ABSTRACT
To acquire language, children need rich language input. However, many parents find it difficult to provide children with sufficient language input, which risks delaying their language development. To aid these parents, we design Captivate!, the first system that provides contextual language guidance to parents during play. Our system tracks both visual and spoken language cues to infer targets of joint attention, enabling the real-time suggestion of situation-relevant phrases for the parent. We design our system through a user-centered process with immigrant families—a highly vulnerable yet understudied population—as well as professional speech language therapists. Next, we evaluate Captivate! on parents with children aged 1–3 to observe improvements in responsive language use. We share insights into developing contextual guidance technology for linguistically diverse families.

CCS CONCEPTS
• Human-centered computing → Ubiquitous and mobile computing systems and tools; Accessibility systems and tools.

KEYWORDS
parent–child interaction, cultural diversity, language acquisition, context-aware systems, early childhood

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

ACM Reference Format:
Taeahn Kwon, Minkyung Jeong, Eon-Suk Ko, and Youngki Lee. 2022. Captivate! Contextual Language Guidance for Parent–Child Interaction. In CHI Conference on Human Factors in Computing Systems (CHI ’22), April 29-May 5, 2022, New Orleans, LA, USA. ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3491102.3501865

We share our code at https://hcs.snu.ac.kr/captivate.
1 INTRODUCTION

Parental language input plays a critical role in the language development of young children. Termed language nutrition, the language that a child encounters acts as vital “nourishment” for neurodevelopment, especially at young ages when the foundation for primary language ability is being formed [72, 76]. Crucially, early linguistic ability has cascading effects: delayed language development at age 3 has been found to affect learning not just during childhood but well beyond—into adolescence and even adulthood [15, 18]. Hence, the quality of parent language and interaction within the short period of early childhood has disproportionate effects on the child’s outcome.

However, studies have found that many parents face difficulties in providing sufficient language nutrition to their children [22, 26]. Importantly, parents of low socioeconomic status (SES), low educational attainment, and diverse cultural backgrounds such as immigrants and refugees have been found most vulnerable [10, 26, 47]. Such cases of low parent language stimulation are linked with high rates of delayed language development in their children: for example, the prevalence of language delay among children of immigrants in South Korea has been measured to be as high as 70% [34, 56]. This problem has been famously termed as the word gap, referring to the gap in both the quality and quantity of language that a growing child encounters depending on their family environment [26].

To aid these families, there exist guidance sessions administered by trained therapists, for both parents (called parent training) and children (speech/language therapy). However, the in-person nature of these sessions impose high time and cost burdens. Consequently, automated systems that enable at-home guidance are recently being explored as complementary solutions to improving parental language. To this date, a small number of systems have been proposed [21, 30, 32, 70]. These systems analyze speech throughout parent–child interaction to provide feedback to parents on their language habits, which include conversational turn patterns, quantity of speech, and dialogue sentiment. With preliminary studies, researchers have demonstrated positive potential for such technology to provide easily accessible and low-cost aid for parents.

Yet a critical limitation of current designs—especially when compared to a human instructor—is that they neglect the context of interaction. As an example, the utterances “That car is fast! Watch out!” can familiarize a child with the linguistic entity that is a car, the concept of speed, and an idiomatic expression relevant to this setting. However, these words would be irrelevant and even counterproductive when there is no fast car around. Context is especially important in the early stages of language acquisition as associations between words and the outside world are beginning to take form [5]. However, existing systems lack awareness of physical surroundings altogether as they rely on speech signals. Moreover, speech is an especially restrictive source of information in settings with younger children, who communicate through body language and underdeveloped spoken language [60].

In this paper, we explore the design of the first system that aids parent–child interaction with contextual guidance that reflects the play situation. Captivate! composites multimodal information from AI models for gaze, scene, and natural language to estimate which objects and toys are being jointly focused on during play—which we call the joint attention distribution—and display relevant phrase cards on a tablet application. The automated guidance requires no direct manipulation of the tablet interface, enabling the parent to stay focused on playing with their child. Through an evaluation of Captivate! with parents–toddler dyads, we show that the contextual phrase cards can help parents engage their child with significantly more responsive dialogue than when using static guides.

Key to our work is an interdisciplinary design process targeted towards a vulnerable population: immigrant families, whose children are documented to be at high risk of developing language delay due to deficiencies in language nutrition. We pursue user-centered design with immigrant parents, children, and professional speech language pathologists who specialize in treating culturally and linguistically diverse families2. Through a formative investigation, we find motivation for a context-aware system that guides parents in providing responsive, diverse, and abundant dialogue to young children. We prototype Captivate! with users and experts to address unique design considerations for context-driven automated guidance. We find and discuss insights into designing guidance technology for linguistically diverse families, which is yet underexplored in the HCI literature.

We contribute:

- Insights from designing language guidance technology with immigrant parents, children, and speech language pathologists.
- Captivate!, the first contextual language guidance system for parents of young children.
- An evaluation of our system with parent–child dyads, demonstrating its potential to improve the quality of parental language input.
- A discussion on key considerations when designing contextual guidance technology for linguistic minority families.

2 BACKGROUND AND RELATED WORK

In this section, we introduce the word gap problem in immigrants. Next, we highlight prior systems for parent–child interaction and second-language learning, which jointly motivate our design.

2.1 Immigrant families and the word gap

A large body of empirical research has found that the quality of early parent language affects child cognitive development [51, 64, 65], vocabulary learning [8, 63, 66], as well as language outcomes for children with disabilities [25, 73]—hence giving rise to the term language nutrition [76]. A grim implication of these findings is that insufficient language exposure may cause some children to fall behind their peers in cognitive and language development. Indeed, the word gap phenomenon was first documented by Hart & Risley in 1995 when they observed that children of low-SES hear an average of 30 million fewer words than their high-SES peers, mostly from their parents—just within the first three years of their lives [26]. This gap in child-directed speech was linked to the gap in the language abilities of children.

2All procedures were approved by the Seoul National University IRB.
In our work, we target the design process towards immigrant families in Korea—defined as those with at least one parent born outside the country—whose vulnerability to the word gap problem is well known. Up to 70% of young children in these families are estimated to exhibit delayed language development [34, 43, 56], an astoundingly high figure when considering that over 260,000 second-generation immigrants are currently estimated to reside in the country [55]. A large part of the problem is attributed to low language use at home, as the primary caregiver’s unfamiliarity with the dominant, domestic language acts as a barrier to parent–child interaction [42]. Ideally, active interaction in the caregiver’s more comfortable language can provide the child with sufficient language exposure. Unfortunately, this is often not the case; as Section 4.2 of our formative investigation will show, factors such as cultural acceptance, educational concerns, and pressure from family members discourage many parents from raising their children in a bilingual environment. Finally, a high percentage of immigrant families are financially burdened, having less means to rely on professional help [54].

This phenomenon is not unique to Korea: studies have observed high rates of language delay and lower amounts of home language stimulation in various immigrant and refugee populations around the world [48, 68]. As a result, there are emerging efforts to design parent-directed language intervention and guidance programs tailored to linguistically diverse families [2]. However, technological aids are yet scarce [1]. We see a need for further research on both understanding the use of technology in immigrant families, as well as designing supportive artifacts, and aim to explore both directions in our work.

2.2 Automated guidance for parent–child interaction

Works in the field of automated language guidance for parents are yet few. Within the domains of HCI, CSCW, and ubiquitous computing, researchers have explored real-time interventions to aid parents on interacting with children affected by language disorders. These interventions mostly take on the form of a mobile app, in many cases accompanied by other sensing hardware such as wearable microphones. TalkBetter [32] monitors conversational turns and triggers a warning when a parent displays detrimental language habits—for example, interrupting the child while they are talking. TalkLime [70] similarly monitors turns, but uses a real-time visualization on the parent’s mobile screen to induce behavior change. Other works have targeted specific contexts. SpecialTime [30] is designed to be used in Parent–Child Interaction Therapy (PCIT), which requires tracking a parent’s performance on a predefined set of guidelines. By using speech recognition and sentence classification on parent dialogue, SpecialTime allows the parent’s language to be evaluated at home instead of clinical locations. On the commercial side, the predominant tool is LENA [21, 57], which estimates word and turn counts of parents and their child, serving as a passive informatics tool. As part of an effort to reduce the word gap, the LENA software has been distributed to low-income parents [75].

Importantly, all prior systems rely on speech processing. However, audio is a noisy and restrictive signal where young children are concerned, as gestures, cries, and prelinguistic vocalizations prevail [33, 60]. This leads to challenges in both accuracy and specificity of guidance. For example, the performance of the LENA system in tracking child-directed words and conversational turns has been found to be low [12, 49]. At the same time, the instructions to parents provided by current systems are context-agnostic—for example, “speak more words”—while being unable to recommend which words to use in the current situation. We see an opportunity to expand the quality of guidance by incorporating visual signals to form a more comprehensive picture of interaction context.

Our work also builds upon a broader body of system designs for parenting. While not providing real-time feedback, Háblame Bebé [1] is a recent mobile app that shows promise in teaching parents about the importance of language nutrition and bilingual home environments. MAMAS [35] aids mealtime situations with specialized hardware that tracks the child’s eating habits, along with an app for parent reflection. MOBOERO [71] assists parents with children affected by ADHD by guiding them through morning and bedtime routines. ParentGuardian [59] also supports parents with ADHD children by detecting moments of high stress, then providing guidance to lower stress levels. DyadicMirror [38] aids parents’ self-awareness by fitting the child with a wearable “mirror” device, which displays the parent’s face throughout interaction. The positive behavior changes demonstrated by these systems points to the many opportunities that lie in designing automated guidance technology for parents.

2.3 Contextual second language learning tools

Since the advent of mobile devices, researchers have explored a variety of context-aware applications to enhance learning. Most of these works have focused on second language learning in adults. Contexts incorporated range from the user’s location to nearby objects [44]. An early work, MicroMandarin [17], is a mobile application that takes the user’s location and generates flashcards of context-relevant phrases. For example, in a coffee shop, the user might be quizzed with a flashcard displaying the Chinese word, “hazelnut”. Vocabura [27] similarly uses location information to recommend words, but through real-time audio. More recently, Draxler et al. [16] proposed an augmented reality (AR) application that dynamically generates quiz questions based on the location of objects. An example might be “the cup is next to the blank” where the user must select the correct noun. Combined, these works have demonstrated that dynamic, context-aware systems are effective educational tools for learning language, which is fundamentally an associational and contextual process.

2.4 Summary of related works

In summary, insufficient language nutrition causes many children to fall behind their peers from early on; one especially vulnerable population are children growing up in linguistically diverse homes. Automated systems that guide parent language use show potential to be an accessible and effective solution for these families. However, currently explored systems do not consider contextual information, which contains diverse word learning cues such as visual and situational information. Meanwhile, many works have
found context-aware technology to be effective tools for second-language learning in adults. Informed by these ideas, we aim to design the first contextual language guidance system for immigrant parents to help them provide effective language nutrition to their children.

3 DESIGN PROCESS
To design our system, we structured a user-centered design process with parents and children of immigrant families, and experts specializing in speech/language guidance for these households. Our procedure, shown in Figure 2, consisted of multiple design stages that can be grouped into two. First, we conducted a formative investigation (Section 4) where we established goals and considered for a technological aid that improves parents’ language, specifically in the context of immigrant families. Here we explored the empirical literature on which parent language qualities affect children’s development. Furthermore, we conducted an interview with language guidance practitioners to understand how we can design a system that meets the guidance needs of the target user population. Combined, these processes revealed key design implications for our system.

Second, we designed features that directly address these implications (Section 5), and iteratively prototyped the resulting system, Captivate!, with users and experts (Section 6). Our methodology included observational studies and usability tests with parent–child dyads, interviews with parents, and interviews with SLPs using low-fidelity mockups and usage videos. We discovered considerations for the novel context-driven interface that functions without user manipulation, and improved its usability through user feedback. We also iterated over the guidance content displayed to parents, and designed phrases that stimulate parent language and interaction. Finally, we improved the accessibility of the app for parents with low Korean proficiency.

3.1 Participants
Parent and expert participants were recruited through the help of Multicultural Family Support Centers1, which direct government efforts to support immigrant and foreigner families in Korea. Among the centers’ initiatives is a language development program for children in these families. In the program, SLPs employed by the center administer speech/language therapy and parent training. We initially reached out to five centers and explained our study goals and procedure, leading to three centers agreeing to participate. It should also be mentioned that previously, we had tried several traditional channels for recruiting, such as online advertisements, but were unable to reach immigrant parents through them.

3.1.1 Parents and children. The parents and children who were recruited are shown in Table 1. All parents were recruited through the three centers either directly (by center personnel calling or asking in-person) or indirectly (through a friend or family member that had been reached). We note that many parents visit the centers because they have children participating in the language development program, which is mainly offered to children who show signs of language delay (as judged by the SLPs through a formal evaluation). This likely affected the prevalence of language delay in our child participants, as well as the level of familiarity the parents had with language guidance. Parents of multicultural families (defined as those with one parent born outside of Korea) or foreigner families (both parents with non-Korean nationality) were eligible to participate. We included children aged 0–5 in our eligibility criteria for the prototyping process, which we narrowed to 1–3 in the evaluation to add control for child age-related factors. As our system provides Korean language guidance, we verified that all parents recruited included Korean among the languages spoken to their children. Otherwise, we did not screen for proficiency in Korean.

3.1.2 Experts. The expert participants are shown in Table 2. With the exception of M1, who was a program manager in charge of the language development program at a center, all were SLPs currently employed at the Multicultural Family Support Centers. The SLPs specialized in screening children of immigrant families for language problems, administering language development sessions, and instructing parents. M1 had multiple years of experience in coordinating programs for immigrant and foreigner families. All three experts participating in the formative investigation were recruited from the same center; all SLPs of the prototyping stage were recruited from another (single) center.
We began our design process with a formative investigation that we conducted a group interview with experts who specialize in counselling culturally diverse families to seek answers to RQ1. Our investigation consisted of two parts. First, we explored the empirical literature on the relationship between parent language and child language acquisition, gaining insights into RQ1. Second, we conducted a group interview with experts who specialize in counselling culturally diverse families to seek answers to RQ2 and RQ3. In this section, we share our findings and summarize the corresponding design implications.

### 4 FORMATIVE INVESTIGATION

We began our design process with a formative investigation that explored the following research questions:

- **RQ1.** Which qualities of parental language input should our system aim to improve?
- **RQ2.** How can our system guide parents into improving these qualities?
- **RQ3.** What special design considerations are needed for immigrant parents?

Our investigation consisted of two parts. First, we explored the empirical literature on the relationship between parent language and child language acquisition, gaining insights into RQ1. Second, we conducted a group interview with experts who specialize in counselling culturally diverse families to seek answers to RQ2 and RQ3. In this section, we share our findings and summarize the corresponding design implications.

### 4.1 Exploring goals of language guidance

Language is complex, encompassing everything from semantics, to grammar, to pragmatics such as nonverbal gestures [19]. We sought to scope this design space by asking, “what are the key qualities of parent language that act as language nutrition, stimulating language growth in young children?” To answer this question, we referred to large-scale meta-analyses of empirical studies that have linked various attributes of parent behaviors to the language outcomes of their children [72, 76]. As a result, we found several key qualities of parental input that are thought to facilitate language acquisition, and summarize them below:

#### 4.1.1 Responsiveness

Parent responsiveness can be defined as the “prompt, contingent, and appropriate reaction to infant behaviors” [50]. For example, a responsive parent would promptly respond to a child pointing at a car with a relevant comment, such as “Yes, that is a red car!”. In this example, the parent demonstrates two important responsive behaviors: **verbal contingency**—responding to the child with appropriate speech—as well as **joint attention**—being focused on the same subject as the child. Responsiveness is thought to be one of the most important qualities of effective parent input as its positive effects on infant language learning has been widely documented [3, 7, 28, 37, 40, 53]. For example, a study has found that infants learned far more effectively when taught about the objects they personally pointed at [3]; other studies have found strong correlations between measurements for parent responsiveness and child development [7, 40, 53].

#### 4.1.2 Lexical diversity

The diversity of a parent’s vocabulary usage has been linked to language ability in children [6, 29, 31, 58, 67]. Quite intuitively, children exposed to richer words have more opportunities to expand the breadth and depth of their vocabulary understanding. Some studies have even found that parent lexical diversity accounts for a significant portion of the learning gap between low and high-SES children [6, 31], which highlights its importance. However, it is important to note that simply including obscure vocabulary words in one’s dialogue just for the purpose of diversification is unlikely to be effective. Instead, the variety of words that are used must exhibit responsiveness, encourage the child’s interaction, and include rich associations between real-world entities and language [36].

#### 4.1.3 Quantity of speech

More talk by the caregiver predicts child language outcomes [20, 26, 64, 66, 69, 74]. Specifically, studies have linked the volume of parent words to the future vocabulary of the child [67] and cognitive development [64]. However, as in the case of lexical diversity, simply speaking without thought or leaving the TV on is unlikely to be effective language input. Current research postulates that words directed to the child are the primary stimuli behind language learning; speech directed to children (but not overheard speech) predicts their future vocabulary size and is correlated with the processing speed of familiar vocabulary to around 30 months [69, 74]. In other words, active language use that, once again, exhibits responsiveness and engages the child should be a goal of parent language.

#### 4.1.4 Notes

It is worth noting that literature on child-directed speech has traditionally described acoustic features such as slower

---

### Table 1: List of parents and children who participated in the design and evaluation studies (separated by the middle line).

| ID | P | C | Age (m) | Language delay | Previous country | Yrs in Korea |
|----|---|---|---------|---------------|------------------|-------------|
| P1, C1 | F | M | 42 | Y | Taiwan | 6 |
| P2, C2 | F | F | 39 | Y | China | 10+
| P3, C3 | F | M | 34 | Y | China | 10+
| P4, C4 | F | M | 39 | Y | Cambodia | 4 |
| P5, C5 | F | F | 48 | Y | China | 10+
| P6, C6 | F | M | 48 | N | China | 6 |
| P7, C7 | F | M | 69 | Y | China | 10+
| P8, C8 | F | F | 19 | N | Vietnam | 10+
| P9, C9 | F | F | 50 | N | Vietnam | 5 |
| P10, C10 | F | F | 31 | Y | Korea | 10+
| P11, C11 | F | F | 41 | N | Vietnam | 3 |
| P12, C12 | F | M | 20 | N | Vietnam | 10+
| P13, C13 | F | F | 47 | Y | Vietnam | 5 |
| P14, C14 | F | F | 31 | N | Vietnam | 8 |
| P15, C15 | F | F | 27 | Y | China | 10+

### Table 2: List of experts who participated in the design process. Experience here refers to the number of years at Multicultural Family Support Centers specifically and excludes prior training.

| ID | Profession | Stage | Experience |
|----|------------|------|------------|
| S1 | SLP | Formative | 1 year |
| S2 | SLP | Formative | 3 years |
| M1 | Manager | Formative | 1 year |
| S3 | SLP | Prototyping | 5 years |
| S4 | SLP | Prototyping | 1 year |
| S5 | SLP | Prototyping | 2 years |
speaking rate, exaggerated intonational contour, and clear pronunciation as some of the key features, but the direct effects of these features on language outcome have been debated [13, 24, 46]. Importantly, many qualities of parent language are intercorrelated: for example, parents who are responsive are likely to display more positive affect [76]. We therefore hypothesize that targeting our guidance towards the three key qualities above can also yield general improvements in the quality of parental input.

4.2 Therapist group interview

Next, we sought to supplement the insights from the literature with the expertise of practitioners. Specifically, we looked for practical guidance techniques that can be adapted to a mobile app-based setting, as well as considerations when designing for immigrant parents and children. We conducted a 90-minute, semi-structured group interview with two SLPs (S1, S2) from a Multicultural Family Support Center and the manager (M1) who led its language development program. We transcribed the interview and applied iterative coding to find the following themes:

4.2.1 There is a need for accessible guidance for parents. The SLPs shared that many immigrant parents rely on professional therapist sessions for their child’s language stimulation. “At my previous institution, the mothers mostly had occupations . . . so they were more dependent on professional language education sessions, but the education did not continue at home. So I often thought about how to extend the education [to home settings]—but should I call it their personal lives? It felt like too much to ask to intrude and tell them, ‘you must act like this [at home]’ . . . they signed up for these sessions because they lack Korean skills, and they have jobs . . . so asking them to do too much can be very burdensome for them” (S1). However, the in-person nature of therapist-led sessions limits their frequency; moreover, the COVID-19 pandemic prevented these face-to-face sessions altogether, leading to a gap in the children’s learning. “If the app is developed, [parents] can use that. I think it would be good if there was a way to provide stimulation at home. Because, language development [classes] are only twice a week.” (M1).

4.2.2 The language barrier often prohibits interaction. A dominant theme throughout the interview was the difficulties many parents experience in interacting with their children when they themselves are uncomfortable in the Korean language. “Many parents of young children shared with me that they find it difficult to linguistically stimulate their child, or to get them to follow directions” (S1). “There are also parents unable to read Korean . . . they express regret that they cannot read a book for their child” (M1). This suggests a need for guidance that helps these parents in providing richer Korean language input while interacting with the child. At the same time, it demonstrates the importance of accessible design that can be used even by parents unfamiliar with the target language, while also being useful to parents more fluent in it.

Importantly, the SLPs reported a lack of bilingual interaction in households despite the low Korean proficiency: “Of the five children that I’m currently treating, only one family has a positive attitude towards a bilingual environment,” (S1); “It’s about the same for me.” (S2). The primary reason was the belief that such environments would induce subtractive bilingualism [41], where the child learns the parent’s language at the expense of Korean, which may disadvantage them socioeconomically. “There are many cases when the primary caregiver, the grandparents, or acquaintances view [bilingual households] negatively” (S1); “It may be a negative effect of focusing on Korean language development since [the child] is going to grow up in Korea” (M1). We fully acknowledge the need for societies to accept and foster linguistically diverse children, but given the status quo, we scope our design towards monolingual (Korean) language stimulation guidance. We later discuss potential ways to extend guidance technology to multilingual households.

4.2.3 There are diverse techniques for language stimulation. When asked about the most effective guidance technique, the SLPs expressed that there is no single answer. “Although a therapist may be able to judge which stimulation techniques are suitable for specific children, we cannot say which techniques are more important in general. Because, it really differs by the child’s case.” (S1). For example, some children have difficulties in pronunciation; their parents would benefit from lessons in making correct mouth shapes. Meanwhile, other children require more exposure to language—in these cases, many of the parent qualities listed above are targeted. Some techniques include the use of situation-relevant words (“it is good [for language stimulation] to repeatedly expose the child to words related to the people and things they encounter in their daily lives” (S2)), or expansions (“if the child says ‘ball’, we can expand it to ‘large ball’ or ‘soccer ball’ to add a semantic element.” (S2)).

Concerning parent language training, one of the SLPs mentioned their experience with triadic guidance, where an expert gives real-time feedback as the parent interacts with their child. “[In these sessions] I watched the child and mother play, and instructed to her, ‘you should provide stimulation like this’ . . . when the parents watched me and also listened to my feedback, it was definitely helpful for them in improving with areas that they could not approach at home.” (S1). While triadic guidance has been found to be effective in the literature [62], in practice the technique is not often used for immigrant parents as many of them feel uncomfortable speaking to their child under observation. Hence, we saw a valuable opportunity for a mobile application to act as an unobtrusive triadic guidance provider, enabling the parent to learn from active feedback rather than passive guidelines.

4.3 Design implications

Combined, the investigations revealed a need for language guidance technology for immigrant parents, as the language barrier and social factors hinder rich language input to their children. The language stimulation techniques shared by the SLPs aligned with our formative findings on the importance of exposing children to responsive, diverse, and active language; they also provided key ideas for mobile app-based parent language guidance.

We summarize the key insights from the formative investigation in Table 3, and map them to design implications for our system. In the next section, we address these considerations through the design of Captivate!.

5 SYSTEM FEATURES

Based on the formative implications, we designed Captivate! (Figures 3, 4), a tablet application that provides language guidance to
### Table 3: Summary of formative insights, corresponding design implications, and the final features designed to address each.

| Formative insight                                                                 | Design implication                                                                 | Designed feature                       |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------|
| There is a need for accessible, at-home language guidance tools for immigrant parents. | A mobile app can function as a convenient, unobtrusive, and active guidance provider. | Tablet app form                        |
| Responsiveness is a key quality in stimulating child language development.         | The app should aid the parent in responding to their child’s actions and interests—without diverting attention from the main interaction. | Joint-attention-aware guidance          |
| Using language that is active, diverse, yet also relevant and engaging is another key quality. | The app should stimulate the parent into speaking actively and diversely about the child’s focus. | Phrase cards with target words (joint attention-aware) |
| Immigrant parents have varying levels of proficiency in the domestic language.  | The app should be accessible to parents with low language proficiency, while maintaining usefulness to more fluent users. | Drawings & read-aloud function         |

**Figure 3:** The main interface consists of six phrase cards arranged in a grid, and a progress bar underneath that fills as the parent uses more target words (colored). The shown cards are dynamically chosen based on the current interaction context.

Parents throughout play. The UI consists of several phrase cards; each card contains a phrase with a target word related to a specific object, such as a flower or teddy bear. **Captivate!**’s defining feature is the real-time, contextual recommendation of cards that reflects the focus of the child and parent. For example, upon attending to a flower toy, **Captivate!** will display phrases corresponding to flowers; the number of flower-related cards will increase in proportion as more attention is focused on it by the parent and child. No direct manipulation of the app is necessary, and the tablet is intended to lay statically on the floor.

In this section, we introduce the core system features. In Section 6, we further describe how these features were concretized through user and expert feedback.

#### 5.1 Joint attention-aware guidance

Our formative investigation revealed the importance of responsive parent language input. However, facilitating responsiveness with a mobile app is challenging for several reasons. First, responsiveness requires being aware of the current interests and communication gestures of the child, as well as the surrounding environment, such as the toys that are being played with. For example, if the child shows interest in a doll, a responsive parent would quickly respond with doll-related dialogue. However, current mobile apps are not able to understand situations occurring outside the screen. Second, responsiveness requires the parent to be focused on the child, not a mobile application. Thus, an app that facilitates responsive behavior in real-time must be able to do so while detracting minimal attention from the parent.

To address these challenges, we conceived of guidance that automatically adapts to joint attention between a parent and child. Joint attention is a broad concept encompassing a shared focus on an object or person [52]. By encouraging language that is relevant to the targets of joint attention, we can facilitate responsiveness. However, yet another challenge lies in that young children’s attention spans are short and dynamic. Within seconds, the child—and a responsive parent—may shift their attention from playing catch, to riding a bike, to eating. Consequently, providing guidance relevant to only a single attended object at a given moment in time would lead to frantic changes in the user interface. We therefore modeled attention as being distributed across several objects, which we call the joint attention distribution. The weight of each object in the distribution determines the corresponding amount of guidance to be shown.

Importantly, attention is not conveyed through a single action; speech, body language such as pointing, and gaze can all signify
one’s focus [4]. Based on this observation, we designed a system that infers targets of joint attention based on multimodal cues—specifically gaze and speech, which are among its most prominent signals. An illustration of the mechanism is shown in Figure 5. The targets of joint attention are signified both through the parent and child’s gaze, as well as the parent’s dialogue “throw the ball!”. Combined with the joint attention distribution model, we can ensure that as focus is shifted to the ball, there is a corresponding increase in the number of ball-related guidance cards on the screen.

5.2 Phrase cards with target words
To stimulate active and diverse parent language, we selected phrase cards as the form of guidance. Phrase cards are widely used by parents and SLPs as both a reference and play object when interacting with children. We conceived a simple form of cards containing target words relevant to an object: for example, a target word for “ball” can be “throw”; one for “flower” can be “colorful”. In effect, the target words can help the parents apply productive language features such as situation-relevant words or expansions. We initially referred to a curated list of words for language-learning children to select target words for common objects and toys [9]. However, we progressively iterated through different target word selections and phrase structures through user and expert feedback—a process which we detail in Section 6.3. Additionally, we added motivation for parents to use the target words with a daily goal progress bar that increments as their usage is detected.

6 PROTOTYPING
We iteratively prototyped Captivate with parent–child dyads and SLPs to improve its usability and effectiveness. A thorough prototyping process was especially important given the novelty of the context-driven guidance interface, as well as the limited guidelines on designing technological language guidance for the target user population.

6.1 Methodology
The participants were 7 parent–child dyads from multicultural homes (P1, C1, …, P7, C7) and 3 SLPs (S1, S2, S3), as shown in Tables 1 and 2. Specifically, we conducted two groups of studies: (1) observational studies, usability tests, and interviews with parent–child dyads; and (2) expert interviews with low-fidelity mockups and prototype usage videos. Due to the COVID-19 pandemic, we conducted two of our parent feedback sessions remotely over Zoom. The other five sessions consisted of on-site studies where a parent brought their child to a playroom to use the prototype. Each play session lasted around 60 minutes, with half the time spent playing with the child naturally (without using the prototype). We left the room but recorded the play footage, which we reviewed afterwards. An interview was conducted after each session. With the SLPs, we conducted 60-minute semi-structured interviews at two different stages of design: once with low-fidelity mockups (with S3) and once using reference videos of dyads using the prototype in a play situation (with S4, S5). We continuously iterated through improved system designs throughout the process.

6.2 Improving the context-driven interface

6.2.1 Attention sensitivity. As the app functioned without direct manipulation from the user, it became apparent that how quickly the interface responded to shifts in joint attention was a critical factor in usability. We termed this attention sensitivity, and explored the answer through observing parents use the prototype with varying degrees of sensitivity. When the recommended phrases updated too quickly to attentional changes, parents commented that they needed more time to read the phrases, as playing with the child was already consuming much of their attention. However, when the app was overly insensitive, many parents spoke about the “slowness” of the app: “It was difficult to use the sentences because the [relevant] cards appeared so slowly” (P5). We asked the SLPs for their opinions on the optimal sensitivity: S3 suggested that roughly 30 seconds would be appropriate. Based on these insights, we modeled the sensitivity such that a shift in attention to an object triggers a relevant phrase to appear quickly (within 10–30 seconds). However, additional phrases appear at a slower rate. The nonlinear sensitivity enabled the interface to be perceived as responsive while not overwhelming the user with UI changes.

6.2.2 Content diversity. On the other hand, our observations also revealed periods of prolonged attention towards the same object. In this case, there would be no changes in the recommended phrases, which was problematic to our goal of stimulating diverse dialogue. Parents who evaluated prototypes in this state pointed out that the same sentences continue to be displayed on the screen. “It’s too much of the same sentence. I want the app to show me some other sentences” (P6). Consequently, we designed a mechanism for ensuring content diversity. We designed our system to update the phrase of an object-related card in two cases: first, if the parent speaks the phrase multiple times, signifying that the child has heard it sufficiently; and second, if a phrase had been displayed for a long time, implying that the parent had enough time to read and consider it. For example, once a parent uses the phrase “throw the ball” multiple times, the card would update itself to now display the phrase “roll the ball”.

6.3 Designing effective phrases
Another focus of iteration was in designing phrases that effectively stimulates language use. When asked about the difficulties they faced in speaking actively, many parents reflected that they often could not quickly think of, and lead the child into, new situations where different words can be applied. “I don’t know Korean well, so [I just say] just throw it! Throw it! … The only word I could come up with [the ball] was “throw”.” (P6). We therefore selected target words for each object that could both induce and be adapted in a wide variety of play situations, such as “roll (ball)” and “bounce (ball)”. Additional considerations were made regarding their presentation. A basic approach that we began with was displaying just a list of target words. However, all SLPs thought that it would be difficult for parents to construct sentences on the fly when just given a single word. “It would be helpful for us [SLPs] to reference a list of words, but for people who find it difficult to make sentences, simple phrases would be better” (S3). Their opinions were mixed on providing complex sentences such as “The ball rolled down the hill,” which includes rich language but is also more difficult to adapt in play situations.
Based on these comments, we created two-word phrases composed of one object and one target word, e.g., “the dog barks”. The simple form enables easy extensibility, such as with expansions (“the brown dog barks”) or onomatopoeia (“the dog barks, ruff ruff!”).

6.4 Supporting low language proficiency
Nearly all parents and SLPs emphasized the need to support parents with low Korean proficiency. P4 shared that “many parents of multicultural families in Korea are worried that their incorrect pronunciation will have a negative effect on their children” (P4). Based on the feedback, we added a “press to read aloud” function and drawings (drawn by the second author) to each card to aid in understanding the pronunciation and meaning of guidance phrases. Subsequently, we observed many parents use the feature to practice their pronunciation of each phrase while speaking it to the child, and received enthusiastic feedback. Additionally, many of the toddlers showed interest in the feature, often repeating each phrase after pressing the cards by themselves.

7 IMPLEMENTATION
To track joint attention, Captivate! analyzes real-time video and audio of parent–child interaction. Three tripod-mounted smartphones at different angles stream data to a remote server, which performs the contextual analysis and subsequently sends the relevant phrases to the tablet application. The app is implemented on Android and communicates with the server via WebSockets. Video and audio streaming are handled through the RTMP protocol. Figure 6 shows an overview of the main processing pipeline of the remote server, which analyzes interaction cues, estimates the joint attention distribution, and selects the relevant phrases. We explain these in more detail below.

7.1 Multimodal joint attention sensing
Captivate! extracts attention-related cues independently from video and audio and use a combination of these features to estimate the final joint attention distribution.

7.1.1 Visual attention cues. As we had selected gaze as the main cue of visual joint attention, we utilize a recent Gaze Following [11] neural network to estimate the target gaze coordinates of both the parent and child’s gaze within the scene. The model requires facial bounding boxes as input, which is obtained with a pretrained RetinaFace [14] network. The system also needs to be aware of which object is located at the attended coordinates. Therefore, in parallel, we perform object detection on the scene using a Faster R-CNN [61] model, which was fine-tuned with labels of 11 toys that were used throughout the study. Combined, the pipeline produces estimations of which toys are being looked at by each individual in each frame.

7.1.2 Spoken attention cues. In parallel, we process the audio stream to find spoken attention cues. Specifically, we detect occurrences of object names in the dialogue using speech recognition. For this purpose, we use Google’s Cloud Speech-to-Text Service to obtain real-time transcriptions of parent speech. Next, we perform morpheme analysis and lemmatization on each transcribed utterance. This serves two purposes: first, the same noun can be modified in many forms in the Korean language; and second, we can normalize usage of modified verb and adjective usages as well, such as in the case of “the dog ran/is running/will run/runs”, to detect usage of the target word “run”. The latter output is not used in joint attention

Note that the English-translated phrases are longer than two words; however, the idea of combining a subject and target word to form a simple phrase still applies.

6https://cloud.google.com/speech/
sensing, but rather for the phrase recommendation stage of the larger pipeline. We use the KHAii library\(^7\) for analysis.

### 7.2 Joint attention distribution

We use the two attentional cue outputs to estimate a joint attention distribution, which weights each toy by the amount of focus that is currently being placed on it. We model the distribution as a temporally dependent set of weights that updates as new cues are detected. In other words, when there is no new attentional information—such as when both people are not looking at a toy—the distribution remains unchanged. However, if cues are detected, such as when the child’s gaze falls on a flower toy, or if the parent speaks the word “flower”, we update the distribution weights with the following policy:

\[
\omega_{\theta,t} = \begin{cases} 
\omega_{\theta,t-1} + \alpha & \text{if visual cue} \\
\omega_{\theta,t-1} + \beta & \text{if spoken cue}
\end{cases}
\]

where \(\omega_{\theta,t}\) denotes the weight of object \(\theta\) at the current time step \(t\) and \(\alpha, \beta\) are tunable constants. After updating \(\omega_\theta\), we normalize the distribution to reflect the fact that the relative weights of all other objects are decreased. This policy has the effect of modeling attention sensitivity nonlinearly, as shown in Figure 7.

### 7.3 Phrase recommendation

Finally, relevant phrases for each object are chosen and sent to the tablet app for display. Six cards are displayed at any given moment, although we note that this number can be changed. The proportion of phrases for a given object reflects its weight in the joint attention distribution; thus phrases for objects with the highest current weights are displayed while the others are hidden. To ensure content diversity, we replace a phrase for an object in two cases: (1) if the parent uses its target word \(N\) times, and (2) if the card has been on display for over \(T\) seconds, where we chose \(N = 2\) and \(T = 120\). We prepared six candidate phrases in total for each object.

---

1. https://github.com/kakao/khaiii

### 8 EVALUATION

We conducted a within-subjects study across two conditions with \(N = 7\) participant dyads (parents: 7F; children: 6F, 1M) to evaluate our final system. We explored the effects of contextual guidance by comparing Captivate! against traditional paper phrase cards with identical content. We note that the selected phrases and card design were already the result of iterative design and thereby expected to stimulate parent language use. However, we used the cards as the control condition to better view the isolated effects of automated contextual recommendations in parent–child interaction.

#### 8.1 Method

8.1.1 Participants. We recruited eight participant dyads from Multicultural Family Support Centers in Korea as described in Section 3. There was no overlap in participants between the prototyping and evaluation procedures. We later excluded one participant (P9) as her child threw an extended tantrum during the experiments. As shown in Table 1, the children were aged 1–3 (19–47 months; mean = 30.85, SD = 10.30). Except for one Korean-born parent, all were immigrants to the country. We did not screen for proficiency in Korean, leading to wide variety in familiarity with the language.

8.1.2 Procedure. Each parent brought their child to a university facility. We first introduced the study background and the importance of active and responsive interactions with children. Next, the parents and child were led into a playroom furnished with a mat, toys, and three cameras set up on tripods. The parents went through two 30-minute play sessions with their child in the room using the toys provided, once with the Captivate! system, and once with paper cards. The order in which these tools were provided was counterbalanced through alternation, with the first session being determined randomly. Also, as to minimize bias, only the tool to be used was introduced prior to each play session. The experimenter then left the room to ensure privacy. Finally, a 10–15 minute exit interview was conducted after the second session.

8.1.3 Metrics and coding procedure. We transcribed and coded a 10-minute segment (beginning from minute 5) from each session to analyze several metrics related to our system goals. First, we...
Weights are updated quickly upon attentional changes, but where child engagement and communication acts were first coded, we followed the two-step coding procedure of Haebig et al. [25]. As shown in Figure 9, on average the number of verbal responses that two parents (P10, P13) showed extremely high increases, one the large variation in parent–child interaction styles—we observed case-by-case—which we believe is more appropriate due to using Captivate! to the child’s focus of attention increased by 38.3% per parent when updates based on Equation 1. Dashed vertical lines indicate shifts in attention to a flower and baby toy respectively. Weights are updated quickly upon attentional changes, but the rate slows down as attention is sustained.

Through reviewing the footage from the sessions, we could attribute the improvement in responsiveness to higher parent engagement towards the child, which in turn led to higher child engagement throughout the play. When using the cards, parents were mostly only able to focus on the cards that they selected, which they tried to force into the play situation. For example, P8 went through the cards one by one. “C8, the fish swam. look at this [card]. . . . Shall we take a look at this again?”—although the child was no longer interested in the fish.

On the other hand, the app’s automated guidance presented parents with several situation-relevant choices, enabling them to use the target words without having to manually navigate a list of information. For example, when one child started playing with a bus, the app increased the number of bus-related phrases to three (Figure 12). When she shifted her focus to a dog, then a ball—all within two minutes—the app was responsive to the change, and enabled the parent to respond with target words while also staying engaged in the interaction. Indeed, the right of Figure 9 shows a visible correlation between parent responsiveness and child engagement. When using the app, the parent was able to follow a child moving around the room and engage in play; on contrary, when using the cards, the parents mostly sat statically near where the cards were placed on the ground. This suggests that contextual language guidance may benefit parents regardless of their language proficiency. As an example, P10—a native Korean speaker—was among those whose interaction improved significantly with Captivate!.

8.3 Effects on quantity and diversity of words
Meanwhile, the effects on the quantity and diversity of parent language were less significant (+8% in quantity, -3% in diversity). The result seemed counterintuitive considering that the number of verbal responses to the child’s focus of attention had increased significantly; however, the footage revealed that much of the dialogue by the parent did not follow the child’s focus. For example, P12 once saw that the child was interested in the fish toy and looked for a fish-related card, but it took more than 10 seconds to find it. In the meantime, the child’s interest had already left. In effect, the parents put in similar efforts to use active and diverse language when using the cards and Captivate!—but their words were significantly more relevant and engaging when using the app, as shown by the higher response counts and child engagement durations. We also note that the parents were clearly instructed beforehand to focus on playing while using the cards only as a reference. However, we found that most parents wanted to teach their children new words and actively used the cards (for the majority of each session) to do so; in our exit interview, all parents reflected that they felt both the cards and app to be useful.

8.4 Contextual recommendation accuracy
Finally, we also measured the accuracy and sensitivity of Captivate! by marking whether the app displayed at least one relevant card to the dominant target of focus in every minute. As shown in Figure 8, we found that a relevant card was correctly displayed in
84.4% of cases. Much of the error in the missed cases was due to occlusions; the spoon showed the highest error as it is small and easily hidden by the child or parent holding it in their hands. Despite the high accuracy within one minute, we found that several parents expected quicker responses when their child rapidly changed toys, and sometimes believed it was their own fault. For example, P11 thought that “If my pronunciation is not right, the app doesn’t work well”. Such cases revealed an important consideration when using AI technology for guidance. We discuss the implications in depth in the next section.

9 DISCUSSION

We discuss aspects of our work that may be relevant to designers of contextual guidance systems and technology for linguistically diverse families.

9.1 Research challenges with linguistically diverse families

One limitation of the evaluation was the small sample size. Although we spent considerable effort in recruiting participants, traditional recruitment channels were unable to reach immigrant parents. Even with the help of three public centers, only a small number of parents were able to be contacted. We note that studies with similarly minority populations tend to have smaller-sample evaluations [52, 45, 70]. The small sample size combined with the relatively large variation in child ages (19–47 months), parent Korean proficiency, interaction styles, and child mood led to large variance in the evaluation results. We would therefore emphasize that the evaluation results serve mainly as an early demonstration of the potential of contextual language guidance to aid parents.

Another challenge throughout the design process lied in sharing ideas across language barriers. As we included immigrants from all countries in our study, it was not feasible to prepare translation resources for all participants. Consequently, in several of our interviews, we could not directly receive detailed feedback from the parent because they were not fluent in Korean while we did not know the languages that they were more comfortable in. We undertook several measures for these cases, such as allowing the parents to invite someone who could translate; we also told participants that they were free to speak in a comfortable language at any point, as we could later translate the recording. These measures were helped communication in many cases: for example, P1 used English in her interview; P8 and P11 conducted the interview with the help of a family member.

However, we still encountered challenging interviews. In these cases we inevitably placed more weight on our own observations relative to the user feedback received. Insights from experts with extensive experience interacting with such families were also valuable in filling the gaps in our understanding. This was, of course, a compromise—ideally design research should aim to hear detailed feedback from the users themselves. There are potential techniques that might have been effective in these cases, such as requesting written feedback in the participant’s comfortable language to later translate. We emphasize that researchers designing for linguistically diverse participants should think extensively about potential challenges in communication and ways to mitigate them. Moreover, with designs involving children, especially infants or toddlers, additional considerations must be made—such as having an interview
Figure 12: Example of a dynamic play situation where the child’s interest shifts from a bus, dog, to ball within two minutes. In the middle, a dog-related card emerges by replacing the flower card. We can observe that the final screen reflects all three interests.

partner play with the child to minimize the parent’s distraction during communication.

9.2 Sociotechnical implications of guidance technology

Technology that prescribes guidance must be especially mindful of the subtle messages that it may convey to its users. For instance, we mentioned in Section 8.4 that some parents believed it was the fault of their Korean pronunciation when the app did not quickly respond to contextual changes. In reality, limitations in the underlying technology induced unavoidable errors and delays in contextual sensing—even for native speakers. However, immigrant parents were more inclined to blame their own pronunciation rather than the technology. This may have in part reflected their experiences with trained AI technology such as speech recognition, which has been found to perform poorly for cultural minorities [39]. Indeed, we found speech recognition accuracy to vary widely across parents. However, as technology designers, it is imperative that we are aware of the sociotechnical biases that users perceive, and take care not to exacerbate them. For the adoption of AI-based contextual systems such as Captivate!, interfaces should be explored so that users do not feel “judged” by technology even in the face of errors.

Lastly, we also propose a need for exploring multilingual guidance interfaces. Although concerns about subtractive bilingualism pressure many parents to speak to their child only in a less comfortable language, this practice is being increasingly discouraged by language development experts [1], including the SLPs we interviewed. We fully support the movement towards multilingual and multilingual homes that can bring unique growing experiences to children. However, guidance technologies such as Captivate! may amplify existing biases when only supporting the dominant language. We invite the HCI community to explore interfaces that can support linguistically diverse homes, such as, potentially, bilingual interfaces or linguistic scaffolds incorporated into the user experience. Such interfaces also have the potential to include other caregivers such as native-born spouses in collaboratively fostering a rich multicultural home environment.

9.3 Adopting contextual guidance systems

While contextual understanding can be a powerful tool in for guidance technology, there remain technical and design challenges that must be addressed for wider adoption. A limitation of our implementation was that the system only recognizes, and provides guidance for, the 11 predefined objects. Adding support for more would require training the object detection model on a larger dataset, as well as creating corresponding phrase cards for each addition. While the latter can be done manually as in our study, it is important to also explore more scalable mechanisms for extending guidance to new settings. One possible direction may be in utilizing semantic networks or distributional word embeddings to find target words for arbitrary objects [23].

Another consideration is in the context-sensing hardware itself. We had chosen smartphone cameras and microphones as they are commodity devices. Furthermore, they emulate key mechanisms through which people sense attention—by visually observing and listening to the opponent. We observed that gaze tends to fluctuate among many interests while speech is a stronger signal of dedicated attention. Therefore, by combining these modalities, a more comprehensive understanding of joint attention can be reached. Three cameras were used in our evaluation—primarily to stabilize the accuracy of AI models—which would be infeasible in most home settings. However, we expect that progress in AI such as in more robust detection and gaze following models, as well as face-tracking cameras, will enable Captivate! to be run entirely on a single device. It is also possible to consider sensing hardware such as gyroscopes attached to the toys that can detect when a child or parent is holding it. One challenge in this case would be in distinguishing between passive holding versus actively attending to the object.
With the rapid advance of AI technology, the future holds a wealth of opportunities for contextual guidance. A key challenge lies in understanding nuanced contextual information as a human can. For example, we once observed a child designating a boat as an ambulance because it was red-colored; however, in this case Captivate! can only designate the context as boat-related. As AI models become able to understand diverse interactions, we believe that future interactive systems will be able to provide diverse guidance—not limited to language—in creative play situations such as building, drawing, or role-playing.

10 CONCLUSION

We presented Captivate!, the first contextual language guidance system that helps parents provide effective language input to their children during interaction. Starting from an exploration of language acquisition literature and an interview with experts of immigrant language guidance, we established design implications for a context-driven language guidance technology. We addressed these implications through a user-centered design process with immigrant parent–child dyads and SLPs, which led to building joint-attention-aware guidance with tablet-based phrase cards. We evaluated Captivate! on parents and children aged 1–3 to find that contextual guidance helps parents stay responsive to their child’s actions while engaging in active and diverse dialogue. Finally, we discussed research challenges, sociotechnical implications, and adoption considerations for such technology. We conclude with an invitation for the HCI community to explore new directions in contextual guidance technology for families.

ACKNOWLEDGMENTS

We first and foremost thank the parents, children, and experts who have participated, as well as the Gwanak-gu, Guro-gu, and Yangcheon-gu Multicultural Family Support Centers. We thank the anonymous reviewers for their insights. We thank Eunjung Oh, members of SNU HCS Lab, Insup Choi, JaeWon Kim, Jaeyoon Song, Jane Im, Ji Won Yang, Taewan Kim, Yoonjeong Cha, and Kyusoon Kim for their feedback. This work was supported by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (No. 2019-0-01371, Development of brain-inspired AI with human-like intelligence). The corresponding author is Youngki Lee.

REFERENCES

[1] Melissa Baralt, Ashley Darcy Mahoney, and Natalie Brito. 2020. Háblame Bebé: A phone application intervention to support Hispanic children’s early language environments and bilingualism. Child Language Teaching and Therapy 36, 1 (2020), 33–57. https://doi.org/10.1177/0265605019895779

[2] Amy Becklenberg, Kimberly A. Hires, Ashley Darcy Mahoney, Melissa Baralt, and Jennifer L. Stapel-Wax. 2021. A Training to Promote Early Language Interactions Among Refugee Mothers Who Are Speakers of Languages Other Than English. Journal of Cultural Diversity 28, 2 (2021), 48 – 55.

[3] Katarina Begus, Teodora Olga, and Victoria Southgate. 2014. Infants Learn What They Want to Learn: Responding to Infant Pointing Leads to Superior Learning. PLOS ONE 9, 10 (2014), 1–4. https://doi.org/10.1371/journal.pone.0108817

[4] Elina Birmingham and Alan Kingstone. 2008. Human social attention. Progress in Brain Research 176 (2009), 309–320. https://doi.org/10.1016/S0079-6123(08)17618-5

[5] Roger Brown. 1958. Words and Things. Free Press.

[6] Margaret Burchinal, Lynne Vernon-Feagans, Martha Cox, and Key Family Life Project Investigators. 2008. Cumulative Social Risk, Parenting, and Infant Development in Rural Low-Income Communities. Parenting 8, 1 (2008), 41–69. https://doi.org/10.1080/1529591070130672

[7] Bonnie W. Camp, Maureen Cunningham, and Stephen Berman. 2010. Relationship Between the Cognitive Environment and Vocabulary Development During the Second Year of Life. Archives of Pediatrics & Adolescent Medicine 164, 10 (2010), 950–956. https://doi.org/10.1001/archpediatrics.2010.169

[8] Anuja A. Cartmill, Benjamin F. Armstrong, Lila R. Gleitman, Susan Goldin-Meadow, Tamara N. Medina, and John C. Trueswell. 2013. Quality of early parent input predicts child vocabulary 3 years later. Proceedings of the National Academy of Sciences 110, 28 (2013), 11278–11283. https://doi.org/10.1073/pnas.1309581110

[9] Hyun Jin Chang, Hee Sook Jeon, Myungsun Shin, and Hyo Jung Kim. 2013. A Study on Selection of Basic Vocabulary for Infants and Toddlers. Journal of Speech-Language & Hearing Disorders 22, 3 (2013), 169–187. https://doi.org/10.1572/jshd.2013.22.3.010

[10] Eun Jung Choi, Sang-In Jung, Dongrun Yim, and Young Tae Kim. 2019. A Needs Analysis of Mothers from Multicultural Family for Child Language Development Screening Tests: Using Focus Group Interview. Communication Sciences & Disorders 24, 3 (2019), 565–565. https://doi.org/10.1093/csd/19k607

[11] Eunjoo Chong, Yongxin Wang, Nataniel Ruiz, and James M. Rehg. 2020. Detecting Attended Visual Targets in Video. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR).

[12] Alejandrina Crista, Maria Lavechin, Camila Saffell, Melanie Soderstrom, Caroline Rowland, Olko Rasinen, John Bunce, and Eliza Bergelson. 2021. A thorough evaluation of the Language Environment Analysis (LENA) system. Behavior Research Methods 53, 2 (2021), 467–486. https://doi.org/10.3758/s13428-020-01939-5

[13] Alejandrina Crista and Amanda Seidl. 2014. The hyperarticulation hypothesis of infant-directed speech. Journal of Child Language 41, 4 (2014), 913–934. https://doi.org/10.1017/S0305000914000669

[14] Jiankang Deng, Jia Guo, Evangelos Ververas, Irene Kotisa, and Stefanos Zaferiou. 2020. RetinaFace: Single-Shot Multi-Level Face Localisation in the Wild. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR).

[15] David K. Dickinson and Michelle V. Porche. 2013. The Contribution Between the Cognitive Environment and Vocabulary Development During the Second Year of Life. Archives of Pediatrics & Adolescent Medicine 164, 10 (2010), 950–956. https://doi.org/10.1001/archpediatrics.2010.169

[16] Fiona Draxler, Audubry Labrie, Albrecht Schmidt, and Lewis L. Chuang. 2020. Augmented Reality to Enable Users in Learning Case Grammar from Their Real-World Interactions. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI ’20), 1–12. https://doi.org/10.1145/3313383.3376537

[17] Darren Edge, Ely Searle, Kevin Chiu, Jang Zhao, and James A. Landay. 2011. MicroMandarin: Mobile Language Learning in Context. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI ’11), 3169–3178. https://doi.org/10.1145/1978492.1978413

[18] Leia Fiester. 2010. Early Warning! Why Reading by the End of Third Grade Matters. KIDS COUNT Special Report. Annie E. Casey Foundation (2010). https://eric.ed.gov/?id=ED507995

[19] Victoria Fromkin, Robert Rodman, and Nina Hyams. 2018. An Introduction to Language: Cengage Learning.

[20] Jill Gilkerson and Jeffrey A. Richards. 2009. The Power of Talk: Technical Report. LENA Research Foundation. https://www.lena.org/wp-content/uploads/2016/07/LTR-01-2_PowerOfTalk.pdf

[21] Jill Gilkerson, Jeffrey A. Richards, Steven F. Warren, Judith K. Montgomery, Charles R. Greenwood, D. Kimbrough Oller, John H. L. Hansen, and Terrance D. Paul. 2017. Mapping the Early Language Environment Using All-Day Recordings and Automated Analysis. American Journal of Speech-Language Pathology 26, 2 (2017), 248–265. https://doi.org/10.1044/2016_ASLP-15-0169

[22] Roberta Michnick Golinkoff, Erika Hoff, Meredith L. Rowe, Catherine S. Tamis-Lemonda, and Kathy Hirsh-Pasek. 2019. Language Matters: Denying the Existence of the 30-Million-Word Gap Has Serious Consequences. Child Development 90, 3 (2019), 985–992. https://doi.org/10.1111/cdev.13123

[23] Ishaan Grover, Hae Won Park, and Cynthia Breazeal. 2019. A Semantics-Based Model for Predicting Children’s Vocabulary. In Proceedings of the 28th International Joint Conference on Artificial Intelligence (IJCAI’19). 1358–1365. https://doi.org/10.24963/ijcai.2019/188

[24] Magnus Haake, Kristina Hansson, Agneta Gulz, Susanne Schötz, and Birgitta Sahlen. 2014. The slower the better? Does the speaker’s speech rate influence children’s performance on a language comprehension test? International Journal of Child Language Pathology 16, 2 (2014), 181–190. https://doi.org/10.3109/17407507.2013.845690

[25] Eileen Haebig, Andrea McDuffie, and Susan Ellis Weismer. 2013. The Contribution of Two Categories of Parent Verbal Responsiveness to Later Language for Toddlers and Preschoolers on the Autism Spectrum. American Journal of Speech-Language Pathology 22, 1 (2013), 57–70. https://doi.org/10.1044/2013-0560-2012-11-0040

[26] Betty Hart and Todd R. Risley. 1995. Meaningful differences in the everyday experience of young American children. Paul H Brookes Publishing.
A CODING PROCEDURE
Following Haebig et al. [25], we extracted a 10-minute segment from each clip for coding. Accounting for the time needed for the participants to adjust to the new tool, we sampled each segment 5 minutes after the start of each session. Next, we excluded intervals where the parent or child was distracted due to unpredictable circumstances, such as when the parent was on a phone call, when the child needed a diaper change, or when the child threw a prolonged tantrum. Finally, we extracted the metrics described in Section 8.1.

To measure the responsiveness of the parent throughout the interaction, we coded verbal responses to the child’s focus of attention or communication acts. Following [25], our coding procedure followed a two-step process. First, segments of child engagement (e.g., a child looking at, pointing towards, or manipulating an object) or communication acts (e.g., dialogue or vocalization) were labeled. Next, within 3 seconds of the segments where the child was engaged or had communicated, all relevant parent utterances were marked. For example, if a child was actively playing with a teddy bear and the parent commented, “Hug the bear!”, the utterance was marked as responsive. On the other hand, if the parent tried in vain to redirect the child’s attention to a different toy, such as a bus, the utterance was not considered responsive. In contrast to [25], we did not responsive acts into subcategories but instead treated them as a single class of “responsive utterances”. After reviewing the coding instructions of [25], the first and second authors independently coded a 10-minute segment and observed substantial agreement in interrater reliability (Cohen’s $\kappa = 0.725$). Judging the coding instructions to be robust, subsequent clips were split and coded independently.

B ADDITIONAL FIGURES
We include additional figures about our experimental setup (Figures 13, 14).

Figure 13: Toys provided during the evaluation.

Figure 14: Paper phrase cards.

Figure 15: A parent using paper cards in the evaluation.
C GUIDING INTERVIEW QUESTIONS

C.1 Guiding topics for the formative expert interview

(1) About the Multicultural Family Support Center and SLPs
   • Experience at Multicultural Family Support Centers
   • Overview of language development support programs at the center

(2) Differences in a language support for children in multicultural families vs. native Korean families
   • Goals of the language development program
   • Procedure of language development program
   • Methods for evaluating the effectiveness of language development sessions
   • Number, age, and language level of children who are participating in the language programs
   • Nationality and language level of the parents whose children are participating in the language programs

(3) Linguistic stimulation in multicultural families
   • The role and importance of language guidance at home in the development of a child’s language.
   • Difficulties commonly encountered by parents of multicultural families during language guidance at home.
   • Effective parental language and interaction habits.
   • The use of bilingualism in multicultural families.

C.2 Questions asked at post-experiment interview

(1) Context-awareness
   • Did you feel that the app responds to match the play situation?
   • Did you think that the response speed was appropriate?
   • Do you think that the automated interface is convenient?

(2) Card vs. App
   • Did you feel a difference in using the two?
   • Is there a more comfortable tool between the two? Why?

(3) Design elements of the app
   • Was the read-aloud function useful?
   • Did the picture help you understand the sentence?
   • Was today’s goal useful?

(4) Usefulness of phrases
   • Are phrases applicable to play situations?
   • If it was hard to use, why?

(5) Language interaction at home
   • Do you usually play with your child?
   • Do you usually use a language card?
   • What is the difference in interaction compared to the usual play situation?

(6) Parents’ exposure to the target language
   • What was your previous country?
   • How long have you lived in Korea?

(7) Children’s experience in a language guidance program
   • Have you ever participated in a language guidance program at the Multicultural Family Support Center?
   • If there is, how low was that?

D PARENT INFORMATICS

Automated tracking of attention can enable useful features beyond real-time guidance. We implemented per-session statistics with (1) a breakdown of the toys attended throughout the play, and (2) how frequently the parent had used each target word in their dialogue. In the long term, these statistics can reveal insights into the development of a child’s interests or a parent’s language habits. However, as the Captivate! prototype was used by each parent only in a single session, the usefulness of long-term statistics was not explored in this study. That said, with the rise of personal informatics (PI) technology, we believe that automated tracking of long term parent–child interaction is a promising direction for exploration.