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Communication of children with autism in a technology-enhanced learning environment

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Abstract

This paper presents the results of a study on the communication of four children with autism in a learning environment with multiple technologies. The main focus of the study was on the amount and forms of the children's expressions produced by voice while working at three technology-based workstations: building with bricks, symbol matching, and storytelling. The results indicate that the number of the children's vocal expressions was high, they used multiple ways in communicating despite challenges in language development, and each child had a different kind of communication profile. The results of the study are considered in respect to the variety of the communication and interaction of children with autism, and the aspects to be taken into account in a technology-enhanced learning environment to support the communication of children with autism.

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Keywords: children with autism; communication; technology-enhanced learning environment

1. Introduction

This paper introduces the results of the communication of four children with autism in a technology-enhanced learning environment during autumn 2011. The research was implemented as a part of the CASCATE research project, which investigates the actions (especially attention, communication, interaction, and creativity) of children with autism in a strength-based learning environment with multiple technologies (Vellonen et al., 2012; Voutilainen et al., 2011). Communication can be broadly defined as consisting of, for instance, speech, vocalizations such as sounds and shouts, body language such as facial expressions and posture, sign language, exchange of pictures, using communication devices, and writing. In this paper, the focus of the investigation is on the amount and forms of the communication of children with autism at three technology-based workstations: building with bricks, symbol matching, and storytelling. The main focus of the research was on the expressions that children produced by their

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voice. Since one of the children used mainly other forms of communicating than speech, the signs of Finnish sign language and sign-like gestures were also taken into account.

Challenges in language development and communication are considered to be one of the central features of autism spectrum disorders (e.g., American Psychiatric Association, 2000; Eigsti, Bennetto, & Dadlani, 2007). According to some researchers (e.g., Charman & Baron-Cohen, 2006), difficulties in social communication may be the primary deficit in autism and the key to understanding, identifying, and distinguishing the early characteristics of autism from other childhood disorders. The difficulties in communication and interaction among individuals with autism have some variation. Some of the individuals with autism learn spoken language but they have difficulties in using it in communicative and social meaning (Bogdashina, 2006a; Jordan, 2005; Williams, 2005). Many people with autism have echolalia, which has usually been defined as unpurposeful repeating of other people's words (e.g., Fay, 1994; Prizant & Rydell, 1984) and not promoting the language development (Tager-Flusberg & Calkins, 1990). However, some of the researchers (e.g., Eigsti et al., 2007; Tager-Flusberg, Paul, & Lord, 2005; Prizant & Duchan, 1981; Tager-Flusberg, 1996) have stated that echolalic speech might also have communicative meaning, since the individuals might express, for instance, fear, pain, need for help, or to conversate via echolalic speech. Along with language development, the amount of echolalic speech is considered to decrease (Tager-Flusberg, Paul, & Lord, 2005; Prizant & Duchan, 1981; Tager-Flusberg, 1996). Finally, some individuals with autism spectrum disorders seem never to acquire functional speech, although many studies suggest that the number of nonverbal individuals is not nearly as high as has been believed (Tager-Flushberg, Paul, & Lord, 2005).

In addition to difficulties in achieving verbal language, individuals with autism are often described as having difficulties in nonverbal communication such as understanding and using facial expressions and gestures (e.g., Boucher, 2003; Koegel, 2003). On the other hand, many individuals with autism spectrum disorders are able to use a vast range of both conventional and unconventional nonverbal means to communicate, but communication partners may not always be able to observe and interpret the meaning of these behaviors properly and effectively (Keen, Sigafoos, & Woodyatt, 2005; Wetherby, Prizant, & Schuler, 2000). Regardless of many difficulties in communication and interaction, individuals with autism do want to express themselves, to be understood, and to interact; they just might do it differently than non-autistic individuals (Bogdashina, 2006b). For the interaction to be successful, it is crucial that the persons involved in the situation understand each other and are able to communicate about their thoughts (Vygotsky, 1986).

2. Methods

2.1 Participants

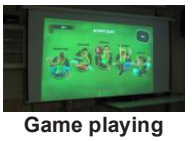
The research participants were four children with autism in one Finnish comprehensive school for children with special needs. Two of the participating children were boys and two were girls (pseudonyms are used to protect their identity). Olivia was 8, Ian 9, Eric 11, and Iris 12 years old. The children had many challenges in their actions and learning. Yet, they also had multiple strengths, for instance, good visual or auditory senses, and a variety of ICT (information and communication technologies) skills. All children had limited verbal language skills. Yet, each child had various ways to communicate; Iris spoke only a few words, Ian tended to imitate other people's words and phrases, Eric liked to speak out some phrases of characters in a famous children's program, and Olivia spoke three- to four-word sentences in some situations. In addition to spoken language, all children used augmentative and alternative communication (AAC) methods: all four of them used picture symbols, Olivia was able to sign a few signs, and Iris used a few signs and gestures as an alternative method of communicating.

2.2 Setting

The CASCATE project ran group sessions, which were known as *action group* meetings, in a technology-enhanced learning environment. The children attended the one-hour group sessions weekly in their own school, approximately nine times during each school semester. The findings of this paper are based on the data that were collected in action group sessions during autumn 2011.

A technology-enhanced learning environment for the sessions was set up in the school's lunchroom, since it was the biggest continuous space in the school building that contained enough tables and chairs. In addition, using the school's lunchroom made the settings natural for the children. There were four technology workstations in the learning environment: building with bricks, symbol matching, storytelling, and game playing. The workstations are presented in Table 1.

Table 1. The workstations of the learning environment

 **Building with bricks**	The children built a LEGO® construction from the model on the computer application. The children chose a task from three alternatives: 1) building from the picture of the whole model (figures or abstract constructions), 2) step-by-step building of the model, or 3) a memory game that hid the model during the child's construction. The children could adjust the difficulty level by changing the number of the bricks in the application. The children could build with Duplo® or basic LEGO® bricks.
 **Symbol matching**	The children had a variety of tasks on a computer application and six tiles on the table or floor. The application included, e.g., matching sounds to visual symbols, matching pictures of emotions, matching shapes, matching the number of objects in a photo to numerals, and recognizing hidden objects. The children chose the topic for the tasks and changed the symbol cards on the tiles according to the selection by themselves. During the task, the children selected the matching symbol by pressing the tile with a hand (tiles on the table or floor) or foot (tiles on the floor).
 **Storytelling**	The children created a story by using a picture-based computer application and a touch screen. Hand-drawn pictures with written one-word descriptions were categorized as people, creatures, places, objects, doings, and own pictures and presented as visible categories. Children created stories by dragging and dropping the pictures to the story's timeline. Children could also draw pictures with drawing application and add them to the stories. The stories were saved to the story library. The children could also continue their own stories and review stories created by other children. The children could print out their stories and put them together as their own story books.
 **Game playing**	The children selected and played two or three short games on Microsoft's Kinect for Xbox 360. Each child played the games by using his or her whole body to control the game, for instance, jumping, dodging, squatting, and using his or her hands. Games were flexible, allowing a variety of movements as long as the player stayed within the play area.

The children worked individually with their teachers or school assistants at each station from 10 to 15 minutes. At the beginning of the session, there was a short warm up with greetings and researchers gave each child a pictured map of the workstations. Using the map, each child saw the order of how to move from one workstation to another during the session. Though the order was predetermined, the children could choose a variety of tasks or games they wanted to work with at each workstation. During the session, the children were encouraged to work intensively with the technologies, and adults were there to help if needed (e.g., managing the menus, setting the difficulty level of the task). The order of the workstations varied for each child every session. The children gave immediate feedback about the workstations with a feedback system consisting of a piece of black cardboard (size A4) with three picture-word feedback cards and a photo of the workstation. The feedback cards had drawn pictures of facial expressions: very happy face, neutral face, and sad face. The pictures were linked with matching words on the feedback cards: I liked it a lot, I liked it a little, and I didn't like it.

2.3 Data collection and analysis

The research was conducted as qualitative action research. The main data were collected by videotaping the children working with their teachers or school assistants at the workstations in the technology-enhanced learning environment during autumn 2011. The additional data were collected by observing the sessions.

The data were analyzed by the means of content analysis. At first, the data were organized, and several passes through the videotaped data were made to map the forms of the children's communication. Two videotaped sessions

were chosen for further analysis. The grounds for selecting the sessions were the following: 1) all four children were present during the whole session, 2) the sessions selected were from the first part and end part of the action group semester in order to get enough space between the sessions, and 3) the videotaped data were not defective. The data videotaped at the game playing workstation was left out of the detailed analysis due to the continuous music and dim light affecting the confidentiality of the analysis. The amount of the videotaped data selected for the analysis is presented in Table 2.

Table 2. The amount of videotaped data selected for the analysis

Workstation	Session	Duration of action (mm:ss)				Total (h:mm:ss)
		Olivia	Ian	Eric	Iris	
Building with bricks	1	12:50	05:12	06:00	12:17	0:36:19
	9	07:55	13:32	07:48	12:40	0:41:55
Symbol matching	1	06:50	09:50	09:10	08:40	0:34:30
	9	13:25	10:35	10:49	06:04	0:40:53
Storytelling	1	10:04	07:38	06:37	11:28	0:35:47
	9	13:55	08:07	15:05	08:33	0:45:40
Total (h:mm:ss)		1:04:59	0:54:54	0:55:29	0:59:42	3:55:04

As can be seen from Table 2, the total amount of the videotaped data was quite high (3:55:04), almost four hours. The amount of the data per child was relatively even, varying only for 10 minutes at the maximum. Similarly, the amount of the data per workstation was evenly distributed. However, there were slight differences in the time children worked at each station between the selected first and ninth sessions. During the ninth session, children acted longer at each workstation in comparison to the first session and therefore, the amount of data was from approximately five to 10 minutes higher per each workstation during the ninth session compared to the first session.

The frequencies of the expressions children produced by voice (e.g., word, syllable) were tabulated and the content of each expression was transcribed orthographically (e.g., “norsu” = elephant, “apua” = help). Unclear parts were marked with two dots (e.g., “koi..”). Sentences (e.g., “I am hungry,” translated into English) or parts of sentences (e.g., “there play music,” “is ready,” translated into English) were coded as utterances. Immediate repeating of another person’s words or longer utterances was coded as imitation. Also, sounds (e.g., whimpering) were coded separately. However, it was not always easy to sort out a sound (e.g., “eeh”) from a phoneme (e.g., “e”). The context within which the child produced the expressions by voice was also written down although the words or actions of the adults were not transcribed in detail. Since the children also used augmentative and alternative communication methods, the signs and other gestures close to signs were coded. Other gestures (e.g., scratching the leg, pointing to the screen, taking objects), body postures (e.g., leaning towards the computer), facial expressions (e.g., raising the eyebrows), and gaze behavior were left out of the detailed analysis since the focus of this research was on the vocal expressions and usage of recognizable signs. The children did not use other pictures in the sessions except the ones in the environment, that is, the pictures at the applications, session maps, and the feedback boards. Therefore, using pictures for communicative purposes was not separately coded in the analysis.

3. Results

3.1 Number of children’s vocal expressions and signs

The findings indicate that the children with autism used a variety of means in communicating in the technology-enhanced learning environment. Children’s expressions produced by voice consisted of separate words, longer utterances, imitation of another person’s words or utterances, syllables, phonemes, and making sounds. The children’s signs were separate signs of Finnish sign language, which the children signed either as such or slightly simplified. The gestures analyzed consisted of gestures close to signs, such as moving hand towards mouth like

eating with an imaginary spoon. The frequencies of children's expressions at each workstation are presented in Table 3.

Table 3. Children's expressions at each workstation during two sessions (f)

Expressions	Building with bricks				Total	Symbol matching				Total	Storytelling				Total
(f)	Olivia	Ian	Eric	Iris	(f)	Olivia	Ian	Eric	Iris	(f)	Olivia	Ian	Eric	Iris	(f)
Words	40	15	21	26	102	23	10	16	13	62	3	12	24	39	78
Utterances	33	15	58	1	107	57	20	45	0	122	27	12	28	0	67
Imitation	3	3	1	0	7	5	1	1	0	7	8	4	1	0	13
Syllables	1	0	2	3	6	0	0	1	5	6	1	0	1	6	8
Phonemes	4	0	0	3	7	1	0	0	4	5	1	0	0	3	4
Sounds	1	8	53	80	142	4	13	32	60	109	9	2	34	123	168
Signs	0	0	0	1	1	2	1	0	4	7	5	1	0	2	8
Gestures	0	1	0	1	2	3	1	0	9	13	0	1	0	5	6
Total (f)	82	42	135	115	374	95	46	95	95	331	54	32	88	178	352

On the whole, the number of children's vocal expressions (N = 1020) at the workstations was very high, whereas the number of signs and sign-like gestures was quite low (N = 37). Certain forms of expressions were emphasized, though there were also individual differences. Thus, the children had different kinds of profiles in using forms of communication. Olivia's total number of vocal expressions (n = 221) consisted mostly of words and utterances, except at the storytelling workstation, where she produced mostly utterances and sounds. Ian produced the fewest expressions by voice (n = 115) of all the children. He mostly produced words, and at the symbol-matching workstation, also sounds. Eric's vocal expressions (n = 318) were mostly utterances and sounds, and at the storytelling workstation, also words. Iris's vocal expressions (n = 366) were mostly words and sounds. The high number of sounds Iris made at the storytelling workstation (n = 123) was due to the problems in the sensitivity of the touch screen to the type of touch Iris used. The signs or sign-like gestures were mostly produced by Olivia (n = 10) and Iris (n = 22). Ian's signs and sign-like gestures were rare (n = 5), whereas Eric did not sign or make sign-like gestures at all during the two sessions.

3.2 Contents of children's communication

Most of Olivia's words and utterances were connected to the contents of the applications. For instance, she calculated the number of the objects aloud, named the pictures on the screen or tiles with one word or with several words describing the object (e.g., "is is worm and cap hat and eyes and mouth"), and reiterated the task instructions (e.g., "What has gone hiding?"). She also explained the process out loud during working, for instance "Now ready picture" (when her drawing was finished), "Let's print" (when she clicked the button for printing), and "No picture yet" (when the printer did not react to the printing command). She also used exclamations like "wow," "oh no," and "ouch" in a suitable context. Olivia clearly expressed her will, especially by saying in a loud and clear voice "No!" but also by saying "I want." Olivia also gave herself positive feedback during working by saying "good" and "really nice" (all expressions in the paragraph translated into English). On these grounds, Olivia's profile considering her communication and interaction in the technology-enhanced learning environment could be described as expressive, task-oriented, and multiply skilled.

Ian produced the fewest expressions by voice of all the children, and most of the expressions came up at the later session in the semester. Though the number of Ian's expressions was low, he produced verbal expressions like "red heart," "change," "it is ready," "cannot be true then" (expressions translated into English). Most of Ian's longer utterances were impossible to be exactly transcribed due to the extremely quiet voice he used. However, he clearly produced at least a few words, inferring from the movements of his mouth, and the syllables that could be heard among the mumbling. Ian paid attention to the adults' expressions, since he usually responded quickly to the adults' initiatives by actions. On the whole, it can be stated that Ian was able to produce multiple expressions but there were other reasons why he did not do so more. First, he might have been concentrating on the task at hand and did not feel a need to express himself by words. Second, when he was mumbling during action, it might have been his way to increase concentration to the task at hand. Third, when Ian produced vocal expressions in a relatively quiet voice,

the adults usually did not respond. Therefore, he might have been lacking the idea of spontaneous communicating and interacting in these situations. Based on the results, Ian's profile considering his communication and interaction in the technology-enhanced learning environment might be described as minimalistic but interactive.

Most of Eric's expressions produced by voice were utterances consisting of sentences or parts of them, and making sounds. Most of his utterances contained at least parts of characters' utterances (names of the characters or some recognizable lines) in a famous children's program. Therefore, it might have been a question of delayed echolalia, at least in some respect. Eric produced most of these utterances connected to the characters at the building with bricks workstation. He also produced some utterances at the symbol-matching workstation, but they were not so clearly connected to the characters' names. In addition, he produced only a few utterances while doing the tasks; most of them came out between tasks. Though Eric produced lots of utterances that did not seem to have anything to do with the situation at hand, he sometimes used characters' phrases in proper situations. For instance, when a LEGO® brick dropped from the construction, Eric said "sorry sorry that I'm disturbing" (translated into English). Eric also repeated some words in a row. Though there seemed to be a lot of expressions without clear intension, Eric both made a few verbal initiatives (e.g., saying "more" when the first task was finished at the symbol-matching workstation) and responded a few times to an adult's initiations (e.g., by naming pictures at the storytelling workstation). Eric's profile considering his communication and interaction in the environment could be described playfully as expressive chatterbox.

Iris produced most of her words to express that she did not want to do something or to name objects, especially animals, which were her favorite. Iris used own versions in naming the objects, especially "huhuhu." She also produced some words, which had only one letter missing, for instance "ree" or "tre" (meaning, "tree," translated into English). Some of her words did not sound like actual names or even parts of the names of the objects, but she clearly tried to name them with the combinations of phonemes she could produce. It is also possible that she named a part of the picture, since she often pointed at little parts in the pictures. Most of Iris's signs and sign-like gestures were connected to expressing that she either wanted to do something by signing "to want" or "help," or did not want to do something by using a sign-like gesture "no" by shaking her head along with saying "no-no" (translated into English). Most of Iris's sounds of annoyance came up at the storytelling workstation. This was due to the problems with the functionality of the touch screen. Iris used her finger in a way that did not make the screen react to her touch. Iris made a lot of initiations to interaction by words and making sounds, and by pointing at the direction of her interest at the same time. Iris responded to most of the adult's initiations by the means she was able to produce. Therefore, Iris's profile considering her communication and interaction in the technology-enhanced learning environment could be described as initiative and instant.

In addition to the results above, an interesting finding of the study was that the children were able to use multiple ways to communicate at once. As presented previously, for instance Iris confirmed verbal denial by shaking her head, confirmed her will to quit the task by signing "finished" and by saying "inish" (translated into English). Olivia showed quite remarkable multi-communication at the storytelling workstation by pointing at pictures on the screen one by one, naming them verbally, and by showing the appropriate sign at the same time. Her actions almost looked like an interpreter working. Also, Ian and Eric were able to use various forms of communicating at once, but it did not come up in their actions as often as did for Iris and Olivia.

Another slightly surprising finding of the investigation was the children's clear awareness of the activities going on in the learning environment. The children's vocal expressions revealed that they were observing the environment while working at a certain workstation. For instance, Ian clearly reacted to Iris's whimpering by making similar kinds of sounds, by saying "quiet" (translated into English), by putting his hands in front of his mouth (gesture close to sign), and by making the actual sign "to be quiet." In spite of this, he continued the task at hand at the symbol-matching workstation. The adult did not seem to pay attention to the actions in the environment and therefore, Ian's actions might have easily been interpreted as irrational behavior considering the task. The adult did not react detectably to Ian's actions and therefore, his actions did not lead to any kind of interaction. In proportion, Ian said "similar" at the storytelling workstation though there did not seem to be anything similar at hand. The word revealed that Ian was paying attention to the discussion going on at another workstation, where the adult instructed Eric to "Find similar." Observing the environment was also evident in Olivia's actions. For instance, Olivia said "narrekkaa" (translation into English is difficult due to reversals and missing phonemes) at the storytelling workstation, which at first seemed like nonsense, or at least it was difficult to find the connection to the things she was just working on. However, it turned out that Olivia was reacting to the task at hand at the symbol-matching

workstation. Olivia could hear the instruction "neljä rannerengasta" (means "four arm bands" in English) and repeated the instruction with a similar-sounding word with some reversals and missing phonemes. Just before this incident, she had looked in the direction of the symbol-matching workstation. Therefore, this result indicates that the openness of the learning environment seemed to work by allowing the children to monitor the others while working. Yet, this did not seem to interfere with the children's own working too much.

The results concerning children's imitations of others' expressions were absorbing in relation to general notions about echolalia and autism. The findings of this study indicated that the children repeated someone else's words only a few times. These expressions might have been interpreted as immediate echolalia, to some respect. However, imitating the word, sentence, or sign seemed many times to have a communicative purpose as the child's reaction to the adult's initiative, or as a confirmation of the adult's expression. For instance, when Ian said "Ready" after the assistant asked, "Is it ready?" (translated into English), could be interpreted merely as an echolalic speech of the adult's last word, but it could also be interpreted as an answer to the adult's question, especially as Ian did actually finish constructing the story. Similarly, most of Olivia's imitations seemed more like confirming the adult's expressions, for instance naming the pictures, since Olivia also named pictures in diverse ways by herself.

4. Conclusions

The purpose of this study was to introduce the amount and forms of communication of children with autism during two sessions in a technology-enhanced learning environment. The main focus was on the expressions the children produced by voice, and on the signs, and sign-like gestures. The findings indicate that the children produced a broad arsenal of vocal expressions measured both in quantity and quality. The children's multiple ways to communicate, even at the same time, was an interesting result considering the many difficulties connected to the communication of children with autism. Undoubtedly, there were many challenges also in the communication and interaction of these four children. However, as attention was paid in this study to the strengths of children with autism instead of mere difficulties, the findings brought out that children with autism have individual communication profiles that should be recognized and taken into account during interactions. The heterogeneity of communication of children with autism spectrum disorders and their communication profiles have gained recent interest also among other autism researchers (e.g., Jones & Schwartz, 2009; Maljaars et al., 2011). If it is a multifaceted picture wanted of the communication of children with autism, the research methods need to be varied since the traditional assessment methods might bring up mostly challenges and difficulties (see Stiegler, 2007). In addition, it would be beneficial to include tasks on a computer to the assessment batteries, since computers are often very appealing to children with autism (e.g., Moore & Calvert, 2000; Robins, Dautenhahn, Boekhorst, & Billard, 2005), and might thus bring an interesting contribution to the communication profiles of the children with autism spectrum disorders. It is also important to do research with children of the whole autism spectrum to get supplementary information to the current knowledge on communication in autism spectrum disorders (see Maljaars et al., 2011).

The features of the technologies (e.g., different kinds of user interfaces) and contents of the applications (e.g., how interesting the tasks were in the children's opinion, the novelty of the tasks) had an impact on the children's communication. This cannot be concluded directly from the numbers of this research since the total amount of vocal expressions was quite congruent between the workstations. On the other hand, a large number of expressions was not necessarily the goal since part of the children's vocal expressions did not seem to be connected to the tasks at hand. However, the contents of the children's vocal expressions revealed that the technologies had an impact on their communication. For instance, if the technology did not react the way the child expected, the child reacted by making lots of sounds of annoyance. Alternatively, if there were interesting pictures on view, the children responded by naming them in the ways they were able to use. On the other hand, the features of the technologies and the contents of the applications also seemed to affect the adult's behavior, though the adult's expressions were not analyzed in detail. For instance, it can be roughly stated, that the adults usually asked fewer questions at the building with bricks workstation while children were building than at the storytelling workstation.

Relating to the previous, it was not just the technologies that affected the communication of children with autism. The teacher or the school assistant working with the child had an effect on both the amount and quality of children's communication. If the adult made initiations like asking the child to make choices and asked about pictures at hand,

the child usually responded in some way. According to Jones and Schwartz (2009), asking more and using fewer comments at least by a child's parents may increase the rate of responding from their child. On the other hand, the questions do not necessarily facilitate the social nature of communication since a discrete answer to a question from the child with autism may end the interaction (see Jones & Schwartz, 2009). In addition, if the adult is constantly keeping up asking forms in his/her communicating, it may decrease the child's opportunities and will to initiate communication and participate in the interaction (see Geils & Knoetze, 2008; Stiegler, 2007). Nadel et al. (2008) have pointed out that if the child is allowed more freedom to initiate, it seems to be effective for eliciting social contact. Nadel et al. (2008) have also emphasized that the interactions in which children with autism showed more approach behaviors were characterized by more interesting behaviors of the adults, for instance, smiling, sound effects, and playfulness. There were glimpses of similar results in the research reported in this paper. Especially Iris seemed to react more positively, when the adult used exciting voice like whispering or exclamations.

The findings also indicate that many ostensibly simple and small aspects in the environment had a considerably strong impact on the communication and interaction of the children with autism. One very interesting yet challenging aspect was the arrangement of the workstations concerning the seating of the children and their school assistants and teachers. Since both the children and the adults were sitting next to each other and facing to the screens during action, it was not always easy to say, if the child was initiating or responding merely to the direction of the application or/and the adult. Concluding from the expressions children produced by voice, it seemed mostly to be both ways, and yet, technology was the focus of the attention. Thus, there were many signs of joint attention, even though there was not usually direct eye contact between the child and the adult. The most typical situations included the adult pointing at a picture on the screen and asking the child a question, or giving an instruction to which the child responded either just by looking at the screen, by answering the question, or by acting according to the question/instruction. This indicates that the child was paying attention to the same object as the adult. However, due to the nature of the activities with the technologies, the direction of the communication could not be undeniably indicated in this research.

There were several limitations in the study. The emphasis of this article was on the amount and ways of communication of children, and therefore, the role of the adult requires more thorough verification in the future in the CASCATE research project. The natural setting in this study can be considered to be a strength considering the generalization of the findings to the everyday school contexts. However, the natural setting also brought some challenges in analyzing the video data, since at times, the background noise was quite loud, and it was very hard to hear what the child said in a quiet voice. Especially Ian used such a quiet voice that it would have been reasonable to have a separate microphone close to him. In addition, the children sometimes turned away for a short moment from the video camera. There were also challenges in coding the data by content. For instance, it was sometimes hard to tell whether the verbal expression (e.g., "no no no," three words in a row) belonged more to the category of words or utterances. Also, sometimes it was hard to tell whether two sounds (e.g., "e i") were separate or the same sound continuing. It also has to be taken into account that the number of the expressions children produced by their voice cannot be compared within the length of the expressions. For instance, an utterance might have included from two to six words and was yet counted as one expression.

The results of this study indicate many opportunities for future research in the CASCATE project considering communication and interaction. Research includes for instance following up and deepening the communication profiles of the children, and factors affecting the construction of the profiles. Future research also includes exact analysis of discourses between children and adults in the technology-enhanced learning environment. Also, peer interaction in the environment is a significant and interesting research area to study during the project.

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