TalkBetter: Family-driven Mobile Intervention Care for Children with Language Delay

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ABSTRACT

Language delay is a developmental problem of children who do not acquire language as expected for their chronological ages. Without timely intervention, language delay can act as a lifelong risk factor. Speech-language pathologists highlight that effective parent participation in everyday parent-child conversation is important to treat children's language delay. For effective roles, however, parents need to alter their own lifelong-established conversation habits, requiring extensive period of conscious effort and staying alert. In this paper, we present new opportunities for mobile and social computing to reinforce everyday parent-child conversation with therapeutic implications for children with language delays. Specifically, we propose *TalkBetter*, a mobile in-situ intervention service to help parents in daily parent-child conversation through real-time meta-linguistic analysis of ongoing conversations. Through extensive field studies with speech-language pathologists and parents, we report the multilateral motivations and implications of TalkBetter. We present our development of TalkBetter prototype and report its performance evaluation.

Author Keywords

Language delay; speech-language pathology; mobile; children; parent; smartphone; conversation; turn-taking; in-situ intervention; everyday life

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INTRODUCTION

The human ability to communicate through language is a unique blessing which is vital to develop our social relations, cognitive functions, and academic achievement [12]. The process of speech-language development is prominent in one's early childhood; young children undergo a sequence of developmental stages during which they respond to others, express themselves, and combine words to communicate with other people [28]. *Language delay* refers to a failure or difficulty in childhood to achieve these stages on the typical developmental timetable even if the child has normal nonverbal intelligence. Language delay acts as a critical risk factor during one's life; it is associated with subsequent reading/learning disorders in childhood and adolescence [12], psychiatric disorders in adulthood [2], and even serious socioeconomic outcomes such as prolonged unemployment and a paucity of social relations [5]. Language delay is also often a sign of high risk of Autism Spectrum Disorders (ASD) or Attention Deficit Hyperactivity Disorder (ADHD) [31]. An epidemiological study reports the prevalence of language impairment of 7.4% in U.S. kindergarten children [39].

Throughout decades of studies, speech-language pathologists (SLPs) have established that effective parent participation in everyday life is a crucial element for the prevention or remediation of language delay in children [9, 28, 29, 34, 36]. Toward bridging the chasm between formative clinical sessions, *parent training* emphasizes a number of guidelines and strategies for parents to keep in

mind and practice in their daily interactions with their child [28]. It includes specific practices for parents to learn and become accustomed to, such as "*waiting long enough for the child to respond*," "*letting the child lead the dialogue*," "*promoting turn-taking to continue the dialogue*," etc. However, as non-experts, altering the parents' own lifelong-established interaction style is quite challenging and requires significant period of time and conscious efforts.

In this paper, we introduce new opportunities for mobile and social computing to reinforce everyday parent-child conversation, with therapeutic implications for children with language delay. As an initial effort, we aim to overlay the parent training program directly onto daily conversations, beyond a-priori prescriptions as it has been done thus far. To this end, we present the design and prototyping of *TalkBetter*, a mobile in-situ intervention service to facilitate parents' habitualization of parent training guidelines in their everyday lives. TalkBetter runs in the background on a parent's smartphone, monitoring the ongoing parent-child conversation. When the parent strays from the guidelines, TalkBetter identifies this moment and provides an in-situ reminder to the parent.

The key inspiration behind TalkBetter began with an intersection of two distinct domains: speech-language pathology and mobile social computing. Through extensive field studies with eight SLPs, we identified important implications within the parent training guidelines. We found that a meaningful number of training guidelines are not related to the linguistic contents but to a meta-linguistic perspective that abstracts a parent-child conversation as a sequence of speaking turns held by one with turn-taking from one to another. We then noted that such meta-linguistic information can be detected on-the-fly by mobile face-to-face interaction monitoring [20, 25], enabling to determine if the parent is departing from guidelines during an ongoing conversation. We carefully designed the basic service flow and key functionalities of TalkBetter. Through extensive studies with eight SLPs and 13 parents of children with language delay, we explore the parents' acceptance and the implications pertaining to the design of TalkBetter. Encouraged by their responses, we developed a working prototype and evaluated the performance of TalkBetter on real parent-child conversation data.

We propose two major CSCW contributions, extending the consistent effort in the community on computationally augmenting human conversation [20, 21]. First, we propose a vision of mobile and social computing support for out-of-clinic, life-immersive, socio-interactive care for children with language delay. Second, we propose the specific design of a mobile service for everyday reinforcement of parent training. Notably, we present inter-domain meta-linguistic intuitions which together establish the pathological foundation and the technical feasibility.

Figure 1. The treatment room for children with language delay. (Photographed at the developmental support center where we conducted our study)

BACKGROUND AND RELATED WORK

Language Delay: Etiologies, Outcomes, and Therapies

In speech-language pathology, language delay [1] broadly describes developmental problems in young children who are not acquiring language as would be expected for their chronological age [33]. The causes of language delay vary widely. For example, biological factors include anomalies in the motor cortex controlling human vocal organs, while cognitive factors include inefficient auditory processing and procedural learning. Interestingly, family environmental factors exhibit high correlations with their child's language delay. These factors include language input from parents, family socioeconomic status, and maternal education [33].

The outcomes of language delay which remain without timely intervention also largely vary in their severity levels. The child with a mild degree delay may be what is termed a *late bloomer*, who eventually catches up, learning to talk without further pathological implication. An empirical study reports that 40% of a group of two-year-old children with language delay developed into those with persistent language difficulties by the age of four [6]. Children with phonological and spelling difficulties are more likely to display difficulties in peer social interactions and problem solving [12]. A cohort with severe childhood language disorders was followed in their thirties, exhibiting severe literacy impairment, significant deficits in terms of the theory-of-mind concept, and low socioeconomic status due to prolonged unemployment [5].

For decades, SLPs have established diverse, well-structured therapeutic procedures for children with language delay. Overall, a typical clinical session for children with language delay is designed as a pair-wise playing and talking session between an SLP and the child with language delay. Figure 1 shows a treatment room with toys for language stimuli and a video camera for record keeping. While the application of specific procedures largely varies based on the preceded

[1] A delay refers to either comprehending others or producing his/her thoughts. Note that the term 'language delay' by itself includes the notion of developmental age. More specific terms such as *developmental language disorder*, or terms with notions of clinical assessments such as *specific language impairment* are also commonly used.

standardized tests and assessment strategies used, many procedures include scaffolding to promote the child's comprehension, verbalization, and sentence combining ability. For example, the SLP may present visual stimuli, syllabic or imitative clues to help the child verbalize the appropriate word. Given a word verbalized from the child, the SLP may give a two- or three-word combined phrase back to the child, such as "*mommy's shoe*" when the child has verbalized "*mommy*" while gazing at the shoe.

Our particular interest lies in the clinical implication of parents' roles and participation in the family, also known as parent training. For example, OWL "*Observe, Wait and Listen (when interacting with your child).*" is one of the guidelines for parents [28]. The basic motivation of parent training is to help the children's language development not only in clinical sessions but also in daily routines. Parent training has recently come again to the fore in speech-language pathology. While the strategy of parent training was originally proposed in the 1970s [29], its contribution has been mostly considered to be minor. However, recent empirical studies report positive changes in children's speech-language output after a parent attended parent training, such as children's increased production of initiations, requests, and information provisions in parent-child conversation [34]. Parent training also positively influences parents' perceptions of success, improving the morale of families undergoing a long struggle against their child's language delays [36]. In the section Preliminary Studies, we report example guidelines frequently given by SLPs to parents as well as the parents' difficulties of getting accustomed to parent training in daily conversations.

Computational Support for Children with Language Difficulties

A number of computer-supported systems have been proposed for SLPs to facilitate phonetics therapies in clinical sessions. Hailpern et al. presented a phonetic visualization system for SLPs, to facilitate multisyllabic speech with children with autism and language delays [10]. It provides 2-D visualization of the pitches and timings of the syllables spoken by the SLP and the child, helping the child closely to imitate the desirable pronunciation. Spoken Impact Project develops an augmented clinical environment with audiovisual cues to encourage vocalizations from children with ASD [11]. Hoque et al. reported a concept called gamification to train clinically those whose speaking rates are excessively fast [14]. By playing a teacher-controlled turtle-racing game, the subject is trained to regulate their speaking rates for better intelligibility.

LENA is a commercial speech acquisition and assessment tool for children with language delay that can be used in clinical and/or daily settings at a cost of USD 700 for a home kit [26]. The child wears on her chest a recording device which is comparable in size with a cigarette pack. Upon uploading a daily recording, the signal processing software conducts a posterior analysis to separate the recorded sound into the child's vocalizations, adult vocalizations, and other noises. LENA provides statistics over time to be examined later by SLPs, such as their vocalizing durations and the number of speaking turn exchanges between them (also known as turn-taking).

While the prior works above provide SLPs with effective computational support and clinical information, we focus on the potential of everyday contributions from the child's primary caregiver and interaction counterparts: the parents. We introduce a mobile in-situ reminder service for parents, enabling everyday conversation that momentarily reinforces the parent training. In addition, the use of commodity smartphones would encourage many parents to participate.

Life-immersive Care for Children by Mobile Sensing

Mobile sensing on children in everyday situations has been studied mostly in behavioral aspects, enabling rich contextual understanding and in-situ help. For children with autism spectrum disorder, wearable sensing technologies to detect characteristic motor behaviors were proposed to extend and enrich their clinical assessment [1, 35]. In public education programs, the children group's microscopic behaviors are monitored to find their behavioral similarities as well as individual differences under the common educational stimuli [16, 17]. Monitoring the fine-grained behavioral similarities among the classmates has been applied to keep both the children's safety and freedom in field activities [18] and to improve the children's scholastic performances [40]. These works have inspired the design goal of TalkBetter in terms of monitoring in everyday life. We believe that TalkBetter would extrapolate the efforts in life-immersive sensing for children toward the aspects of conversational interaction.

Meta-linguistic Face-to-Face Conversation Monitoring

A session of human conversation consists of a sequence of speaking turns continuously taken and given from one to another participant. In group discussion settings, Hung et al. analyzed the durations of each speaking turn and the turn-taking patterns to infer who dominated at meetings, e.g., who led the agenda or asserted themselves most often [15]. In ongoing group brainstorming settings, Meeting Mediator continuously updates the visualization of turn-related information, e.g., the durations of per-participant turns, expecting stimulatory effects such as balanced participation and active idea generation [20]. SpeakerSense is a smartphone-based system for the online identification of conversation participants based on their vocal signatures [27]. Notably, SocioPhone proposed a smartphone-based platform and meta-linguistic APIs for multi-personal face-to-face interaction monitoring in everyday natural conversations [25]. These works inspired us by suggesting that the specific ongoing mood or status of a conversation session may be intelligible by analyzing the turn-taking patterns among the participants, without inferring the linguistic meanings inside the speaking turns.

For convenience, we hereinafter use the term meta-linguistic information to refer to the turn-related attributes; i.e., for each turn, these refer to speaker's identity, the timestamps when the turn started and ended, and its prosodic effects such as pitch, tone, and speech rate.

MOTIVATION AND STUDY PROCEDURE

Initial Motivation and Intuition

It is generally known that, when the patients themselves' everyday efforts are added to existing formative treatments or medication, better clinical outcomes can be expected. The idea of parent training for children with language delay stems from such notion. Aside from a few hours a week when the child is visiting the SLP, the parents should be the primary helper for the child. To assist the parents, the SLP provides guidelines to the parents to be effective helpers. (See Table 3 for examples.) Many guidelines require the parents to alter their lifelong conversational habits, i.e., how patiently they listen and respond to their child, how fast they speak, etc. As one may expect, adhering to such guidelines during every interaction with their child requires a persistent effort and conscious attention at all times. In addition, much of the interactions can occur at any time, regardless of whether the parents themselves are tired, depressed, or preoccupied with something else.

We propose that a mobile computing opportunity exists to help parents to expedite establishing new conversational habits according to the guidelines. In particular, we identify that a meaningful subset of these guidelines are based on meta-linguistic aspects of the conversation, which implies their service feasibility based on current mobile technologies. We focus on smartphones as a platform to provide service parents with appropriate reminders at the right times to improve.

Study Procedure and Methods

Figure 2 illustrates the overall study procedure and methods. To explore our vision, our research employed a two-phase design process (Phases 1 and 2) followed by core system prototyping and performance evaluation (Phase 3).

Participants: Table 1 and Table 2 summarize the SLPs and the parents who participated in this study, respectively. We invited eight SLPs with clinical experience. For Phases 1 and 2, we recruited 13 parents who regularly visit a developmental support center (DSC) affiliated with a university in South Korea. Their children have been under treatment for only language delay or with comorbidity. For Phase 3, we recruited three parent-child pairs who visited a municipal welfare center (MWC). The children in Phase 3 were suspected of language delay based on their previous assessment but were not yet conclusively diagnosed. All the parents except one were mothers as the children are mostly accompanied by their mother when visiting the clinical facilities. We believe that this is a reasonable participant group for the purpose of our study since, particularly in the

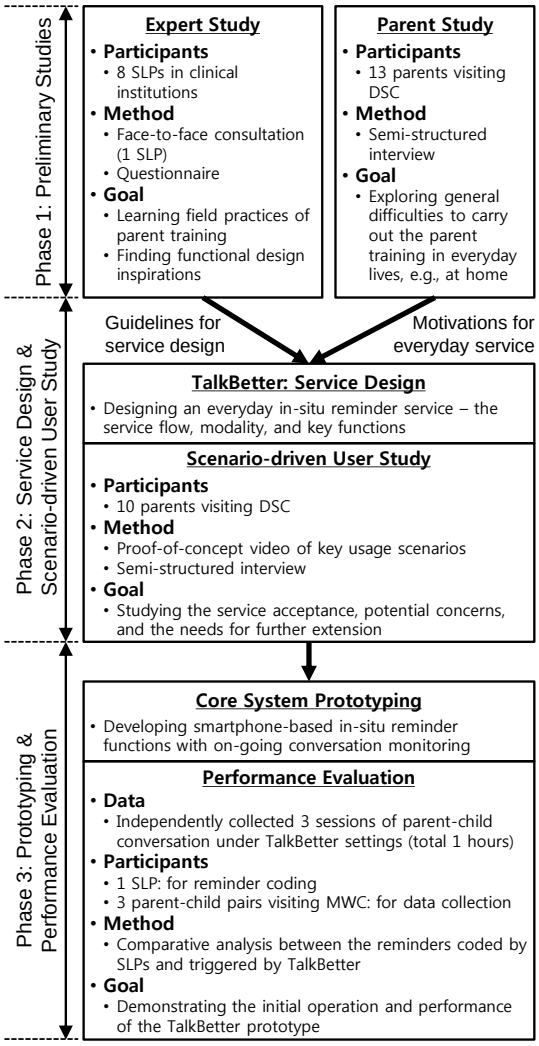

Figure 2. Overall study procedure and the phase-specific participants, methods, goals, etc. (DSC: Developmental Support Center; MWC: Municipal Welfare Center)

Korean culture, since the mother is most likely to spend significant amount of time with her child at home. As a result, the mother is often the primary caregiver and interaction counterpart of the child while having dominant influence on the child's language development. We still expected a certain extent of diverse response from the inclusion of one father (F1), but later we did not found any conflicting responses between those from F1 and his wife (M1).

Phase 1 consists of preliminary studies designed to learn the SLPs' field practices and the parents' difficulties in parent training. We first consulted one SLP via two times of face-to-face meetings (2 hours each) and a number of phone meetings. We outlined the overall clinical procedure for children with language delay and the field practices of parent training. To learn the detailed practices and extended clinical experiences from a larger group of SLPs, we conducted questionnaires with eight SLPs. Along with questions to collect their own clinical practices, the key

SLP ID	Clinical career (year)	Doctor-in-training history (year)	Approx. # of patients treated	Min. age of patients treated	Max. age of patients treated
S1	7	5	150	2	19
S2	20	7	200	0	70
S3	12.5	5	100	2	21
S4	9	6	150	2	50
S5	4	4	100	2	75
S6	5	5	70	2	31
S7	22	9	100	1	78
S8	3	3	200	0	81

Table 1. List of SLPs who participated in the study

Phases	Parent ID	Child's gender	Child's age	# of siblings (older, younger)	Child's age at beginning of treatment	Total treatment period so far (months)	Child's diagnosis
1, 2	M1, F1	F	7	0,0	5	24	LD, PDD
1	M2	F	3	1,0	3	1	LD
1	M3	F	3	0,1	2	15	LD
1	M4	M	7	0,0	7	1	LD
1, 2	M5	M	3	1,0	2	20	LD
1, 2	M6	M	3	0,0	2	8	LD, ASD, PDD
1, 2	M7	M	4	0,1	2	25	LD, ASD, PDD
1, 2	M8	M	5	0,0	3	30	LD, ASD, PDD
1, 2	M9	M	5	0,1	2	43	LD
1, 2	M10	M	5	1,0	3	24	LD
1, 2	M11	M	5	0,1	1	47	LD
1, 2	M12	M	3	0,0	3	6	LD, MR, PDD
3	M13	F	4	2,0	N/A	N/A	N/A
3	M14	M	3	0,1	N/A	N/A	N/A
3	M15	M	4	0,0	N/A	N/A	N/A

Table 2. List of parents who participated in the study (M1~M15: mothers; F1: father; LD: Language Delay; ASD: Autism Spectrum Disorder; MR: Mental Retardation; PDD: Pervasive Developmental Disorder)

questions were: "*Please list the guidelines for parent training which you frequently give to parents.*" and "*Have you received parents' feedback on the parent training guideline? If yes, please state your experiences.*"

In parallel with the study with SLPs, we conducted semi-structured interview with 13 parents individually at DSC. Each interview lasted one hour on average. (30 min~1 hour 20 min) We focused on collecting the parents' experiences in applying the parent training guidelines in their everyday conversations with their children. By coding and iteratively clustering the interview data, we found a number of difficulty factors the parents have undergone in terms of human errors, circumstantial causes, mental fatigue, etc.

Phase 2 consists of the service design of *TalkBetter* and its scenario-driven user study. Based on our findings in Phase 1, we set the major design goals of TalkBetter and designed its service flow and key functions: a background service which runs on the parent's smartphone and provides in-situ reminders based on a real-time meta-linguistic analysis of the parent-child conversation. To design the reminders, we adopted a subset of parent training guidelines which are frequently given by SLPs and would be technologically feasible with meta-linguistic information in conversations.

To study the implications of TalkBetter carefully with the clinically delicate population, we created a proof-of-concept video [18]. The video shows usage cases of TalkBetter in typical daily parent-child conversation in which five different reminders are triggered at appropriate situations. We conducted face-to-face interviews with ten parents out of those listed in Table 2. The interviews focused on finding their service acceptance levels, the prevalence of such situations in their everyday lives based on their personal episodes, and the needs for further extension.

All the interviews in Phase 1 and 2 were recorded and transcribed. Two researchers initially coded the data line by line, and iteratively clustered the codes into high-level categories until arriving at broad themes. The quotes presented in this paper are representative of the broad themes grounded in our data [37]. The interview questions are designed and organized to be nonjudgmental, open-ended, and to trigger further ideas from the participants following their responses [23]. For in-depth exploration of the participants' personal experiences in their daily lives, we adopted intensive interviewing as well [4]. All quotes in the paper are directly translated from Korean language.

Phase 3 is to study the operation and evaluate the performance of TalkBetter. Phase 3 consists of the prototyping of the core system functions and evaluating its operation with one hour of real parent-child conversation data. To avoid potential bias of the subjects influenced by the previous studies, we collected the data from parent-child pairs who did not have prior knowledge of TalkBetter (i.e., parents who were not involved in Phases 1 and 2.) We recruited three mother-child pairs who visited MWC for suspected language delay in their children. The parent-child conversation was a part of the clinical assessment process. The same conversation data were analyzed by an SLP and TalkBetter independently. The SLP listened to the conversation recording and annotated it with appropriate parent guidelines where necessary. We then conducted comparative analysis between the guidelines coded by the SLP and those triggered by TalkBetter.

PHASE 1: PRELIMINARY STUDIES

In this section, we report our major findings derived from the preliminary studies with the SLPs and the parents through the aforementioned methods.

SLPs' Field Practices in Delivery of Parent Training

The SLPs stated that the average period of language treatment for a child is roughly 12~24 months, but it largely varies depending on the child's intellectual development, the severity of language disorder, and the presence of comorbidity. Typically, a child meets her SLP two times a week, and a single clinical session takes 30~60 minutes. A session typically consists of 5~10 minutes of relaxation for the child, 20~40 minutes of clinical conversation with the child, and 5~10 minutes of a parent interview.

Guidelines to the parents		S1	S2	S3	S4	S5	S6	S7	S8
Meta-linguistic	"*Talk more slowly.*"		X	X	X	X	X	X	X
	"*Wait for the child to talk back.*"	X			X	X	X	X	X
	"*Do not interrupt the child before she completes what she says.*"		X			X		X	X
	"*Talk in short (and simple) sentences.*"	X	X	X	X	X		X	X
	"*Respond immediately when the child talks first.*"	X	X	X				X	X
	"*Make more turn-takings with the child.*"			X			X	X	X
	"*Spend more time talking with the child.*"					X			
	"*Articulate what you speak.*"		X					X	X
Semantic-aware	"*Praise the child.*"				X		X	X	
	"*Set a topic that the child is interested in.*"		X			X			
	"*Use positive words.*"				X		X	X	
	"*Refrain from making one-sided instructions.*"			X	X		X		
	"*Repeat the important keyword.*"	X	X						X
Facial	"*Make eye-contact with the child.*"				X	X	X	X	

Table 3. Frequent parent training guidelines: the categorization and the respondents

For a parent-child pair who begins the treatment for the first time, an initial observation session is often done where the SLP observes how the parent and the child play together and interact with each other. Based on the observation, the SLP provides specific parent training guidelines to the parent. We asked the SLPs to respond with up to seven guidelines frequently given to parents. Table 3 lists the guideline responses from each SLP. These were essay questions; the original wording varied slightly, and we reworded a few responses which included multiple guidelines simultaneously, e.g., "*Praise the child and use positive words.*" SLPs sometimes give guidelines during the parent interviews in the regular sessions upon questions by a parent on how to deal with a specific situation at home.

The SLPs stated that the parents often complained about difficulties to follow the guidelines. S7 quoted a parent: "*Actually I don't talk much. I feel I became an actress. It's really weird.*" Becoming tired of the parents' own work was a common excuse. S5 quoted a parent: "*When I get back home from work, I am really tired. I'd rather turn on the TV for my kids.*" Similarly, S7 quoted a parent: "*I am too busy doing household chores, so I tend to say something first. I even yell at my kid without looking at his eyes.*"

The SLPs also noted a number of theories explaining parents' difficulties: (S1) "*Parents are often unaware of their own faults. I recorded what they said, and they were really surprised when hearing how fast they spoke.*" Sometimes the parents have an incorrect belief: (S1) "*They might believe that, if they ask again and again, then their children will eventually talk back.*", and (S3) "*They often don't understand their children's true developmental status, believing that their children are not doing what they actually can.*" The parents' former experiences of bringing up a normal child may also increase the difficulty: (S2) "*Giving totally different types of language stimuli should be hard for them.*" S2 and S4 recalled a few worse cases of parents with little effort who believed that just paying the bill for the therapy would cure their children. S6 and S7 noted that giving one guideline per week may alleviate the parents' difficulties in becoming accustomed to them.

Parents' Experiences in Reception of Parent Training

Not surprisingly, the parents we interviewed were commonly aware of many parent training guidelines. Struggling for years with their child's difficulties, some parents have studied on their own, obtaining knowledge on parent training from books or the Internet. We found there was a general consensus on positive experiences of applying the guidelines in parent training at home.

Momentary negligence: Nearly all parents confess they had (or are having) very difficult time following the guidelines all the time. A common response was, when they are busy doing household chores or preoccupied with something such as watching TV, they often do not notice that their children are talking nearby. Losing temper is a frequent reason, because the child's performance does not meet the parent's expectation: (M1) "*When I teach my daughter at home over and over, she doesn't understand what I teach her. (…) I get upset in spite of myself. (…) I start to talk faster and push her. (…) She just shuts up.*"

Extensive period of time to alter their habits: We asked how long it took until the guidelines became a part of their natural conversation habits. They responded it took almost one year on average. Notably, M1's effort was quite surprising: "*It took almost two years, but still I often make mistakes. (…) I wrote the guidelines on post-its, and put them everywhere in our home, to remind myself every moment.*" M9 was the fastest, reaching that point within three months, but she strongly emphasized: "*I was really desperate.*" We found that taking a considerable amount of time aggravated the parents' mental status, leading to, for instance, depression and feelings of failure. (M5) "*I have gone through a really long, hard time trying to get used to the [guidelines], and feel like I am a stupid mother.*"

Delayed realization of straying from the guidelines: It is also noteworthy that it often takes some significant amount of time until the parents realize themselves that they have strayed from the parent-training guidelines. (M12) "*I found myself just talking alone to explain a bird flying by, not responding to my son's responses. (…) I later realized that*

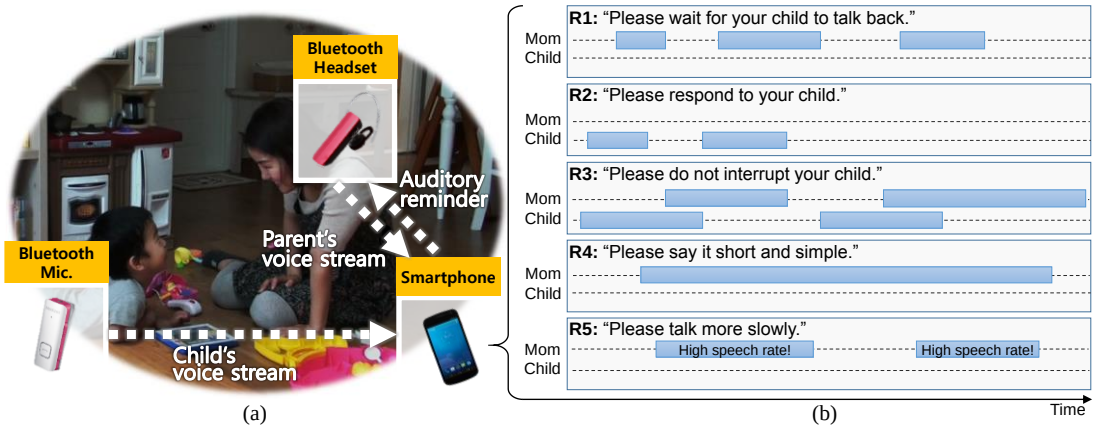

Figure 3(a) TalkBetter: data and service flow, (b) reminder IDs and triggering situations based on meta-linguistic conversation lineation (The child in the photograph does not have language delay or a developmental disorder.)

he didn't understand what I was saying, and talked to him again with just a couple of words." M6 stated a similar experience, "*I often don't realize that I am upset until somebody else asks 'what's wrong with you?'*"

Extra burden to train family members: M5 pointed out an excessive burden of herself, trying to change not only her own conversation habits but also those of other family members. "*I am usually the only one in our family who finds and learns [parent training guidelines]. You know, my husband has to make money. (…) Then, I have to teach my husband and [the older son] what I've learned.*"

Too slow start: We conjecture that the parents' perceptions of success also greatly impact upon their will whether to keep trying to practice the guidelines or not. M6 stated, "*At first, I was really enthusiastic to try anything that might help. You can find from the Internet tons of things that claim to be effective. [After several months], however, my son's change was too subtle. I could hardly see any. (…) Later on, I learned about [parent training], but I got tired of pushing myself so hard to try something new.*"

PHASE 2: SERVICE DESIGN OF TALKBETTER AND SCENARIO-DRIVEN USER STUDY

The preliminary studies delivered a number of cornerstones with which we began designing the overall system and its key functionalities. First, expediting becoming habituated to the parent training guidelines is highly beneficial to the parents to bring forward their perception of success, retain a high level of motivation, and prevent prolonged mental suffering. The parents are motivated to learn and become accustomed to the guidelines, especially early in the treatment process. However, they have undergone year-long struggles, which gradually consumed their motivation and patience. Second, opportunities to cover instances of momentary negligence in everyday life are quite prevalent. In particular, becoming aware of one's own straying from a guideline may not be immediate. A prompt reminder would be helpful to identify one's own frequent habits and to correct them as early as possible. Third, as shown in Table 3, a meaningful number of parent training guidelines frequently given by SLPs are based on meta-linguistic aspects of ongoing conversations. This observation sheds light on the technical feasibility of these guidelines in which recent advances in mobile computing and meta-linguistic conversation monitoring can be utilized.

Service Design and Key Functions

Figure 3(a) illustrates the data and service flow of TalkBetter, a mobile in-situ intervention service to reinforce parent training in daily parent-child conversation. For unobtrusive access to many of the daily conversations, TalkBetter runs on the parent's smartphone in the background. The key functions of TalkBetter are three-fold: continuous capturing of voice activities from the parent and the child, meta-linguistic conversation lineation to monitor the ongoing turn-taking patterns, and in-situ triggered gentle auditory reminders through the parent's earphone.

To reliably detect voice from the parent, the child, or both, TalkBetter employs two wearable 5-cm-long Bluetooth microphones: a clip-type microphone for the child and an ear-worn headset for the parent. In the process of meta-linguistic conversation lineation, the ongoing conversation is graphed into a turn-taking sequence, as shown in Figure 3(b). To identify moments when the parent is likely straying from a predefined guideline, the following basic attributes are monitored: the length of ongoing individual turns, the length of ongoing pauses between adjacent turns, the temporal overlap of a parent's turn over a child's turn, and the switches of turns from the parent to the child, and vice versa. In addition, TalkBetter estimates the speech rate for each turn based on the rates of syllable production [7, 41].

Figure 3(b) lists the five reminders and their IDs (R1-R5) for the initial service design, which we carefully chose out of those in Table 3. On average, 5.8 SLPs out of the eight included these guidelines within their list of guidelines frequently given to parents. Note that a few meta-linguistic guidelines in Table 3 are not included in our initial design. The guidelines "Make more turn-takings." and "Spend more time talking with your child." focus on changing the parents' overall conversation style in a comprehensive

Parent ID	Service acceptance	Personal episodes similar to the demonstrated cases					Reminder-specific extension	Concerns	
		Case 1	Case 2	Case 3	Case 4	Case 5		Wearability problem	Privacy problem
M1,F1*	Y	2	2	1	1	-	R4	N(c)	N(c)
M5	Y	1	1	3	3	1	-	N(c)	N
M6	Y(c)	2	-	1	2	-	R4	N(c)	N
M7	N	-	-	1	1	1	-	Y	N
M8	Y	1	1	-	2	2	-	N	N
M9	Y	1	1	-	1	1	-	N(c)	N
M10	Y	3	1	1	1	2	R3	N(c)	N
M11	Y	1	1	2	2	1	R3	N(c)	N
M12	Y(c)	-	-	-	2	1	R1, R5	N(c)	N

Table 4. High-level summary of the parents' responses. Y: yes | N: no | (c): with a conditional remark. (*M1 and F1 are considered as a single respondent because most responses from one were followed by the other's agreement, and also they referred to episodes they commonly experienced in their family)

manner, while we initially focus on spotting momentary opportunities for a specific reminder to be applied at once. To develop the guideline of articulation, we believe a highly sensitive speech dictation would be required for everyday application. We leave this as a future work.

A reminder of a specific guideline is triggered upon a match between the ongoing turn-taking patterns and the predefined conditions. For example, R1 in Figure 3(b) is triggered if the parent's turns appear repetitively without sufficiently long pauses between them and no child's turn appears along the parent's turns. S8 noted that the parameters – the number of repetitions and the upper limit defining an insufficient pause – are subject to the SLP's prescription followed by an assessment of each parent-child pair. Whether to activate a specific reminder or not is also subject to the prescription. The prescription depends on factors such as the developmental age of a child, her responsiveness to external stimuli, and the parent's conversational habits. However, an in-depth study of child-specific prescription is beyond the scope of this paper.

Scenario-driven User Study

When a service is used for a clinically delicate population, the premature deployment of the service on the population is unacceptable. To be cautious, we instead conducted scenario-driven user study to find the implications of service acceptance, potential concerns, and the needs for further extension. To facilitate the user studies, we created a proof-of-concept video which included multiple usage scenarios [18]. With proper consent, we filmed a half-day routine of a mother and her three-year-old son, including typical daily conversations both at home and while taking a walk. We included the following use cases in the three-minute video at which the appropriate reminders are triggered in-situ by TalkBetter.

- **Case 1:** Their activity involves cutting colored paper. The mother shows her son what she has cut out and repeatedly asks "*What does it look like?*" while the son is neither responding nor showing interest. (R1 is triggered)
- **Case 2:** The mother is focusing on her smartphone, and does not respond to her son nearby who has initiated short verbalization twice. (R2 is triggered)
- **Case 3:** In the paper cutting situation, the son babbles but the mother interrupts him, asking what she wants to ask, "*Shall we go out? When?*" (R3 is triggered)
- **Case 4:** They are playing at a local playground; the mother explains to her son playing seesaw is dangerous to him but her explanation is very long. The son remains quiet and hardly makes eye contact. (R4 is triggered)
- **Case 5:** They are walking; the mother tells her son that they should stop by a place, but she speaks so fast that her son just says "*No*" repeatedly. (R5 is triggered)

With the video, we conducted semi-structured interviews with 10 parents individually, each interview lasting approximately one hour. Table 4 summarizes their responses in major categories obtained through the methods described previously. Our questioning sequences varied depending on the parent's responses for effective exploration within the given time, but to list the key leading questions: "*Did you have personal experiences similar to [the cases in the video] this week (or month)?*", "*If TalkBetter is available now, would you like to use it with your child?*", "*What are the reasons for you to use (or not to use) TalkBetter?*", "*If you can modify or add something to the current TalkBetter service, what would you like to do?*", "*If you use TalkBetter with your child at your home, do you expect problems or concerns?*", etc. To report the detail, we present the representative quotes below.

Prevalence of personal episodes similar to the cases demonstrated: Within each individual interview, we could elicit on average five personal episodes per parent similar to the cases shown in the video. There was a consensus among the parents that such situations are very frequent in their everyday routines. Situations similar to Case 1, 3 and 5 commonly occur when they are doing what they should do, e.g., having the child eat meals, getting the child dressed, and preparing to go out, as the parents get hasty and expect their child to cooperate in doing such imminent tasks. Situations similar to Case 2 commonly occur when the parents are preoccupied with things like web surfing or texting with their mobile devices. Situations similar to Case 4 often occur when the parents keep talking and explaining, believing that doing so may elicit the children's response. Getting upset is a frequent cause for Case 3, 4, and 5.

Service acceptance of TalkBetter: Nine parents showed strong interest in using TalkBetter. (M5) "*I would not have spent a year to get used to [the guidelines] if I had [TalkBetter]. (…) I am very curious if [her son] can extend his language much faster (with TalkBetter).*" Even M1 and F1 asked: "*Can we buy this now? How much is this?*" M6 liked that TalkBetter is simple and easy: "*Once your child is diagnosed with language delay, you will find tons of*

things that claim clinical effects. It's simply impossible to learn and try everything. (…) I love that this is ready-made, doesn't ask me to learn." M11 liked its language-independent characteristics: "*My son is bilingual in Korean and English. I buy this, and it will work on both, right?*" A clinical implication regarding M11's comment is that parent-mediated intervention is important to facilitate the development of bilingual children's home language, which SLPs do not speak [22]. Notably, F1 liked the phone-driven reminders for an interesting reason: "*When I make a mistake (against the guidelines), [M1] points out that I was wrong. Over and over, I feel like I am insulted by my wife. (…) I like [the reminders] are coming from the machine, not my wife. (…) It would not be a matter of affection between us.*"

M6 and M12 appended minor concerns while agreeing to the effectiveness of TalkBetter. (M6) "*(Referring to her experiences that she tried many things without much effect) I might lose interest if I don't perceive improvement within several months.*" M12 pointed out that TalkBetter would be appropriate to children who attained at least a minimum level of making responses and turn-takings. "*My son could hardly do turn-takings until a few months ago. I might not have been interested if I saw [TalkBetter] at that time.*"

M7 declined to use TalkBetter because she had an urgent priority in her son over his language delay, which is the recently aggravated hyperactivity disorder accompanied by his autism. Her immediate demand was a tool to prevent her son's sudden violent behaviors such as hitting other people or taking other people's belongings.

Further needs for functional extension: The parents were enthusiastic to suggest extended features based on their own experiences. Regarding the reminder R4, M1 wanted different presets of triggering conditions or selective turn-on/off instances: "*When I read a book for her, I am supposed to keep talking.*" M6 suggested a different extension regarding R4: "*(Upon a reminder to say it short) What if I don't know how to rephrase it to be shorter? I would like a handy interface to make instant search.*"

M10 and M12 pointed out that, in urgent situations, they cannot help but ignore the reminders such as R1, R3, or R5. For example, M12 stated, "*When he is touching the electrical outlet, I must rush and say 'Don't! Don't! Don't!'*", where she is forced to say fast and repeatedly, no matter what her child says. The urgent and unpredictable nature may render the aforementioned multi-preset strategy inapplicable. A quick and simple workaround would be an one-touch reminder suspension feature that works by overriding one of the buttons embedded in the Bluetooth headset. Likewise, M11 stated that sometimes she purposely interrupted her son while he was talking in order to clarify what he meant. We believe the instant override strategy may be applicable in this case.

Besides the initial five reminder functions, M1, F1, M6, M9, and M10 wanted a reminder when they were about to lose (or have lost) their tempers. Interestingly, F1, who is a software developer, suggested technical clues such as capturing the steep rise of the vocal tone and fluctuations in the pitch. M11 asked for an additional function to determine if an utterance is either a question or a declarative sentence: "*Our SLP advises me to speak in sentences, rather than in questions, (…) such as 'Don't say 'Do you like that flower?' but instead say 'Oh, you are watching the flower.'*"" A notable suggestion was given by M1, which gives verbal rewards to herself when she is conforming well to the guidelines: "*It's exhausting to care for [a child with prolonged disorder]. Sometimes I need to be cheered up.*"

Wearability of the microphone: Nine parents expected that the 5-cm-long microphone would be acceptable to their children. They expected that at first, their children might show excessive interest in the new item. M5 and M9 expected a few days for their children to get used to the microphone. M1, F1, M6, and M11 suggested redesigning the microphone to look more natural, like a button or a name-tag. M10 and M12 suggested making a small pocket on the child's shirt to hide the microphone. However, M7 was not optimistic in microphone usage because of her son's hyperactivity disorder.

Privacy concerns: Not surprisingly, the clinical concerns for the parents by far exceeded any privacy concerns. No parents raised privacy concerns as long as only the meta-linguistic features are extracted. M5 did not care whether the raw conversation would be saved or not. M8 even insisted that the raw conversation should be kept for potential future use. However, M1 and F1 were cautious in terms of third-party privacy in case of TalkBetter usage is extended beyond the family: "*We are perfectly fine, but we should respect the privacy of kindergarten teachers or other children. We may need to be careful when [TalkBetter] goes beyond family conversations.*"

PHASE 3: PROTOTYPING AND EVALUATION

Encouraged by the promising user responses in Phase 2, we proceeded toward building a working prototype. The implementation was inspired by previously proposed context sensing platforms in terms of peer detection, cross-device cooperative sensing, and conversational interaction monitoring [24, 25]. We describe the key architecture of TalkBetter prototype, and provide its performance evaluation results on parent-child conversation datasets.

Core System Prototyping

Figure 4 shows an overview of the architecture on a Google Galaxy Nexus running Android OS 4.1+. To work around the limitations of the default Bluetooth headset profiles allowing only one Bluetooth microphone to be connected, the prototype runs on two smartphones: Phone A paired

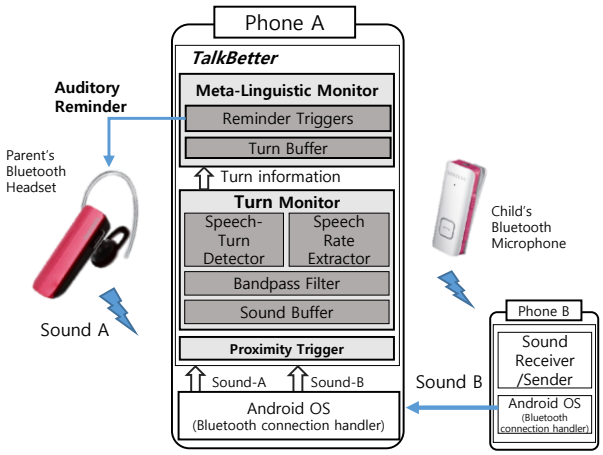

Figure 4. Architecture overview of TalkBetter prototype

with the parent's headset and Phone B with the child's microphone. [2] Each phone continuously receives sound signals from its microphone through a band-pass filter focused on the human voice spectrum. Phone B forwards the filtered signals to Phone A in real time. Phone A is responsible for combining and processing the sound signals, performing the meta-linguistic lineation as shown in Figure 3, and determining when and which reminder should be triggered. As a result, Phone A has two major processing components: a *Turn Monitor* and a *Meta-Linguistic Monitor*.

Turn Monitor extracts conversational *turns* by abstracting raw sound signals collected from both phones. As a conversation progresses, it identifies turns continually and annotates each turn with a quadruple consisting of the following information, (*speaker*, *start time*, *duration*, *speech rate*). We devised a simple but effective turn-detection method assuming reasonably calm home situations. Intuitively, a turn is detected when the volume of an input sound signal exceeds a certain threshold. Since the microphone is in close proximity to the speaker's mouth, the volume of the speaker's voice is prominent to the microphone. Accordingly, our method first segments the continuously incoming sound signal into unit of frames, e.g., 0.3 seconds, and calculates the average volume for each frame. A frame whose volume exceeds a threshold is considered as a part of a turn. This process repeats over continuous signals, growing the duration of the turn until it ends if the succeeding frame is determined as silence.

The parent and the child may talk at the same time, which we call an overlapped turn. However, we observed that a static threshold sometimes outputs falsely overlapped turns; one's utterance undesirably increases the volume captured by the other's microphone but by a far reduced scale. To filter out false overlaps, we employ a second-stage threshold determining the overlapped turns only if the ratio between two concurrent frames' volumes does not exceed it. Along with the turn information, *Speech Rate Extractor* detects the speed of a parent's speech by estimating the number of syllables pronounced during the turn [7, 41].

[2] Single-phone-based implementation is possible in many ways, for example by connecting two custom-designed sound sensors via Bluetooth serial port profile.

Session (parent's ID)	Person	# of turns	Precision	Recall
M13	Parent	301	0.83	0.93
	Child	205	0.73	0.78
M14	Parent	293	0.83	0.87
	Child	139	0.69	0.77
M15	Parent	263	0.81	0.89
	Child	239	0.73	0.83

Table 5. Summary of turn monitoring evaluation

Meta-Linguistic Monitor continuously matches the ongoing turns with the triggering conditions for the reminders in Figure 3. Upon the detection of each turn, it evaluates if any triggering conditions for reminders are newly satisfied based on the previous turn histories stored in its buffer. The conditions to trigger each reminder are as follows.

R1: triggered if a parent's turns repeat $N_{\text{dominance}}$ times in which pauses between adjacent turns are shorter than T_{wait} AND no child's turn appears during these parent turns.
R2: triggered if the following condition repeats N_{grace2} times: Given a child's turn, neither a parent's nor a child's turn follows within time duration T_{neglect}.
R3: triggered if a parent's turn begins before the child's turn ends for N_{grace3} times.
R4: triggered if the duration of a parent's turn is longer than T_{long} AND no child turn follows within $T_{\text{response4}}$ after the parent's turn ends.
R5: triggered if the estimated syllable rate of a parent's turn is higher than R_{fast} AND no child turn follows within $T_{\text{response5}}$ after the parent's turn ends.

Performance Evaluation

We evaluated the performance of the TalkBetter prototype in terms of turn-monitoring and reminder-triggering with real parent-child conversations. For the evaluation, we recruited three parents who visited MWC, i.e., M13, M14, and M15 in Table 2, who did not have prior knowledge of TalkBetter. For assessment purposes, each parent-child pair had a 20-minute free conversation session under an SLP's observation. We recorded the conversation from each session by deploying the TalkBetter prototype, obtaining 1 hour of conversation data consisting of 857 parent turns and 583 child turns. Note that we disabled the in-situ reminder triggers for clinical precaution so as not to affect the original assessment.

Turn-monitoring evaluation: We first report the accuracy of turn monitoring performed by TalkBetter. For each 0.3-sec frame, we compare the output from Turn Monitor with the ground truth coded manually. If a frame is classified as a part of a turn from both TalkBetter and ground truth, we consider it as a true-positive. If a frame is classified as a part of a turn from TalkBetter but not from the ground truth,

we consider it as a false-positive, and so on. Table 5 summarizes the evaluation results for each session and each person of the turns (either the parent or the child).

The major factor degrading the precisions was the noises from the parent-child pairs' playing activities during the assessment. They played with various toys many of which often generate nontrivial sound such as speaking dolls. The choices of toys varied for each child, so that frequent use of sound-generating toys resulted in a lower precision such as that of M14's child. On the other hand, the recalls are degraded mainly due to mumbling or quiet utterances below the conservatively set threshold against activity noises.

Overall, we observe lower precision and recall for the children's turns than the parents'. This is mainly because the children often touched the microphone clipped on their shirts. Note that the parents in Phase 2 expected a few days to get used to or minor design modifications for the children.

Reminder-triggering evaluation: We also evaluate the validity of the reminder triggering. For the purpose, we compare the reminders generated by TalkBetter with those hand-coded by an SLP. The SLP listened to the recordings from the conversations and examined the transcriptions as well. The SLP then coded the conversations with the reminders R1 ~ R5 where she determined appropriate.

We first demonstrate a case of TalkBetter operation where it triggered an appropriate reminder. Figure 5 shows a 7-sec snapshot from the M14's session in which the parent turns repeated without a child turn in the middle, where R1 was triggered by TalkBetter. We can observe the raw sound signals of the parent-child pair, the detected turns, and the triggered reminder.

Table 6 summarizes the results: the reminders coded by the SLP, triggered by TalkBetter, and the matches between those two, for each session and each reminder type. In total, we observed 22 correctly matched reminders, 9 falsely triggered ones by TalkBetter, and 11 missed ones. We analyzed every mismatch, and discuss the findings below.

Nonverbal responses: In two cases, TalkBetter falsely triggered R1. Although there was no apparent turn from the child while the parent was making repeated turns, the SLP did not suggest reminders on these cases. Based on the recorded conversation, she presumed that the child likely made proper responses in a nonverbal, behavioral way. Similarly, in one case, TalkBetter falsely triggered R2. No parent turn followed the child's turn, but the SLP thought that the parent likely made a nonverbal response.

Speech rate changes in mid-turn: In one case, the SLP suggested R5 for a 3-sec parent turn since she determined that the parent spoke too fast, but TalkBetter did not. We found that the speech rate was fast indeed for the first one second. But it dropped and remained at a typical rate for the rest of the turn, resulting in an average rate not exceeding R_{fast}. The SLP later explained that the speech rate was fast

Session	Reminder by	The Number of Reminders					
		R1	R2	R3	R4	R5	Total
M13	SLP	0	0	4	2	5	11
	TalkBetter	1	1	3	2	4	11
	Match	0	0	3	2	3	8
M14	SLP	7	1	0	1	0	9
	TalkBetter	5	2	0	1	0	8
	Match	3	1	N/A	1	N/A	5
M15	SLP	2	8	3	0	0	13
	TalkBetter	3	7	2	0	0	12
	Match	2	6	1	N/A	N/A	9

Table 6. Summary of reminder triggering evaluation

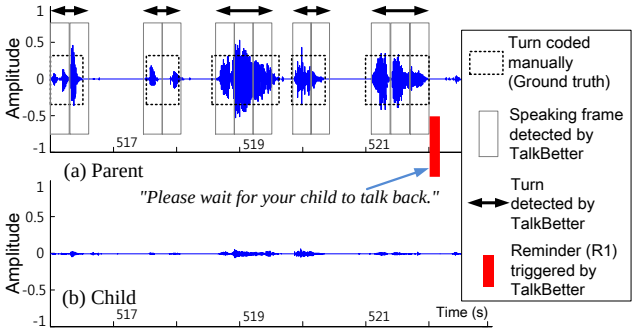

Figure 5. A snapshot of turn-detection and reminder-triggering

particularly around the keywords in the turn, thereby perceived the overall speech rate to be higher.

Linguistic factors affecting reminder suggestions: In one case, the parent repetitively made her turns more than $N_{\text{dominance}}$ times, and TalkBetter triggered R1. But the SLP thought that the parent's turns were not that many because the parent changed the topic of question after a couple of turns. In another case, the repetition of parent's turns was less than $N_{\text{dominance}}$ times but the SLP suggested R1 because those turns were exactly the same questions.

Misidentified turns: The majority of mismatched reminders were caused by the misidentified turns from the underlying Turn Monitor. We discuss potential technical approaches to improve turn-monitoring in the Discussion section.

Interestingly, we observed distinctively higher frequencies of specific reminders for each parent, which were consistent with the SLP's assessment of their individual conversation styles. In Table 6, M13 has relatively higher reminders of R3 and R5. The SLP assessed that M13 tends to speak fast, resulting in frequent interruptions and fast utterances. The SLP assessed that M14 tends to make many questions, which is consistent with the higher frequency of R1 for M14. The SLP stated that M15 tends to pay less attention to the conversation with her child, which explains the notably high frequency of R2. This observation demonstrates that each parent has certain conversation habits for which they may require focused help. We believe that the specific set of reminders fit to each parent could be determined by SLPs. By selectively enabling only the reminders prescribed, we may be able to further reduce little necessary or falsely triggered reminders and improve the usability of TalkBetter.

DISCUSSION

Limitations

Participant recruitment in Phases 1 and 2: As discussed earlier, we believe that the dominance of mothers in our participants is reasonable as an initial study group because of the Korean cultural factors. Nonetheless, including various opinions from other family members such as more fathers and siblings would make our system more concrete. It would be worth exploring to extend TalkBetter to encompass the social peers in the trusted network [13] who are willing to support the child with language delay.

Most of the recruited parents had prior knowledge of parent training at home, despite their difficulties in applying it on everyday conversations. Although we invited such experienced parents during our design process, we expect the TalkBetter service would be useful and helpful for the parents who have just started language care for their children, i.e., who lack knowledge and experience in parent training. In near future, we plan to derive the effectiveness of TalkBetter from inexperienced parents.

Social burden of the primary conversation partner: To use TalkBetter, parents need to pay attention to the auditory reminders during conversations, which might act as additional burden. However, according to our interview, the parents are willing to accept it for the treatment purposes. They state that they are able to keep their motivation high if they see the progress of their child's language. One may be concerned that the parents might feel nagged as they hear the same auditory reminders again and again for months. We expect that simplified reminders, such as short chimes, would suffice for long-term users. To be optimistic, we believe that such experienced parents may receive less and less reminders, mitigating the issue of getting bored as well.

Technical limitations: From the evaluation, we observed falsely detected turns mainly caused by unexpected noises. For example, the speaking doll's speech was misclassified as human voice. Another case occurred when a child touched the attached microphone. There are other scenarios at home that may introduce noise problems such as the TV or radio. The child's microphone may shake when the child runs around. TalkBetter may also falsely detect overlapped turns at home when the parent and the child are talking very close to each other, e.g., the mother reads a book while holding her child in her arm. In this case, one's speech may be captured by the both microphones at a similar volume.

Although these limitations have not resulted in severe concerns in our evaluation, we need to improve TalkBetter for further deployment in more diverse environments. For example, to suppress background noise and separate the speaker's voice, we can apply noise cancellation techniques [3] or employ highly selective microphones [8, 32, 38]. We internally conducted a pilot test with a throat microphone [38] that was very effective in preventing falsely overlapped turns. The throat microphone was designed to be in contact with the skin around the vocal cord, thereby sensing only the speaker's own voice. However, we are cautious about potential discomfort of the child with commercially available throat microphones. Employing a statistical model for speaker identification would be also practical, as we need only a few speaker models for home use [27]. Overall, we believe that these strategies would further help overcome the technical limitations.

Extensibility in Various Settings

We believe the key feature of TalkBetter monitoring and intervening in ongoing conversations can be extended for a broad range of applications beyond the setting of this paper.

Beyond parent-training: To assist the social lives of children with language delay, it is important to guide not only the parents but also other people in the children's daily social circles. The SLPs consider the peer friends such as kindergartens as one of the most concerning groups. They are too young to understand the language delay of their friend and the needs for attentive care. They often consider the child idiotic and make him isolated. The SLPs and we discussed a social game designed to elicit the children's responses in a well-balanced manner. It shows an interesting avatar, which gradually grows when the game detects evenly distributed utterances from the children. Not necessarily to be two-way interactive, TalkBetter can also create a log of conversational patterns for diverse daily conversations. These logs can be leveraged afterwards by SLPs to evaluate the progress of language ability in more natural settings, compensating the SLP's highly limited interaction with the child in terms of duration and place.

Other clinical training program: S8 suggested that TalkBetter can be also useful when used with the Lee Silverman Voice Treatment (LSVT) – a speech training for patients with Parkinson's disease to increase vocal loudness. These patients have difficulties in sending neural signals to voice-producing muscles, resulting in a much quieter voice even when they believe it is sufficiently loud. TalkBetter may extend LSVT toward the patients' daily lives without necessarily visiting a therapist at a clinic.

Daily face-to-face conversations: We believe there would be opportunities in normal people's daily conversations where useful in-situ assistance can be provided. We address mitigating the awkward silences [30], i.e., uncomfortable pauses in the middle of conversation. The people in the conversation feel anxieties and pressure to speak something but have no idea what to talk next. With help from social networking services, TalkBetter can be extended to suggest a topic of common interest once it detects characteristic patterns of pauses indicating a possible awkward silence [30]. Another extension of TalkBetter would be to facilitate balanced participations in group brainstorming such as in Meeting Mediator [20] with commodity smartphones.

Implications in Parents of Normal Children

The SLPs commented that they believe a large number of undiscovered children with language delay exist. Especially in Korean culture, parents are often reluctant to consult SLPs despite their suspect of slower language development in their children; they may blindly believe it will disappear, deliberately not accept the presence of it, or be afraid that people will learn that their child has a disorder. The SLPs expect that commodity services like TalkBetter may narrow the chasm between consulting an SLP and doing nothing.

Inspired by these comments, we conducted interviews with seven parents of normal children after showing our video. Two of them have pressing concerns about their children's language but mostly related to learning slang from the local community. Nevertheless, they agree the problematic situations in our video apply to their daily routines. One was shocked at her own habits and the outcomes: "*[Ignoring what my kid says] happens every day, when I am watching my smartphone. [In the video], I clearly see in [the child's] face that he is disappointed [as soon as he is ignored by his mom]. (…) Perhaps the same thing happens to my kid and I feel really sorry [to my child].*"

CONCLUSION

In this paper, we present new opportunities for mobile and social computing to facilitate everyday parent-child conversation with therapeutic implications for children with language delay. As a first step, we developed TalkBetter, an in-situ intervention service for parents to reinforce parent-training. We conducted extensive domain-specific studies with speech-language pathologists and parents whose child has language delay. We found the clinical and habitual motivations, reinforced our design, and derived further implications. We explored the inter-domain intersection from the meta-linguistic aspect of speech-language pathology and mobile computing. We envision that TalkBetter is the first step toward life-immersive socially-driven care for those with speech-language difficulties.

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REFERENCES

1. Albinali, F., Goodwin, M. S., Intille, S. S. Recognizing Stereotypical Motor Movements in the Laboratory and Classroom: A Case Study with Children on the Autism Spectrum. Proc. *UbiComp 2010*.
2. Beitchman, J. H., Wilson B., Johnson, C. J., Atkinson, L., Young, A., Adlaf, E., Escobar, M., Douglas, L. Fourteen-year Follow-up of Speech/Language-impaired and Control Children: Psychiatric Outcome. *American Academy of Child and Adolescent Psychiatry*, 40, 1 (2001), 75-82.
3. Boli, S. Suppression of acoustic noise in speech using spectral subtraction. *IEEE Trans. Acoustics, Speech and Signal Processing*, 27, 1 (1979), 113-120.
4. Charmaz, K. *Constructing Grounded Theory: A Practical Guide through Qualitative Analysis*. Sage Publications, 2006.
5. Clegg, J., Hollis, C., Mawhood, L., Rutter, M. Developmental Language Disorders: a Follow-up in Later Adult Life. Cognitive, Language, and Psychosocial Outcomes. *Child Psychology and Psychiatry*, 46, 2 (2005), 128-149.
6. Dale, P. S., Price, T. S., Bishop, D. V. M., Plomin, R. Outcomes of Early Language Delay: I. Predicting Persistent and Transient Language Difficulties at 3 and 4 Years. *J. Speech, Language, and Hearing Research*, 46 (2003), 544-560.
7. De Jong, N. H., Wempe, T. Praat Script to Detect Syllable Nuclei and Measure Speech Rate Automatically. *Behavior Research Methods*, 41, 2 (2009), pp. 385-390.
8. Electret condenser lavalier microphones. http://pro.sony.com/bbsc/ssr/product-ECM66B/
9. Girolametto, L. E., Greenberg, J., Manolson, H. A. Developing Dialogue Skills: The Hanen Early Language Parent Program. *Seminars in Speech and Language*, 7, 4 (1986), 367-382.
10. Hailpern, J., Harris, A., LA Botz, R., Birman, B., Karahalios, K. Designing Visualizations to Facilitate Multisyllabic Speech with Children with Autism and Speech Delays. *Proc. DIS 2012*.
11. Hailpern, J., Karahalios, K., Halle, J. Creating a Spoken Impact: Encouraging Vocalization through Audio Visual Feedback in Children with ASD. *Proc. CHI 2009*.
12. Hay, I., Elias, G., Fielding-Barnsley, R., Homel, R., Freiberg, K. Language Delays, Reading Delays, and Learning Difficulties: Interactive Elements Requiring Multidimensional Programming. *Learning Disabilities*, 40, 5 (2007), 400-409.
13. Hong, H., Kim, J. G., Abowd, G. D., Arriaga, R. I. Designing a Social Network to Support the Independence of Young Adults with Autism. *Proc. CSCW 2012*.

14. Hoque, M. E., Lane, J. K., El Kaliouby, R., Goodwin, M., Picard, R. W. Exploring Speech Therapy Games with Children on the Autism Spectrum. *Proc. InterSpeech 2009*.
15. Hung, H., Huang, Y., Freidland, G., Gatica-Perez, D. Estimating Dominance in Multi-Party Meetings Using Speaker Diarization. *IEEE Trans. Audio, Speech, and Language Processing*, 19, 4 (2011), 847-860.
16. Hwang, I., Jang, H., Nachman, N., Song, J. Exploring Inter-child Behavioral Relativity in a Shared Social Environment: A Field Study in a Kindergarten. *Proc. UbiComp 2010*.
17. Hwang, I., Jang, H., Park, T., Choi, A., Lee, Y., Hwang, C., Choi, Y., Nachman, N., Song, J. Leveraging Children's Behavioral Distribution and Singularities in New Interactive Environments: Study in Kindergarten Field Trips. *Proc. Pervasive 2012*.
18. Hwang, I., Yoo, C., Hwang, C., Yim, D., Lee, Y., Min, C., Kim, J., Song, J. TalkBetter: Smartphone-supported Intervention in Family Conversation for Children with Language Delay. *Proc. CSCW 2014 Videos*.
19. Jang, H., Choe, S. P., Hwang, I., Hwang, C., Nachman, L., Song, J. RubberBand: Augmenting Teacher's Awareness of Spatially Isolated Children on Kindergarten Field Trips. *Proc. UbiComp 2012*.
20. Kalnikaitė, V. Ehlen, P., Whittalker, S. Markup as You Talk: Establishing Effective Memory Cues While Still Contributing to a Meeting. *Proc. CSCW 2012*.
21. Kim, T., Chang, A., Holland, L., Pentland, A. Meeting Mediator: Enhancing Group Collaboration using Sociometric Feedback. *Proc. CSCW 2008*.
22. Kohnert, K., Yim, D., Nett, K., Kan, P. F. Intervention with Linguistically Diverse Preschool Children: A Focus on Developing Home Language(s). *Language, Speech, and Hearing Services in Schools*, 36, 3 (2005), 251-263.
23. Kuniavsky, M., *Observing the User Experience: A Practitioner's Guide to User Research*. Morgan Kaufmann, 2003.
24. Lee, Y., Ju, Y., Min, C., Kang, S., Hwang, I., Song, J. CoMon: Cooperative Ambience Monitoring Platform with Continuity and Benefit Awareness. *Proc. MobiSys 2012*.
25. Lee, Y., Min, C., Hwang, C., Lee, J., Hwang, I., Ju, Y., Yoo, C., Moon, M., Lee, U., Song, J. SocioPhone: Everyday Face-to-Face Interaction Monitoring Platform Using Multi-Phone Sensor Fusion. *Proc. MobiSys 2013*.
26. LENA. http://www.lenafoundation.org
27. Lu, H., Brush, A. J., Priyantha, B., Karson, A. K., Liu, J. SpeakerSense: Energy Efficient Unobtrusive Speaker Identification on Mobile Phones. *Proc. Pervasive 2011*.
28. Manolson, H. A. It Takes Two to Talk: A Parent's Guide to Helping Children Communicate. *Hanen Centre Publication*, 1992.
29. Manolson, H. A. Parent Training: A Means of Implementing Pragmatics in Early Language Remediation. *Human Communication* (Summer 1979), 275-281.
30. McLaughlin, M. L., Cody, M. J. Awkward Silences: Behavioral Antecedents and Consequences of the Conversational Lapse. *Human Communication Research*, 8, 4 (1982), 299-316.
31. Miniscalco, C., Nygren, G., Hagberg, B., Kadesjo, B., Gillberg, C. Neuropsychiatric and neurodevelopmental outcome of children at age 6 and 7 years who screened positive for language problems at 30 months. *Developmental Medicine and Child Neurology*, 48 (2006), 361-366.
32. Noise canceling microphone array. http://www.andreaelectronics.com/da250.html
33. Paul, R., Norbury, C. F. *Language Disorders from Infancy through Adolescence: Listening, Speaking, Reading, Writing, and Communicating*. Mosby (2011).
34. Pennington, L., Thomson, K., James, P., Martin, L., McNally, R. Effects of It Takes Two to Talk – The Hanen Program for Parents of Preschool Children with Cerebral Palsy. *J. Speech, Language, and Hearing Research*, 52, 5 (2009), 1121-1138.
35. Ploetz, T., Hammerla, N. Y., Rozga, A., Reavis, A., Call, N., Abowd, G. D. Automatic Assessment of Problem Behavior in Individuals with Developmental Disabilities. *Proc. UbiComp 2012*.
36. Romski, M., Sevcik, R. A., Adamson, L. B., Smith, A., Cheslock, M., Bakemana, R. Parent Perceptions of the Language Development of Toddlers with Developmental Delays Before and After Participation in Parent-coached Language Intervention. *American J. Speech-Language Pathology*, 20, 2 (2011), 111-118.
37. Strauss, A., Corbin, J. *Basics of Qualitative Research Techniques and Procedures for Developing Grounded Theory*. Sage Publications, 2007.
38. Throat microphones. http://www.jeancouk.com/?post_type=product&p=434
39. Tomblin, J. B., Records, N. L., Buckwalter, P., Zhang, X., Smith, E., O'Brien, M. Prevalence of Specific Language Impairment in Kindergarten Children. *J. Speech, Language, and Hearing Research*, 40, 6 (1997), 1245-1260.
40. Watanabe, J., Matsuda, S., Yano, K. Using Wearable Sensor Badges to Improve Scholastic Performance. *Proc. UbiComp 2013 Adjunct.*
41. Wyatt, D., Choudhury, T., Bilmes, J., Kitts, J. A. Inferring Colocation and Conversation Networks from Privacy-sensitive Audio with Implications for Computational Social Science. *ACM Trans. Intelligent Systems and Technology*, 2, 1 (2011), 7:1-41.