a coherent set of principles, insights, and skills that can guide them in understanding the development of communication and in improving their skills in communication with people who are deafblind (Damen et al., 2015). Many studies in typically developing children have revealed that it is a child’s natural “self-other awareness”, engaging the interest and motivation of affectionate parents, that leads a child towards the development of trust in their parents, acts of meaning, and eventually to advanced communication and language (Bråten & Trevarthen, 2007; Linell, 2009; Trevarthen & Aitken, 2001; Trevarthen & Hubley, 1978). This strong evidence from studies in typical development makes a comparison possible and may help to clarify the specific adaptations and challenges faced by people with deafblindness.

Intersubjective communicative development is viewed in three different layers of primary, secondary, and tertiary intersubjectivity. The layers can be seen as key steps that prepare the way for and support the elaboration of higher order competencies in communication, thinking, and language (Bråten & Trevarthen, 2007; Linell, 2009). The layers emerge in a sequential order in typical development, and occur simultaneously in life experiences and play a role throughout life. The first layer of mutual interactions and affect attunement forms the basis for the other higher order developmental layers (Bråten & Trevarthen, 2007; Trevarthen & Aitken, 2001; Trevarthen & Hubley, 1978). Deafblind studies also hypothesize that the first layer is the basis for further communication (Janssen et al., 2003a, p. 198), but this has not yet been demonstrated.

In the following section of this study, the three layers of intersubjective development will be discussed in detail, and characteristic communication behaviors described for each layer based on research on typically developing children. The overview of these communicative behaviors will be presented in a Layered Communication Model (Table 1), which will be used in this study to explore the communication development of students with congenital deafblindness.

1.1. Introduction of the layered communication model

1.1.1. Primary intersubjectivity

The first layer of intersubjectivity starts at birth. This discovery was made possible by technological progress in the 1970s, which enabled researchers to make frame-by-frame analyses of video recordings. These recordings of naturally occurring conversations

Table 1
The Layered Communication Model: characteristic behaviors for each layer of intersubjective communication development.

Layer of inter-subjective development	Average age in typical development	Characteristic behaviors	Description	References from studies on typically developing children ^a	References from children with CDB
Primary layer	0-9 months	(Neonatal) imitation	Imitating other people's facial expressions and other movements	Kugiumutzakis (1998), Meltzoff and Moore (1977), Nagy and Molnar (2004), Trevarthen and Aitken (2001)	Hart (2006)
		Mutual attention	Sharing attention to each other or to the shared activity	Trevarthen and Hubley (1978)	Bloeming-Wolbrink et al. (2015, 2018), Boers (2015), Janssen et al. (2003a, 2003b)
		Affective involvement	Sharing positive and negative emotions	Bråten and Trevarthen, (2007)	Bloeming-Wolbrink et al. (2015, 2018) Boers (2015), Damen et al. (2014, 2015), Janssen et al. (2003a, 2003b), Martens et al. (2014, 2016)
	9-18 months	Turn-taking	Alternating turns in interactions like songs and games	Bråten and Trevarthen (2007), Trevarthen (1979)	Janssen et al. (2003a, 2003b, 2007, 2010, 2011)
		Joint attention	Focusing on an object or sharing it with others outside the dyadic child-parent interaction	Tomasello (1995)	Hart (2010)
Secondary layer		Imitative learning	Learning to use objects by imitating others who are using those objects	Trevarthen and Aitken (2001)	
		Naming objects	Using and understanding symbols for objects or people that are directly present	Bråten and Trevarthen (2007)	Daelman et al. (1999), Souriau et al. (2009)
Tertiary layer	From 18 months	Symbolic communication	Making and understanding conversations about absent things and people Talking about future and past events Talking about wishes and desires Discovering deceit (lying and joking)	Bråten and Trevarthen (2007), Linell (2009)	Boers (2015), Damen et al. (2014, 2015, 2017)
	From 3-4 years to 6 years	Perspective-taking	Attributing false beliefs to others Understanding others' minds and emotions	Bråten and Trevarthen (2007), Linell (2009)	
			Exhibiting prosocial behavior Roleplaying		

^a The references listed here are all relevant sources from the running text, and do not present an exhaustive overview.

showed that the timing and expressions of very young babies and their mothers were similar to those used by adults in conversations; this sort of communication was first named protoconversation by Bateson in (1971). Several studies demonstrated that both mother and child took turns displaying and attending, convincingly indicating that “the infant proved to possess an active and immediately responsive conscious appreciation of the adult’s communicative intentions” (Trevarthen & Aitken, 2001, p. 5). This formed the basis for the definition of primary intersubjectivity (Trevarthen, 1979). Within this primary layer, four characteristic communication behaviors can be distinguished (see Table 1).

The first behavior—*turn-taking*—is based on reciprocity and alternating turns between mother and child. Without any formal language, children as young as two-months old (Trevarthen, 1979) can initiate actions in others and respond to their behaviors (e.g., in person-person games or songs). This helps infants be aware of others. Songs and games that are offered in a teasing or provocative way elicit initiatives from the baby (Bråten & Trevarthen, 2007). For infants with CDB, songs and games can be tactically adapted and initiation can be evoked from the infant by waiting and building up tension through repetitions and narrative games and songs (Janssen et al., 2003a, 2003b, 2007, 2010, 2011; Souriau, Rødbroe, & Janssen, 2009).

Clinical tests have revealed other intersubjective behaviors, further proving infants’ emotional awareness of others. When a mother deliberately disrupts interaction—for example, in a still-face test (Murray & Trevarthen, 1985; Murray, 1980; Trevarthen, Murray, & Hubley, 1981; Tronick, Als, Adamson, Wise, & Brazelton, 1978)—the mother’s unresponsiveness leads the infant to become distressed and avoidant. Similar reactions have been found in studies that use a double video link in which infants communicate with their mothers through a TV screen. After fluent communication between the two has been achieved, a one-minute recording of the mother is replayed to the infant, so that her reactions do not match the infant’s initiatives and reactions. As in the still-face test, children responded in a distressed manner. Both these clinical tests and the analysis of natural communication provide evidence that infants who are only a few months old are aware of and responsive to the communicative intentions of others (Trevarthen & Aitken, 2001).

The Layered Communication Model (LCM) describes the synchrony between mother and child in sharing emotions and attention as two other characteristic communication behaviors of the primary layer of intersubjectivity. The first is *mutual attention*, in which communication focuses on sharing movements and facial expressions with no interference from objects or other people. Even though most infants start to display interest in objects at six months of age, they are not yet capable of sharing these *with* others: “infants under 9 months share themselves with others, but not their knowledge or intentions about things” (Trevarthen & Hubley, 1978, p. 184). *Mutual attention* is an act in which both interaction partners pay attention to each other. This can often be seen in shared eye contact or a shared focus on an activity. Children with CDB may require physical contact to achieve and maintain mutual attention, but earlier studies show it is possible to demonstrate mutual attention in people with CDB (Bloeming-Wolbrink et al., 2015, 2018; Boers, 2015; Janssen et al., 2003a, 2003b).

Another finding of the clinical tests is an emotional awareness between infants and familiar others. Infants express a readiness to share emotions, and distress emerges when parents’ emotional reactions do not match their infants’ intentions (Bråten & Trevarthen, 2007). For the model, this is labeled *affective involvement*, which can be defined as “the mutual exchange of emotions between people” (Martens, Janssen, Ruijsenaars, Huisman, & Riksen-Walraven, 2016). Affective involvement arises spontaneously in typical development and is mainly supported by hearing and seeing. It is important that the interaction partners of children with CDB actively foster affective involvement, since these children cannot directly hear or see others’ responses to their emotional expressions (Martens et al., 2014).

Imitation is the last characteristic communication behavior of primary intersubjectivity. Several studies have examined the reactions of very young babies (some only a few hours old) to acts of their parents, such as tongue protrusion or facial expressions (Meltzoff & Moore, 1977). They discovered that even the youngest babies could imitate these movements. Imitation is used as a form of social interaction, to maintain lively communication with each other (Hart, 2006; Kugiumutzakis, 1998; Nagy & Molnar, 2004; Trevarthen & Aitken, 2001). Children with CDB may find imitation through hearing and seeing difficult or even impossible, so they may require multimodal or multisensory adaptations. For example, a child with CDB might be able to feel the movements the other person makes when saying words and repeat these movements with his or her hands (Van Dijk & Janssen, 1993).

1.1.2. Secondary intersubjectivity

Secondary intersubjectivity is defined as the start of sharing objects in a person-person-object triadic interaction (Trevarthen & Hubley, 1978), which emerges in typically developing children around nine months. Three characteristic communication behaviors in this layer are described in the LCM (Table 1).

The first is *joint attention*, which involves the child and adult coordinating mutual engagement with their mutual focus on a third entity (Tomasello, 1995). Infants can use gazing, pointing, showing, or grasping to indicate their interest in something outside the dyadic interaction which evokes a reaction from the other. Because of the large role assigned to gaze direction in joint attention, blind children were long regarded as incapable of this behavior. However, several studies argue that joint attention is possible for blind children, but they might acquire it later and differently than do sighted children (Bigelow, 1995, 2003; Pérez-Pereira & Conti-Ramsden, 1999; Preisler, 1991). For example, they can learn it through hearing or feeling objects rather than looking at them. Such adaptations might also be feasible for children with CDB (Hart, 2010).

Joint attention is a precursor to *naming objects*, which is the second characteristic behavior for the model at the secondary layer of intersubjective development. Around their first birthday, children start using words to refer to an object, and soon after they start to combine words to indicate what they want to say about the object or what they want others to do with it. Combination of words like “ball red” or “car want” could indicate that the ball is red and that the adult should hand the child the toy car (Bråten & Trevarthen, 2007). Not all children with CDB acquire a form of language, but most of them are capable of naming objects in a certain way or

modality (Daelman et al., 1999; Souriau et al., 2009). A child with CDB might be able to use a tactile sign or pictogram to ask for an object or gain information about it.

Bråten and Trevarthen (2007) point out a third characteristic behavior in the secondary layer of intersubjectivity: *imitative learning*. That describes the point at which a baby starts to imitate sounds and gestures, as well as other people's actions (Trevarthen & Aitken, 2001). The difference between imitation in this layer and imitation in the first layer is the involvement of objects. The social function of using imitation to maintain contact by imitating the expressions and emotions of others changes to a more cognitive function that infants use to learn new actions by copying those of others. The infant thus demonstrates what Bråten (1998) and Stern (2004) call other-centered participation or altercentricity. Because children with CDB have difficulty hearing and seeing others using objects, imitative learning might occur less spontaneously in this population. Children with CDB might need more explicit help in learning how to use objects.

1.1.3. Tertiary intersubjectivity

A tertiary layer of intersubjective development was introduced by Bråten and Trevarthen (2007). They state that tertiary intersubjectivity starts with advanced linguistic skills (e.g., interpersonal conversation mediated by symbols and concepts), which mostly starts around eighteen months, and the beginning of perspective-taking which most children acquire when they are between three to six years. For the LCM, two characteristic communication behaviors are described (Table 1).

The first characteristic behavior—*symbolic communication*—is the ability to communicate about things or people that are not directly present. It can be distinguished from naming objects in the secondary layer by the abstract nature of what is being communicated. In addition to the ability to communicate about absent things and people, symbolic communication also includes sharing past experiences or expressing wishes and desires for events in the future.

An even more complex communication behavior that emerges in the third layer is the second-order understanding of others' minds (Bråten & Trevarthen, 2007) which the model labels *perspective-taking*. Children learn about the feelings of others and can react to them (e.g., by showing prosocial behavior). They also start to understand that their own desires do not always match those of others; people can have different feelings, emotions, opinions, or desires. Perspective-taking also includes learning about lying and deceiving others and making and understanding jokes. In all kinds of situations, the infant learns to take the perspective of others.

Children with CDB who have acquired a form of language (e.g., tactile sign language) might also be able to communicate about abstract and absent things. (Enlarged or tactile) drawings, pictures, videos or other tools might be necessary at first to support their thinking about abstract things. Taking someone else's perspective may also be possible, but it might require help and explicit explanations since their sensory impairments often make it difficult for them to overhear or observe other people to hear their opinions or see their preferences (Boers, 2015; Damen et al., 2014, 2015, Damen, Janssen, Ruijsenaars, & Schuengel, 2017).

Earlier intervention studies on children and adults with deafblindness based on intersubjective communication development provided most evidence on the primary layer of intersubjectivity. These interventions were performed mainly to address communication problems and to coach communication partners in strategies to improve mutual interaction and affect attunement (Janssen et al., 2003a, 2003b, 2010, 2011). The interventions also proved to be effective for people with deafblindness and intellectual disabilities (Bloeming-Wolbrink et al., 2015; Martens et al., 2016) and people with visual and intellectual disabilities (Damen, Kef, Worm, Janssen, & Schuengel, 2011).

More recent studies have focused on improving partner strategies for shared meaning and symbolic communication, which are at the secondary and tertiary layer of intersubjectivity (Boers, 2015; Damen et al., 2015). These studies found that communication partners could improve the abilities of the people with deafblindness at these higher layers by changing their strategies. It proved important to coach communication partners in the higher layer competences; almost all the secondary and tertiary layer behaviors of the people with deafblindness were preceded by the same types of partner behaviors (Damen et al., 2015).

The present study is the first to focus on all three layers of intersubjective communication at the same time. It provides a framework that helps staff and communication partners to understand the development of communication and to set their own goals in educational interventions. The aim here is to study a) whether all behaviors described in this framework developed for children without impairments can be used to describe and evaluate communication development in children with deafblindness and b) whether this framework is suitable for communication partners in the long term to monitor development and determine goals regarding individual educational plans.

This study takes a quantitative approach, by coding video recordings of four students with CDB with varying developmental ages at four different moments during a half-year period. We use these recordings to explore three aspects of communication between the students with CDB and their teachers.

First, we examine to what extent all LCM behaviors can be coded in communication between students with CDB and their teachers, and in what frequency the different behaviors will be present at the three layers of the model. Second, we examine the contribution of teachers and students in the presence of the different LCM behavior at the three layers. And third, we examine changes in the LCM behaviors over a half-year period, both for the presence of the different behaviors and for the contributions of the teachers in communication.

The above description of the theoretical framework on intersubjective communication development shows there is a hierarchical order in the three LCM layers. This order means we expect to find differences in the presence and frequency of the LCM behaviors between dyads, with students with higher developmental ages showing more behaviors more frequently compared to students with lower developmental ages. Furthermore, we hypothesize that the teachers' contribution relates to the students' developmental ages. The teachers' contribution is expected to be higher in students with lower developmental ages than those with higher developmental ages. In terms of development over time during the half-year period, we expect that some behaviors will occur more often and that

the students' contributions to some behaviors will increase more than the teachers' contributions. It is important to note that these assumptions are mainly based on research conducted on typically developing children. The current study explores whether these developmental patterns can also be found for students with congenital deafblindness.

2. Methods

This study uses the LCM (Table 1) to quantitatively explore the communication development of students with CDB. Video recordings of four students with CDB and their teachers were scored using a coding scheme based on the LCM. Recordings were made in a natural education situation at a school for children with deafblindness, without any specific intervention other than their daily education. Students were selected based on their developmental ages, in such a way that all the layers of the LCM were expected to be represented by at least one student.

2.1. Participants

This study was approved by the ethical committee for Pedagogical and Educational Sciences at the University of Groningen in the Netherlands. The teachers and parents or legal representatives of the students were informed and gave written consent for participation.

Four students with CDB and their teachers from a school for children with deafblindness in the Netherlands participated in this study. The cause of deafblindness and degree of hearing and vision impairment varied widely between students, which is coherent with the overall population of people with CDB (Dalby et al., 2009; Dammeyer, 2014). Dutch schools for children with CDB use the following criteria for their students. They have both a hearing and vision impairment, in which the hearing loss is 35 decibel or more in the better ear when not wearing hearing aids or a cochlear implant. They have vision impairment with a visual acuity of 30% or less, or a purview of 30 degrees or less. Students are also admitted to the school if they have a syndrome or neurological impairment that causes sensory processing issues to such a degree that the student functions as a person with deafblindness. In these cases, the student needs to have the potential to develop a form of communication (Kentalis, 2017). In this study, one student was completely blind, the other three students had residual vision, and all four students had residual hearing (Table 2).

The students' ages ranged from 4 to 17 years at the time of the recordings, and their school files showed estimated developmental ages of between 8 months and 14 years. These developmental ages are estimates, as no diagnostic tests exist specifically for children with CDB. The participating school uses adaptations of diagnostic tests such as the Snijders-Omen non-verbal intelligence test (SON-R) (Tellegen & Laros, 2011), the Dutch version of the Bayles Scales of Infant Development-II (BSID-II) (Ruiter, Van der Meulen, Lutje Spelberg, & Smrkovsky, 2003), and the Southern Californian Ordinal Scales of Development (SCOSD) (Ashurst et al., 1985). The use of different tests and different scales can sometimes cause a wide range in estimated developmental ages of the students, as can be seen in Table 2.

The estimated layer of intersubjective development is based on the students' developmental ages, combined with information from school files and the school's educational psychologist. We wanted to include a student who communicates at the highest layer of the LCM. This is why we included the student from dyad 4, who has a developmental age of between 8 and 14 years, which is higher than the age range at which the highest layer of the model emerges for typically developing children (between 18 months and 6 years).

On average, the teachers had more than 20 years' experience working with children with CDB and all teachers had worked for at least one year with the student described in this study.

2.2. Data collection

We recorded eight videos of each student with CDB communicating with their teachers in a one-on-one situation in the classroom. Teachers were asked to indicate a time in their school day schedule that was dedicated to communicating and interacting with their student, and this chosen activity was repeatedly video recorded over a half-year period. Every six weeks a recording period of two weeks was planned, in which one video recording was made per week of each dyad. This was repeated four times, resulting in a total of eight recordings for each dyad. One of the two videos per recording period was randomly selected for analysis in this study; the other video was used in training sessions to improve interobserver reliability between the two coders.

The duration of the recordings varied from 15 to 30 min. For comparison reasons, we selected ten minutes per recording to analyze with the coding scheme. Selection was made by cutting ten consecutive minutes of the recording in which there was minimal interference from other people or transfer moments within the classroom or to other locations.

2.3. Data coding

Partial interval sampling was used to code the recordings in intervals of ten seconds in two rounds (Table 3). In the first round, the observer coded whether a certain behavior from the LCM was present (1) or absent (0) within an interval. For example, when coding the behavior *mutual attention*, a code 1 was given when the teacher and student paid attention to each other within an interval. Each behavior only had to last for one second to be coded as present. Partial interval sampling has the benefit of capturing all behavior that occurs (MacLaren Chorney, McMurtry, Chambers, & Bakeman, 2014) but it can overestimate behaviors that occur for just a fraction of the interval and underestimate behaviors that occur multiple times within one interval.

Table 2
Characteristics of the participating dyads.

	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Estimated developmental age of the student ^a	8 months	18–24 months	12–25 months	8–14 years
Estimated layer of intersubjectivity ^b	Primary	Secondary	Between secondary and tertiary	Tertiary
Hearing impairment ^c	Moderate hearing impairment without hearing aids, slight with hearing aids	Slight hearing impairment in both ears, no hearing aid	Slight hearing impairment when wearing hearing aids	Moderate hearing impairment in one ear, profoundly deaf in the other
Visual impairment ^d	Mild visual impairment	Completely blind	Completely blind in one eye, low visual impairment in other eye	Mild visual impairment

^a Based on test results of the SON-R (Tellegen & Laros, 2011), the Dutch version of the BSID-II (Ruiter et al., 2003), and the SCOSD (Ashurst et al., 1985). Since these tests are not specially developed for children with congenital deafblindness, the developmental ages of our participants are estimates.

^b Based on school files and the students' educational psychologist.

^c Slight hearing impairment: 26–40 dBHL, Moderate hearing impairment: 41–60dBHL, Severe hearing impairment, 61–80 dBHL, Profound hearing impairment/deafness: 81 dBHL and greater (World Health Organization (WHO, 2001)).

^d Normal vision: visual acuity 1.0-0.8, Mild visual impairment: 0.63-0.32, Low vision-blindness: 0.3-0.0 (World Health Organization (WHO, 2003)).

Table 3

Description of the codes used in the two rounds of the coding scheme.

Round of coding	
1	2
1: LCM behavior is present	A: teacher mainly showed the behavior B: both equally showed the behavior C: student mainly showed the behavior
0: LCM behavior is absent	D: teacher showed the behavior, but student missed or ignored it E: neither showed the behavior F: student showed the behavior, but teacher missed or ignored it

To overcome this disadvantage of interval sampling, we conducted a second round of coding with grouped nominal codes (MacLaren Chorney et al., 2014). This round of coding shows who contributed most to the behaviors that were coded as present or absent in the first round of coding (see Table 3). For example, if the teacher paid attention to the student for the whole interval, but the student was distracted and only paid attention to the teacher for one second, the interval was still scored as present following the rules of interval sampling. The addition of the letter C in the second round of coding indicates that the student's contribution was minimal in this interval. In another example, when the student pointed at something to start an act of joint attention, but the teacher missed it, the interval was coded with a zero for the behavior of *joint attention*. Adding the letter F in the second round of coding explains that it was the student who showed the behavior that was missed by the teacher.

Each of the nine LCM behaviors was coded separately, meaning that one video recording was replayed up to nine times to code all the behaviors. A general coding manual was used for all dyads, but in some cases extra information needed to be added to this manual, because of differences in the students' abilities to hear and see. For example, it is difficult to determine when a completely blind student pays attention to their teacher, so additional agreements were made for when this student showed this behavior. These adjustments were only made during training sessions to improve interobserver reliability.

2.4. Interobserver reliability

Given the complex nature of coding interactions between people with CDB and others, Cohen's Kappa (Cohen, 1960) and percentage agreement (Prain, McVilly, & Ramcharan, 2012) are recommended for determining the interobserver reliability of a coding scheme. Sufficient agreement between coders is considered when the percentage agreement exceeds 80% and Kappa is higher than .60 (Prain et al., 2012).

For each dyad, three training recordings were scored by both the first author and a second coder. Only during training sessions, remarks could be added to the manual, in order to improve agreement. Unfortunately, *imitative learning* could not be scored with sufficient interobserver agreement during training sessions and was therefore omitted from the coding scheme. The training ended after percentage agreement exceeded 80% and Kappa was higher than .60 on all behaviors for a certain dyad. Next, the first observer coded the four recordings of one dyad and the second observer coded half of these to calculate interobserver reliability. This procedure was repeated for each of the four dyads. Recordings per dyad were renamed and randomized in such a way that both observers were unaware of the chronological order in which the videos were recorded.

The results of interobserver agreement on the recordings of this study varied. In the first round of coding, percentage agreement exceeded 80% for all dyads in each of the four recordings when behaviors were combined. However, agreement was lower for some dyads when calculated for each behavior separately. For dyads 1 and 2, agreement varied in some of the four recordings between 65% and 80%, mainly in the *turn-taking* and *joint attention* behaviors. The same results were found when calculating Kappa scores. Agreement between coders in the first round of coding was higher than .60 for all dyads when all behaviors were combined. When agreement was calculated for each behavior separately, Kappa scores varied more. Some behaviors had low Kappa scores (e.g., *imitation* and *mutual attention* for dyad 1 and *affective involvement* for dyads 3 and 4).

In the second round of coding, with six codes assigned, percentage agreement was also higher than 80% for all dyads when all behaviors were combined. Agreement was lower for some of the behaviors for certain dyads (e.g., *affective involvement*, *imitation*, *turn-taking*, and *joint attention*, especially for dyads 1 and 2). Kappa exceeded .60 for each dyad when behaviors were combined, and Kappa scores were more diverse when behaviors were analyzed separately.

2.5. Data analysis

First, we analyzed whether all LCM behaviors could be coded for the four dyads. The first round of coding was used to calculate the percentage of presence of the different LCM behaviors for each dyad. The four recordings per dyad were combined and averages were calculated and presented for the three layers of the LCM. Differences between the dyads were analyzed to examine the extent to which the results reflect the differences in developmental ages between the four students with CDB, and the developmental character of the LCM. Some of the behaviors were expected to be coded less frequently, or not at all, for students with lower developmental ages. Furthermore, behaviors at the higher layers of the LCM were expected to be less frequently coded than behaviors at the lower layers.

Table 4

Percentages of intervals in which each of the behaviors of the LCM was scored as present.

Development layer	Behavior from the LCM	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Primary layer	Affective involvement	16.3	2.5	5.1	7.5
	Imitation	15.1	6.3	15	36.7
	Mutual attention	85.4	83	82.9	99.2
	Turn-taking	81.6	86.7	84.4	96.7
Secondary layer	Joint attention	50.1	57.5	72.4	28.3
	Naming objects	5.4	30	49.4	92.5
Tertiary layer	Symbolic communication	0	0	18.8	81.3
	Perspective-taking	0	0	0	36.7

Second, we analyzed the students' and teachers' contributions to the presence and absence of the different LCM behaviors. The distribution of the codes in the second round of coding was calculated for the intervals in which behaviors were present or absent, to analyze the students' and teachers' contribution in the communication. Again, the dyads were compared to analyze whether there were any differences based on the students' developmental ages and the increasing difficulty of the layers in the LCM. The teachers' contributions was expected to be higher for students with lower developmental ages. Also, the teachers' contributions are likely to be higher in the second and third layers of the LCM compared to the first layer for all four dyads.

Third, to gain more insight into the models ability to describe communication development over time, we analyzed whether changes could be found in communication over the six-month period. The four recordings per dyad were analyzed separately and the percentage of intervals in which the behaviors of each layer were scored as present was calculated and compared between the four recordings for each dyad. We expected that over a half-year period, some behaviors would be more present, and that for some behaviors the students' contributions would increase more than the teachers' contributions.

All calculations were made with the aim of exploring the applicability of the model to describe communication development between students with CDB and their teachers.

3. Results

3.1. The behaviors of the LCM

In the first round of coding, we scored whether an LCM behavior was present (1) or absent (0) within an interval. For each dyad, the percentage of presence of the different behaviors is calculated and summarized in Table 4. Results are presented for each layer of the model.

3.1.1. Behaviors at the primary layer of the LCM

Although all four dyads exhibited each behavior at the primary layer of the LCM, the first two behaviors were coded less frequently than the other two. *Affective involvement* was found in 2.5% (dyad 2) to 16.3% (dyad 1) of the intervals, and *imitation* was found in 6.3% (dyad 2) to 36.7% (dyad 4) of the intervals. *Mutual attention* and *turn-taking* were coded more frequently; the lowest percentage was 81.6% (dyad 1) in *turn-taking* and the highest was 99.2% (dyad 4) in *mutual attention*.

When comparing the four dyads, *affective involvement* was clearly most frequently coded for the first dyad, while this behavior and *imitation* were rarely coded for dyad 2. Apart from *affective involvement*, all other behaviors at the primary layer were scored most frequently for dyad 4.

3.1.2. Behaviors at the secondary layer of the LCM

Both behaviors at the secondary layer, *joint attention* and *naming objects*, were scored for all four dyads. However, large quantitative differences were found in the presence of both behaviors. For the first three dyads, *joint attention* was scored at least 20% more often than *naming objects*, and almost 50% more often for dyad 1. The reversed result was found for dyad 4: *joint attention* was scored almost 60% less often than *naming objects*.

Comparing the four dyads in this layer found an increase from dyad 1 to dyad 3 in the presence of *joint attention* and from dyad 1 to 4 for *naming objects*. The most divergent result in this layer was the low frequency of *joint attention* for dyad 4, which was the lowest of all dyads (28.3%).

3.1.3. Behaviors at the tertiary layer of the LCM

The two behaviors at the highest layer of the LCM could not be scored for all four dyads. Neither behavior was coded for dyads 1 and 2, and only *symbolic communication* could be coded for dyad 3 (but in only 18% of the intervals). Dyad 4 was the only dyad for whom both behaviors were coded at the tertiary layer of the LCM. *Symbolic communication* was present in over 80% of their intervals, while *perspective-taking* was coded in 36.7% of the intervals.

Comparing the four dyads at the tertiary layer shows that these behaviors were scored more often for the dyads with higher developmental ages. Furthermore, the percentage of presence of *symbolic communication* was more than four times higher for dyad 4

Fig. 1. Percentage of intervals in which the behaviors per layer of the LCM were coded as present.

than for dyad 3.

3.1.4. Behaviors of the LCM combined per layer

The percentage of the combined behaviors per layer of the LCM is calculated and presented for each dyad in Fig. 1. This figure shows that the presence of the combined behaviors at the primary layer decreases from dyads 1 to 3, and that the presence of the behaviors at the secondary layer between the same dyads increases. At the tertiary layer, the presence of the behaviors is much higher for dyad 4 than for dyad 3.

For dyads 1 and 2, behaviors at the primary layer were coded more frequently than at the secondary layer, although this is just a small difference for dyad 2. Dyad 3 shows an increase in the presence of behaviors from the primary to the secondary layer, but the presence of behaviors are lowest at the tertiary layer for this dyad. Dyad 4 shows almost similar percentages of presence of behaviors at all three layers.

3.2. Teachers' and students' contributions to communication

The second round of coding examined who contributed most to the presence or absence of the behaviors within each interval: the teacher, the student, or an equal contribution of both. For each dyad, the student's and teacher's contribution was calculated as a percentage of the total number of intervals in which the behaviors were coded as present or absent. Since not all behaviors were coded for each dyad (see Table 4), the total number of intervals varied: from 1440 intervals for dyads 1 and 2, to 1680 for dyad 3 and

Table 5

Teachers' and students' contributions to the presence or absence of behaviors, for all behaviors combined.

Total number of intervals coded	Coding round 1: Behavior coded present (1) or absent (0)	Coding round 2: Reason for coding the behavior as present or absent (teacher's and student's contributions)	Freq.	%
Dyad 1 N = 1440	Present N = 609	1 A: Mainly teacher showed behavior	171	28.1
		1 B: Both showed behavior equally	382	62.7
		1 C: Mainly student showed behavior	56	9.2
	Absent N = 831	0 D: Teacher showed behavior, student missed/ignored	84	10.1
		0 E: Neither showed behavior	732	88.1
		0 F: Student showed behavior, teacher missed/ignored	15	1.8
Dyad 2 N = 1440	Present N = 638	1 A: Mainly teacher showed behavior	182	28.5
		1 B: Both showed behavior equally	408	63.9
		1 C: Mainly student showed behavior	48	7.5
	Absent N = 802	0 D: Teacher showed behavior, student missed/ignored	51	6.3
		0 E: Neither showed behavior	720	89.8
		0 F: Student showed behavior, teacher missed/ignored	31	3.9
Dyad 3 N = 1680	Present N = 792	1 A: Mainly teacher showed behavior	255	32.2
		1 B: Both showed behavior equally	431	54.4
		1 C: Mainly student showed behavior	106	13.4
	Absent N = 888	0 D: Teacher showed behavior, student missed/ignored	82	9.2
		0 E: Neither showed behavior	788	88.7
		0 F: Student showed behavior, teacher missed/ignored	18	2.0
Dyad 4 N = 1920	Present N = 1149	1 A: Mainly teacher showed behavior	286	24.9
		1 B: Both showed behavior equally	757	65.9
		1 C: Mainly student showed behavior	106	9.2
	Absent N = 771	0 D: Teacher showed behavior, student missed/ignored	16	2.1
		0 E: Neither showed behavior	748	97.0
		0 F: Student showed behavior, teacher missed/ignored	7	0.9

1920 for dyad 4. An overview is given in Table 5.

3.2.1. Intervals in which the behaviors were present

In the intervals in which the behaviors were coded as present, code 1B was scored most often for all four dyads (54.4–65.9%). Code 1B signifies that the behaviors were coded as present and that both the student and teacher made an equal contribution to showing the behavior. Code 1A was scored in the second most intervals (24.9–32.2%). In those cases, it was mainly the teacher who showed the behavior and the student either briefly paid attention to the teacher (e.g., *mutual attention*) or passively ‘listened’ or paid attention to the teacher (e.g., *turn-taking* or *naming objects*). Code 1C was the least often scored (7.5–13.4%). In those intervals, the student mainly showed the behavior and the teacher made a more passive contribution.

3.2.2. Intervals in which the behaviors were absent

In the intervals in which the behaviors were coded as absent, code 0E was scored most often. Neither teacher nor student showed the behavior in those intervals (88.1–97.0%).

In the other 3–15% of the intervals in which the behaviors were absent, code 0D (2.1–10.1%) was given more often than code 0F (0.9–3.9%). In these intervals it was more often the student who missed or ignored the teacher than the other way around. However, neither code was frequently scored.

3.2.3. Distribution of students’ and teachers’ contributions

The distribution of the students’ and teachers’ contributions to the presence of the behaviors was comparable for all four dyads (see Table 5). However, this was only true when all the behaviors were combined. When the behaviors were analyzed separately for the three layers of the model, we found differences between the dyads. At the primary layer of the LCM, the teacher’s contribution was around the same percentage for each dyad, but at the secondary and tertiary layer, the teacher’s contribution was larger for students with lower developmental ages than for students with higher developmental ages (Fig. 2). Also, the teacher’s contribution was lowest at the primary layer and increased in the secondary and tertiary layer for dyads 1, 2, and 3. For dyad 4, the teacher’s contribution was more comparable over the three layers.

3.3. Changes in communication over a six-month period

To analyze changes over a six-month period, the videos of the four different recording periods were analyzed separately for each dyad. We calculated and analyzed the percentage of presence of the eight behaviors and their increase over time (Table 6). For dyad 1, we observed an increase over time for the behaviors *mutual attention*, *turn-taking*, and *joint attention*. However, this increase was only shown in the first three recordings; it was followed by a drop in almost every behavior in the fourth recording.

For the other three dyads, the percentage of presence of most behaviors varied widely between the different recordings. The only clear increase between the first to the fourth recording was found for dyad 3 on the behavior of *imitation*.

Another calculation that was made to analyze development over time examined whether the teachers’ contributions would decrease over the four recordings. For each layer of the model, we calculated the proportion of teachers’ contributions in the intervals that were coded as present (see Fig. 3a–d). At the primary and secondary layer of the model a clear decrease can be seen in the teacher’s contribution from the first to the last recording in dyad 3. For the other three dyads, the teachers’ contributions vary between the recordings at each of the three layers of the LCM.

4. Discussion

This exploratory study is the first to use the Layered Communication Model to examine communication development between students with CDB and their teachers at three layers. It was used to quantitatively analyze video recordings of four dyads and revealed interesting results.

Fig. 2. Percentage of teachers’ contributions in the intervals that were coded as present, compared for the three layers of the LCM.

Table 6

Percentage of intervals in which the different behaviors were present for each of the four recordings with six-week intervals during a six-month period.

Behavior	Dyad 1	Dyad 2	Dyad 3	Dyad 4
Affective involvement				
recording 1	5.0	6.7	3.3	11.7
recording 2	33.3	0	1.7	3.3
recording 3	26.7	3.3	8.3	5.0
recording 4	0	0	6.7	10.0
Imitation				
recording 1	15.0	0	10.0	53.3
recording 2	26.3	13.3	15.0	35.0
recording 3	13.3	6.7	16.7	30.0
recording 4	8.3	5.0	18.3	28.3
Mutual attention				
recording 1	88.3	85.0	76.7	100.0
recording 2	98.3	83.3	95.0	98.3
recording 3	97.7	75.0	85.0	98.3
recording 4	63.3	88.3	75.0	100.0
Turn-taking				
recording 1	86.7	91.7	81.7	96.7
recording 2	90.0	85.0	100.0	98.3
recording 3	96.7	78.3	90.0	98.3
recording 4	53.3	91.7	70.0	98.3
Joint attention				
recording 1	45.0	56.7	61.7	21.7
recording 2	50.0	51.7	91.7	26.7
recording 3	70.0	75.0	75.0	36.7
recording 4	35.0	46.7	61.7	28.3
Naming objects				
recording 1	0	25.0	41.7	95.0
recording 2	5.0	46.7	58.3	95.0
recording 3	6.7	3.3	46.7	90.0
recording 4	10.0	45.0	55.0	90.0
Symbolic communication				
recording 1	0	0	16.7	78.3
recording 2	0	0	26.7	86.7
recording 3	0	0	18.3	85.0
recording 4	0	0	13.3	75.0
Perspective-taking				
recording 1	0	0	0	40.0
recording 2	0	0	0	31.7
recording 3	0	0	0	30.0
recording 4	0	0	0	25.0

4.1. The behaviors of the LCM

Given the developmental nature of the model, with the first layer emerging at birth, the second around nine months, and the tertiary layer around the age of eighteen months to four to six years in typically developing children, and the differences in developmental ages between the students, we expected the LCM behaviors of the higher layers to be coded less frequently than behaviors at the lower layers. We also expected the frequency of presence of the LCM behaviors to be lower for the dyads with lower developmental ages than those with higher developmental ages.

Results showed that for dyads 1 and 2 behaviors at the primary layer were coded more often than at the secondary layer. Also for dyad 3, the least present intervals were coded at the highest layer of the model. This was also found for dyad 4, but the differences between the presence of each layer was minimal for this dyad. Next, we found that some behaviors were coded less frequently for dyads with lower developmental ages, but not for all behaviors or all layers. We will discuss the results for each layer of the model next.

At the primary layer of the LCM, all behaviors could be scored for all four dyads. This underlines a core principle of Bråten and Trevarthen's (2007) theory of intersubjective communication development: all communicative behaviors remain operative during life. This is best reflected by the finding that even though the students in dyads 3 and 4 have developmental ages that correspond with the tertiary layer of the model, we also observed behaviors at the primary and secondary layers for these dyads. The three layers of the model build on each other in such a way that as behaviors from higher layers emerge, the behaviors from the lower layers do not disappear. This is also supported by the finding that no large quantitative differences were found in the appearance of the behaviors

Fig. 3. a–d. Percentage of teachers' contribution in intervals coded as present at the three layers of the LCM, in videos recorded at four different times during a half-year period.

at the primary layer between the four dyads. Even though the four dyads represent students with CDB who have different developmental ages, the percentages of presence of the combined behaviors at the first layer were comparable between the four dyads (42–60%).

Quantitative differences were found at the primary layer *between* behaviors. For all four dyads, the behaviors of *affective involvement* and *imitation* were scored in only 2.5–36.7% of the intervals, while *mutual attention* and *turn-taking* were coded in more than 80% of the intervals, and in almost 100% of the intervals for dyad 4 there was *mutual attention*. The large quantitative differences can be explained by the fact that the first two behaviors are more momentous instances that happen during communication, while the last two are more of a continuous nature. Dyad 1 scored highest on *affective involvement* (16.3% of the intervals), which can be explained by this teacher singing songs during the communication moments. These songs were generally emotional, which led to this behavior being coded as present more often than in the other dyads. The high frequency of *imitation* for dyad 4 (compared to the other dyads) can be explained by the amount of sign language used in their communication. They both tended to imitate the signs of the other to request clarity about the sign or to confirm each other's signs. Imitation can be used as a way to maintain lively communication with each other (Hart, 2006; Kugiumutzakis, 1998; Nagy & Molnar, 2004; Trevarthen & Aitken, 2001), but earlier studies on deafblindness also found it could be used to confirm the communicative acts of others (Bloeming-Wolbrink et al., 2018; Damen et al., 2011; Janssen et al., 2003a, 2003b, 2010).

At the secondary layer of the LCM, we found differences between the dyads regarding the quantity of presence of the two behaviors. The frequency of presence increased from dyads 1 to 3 for the behavior of *joint attention* and from dyads 1 to 4 for *naming objects*. These results reflect the differences in the students' developmental ages, and confirm the developmental aspect of the model. The dyads with students with lower developmental ages showed both behaviors less often than the dyads with students with higher developmental ages.

Results also showed large quantitative differences *between* the two behaviors at the secondary layer. For almost all the dyads, *joint attention* was scored much more often than *naming objects*. According to Bråten and Trevarthen (2007), *joint attention* emerges in typically developing children around the age of nine months, while the first words are usually uttered around an infant's first birthday. This developmental aspect between the two behaviors is reflected by the difference found in frequency of presence of the behaviors for the students with CDB. Consequently, the behaviors at the secondary layer can be used to describe developmental differences between dyads.

A divergent result at the secondary layer was the low frequency of *joint attention* for dyad 4. Again, this can be explained by their use of sign language to communicate. This dyad uses (tactile) signs to refer to objects, instead of using the actual objects to communicate about them. The other dyads use (tactile) sign language less and therefore need to share the object itself (e.g., point at it, feel it) to communicate about it.

At the tertiary layer, neither behavior was found for dyad 1 or 2, which corresponds with the students' estimated developmental ages. Dyads 3 and 4 showed both behaviors in this layer, but they also showed quantitative differences in favor of dyad 4. These results emphasize the developmental nature of the model; behaviors are more often coded as present for the dyads with higher developmental ages.

Just as in the secondary layer, the results also reflect a developmental pattern *within* the tertiary layer. *Perspective taking* was coded less often than *symbolic communication* (and not at all for dyad 3). Research on typically developing children shows that children first learn to communicate about absent things and past and future experiences, and they achieve *perspective taking* in a later stage (around the ages of three to six years) (Bråten & Trevarthen, 2007; Linell, 2009). Coding with the LCM shows these same differences between students with CDB and their teachers. The quantitative differences between the two behaviors at the tertiary layer of the model can be used to distinguish between the communicative levels of the students with CDB.

4.2. Students' and teachers' contributions to communication

Students with CDB largely depend on other people's ability to understand them and make the world around them understandable (Janssen et al., 2003a). A second round of coding was conducted to find out more about the students' and teachers' contributions to the presence of the different LCM behaviors. For the intervals in which behaviors were coded as present, we scored whether this behavior was mainly shown by the teacher, by the student, or equally by both. Based on the developmental differences between the students, the contribution of teachers was expected to be highest for dyad 1 and lowest for dyad 4. Furthermore, given the developmental nature of the model, we expected to find an increase in the contribution of the teacher from the primary to the tertiary layer of the LCM for each dyad.

Results showed that when all behaviors of the LCM were combined, no differences could be found in teachers' contribution between the dyads. For all four dyads, in around 30% (25–32%) of the intervals in which behaviors were coded as present, it was mainly the teacher who showed the behavior and the student had a more passive role (e.g. listening to, waiting for, or looking at the teacher). However, when behaviors were combined per layer of the model, differences between dyads could be found at the secondary and tertiary layer of the LCM. At the primary layer, the contribution of the teacher was similar between all four dyads (32–36%). This again confirms that the primary layer is a basic layer for all communication development regardless of students' developmental ages (Bråten & Trevarthen, 2007; Trevarthen & Aitken, 2001).

At the secondary layer, differences could be found in the teachers' contribution between the dyads. In more than 60% of the intervals that were coded as present for dyad 1, the teacher mainly showed the behavior, while this was the case in only 30% of the present intervals for dyad 4. Also, a clear decrease was found in the teachers' contribution from dyad 1 to dyad 4. This indicates that the lower the student's developmental age, the more often behaviors are mainly shown by the teacher, rather than being equally shown by the dyad or mainly by the student.

At the tertiary layer the same pattern was found. For dyad 3, 62% of the intervals at this layer were coded as present because the teacher mainly showed the behavior, while this was only the case in 41% of the intervals for dyad 4. This also confirms that students with lower developmental ages depend more on their teacher than students with higher developmental ages.

Results also show that for dyads 1, 2, and 3, the contribution of the teachers is lowest in layer 1 and increases in the second (for dyads 1 and 2) and third (dyad 3) layers. These results show that the teachers' contributions become larger as the difficulty increases in the layers of the model. This coheres to earlier studies, which found that people with CDB are only able to show behaviors from the secondary and tertiary layer after the interaction partner first shows these behaviors (Damen et al., 2015). Teachers need to contribute more in communicative behaviors at the higher layers to stimulate students with CDB to show these behaviors. For dyad 4, the contribution of the teacher was comparable at all three layers. We included this student in our study to ensure the inclusion of a student communicating at the tertiary layer. The small differences in the teacher's contribution between the three layers for this student indicates that this dyad acquired all behaviors to the same extent, and that this student does not need much support from its teacher to show communicative behaviors at the three layers of the model.

4.3. Changes in communication over a six-month period

Finally, we examined whether changes over a six-month period could be detected, to learn whether the model can be used as an instrument to describe development over time. We expected behaviors would be more frequently coded as present during the half-year period. Also, we expected that the teachers' contribution would decrease over time in the intervals in which behaviors were coded as present. An increase in presence of behaviors was only found in the results for dyad 3 on the behavior of *imitation*. For all other dyads, the frequency of the presence of all behaviors varied between the four recordings and no increasing pattern could be found over time.

Results of the second round of coding gave insights into the teachers' contributions in the presence of the behaviors. Behaviors were expected to be coded less often because the teachers mainly showed them and more often because of an equal contribution of student and teacher or because it was mainly shown by the student. The results for dyad 3 reflect this pattern. At the secondary layer, the teacher's contribution clearly decreases from 56% to 37% of the intervals during the four recordings. This shows that over time, the teacher started acts of *joint attention* or *named objects* less often and that this student contributed more to these behaviors over time. When excluding the first recording, the same pattern was found for dyad 3 at the tertiary layer. The other dyads showed more varied frequency patterns in the teachers' contributions.

4.4. Limitations

This study quantitatively examined the applicability of a model described for typically developing children to students with CDB. Quantitative measures were used to improve the reliability of the data and examine the possibilities of the model being used to describe communication levels of students with CDB.

The use of video recordings has been beneficial, especially in terms of the ability to analyze recordings multiple times in detail and to obtain more objective data through the ability to calculate interobserver reliability. Recordings also provide the best opportunity to observe people in a natural situation. However, during the training sessions the use of videos did not appear suitable to code all communication behaviors of the LCM. *Imitative learning* appeared to be a behavior that does not emerge frequently enough to be coded in a ten-minute recording. In addition, the behavior was defined as the imitation of how others use objects, which proved to be very difficult to objectively determine in a recording. It was difficult to distinguish between a student who uses an object out of his or her own interest and a student who uses an object because he or she is imitating the teacher using it at some other time that day. Therefore, we decided not to score this behavior and to leave it out of the coding scheme.

Compromises in defining a certain behavior sometimes needed to be made to analyze recordings objectively. This is what happened to *joint attention*. We limited the definition of that behavior to visually detectable behaviors in the recordings. This means that it was restricted to drawing the attention of the other to a visible object and/or sharing an object together. In a broader sense, joint attention can also be defined as a shared mental representation of an object (that is not necessarily present). Since such mental representations are difficult to objectively code, we decided to limit the definition of joint attention to visually detectable behaviors in the recordings.

Interactions between people with CDB and others are often complex, subtle, and idiosyncratic (Prain et al., 2012). As suggested by Prain et al. (2012), we calculated both Kappa and percentage agreement to determine interobserver reliability. During extensive training, sufficient agreement was obtained between the coders, but the level of interobserver reliability in the recordings for this study was not satisfactory in all cases. All recordings were coded by the same observer, so the differences in interobserver reliability did not affect the results on development over time.

Some of the results can be explained by the activity chosen by the teacher. We asked teachers themselves to indicate a moment in their daily schedule that was dedicated to communication and interaction. This resulted in different activities between the dyads: dyad 1 sang songs, dyad 2 did hand and crafts, and dyads 3 and 4 had more conversational settings in which they discussed their plans. This option for the teachers to choose the activity caused some deviant results, for example, dyad 1 scored much more frequently on *affective involvement* than the other dyads because of the emotional songs the teacher sang. However, this does not seem to have influenced the results of the development over time, since the same activity was repeatedly recorded for each dyad.

4.5. Recommendations

Recordings in this study were quantitatively analyzed for the four dyads of students with CDB and their teachers. Given the heterogeneity of the population of people with CDB, it would be interesting for future research to use the LCM to analyze video recordings of more dyads. The LCM could be used to perform an in-depth analysis of more student-teacher dyads, child-parent dyads, or adults with CDB communicating with their caregivers. The quantitative measures in this study were used to objectively explore the LCM for the first time on people with CDB. In future research, the LCM could also be used in a more qualitative way, to gain more detailed information on the appearance of the different behaviors from the model.

No increases were found in the presence of the behaviors between the four moments during the half-year period. This could indicate that the communication of students with CDB did not improve or that it develops slowly. It could also indicate that recording and analyzing one video at one time point does not give a reliable representation of the communicative potential of the dyad (Damen, 2015). For example, dyad 1 showed increase in the presence of many behaviors during the first three recordings, but all behaviors were less frequently present in the fourth recording. This might have been a poorer representation of their communicative potential. We therefore recommend making multiple recordings per day or week and using the average for coding these recordings to compare to the average of multiple recordings at later moments.

The current study analyzed communication development over time with no intervention involved. Results showed no clear development over a half-year period in for example an increase in presence of the behaviors. Intervention studies on people with CDB have shown that improving communicative behaviors over time can be achieved (Bloeming-Wolbrink et al., 2015; Damen et al., 2015; Janssen et al., 2003a, 2003b; Martens et al., 2014, 2016). It would therefore be interesting to analyze whether the LCM could be used to measure development over time when an intervention is conducted. This study showed that the LCM can be used to describe the current communication level of a dyad, which can be used as a starting point to improve the presence of certain LCM behaviors.

5. Conclusion

In this study, we examined to what extent the LCM can be used to describe the communication development of students with CDB, by coding video recordings of four students with CDB with different developmental ages at four time points during a half-year period. Based on the results, it can be concluded that all LCM behaviors can be quantitatively measured in communication between students with CDB and their teachers.

The frequency of presence of the behaviors at the primary layer were similar for all four dyads, which indicates that this layer is a

basic layer for communication and can therefore not be used to distinguish communication levels between dyads. The frequency of presence of the behaviors at the secondary and tertiary layer is more suitable for this purpose, both between layers as well as within these layers. Students with higher developmental ages showed a higher frequency of presence of behaviors at the secondary and tertiary layer compared to students with lower developmental ages. In addition, for all dyads *joint attention* was more frequently coded than *naming objects* at the secondary layer, and at the tertiary layer *symbolic communication* was more frequently coded than *perspective taking*. This indicates that there is a developmental structure between these behaviors that can be used to describe the communication level of the student.

Finally, the analysis of teachers' and students' contributions showed that for students with lower developmental ages a behavior was more often shown by the teacher than that is was an equal contribution of both student and teacher, or that a behavior was mainly shown by the student. Again, these differences between dyads were found only at the secondary and tertiary layer and not at the primary layer of the model, which confirms the developmental nature of the model.

In conclusion, no changes in communicative behaviors at four time points during a half-year were found for all dyads, but using the LCM was useful to gain insights into the current communication level between a student with CDB and his or her teacher, which in turn could be helpful as a starting point for interventions, at moments when students make the transition to a new classroom or day care, or to facilitate and improve communication development.

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CRediT authorship contribution statement

Kirsten Wolthuis: Conceptualization, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization, Project administration. **Gerard W. Bol:** Conceptualization, Validation, Writing - original draft, Writing - review & editing, Supervision. **Alexander Minnaert:** Conceptualization, Validation, Writing - original draft, Writing - review & editing, Supervision. **Marleen J. Janssen:** Conceptualization, Validation, Resources, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition.

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