

Baby Steps Text: Feasibility Study of an SMS-Based Tool for Tracking Children's Developmental Progress

Hyewon Suh, MS, John R. Porter, MS, Robert Racadio, MS,
Yi-Chen Sung, MS, Julie A. Kientz, PhD
¹University of Washington, Seattle, WA

Abstract

To help reach populations of children without consistent Internet access or medical care, we designed and implemented Baby Steps Text, an automated text message-based screening tool. We conducted preliminary user research via storyboarding and prototyping with target populations and then developed a fully functional system. In a one-month deployment study, we evaluated the feasibility of Baby Steps Text with fourteen families. During a one-month study, 13 out of 14 participants were able to learn and use the response structure (yielding 2.88% error rate) and complete a child development screener entirely via text messages. All post-study survey respondents agreed Baby Steps Text was understandable and easy to use, which was also confirmed through post-study interviews. Some survey respondents expressed liking Baby Steps Text because it was easy, quick, convenient to use, and delivered helpful, timely information. Our initial deployment study shows text messaging is a feasible tool for supporting parents in tracking and monitoring their child's development.

1. Introduction

Approximately 1 in 6 children between the ages of 3 and 18 in the United States are diagnosed with developmental disorders, such as autism, ADHD, or anxiety disorders¹. It is known that the earlier these disorders can be diagnosed, the sooner early interventions can start, resulting in better outcomes for these children⁸. Unfortunately, approximately half of children who eventually receive diagnoses of developmental disorders are not identified until they reach kindergarten in the United States³, with lower-income populations being missed at a higher rate³⁰. Tracking and regular screening of child development is the key to early detection of many types of developmental disabilities. Developmental screening involves regular checks for developmental milestones at up to 22 different intervals across a child's first 5 years of life². Milestone screening includes age-based questions such as "does your baby turn her head towards a loud noise?" and "can your child climb stairs?" Because these activities take place in daily life outside of traditional clinical settings, parents' and caregivers' reports for the early signs of developmental delay are the most reliable way to track them. Therefore, it is important to engage, inform, educate, and empower parents to track and assess their child's development in an easy way in order to make monitoring more accurate and meaningful. Unfortunately, 5 years is a long time to keep parents engaged consistently. In addition, parents without access to developmental screening often have difficulties in monitoring because they may not be aware of what to watch for. Pediatricians provide parents milestone questionnaires to complete at Well Child Visits (regularly scheduled checkups in the U.S). However, given Well Child Visits are months to up to a year apart depending on the child's age, it is not the timeliest solution. In addition, many resource-constrained populations, such as low-income or immigrant families, lack the insurance to cover Well Child Visits, and frequent moves or language barriers make it difficult to access information about normal child development.

The ubiquity and penetration of mobile phones presents an opportunity, particularly in under-resourced health ecosystems, via SMS (Short Message Service), a low-cost communication channel that is supported on even the most basic of mobile phones. Between 2000 and 2012, the number of mobile phones in use worldwide grew from fewer than 1 billion to around 6 billion⁴¹. In the United States, 91% of adults own a cell phone as of 2013¹¹. This widespread distribution of mobile phones across diverse populations may solve one of the most difficult problems in public health domain – barriers to access. Thus, mHealth (mobile health) can make it possible to inform caregivers and let them collect and share relevant data at any time, allowing more rapid convergence to optimal treatment.

To attempt to reach more underserved populations with child developmental screening, we have developed Baby Steps Text, a tool that prompts parents to track and review developmental milestone data and connect them to resources using only text messages. Baby Steps Text is a completely automated, personalized, and self-contained two-way communication system that also works seamlessly with a larger set of tools that have been developed as part of a developmental screening ecosystem (including a web portal and Twitter-based tools³⁹) Baby Steps Text provides a way to understand how we can include resource-constrained populations who may not yet have constant Internet access or sophisticated smartphones. This paper presents the design, development, and feasibility study of the Baby Steps Text system. Our research brings SMS-based mHealth interventions to a new domain (childhood developmental

screening) and helps expand knowledge about how parent-generated health data can be collected in a simple but thoughtful way, thus expanding the reach of its benefits.

2. Related work

2.1. Domains of SMS-based mHealth

Using mobile phones to support health interventions has a number of advantages over other technologies. The biggest advantages of using mobile phones for supporting public health are that they are personal, connected, relatively inexpensive, and always with people. Current evidence suggests that SMS-based mHealth supports the following four health domains: **1) Disease Management & Treatment Adherence:** Use of text messaging to reinforce treatment (e.g. HIV/AIDS^{6, 40}, diabetes^{14, 24}, asthma^{38, 42}, smoking cessation treatment^{15, 37}, weight loss³⁴, mental illness⁹, and medication adherence²⁸); **2) Health Information Delivery and Behavior Change:** Text messaging as an inexpensive tool for behavior change and the delivery of health information (e.g. educating about pregnancy and newborns^{10, 33}, vaccination⁴¹, youth sexual health²⁹, weight management¹⁶, and encouraging physical activity¹²); **3) Patient-Provider Communication:** Use of mobile phone as a communication channel between patients and providers (e.g. clinic appointment reminders^{5, 27} and communication with visually impaired patients about health information²⁵); **4) Early Detection & Screening:** Screening for early detection of disease (e.g. cervical cancer screening²⁶, and breast self exams²⁰). However, despite advantages of SMS in delivering information at the appropriate time, use of SMS for screening purpose has not been as well-explored as much as other areas. Baby Steps Text fits into this domain most closely, and addresses a new area within it for children's developmental screening.

2.2. One-way vs. Two-way SMS Communication

One-way SMS communication is similar to mass media in that it "pushes" information to subscribers' phones by using messages tailored to personal needs. A large body of SMS-based research has typically been designed this way. This includes simple reminder programs such as reminding clinic appointments and other systems such as sending health promotion and dietary and disease management information. In one-way SMS systems, the subscriber is more of a passive recipient rather than an active user. In order to solve this problem, some projects used two-way communication in their communication message design. For users, the interactive nature of two-way communication may require greater effort and generate greater interest¹⁹. While some projects support a fully natural way of communication by having a humans responding to questions and concerns sent by users²⁸, other projects support fully automated communication by requiring users to follow a specific structure to enable automated parsing by the system^{7, 31}. Recently, Perrier et al.³⁵ deployed a hybrid two-way communication where the system sends out bulk messages to its users automatically, and a human behind the scenes takes care of user replies.

2.3. Technology Design for Infant and Children's Health

Researchers in the human-computer interaction community have sought to design technologies in support of children's health. These areas have primarily been focused on general studies on the opportunities for design of technologies for children's health, technologies for use of parents and doctors, and technology to be used by children themselves. For general studies of opportunities, Kientz et al. conducted a formative study on the opportunities for the design of developmental tracking systems²¹, and then later conducted an in-depth evaluation of the opportunities for supporting parent-pediatrician interaction²³. Jeong et al. studied parents with the purpose of providing insights for the design of technology for tracking general health data about children¹⁸.

This prior formative work has informed a number of systems designed to support parents in tracking their children's health. The original Baby Steps system²² was a software application to track developmental progress, with follow on work expanding it to using Twitter³⁹. Baby Steps Text seeks to build upon this previous literature by exploring a new delivery mechanism for developmental screening. Additional designs for helping parents monitor their children's health include ENSURE³², which help parents track daily health data such as meal intake and diapering, and Fitbaby¹⁷, which helps parents of premature infants track their child's physical exercises and overall wellbeing. Both ENSURE and Fitbaby focus on general health observations and are not intended for screening, as is the goal of Baby Steps Text.

3. User-Centered Design Process

One of the primary goals for the overall Baby Steps project was to identify ways to reach underserved families for developmental screening. We conducted a user-centered design approach that formed the basis for the final design of Baby Steps Text, which we describe in the following section (see Figure 1) to engage with key members of this initiative to explore the use of technology in helping to reach underserved populations in collaboration with Washington State's Department of Health. We focused specifically on Latino populations in our state, as they represent a large percentage of underserved populations and experience a number of challenges that may affect other underserved populations, such as access to health insurance, access to mobile technology, and cultural and language barriers¹³. However, the intended users of Baby Steps Text are broader than just this specific population.

3.1. User Research

To get a broader perspective on our target population, we conducted semi-structured interviews with five stakeholders, including one Latino parent of a child with a developmental disability, two health care providers, and two Latino community health advocates. The interviews aimed to understand how parents engage in healthcare for their child and participate in developmental screenings and how health information is communicated. The research team members also visited a Latina health fair located in a predominantly working class Latino neighborhood in Seattle. The health fair was organized by a Latino-focused community health center, attended by Latina women, their families, and community leaders. We administered short surveys to 15 mothers and asked questions related to technology use, the number of children in their family, and their language use.

From the interviews, we learned that Latino households are commonly multi-generational—consisting of children, their parents, and their grandparents—and the responsibility of caring for children is shared with members of the extended community. When asked to describe the technologies that members of the Latino community would most likely have access to, the most common answer was the mobile phone with basic capabilities. They suggested that home computers or home Internet access would not be common, but families might use computers in public venues, such as at the library. Findings from the survey supported several findings from the interviews. In particular, mobile phone use was prevalent (93% of respondents), as was text messaging (87%). Only 6 participants (40%) used their phone to access the Internet and only two (13%) downloaded applications, which meant an entirely text message-based system would have broader reach than a mobile website or app, as home computer and Internet access were not as prevalent (60% and 53% respectively). Two mothers (13%) also mentioned they did not use services like mobile Internet or Facebook, but that their spouses did. We learned from the providers and health advocates that they serve a community that varies widely on literacy skills. The Latina fair survey confirmed these numbers, with the majority of participants preferring Spanish, but nearly half also having English proficiency.

To summarize our preliminary user research, we developed a set of 9 personas representing stakeholders of the potential system, including three different family caregiver types, community members, healthcare providers, and advocates in the state (see Figure 2 for an example persona). These personas were used during the ideation and design process to ensure the needs of stakeholders were represented in the design of the tools.

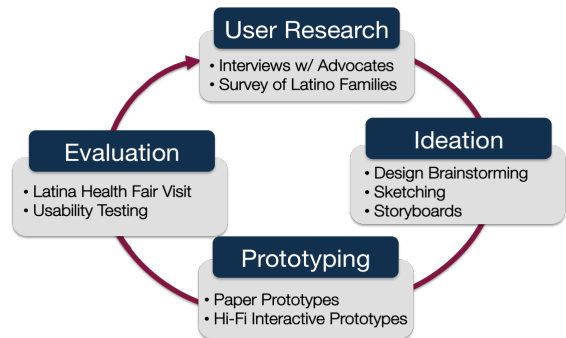


Figure 1. User-centered design process that resulted in the design of Baby Steps Text

SARITA
THE SPECIAL NEEDS PARENT

"I wish I had known sooner. It want to do everything I can to see where my child stands and help him grow."

PERSONAL INFORMATION
Age: 31 | Income: \$25k
Profession: House cleaning
Children: Elias (8) and Ramon (2)
Technical Proficiency: Computer use at library, mobile phone at home
Country of Origin: Mexico
Languages Spoken: Spanish, some English

HEALTHCARE INFORMATION
Health Insurance: Yes, but limited coverage
Doctor Visits: About once monthly for Ramon or her children. Visits local health clinic.
Healthcare Background: No professional medical training

GOAL: To understand where Elias stands developmentally and connect him with treatment services, and to watch for warning signs in Ramon.

Sarita is a working mother of 2 children. Her older son, Elias, had difficulty speaking when he was nearly three. She did not notice as much at first, but it became apparent when her sister's family moved in with them, and Elias's similarly aged cousin could speak much more than him. She mentioned this to the local *husuero*, or community healer. She suggested that Sarita have her child evaluated by a local early intervention specialist. Elias was diagnosed with speech delay and referred to a speech-language pathologist, who has been seeing Elias for the last two years, and he now speaks at a developmentally appropriate level for his age.

Because early intervention worked so well for her son, Sarita is vigilant about looking for the early warning signs for her younger son Ramon. She also continues to track Elias's progress to make sure his therapies are keeping him on target.

SUPPLEMENTAL PERSONA: Parents of children diagnosed with special needs are a smaller portion of target users.

The storyboard on the right consists of seven panels showing a person using a mobile phone. The panels contain Spanish text and icons representing different stages of the process: '¿Cómo se llama el niño?', '¿Cómo se llama el niño?', '¿Cómo se llama el niño?', '¿Cómo se llama el niño?', '¿Cómo se llama el niño?', '¿Cómo se llama el niño?', and '¿Cómo se llama el niño?'.

Figure 2. Left: Persona for a parent of a child with special needs. Right: Spanish-language Storyboard of Baby Steps Text used for generating feedback from participants at the Latina health fair.

3.2. Ideation & Prototyping

The research team conducted a design ideation brainstorming session and generated 63 unique ideas for potential technologies to reach Latino families in the state with developmental screening. We kept copies of the personas present during the brainstorming to ensure designs were grounded in the needs of the stakeholders. From there, we narrowed design ideas into the most promising and feasible three ideas for which we developed storyboards in both English and Spanish suitable for user feedback (Figure 2). The three ideas included text messaging, a website, and a public kiosk. We also developed high-fidelity interactive prototypes of a public kiosk and a website using the Axure prototyping

tool (<http://axure.com>) and a Wizard-of-Oz prototype³⁶ of the text messaging tool using Google Voice to send messages to participants' phones and a detailed script of messages.

3.3. Evaluation

We reviewed the storyboards and prototypes with stakeholders, including advocates and families attending the Latina health fair. When reviewing the storyboards with potential users, the text messaging-based system seemed to be the most promising approach for the furthest reach. Stakeholders and parents all responded positively to a text-messaging based system, as long as the costs were kept low. Participants were unsure if they would use or have consistent access to a public kiosk, and though a website would be helpful and provide a richer experience, the lack of a home computer or data plans on their phones limited potential access. After deciding to move forward with the text messaging design, we iterated on the design and wording of the Baby Steps Text system through initial Wizard-of-Oz usability studies with 10 parent participants. We had two researchers simulate the experience of using Baby Steps Text for the participant. Participants used their own mobile phones to send and receive text messages to the researcher playing the part of the "wizard," who used the Google Voice interface on a laptop, along with a script (see Figure 3), to quickly customize responses for the users during testing. We had a total of 12 tasks that covered all aspects of the system, including registering, responding to several milestone questions, receiving a report, requesting help, and stopping the service. Participants had a printed sheet with each task, and a study coordinator guided them through the process while the "wizard" read and responded to the system. Participants offered suggestions on improving the content and process for receiving and responding to text messages. In particular, our original design for the progress report only included the number of questions answered and no real information about how the child was progressing in each category. We thus added more information about the child's progress and added information about what to do if the child's result in any given category of development was "More evaluation needed." The registration component was also confusing, as we required the child's name, birthdate, and gender to be separated by spaces. We found participants could easily remember the "y" "s" and "n" responses after a few milestone prompts and thus only needed simple instructions rather than the full instructions with each message.

<p>Task 3: Responding to Milestone Questions</p> <p>Participant task: You will soon receive a message with a question about your child. When you receive the message, respond to it based on your child's experience using the instructions.</p> <p>Wizard response: <i>Send message: "Can NAME drink water, juice, or formula from a cup while you hold it? (Reply Y for "yes," S for "sometimes," N for "not yet")"</i></p> <p><i>If response is anything but Y, S, or N, reply back with:</i></p> <ul style="list-style-type: none"> o <i>Reply to ?'s with "Y" for yes, "S" for sometimes, or "N" for not yet. New msg sent after you reply. Txt "stop" to cancel. Txt "report" for NAME's progress.</i> 	<p>Task 11: Requesting a Report</p> <p>Participant task: Request a progress report on how many milestones your child has completed so far.</p> <p>Wizard response: <i>Expect to receive the word "report" from parent. Send back:</i></p> <p><i>NAME's Progress, Number of milestones completed:</i></p> <p><i>Personal-Social – 34</i></p> <p><i>Gross Motor – 23</i></p> <p><i>Fine Motor – 22</i></p> <p><i>Communication – 40</i></p> <p><i>Problem Solving – 22</i></p>
--	---

Figure 3. Example script for "Wizard" in Wizard-of-Oz prototype for two of the twelve tasks. Wizard instructions are in italics and **BOLD CAPS** indicate parts customized by the Wizard for the user's child.

4. Baby Steps Text Design & Implementation

Based on the results of our initial studies, we finalized a fully functional version of Baby Steps Text that would be suitable for a deployment study. The milestone question content used in Baby Steps was inspired by the Ages and Stages Questionnaire². In this section, we describe the design features of the messaging system.

4.1. Personalized Milestone Questions

Several previous studies also have shown the benefits of individually tailored messages that are personalized for the user²⁶. Because each message is sent to an individual, we can personalize the content of the messages. Using information from enrollment such as child birthdate, name, and gender, Baby Steps Text can send age appropriate messages and can include the child's name and gender-specific pronouns (unlike paper-based screeners), conveying a feeling of personal attention cost-effectively. To automate this process, we used placeholders such as %n% and %s% for words that needed tailoring and replaced those via an automated script. Overall, Baby Steps Text consists of 660 distinct milestone questions that are tailored for each child and delivered based on age. Our system differs from many other SMS-based approaches in that all milestone questions are personalized to increase user engagement and is entirely automated to run without behind-the-scenes human effort.

4.2. Simplified Response Structure

There are four response options to milestone questions: ‘Yes,’ ‘Sometimes,’ ‘Not Yet,’ and ‘Revisit’ (all case-insensitive) to skip to the next question and respond to it later. To reduce typing, parents could also use first letter of each response type (e.g., Y for ‘Yes’ and R for ‘Revisit’) (see Figure 4). If the caregiver has multiple children registered with Baby Steps Text, they need to also include their child’s name. Beyond these required elements, caregivers can add free text in their response (e.g., “Yes, Tommy can drink milk from a cup!”) like a natural text conversation, which does not interfere with the system’s automated parsing mechanism. We wanted to repeat instructions for using “Y” “S” and “N” with each milestone prompt to remind participants, but even after shortening, some questions were too long to include the full instructions within the 160-character limit. Thus, for shorter milestone questions, we included the full instructions (“reply ‘Y’ for “Yes”, ‘S’ for “Sometimes”, or “N” for “Not Yet”) whereas for longer questions, we used a simplified instruction (reply ‘Y’, ‘S’, or ‘N’). When we shortened the screener content, we made the longest message a maximum of 130 characters to ensure we had at least 30 characters remaining for the simplest instructions.

4.3. Progress Report

If parents text “Report” to Baby Steps, we generate a child’s progress report based on parents’ responses to individual questions (e.g., whether they are developing on schedule or if they should get in touch with their provider for additional assessment). To fit the progress report into a single text message, we used three simple reporting levels (“On track,” “Let’s watch,” and “More evaluation needed”) for each development category (e.g., Communication, Fine Motor, Gross Motor, Problem Solving, Personal & Social). We aimed to carefully convey progress to reduce unnecessary caregiver anxiety by working on the exact wording with experts a local non-profit organization that provides a free statewide program for family health that serves many low-income families and also runs a toll free parent help hotline to connect parents to early intervention services. If a parent requests a progress report before they answer half of the questions, we provide a message to answer more questions first. If they answer more than half but not all 30 questions, we send an additional message that the progress report they receive may not be an accurate reflection of their child’s development until all questions are completed. If a child is not ‘On Track’ in any development categories based on

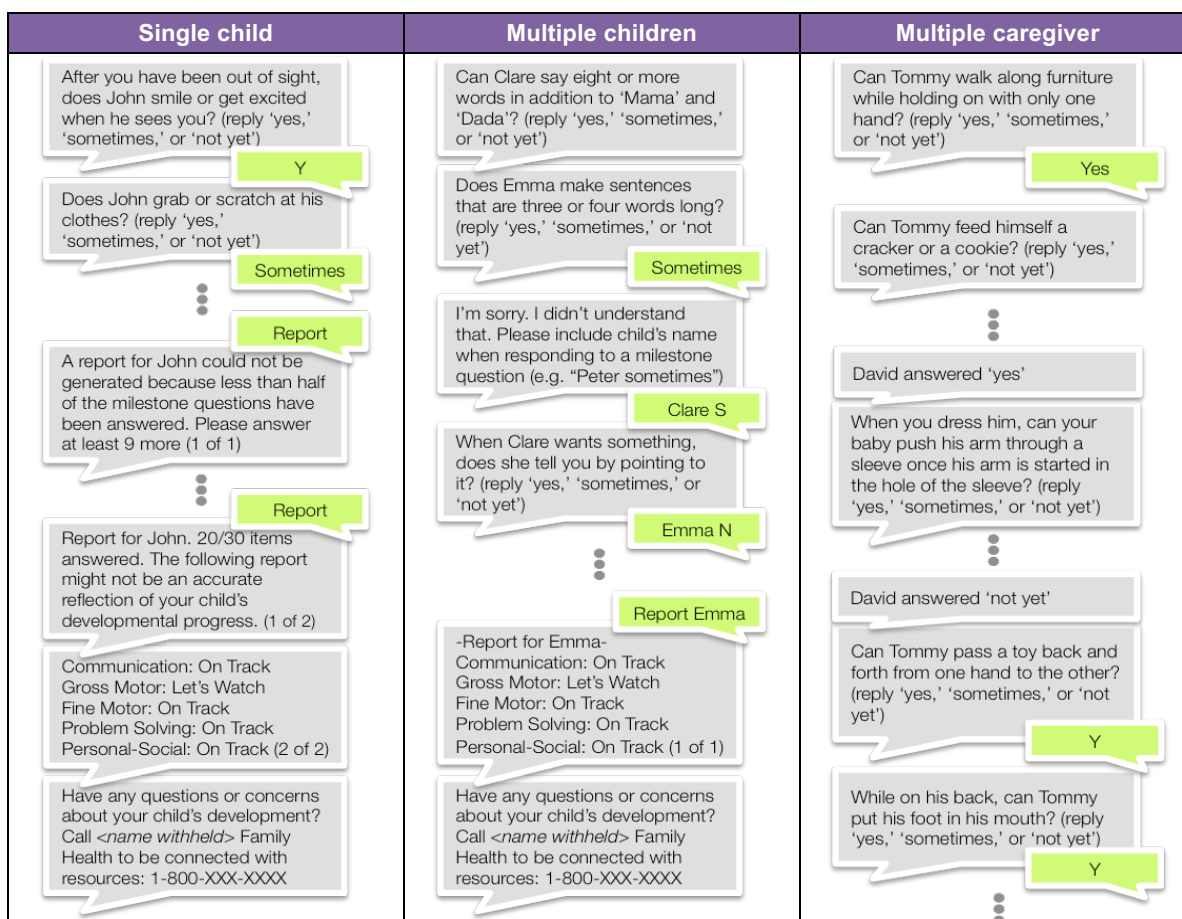


Figure 4. Example of Baby Steps Text syntax usage. Gray (left) indicates messages sent by Baby Steps and green (right) indicates messages sent by caregiver.

parents' responses, we provide the toll free hotline number for the non-profit mentioned above in a message following the progress report so that parents have contact points for questions or concerns about child.

4.4. Intervals of Screening Questions

Because our user research indicated that mobile phone plans used by lower income families may vary and be limited (e.g., pay-per-use plans), we had to find ways to deliver complete screening questionnaires within a certain time frame so that those screening questions are still valid to the child's age. We originally intended to send one screening question per day to avoid information overload, but due to this finding, we designed Baby Steps Text to send the next question immediately after they respond to one because it signals that 1) they are active on mobile texting, and 2) they are able to send and receive messages at the current moment. If the parent does not respond to a question within 48 hours, we resend the same question again.

4.5. Supporting Multiple Caregiver Engagement

Child development happens in daily life, and it is not always one parent who observes when their child hits certain milestones. In our user research, we found that often family members shared child-raising responsibility with aunts, uncles, and grandparents, with not every member of the family having consistent access to mobile phones. To coordinate tracking child development across multiple caregivers, we allowed our system to register multiple users' phones. The same question is sent to all caregivers' mobile phones, and if one answers a question, the others receive a message saying "[name of other caregiver] answered [response type]" (e.g., "Juan answered yes") and all will receive the next milestone question to answer. This allows all caregivers follow their child's development and coordinate responses.

4.6. System Implementation

Baby Steps Text is a custom-built Python application and associated MySQL database, which uses the Twilio cloud communications platform (<https://twilio.com>) for SMS and MMS handling. Incoming messages sent by users to our phone number are received by Twilio, which then relays the data to our system via HTTP request to be parsed for keywords. Similarly, by sending HTTP requests to Twilio, we can send both SMS and MMS messages to our users programmatically. When our system receives an incoming message, the content is parsed to determine if it is a milestone response or another of our recognized keywords (REPORT, START, STOP, HELP); responses are stored in the relevant child's database entry and sends an appropriate error message to any message that does not fit into the response structure. Outgoing messages are sent in two distinct scenarios. When a user answers a milestone question, the next question is sent immediately. They can also be sent via a daily check (handled by a cron job on the server), which determines on a child-by-child basis if it is time to either send the first question of a new milestone set (if the child has entered a new age range) or resend the last outgoing message (if 48 hours have elapsed without a response).

5. Feasibility Study

In Winter 2015, we conducted a month-long deployment study with 14 participants to test the feasibility and usability of Baby Steps Text. This study included collecting usage logs and qualitative data from pre- and post-study surveys. The study was reviewed and approved as minimal risk research by our university's human subjects board.

5.1. Participants

Although we did not exclude participants based on income, we aimed to recruit resource-constrained families in our study through the waiting room of local pediatric clinic that serves a high number of underserved, low-income, and immigrant families. Because our current prototype only has English-based questions, we required participants to have basic English literacy. The clinic receptionist introduced eligible parents of children under five years old to our study at check-in and directed them to the researcher in the waiting room to enroll in the study. We recruited 14 participants from a variety of backgrounds and none of feasibility study participants participated in any of our preliminary user studies. The participants were caregivers (M:2, F:12) of at least one child under 5 (Table 1). We aimed to recruit a balance of genders, but in all but three cases (two fathers and one aunt), it was the mother who checked in at the clinic. The majority were aged between 33 and 40 years old (n=8), and the total children in the household varied from zero (aunt) to seven. All owned smartphones and were active text users. Half were single and half were married. Child participant ages ranged from 4 months to 60 months. One participant (P11) used Baby Steps Text with two children.

5.2. Study Procedure

Participants received instructions, signed a consent form, and completed a pre-study survey on family demographics, current mobile phone use, and parenting experience. We also provided a one-page instruction sheet that explained how to use the system. We then registered them with Baby Steps Text, and participants started receiving screening milestone questions. After the first visit, the research team did not interact with participants until one month had passed. After one month, we mailed an exit package that included a study completion brief, compensation, and a post-study survey with a self-addressed, pre-stamped return envelop. Participants received \$20 for their study participation

Table 1: Participant details (* *A*: Asian, *B*: Black or African American, *H*: Hispanic or Latino, *W*: White)

ID	Relation to child	Age	Race *	# of child	Marital status	Education level	Household Income	# of texts per day	Child age (mos.)	Child sex	post-study survey	Interview
P1	Father	33-40	A	1	Married	Some college	\$35,000-\$49,999	1-10	20	F	O	
P2	Mother	33-40	H	7	Single	8 th grade or less	< \$15,000	1-10	30	M		
P3	Mother	33-40	W	3	Married	College degree	> \$100,000	1-10	36	F	O	
P4	Father	33-40	B	3	Married	Graduate degree	\$50,000-\$74,999	1-10	20	F		O
P5	Mother	25-32	B	-	Single	High school or GED	Under \$15,000	1-10	54	M	O	
P6	Mother	18-24	B	1	Single	High school or GED	\$15,000-\$24,999	101-500	27	F		O
P7	Mother	33-40	B	6	Married	High school or GED	< \$15,000	1-10	14	M	O	O
P8	Aunt	33-40	A	0	Single	College degree	\$50,000-\$74,999	11-30	20	F		
P9	Mother	33-40	W	1	Married	Graduate degree	\$75,000-\$99,999	1-10	4	F	O	O
P10	Mother	25-32	H	2	Married	High school or GED	\$25,000-\$34,999	101-500	60	F		
P11	Mother	25-32	H	3	Married	High school or GED	\$25,000-\$34,999	1-10	30, 4	F, F	O	
P12	Mother	18-24	B	1	Single	High school or GED	< \$15,000	1-10	27	M		
P13	Mother	41-50	B	2	Single	High school or GED	< \$15,000	1-10	48	M		O
P14	Mother	33-40	-	3	Single	College degree	Prefer not to say	1-10	4	F		

and \$10 each for the pre- and post-study survey completion (post-study survey had to be mailed back). Five participants (two were survey respondents and three were not) also participated in the post-study interview to provide us richer feedback. As a token of appreciation, participants received \$20 for their participation. All interviews were audio recorded and transcribed. Participants without unlimited text messaging plans were also compensated an additional \$20 at their sign up to cover any texting fees incurred using Baby Steps Text.

6. Results

6.1. Baby Steps Text Usage

Among the 14 parent participants, one (P2) withdrew from the study in the early stage by replying “STOP.” The remaining 13 participants successfully used text messages to track their child’s development and completed the study. Over their one month-long participation, Baby Steps sent 557 messages and received 520 SMS messages in response from participants. On average, each participant who completed the study received 42.3 messages (SD = 18.6) and sent 39.4 messages in response (SD=19.7). The high standard deviation is due to three participants whose child transitioned from one milestone question set age range to another during the course of study (therefore answering 60 questions) and among them, one participant used Baby Steps Text for two children and responded to 90 questions. Four participants (P1, P5, P6, P8) responded to all 30 milestone questions almost in one sitting (Table 2). We did not see a completion rate difference between the two strategies (e.g., responding to all at once vs. periodically).

6.2. Use of Baby Steps Text Syntax

For Baby Steps Text to recognize and store user responses in the database automatically, we required participants to use one of the four response options. We provided an instruction sheet when participants enrolled in our study and continuously included these instructions within the question message itself. As a result, 505 of the 520 user messages were correctly formatted, yielding a very low error rate of 2.88%, and participants were able to self-correct errors early due to an automated response that informed them of syntax errors. About 15% of the text message responses used shortened response types such as Y/S/N, but there was no particular pattern as many participants used both full and

ID	# of outgoing texts	# of in-com-ing texts	# active days	# texts per active day	Texting activity across study duration
P1	43	33	2	16.5	
P2*	8	7	1	7	
P3	36	32	5	6.4	
P4	36	32	5	6.4	
P5	30	30	1	30	
P6	60	60	2	30	
P7	32	33	4	8.3	
P8	30	30	2	15	
P9	62	62	3	20.7	
P10	31	30	4	7.5	
P11	92	91	5	18.2	
P12	33	31	4	7.8	
P13	27	18	3	6	
P14	37	31	6	5.2	
Total	549	520	24	21.7	

Table 2. Overall text activity by 14 participants. The rightmost cell shows a sparkline plot of the month-long timeline of texting activity. (*P2 withdrew from the study.)

shortened responses interchangeably. Although we included the “Revisit” feature on the instruction sheet, it was not included as a response type in question messages, and thus no participants used this feature during the study. One post-study survey respondent mentioned she did not know about the option but would appreciate having it.

6.3. Participants’ Experience with Baby Steps Text

Six out of the thirteen participants completed and mailed back the post-study paper survey. Meanwhile, five participants participated in a phone interview to share their experience (see Table 1). Although the survey response rate was low, this is not unexpected for mail-in surveys with lower-income populations. All survey and interview participants agreed that milestone questions asked by Baby Steps Text were understandable and the system was easy to use, respectively scoring 4 and 4.3 where 5 is strongly agree. They also agreed the total number of milestone questions (30 per 2-6 months age range) asked was appropriate, which we could also confirm from interviews. However, P9 was not as satisfied with receiving one message immediately after the other: “*the constant stream of texts on the 1st day was a little overwhelming.*” This may be due to not clearly explaining they could take time between questions and they would receive reminder messages after 48 hours, which some participants appreciated – “*At times I forget to answer and it would hit me up again to make sure I answer them. (P4)*” When asked about message frequency, survey respondents were mixed. Half (n=3) preferred to receive the next question immediately and answer in one sitting, and the other half preferred to receive questions periodically. However, most of the interview participants (4 out of 5) preferred to receive questions one after another, as P6 said, “*I think that was really cool that you can keep going and don’t need to wait a while for the next question*” and P4 also noted, “*even though it’s first annoying, I think you should keep them one after the other. My schedule is hectic and if it’s periodic, I am not going to think about it as much.*” In their interviews, P4 and P7 mentioned that although milestone pictures were helpful, they had to make space for them because their phone’s storage was full. P7 also noted shortcomings of milestone questions – “*There are some didn’t apply because – the ones with stairs, we don’t have stairs. So I couldn’t really answer. Some of them didn’t apply. So I answered ‘no’*” For the open-ended survey question about what they liked, P3 and P9 reported that it was easy, quick, and convenient. Several also liked receiving useful information that can be helpful to their child in timely manner (P5, P9, P10). P10 noted, “*I really enjoyed participating in this study. I think the texting format is really great and unique. It’s nice to receive personalized texts and not have to go to the Internet to look things up!*”

6.4. Continued Usage After Study Completion

The exit package explained to participants that they could choose to continue using Baby Steps Text beyond the study. P10 finished the 60-month milestone questionnaire during our study, which was the last questionnaire of Baby Steps Text system, thus there was no more milestone questions to send. None of the remaining twelve participants who completed the study explicitly opted out of Baby Steps Text. Nine out of 12 participants were still responding to milestone prompts three months study completion, where we received an additional 385 messages from participants. Due to a software glitch, we were not able to send messages longer than 3 months. However, this is promising in that participants found our system engaging and worth using outside of study compensation.

7. Discussion

7.1. Recommended Changes to Baby Steps Text Design

1) More Detailed Progress Report: To fit the progress report into a single text message, we had to make it brief. Although the report design worked well in usability testing, when we provided real data to participants, they were not as satisfied with minimal data. P3 noted that, “*I felt the report was too high level and vague. Didn’t tell me much of anything.*” To reflect this feedback, the next version of Baby Steps Text will convey more information on interpreting each item by allowing parent to text “more” after a report to receive explanations about each developmental category, what the child’s result means, and what actions they can do beyond calling the family health hotline. For users with Internet access, providing a link to a web-based report with more detail could be useful, as others have done³⁹.

2) Providing Ideas for Activities to Encourage Development: To support parents in encouraging development beyond tracking, we plan to implement an opt-in feature where the system sends a message asking if they want to receive ideas for activities they can do to encourage development with their child. If yes, the system would send age-appropriate items automatically (e.g., “Activity Idea: Put dry rice inside an empty bottle to encourage shaking and turning behaviors”). Because activities are suggestions rather than screening, no response would be required.

3) Sentimental Records along with Developmental Records: Previous research indicates that tracking sentimental childhood records, such as memories and “firsts and favorites,” along with development can increase parent engagement^{21, 22}. We plan to expand Baby Steps Text to make keeping sentimental records as easy as sharing photos and videos of their child. The new version will allow parents to text memories via SMS or send photos and videos via MMS with the keyword “memory” to the system. Parents who have access to the Internet can view their records on a companion website³⁹ alongside developmental reports for a complete picture of their child’s life.

7.2. General Implications for Text-Based mHealth

From our study, we found that extra keywords explained only on the instruction sheet (REVISIT, REPORT, HELP, etc.) were rarely used, except for one “HELP” and one “STOP” message. We had to ask participants to use the REPORT feature in the post-study survey to get their feedback on that feature. Therefore, we recommend to make all information inclusive in outgoing messages. Another suggestion is to allow adjustment of message frequency based on user preference if possible (immediately vs. periodically). System designers may also consider adding non-text features, such as web links or photos, to extend capabilities for users with Internet access to read detailed explanations that might help understanding or features that improve engagement (e.g., online photo albums). Future studies will explore these features and how technology interventions might “gracefully degrade” based on financial constraints. Next, shortening an already validated screening tool (e.g., ASQ³) to 160 characters was necessary for the tool to function, but may have broken its validity. As using SMS (160-character limit) for health interventions becomes more common, we encourage creators of screening questionnaires to consider making questions fit within 140 characters or less to accommodate these constraints and to allow for additional characters for any instructions. Finally, communicating the results of a screener entirely via text message could create unnecessary anxiety [4] if done without including actionable information (such as calling a hotline) or without acknowledging the user’s feelings. Careful testing of wording in the results with potential users can help mitigate the potential for anxiety. Finally, our Wizard-of-Oz prototype was very useful in identifying problems with the messaging and syntax and required no technical skill to implement, as the only components were the scripts and the use of Google Voice. We suggest designers consider adopting this method for designing SMS-based applications.

7.3. Limitations & Future Work

Due to 160-character limit of SMS, we needed to shorten a validated screening tool and thus the validity of content needs to be reevaluated. We also did not follow up with the family health hotline to determine if any of the participants called to request access to services for early intervention, and only tested an English-language version of the tool. In the next iteration of Baby Steps Text, we plan to use a shorter validated screening tool that fits within character constraints (<http://theswyc.org>) and provide support in Spanish. Also, as this was an initial feasibility study, participants used Baby Steps for a brief period and we do not have sufficient data to tell how our system impacts parents in a long term (e.g. how it changes parental efficacy, their knowledge on child development, etc.) Therefore, we plan to conduct a longer study to answer questions about long-term engagement, identify ways to combine developmental tracking with sentimental record-keeping, and compare it to other approaches to technology-based developmental screening.

8. Conclusion

The primary objective of this study was to design and evaluate the feasibility of using SMS for childhood developmental screening. We presented our design process and implementation details for Baby Steps Text, an automated text messaging system to collect and screen child development using everyday technology available to resource-constrained populations. Our initial month-long deployment study shows that text messaging is a feasible tool for supporting parents in monitoring and screening their child. Continued use of our system beyond the study participation also indicates that the approach is promising in encouraging parent engagement.

References

1. Boyle CA, Boulet S, Schieve LA, et al. Trends in the prevalence of developmental disabilities in US children, 1997–2008. *Pediatrics*. 2011 Jun 1;127(6):1034-42.
2. Bricker DD, Squires J, Mounts L. Ages & stages questionnaires: A parent-completed, child-monitoring system. Baltimore (MD): Paul H. Brookes. 1999.
3. Baio J. Prevalence of Autism Spectrum Disorders: 14 Sites, United States, 2008. *Morbidity and Mortality Weekly Report*. 61(3). Centers for Disease Control and Prevention. 2012 Mar 30.
4. Choe EK, Duarte ME, Kientz JA. Understanding and Designing Computing Technologies that Convey Concerning Health News. *Design & Emotion*. 2010.
5. Da Costa TM, Salomão PL, Martha AS, et al. The impact of short message service text messages sent as appointment reminders to patients’ cell phones at outpatient clinics in Sao Paulo, Brazil. *IJMI*. 2010;79(1):65-70.
6. Da Costa TM, Barbosa BJ, e Costa DA, et al. Results of a randomized controlled trial to assess the effects of a mobile SMS-based intervention on treatment adherence in HIV/AIDS-infected Brazilian women and impressions and satisfaction with respect to incoming messages. *IJMI* 2012;81(4):257-69.
7. Danis CM, et al. Mobile phones for health education in the developing world: SMS as a user interface. *DEV’10*. ACM.
8. Dawson G, Osterling J. Early intervention in autism. *The effectiveness of early intervention*. 1997:307-26.
9. Depp CA, Mausbach B, Granholm E, et al. Mobile interventions for severe mental illness: design and preliminary data from three approaches. *The Journal of nervous and mental disease*. 2010 Oct;198(10):715.

10. Evans WD, et al. Pilot evaluation of the text4baby mobile health program. *BMC public health*. 2012;12(1):1.
11. Duggan M. Cell phone activities 2012. Pew Research Center's Internet & American Life Project. 2013 Sep 16.
12. Fattor J and Friedlander A. Texting 2 increase physical activity. *Texting 4 Health: A Simple, Powerful Way to Change Lives*, 2009: 67-74
13. Flores G, et al. Access barriers to health care for Latino children. *Arch Pediatr Adolesc Med*. 1998;152(11):1119-25.
14. Franklin VL, Waller A, Pagliari C, Greene SA. A randomized controlled trial of Sweet Talk, a text-messaging system to support young people with diabetes. *Diabetic Medicine*. 2006 Dec 1;23(12):1332-8.
15. Free C, Knight R, Robertson S, et al. Smoking cessation support delivered via mobile phone text messaging (txt2stop): a single-blind, randomised trial. *The Lancet*. 2011 Jul 8;378(9785):49-55.
16. Gerber BS, Stolley MR, Thompson AL, et al. Mobile phone text messaging to promote healthy behaviors and weight loss maintenance: a feasibility study. *Health informatics journal*. 2009 Mar 1;15(1):17-25.
17. Hayes GR, Patterson DJ, Singh M, et al. Supporting the transition from hospital to home for premature infants using integrated mobile computing and sensor support. *Personal and Ubiquitous Computing*. 2011:871-85.
18. Jeong HY, Park SY, Zimmerman J. Opportunities to support parents in managing their children's health. CHI 2008 Extended Abstract (pp. 3225-3230). ACM.
19. Källander K, et al. Mobile health (mHealth) approaches and lessons for increased performance and retention of community health workers in low-and middle-income countries: a review. *JMIR*. 2013;15(1):e17.
20. Khokhar A. Short text messages (SMS) as a reminder system for making working women from Delhi Breast Aware. *Asian Pac J Cancer Prev*. 2009 Jan 1;10(2):319-22.
21. Kientz JA, Arriaga RI, Chetty M, et al. Grow and know: understanding record-keeping needs for tracking the development of young children. CHI 2007 (pp. 1351-1360). ACM.
22. Kientz JA, Arriaga RI, Abowd GD. Baby steps: evaluation of a system to support record-keeping for parents of young children. CHI 2009 (pp. 1713-1722). ACM.
23. Kientz JA. Understanding parent-pediatrician interactions for the design of health technologies. IHI 2010. ACM.
24. Kim SI, Kim HS. Effectiveness of mobile and internet intervention in patients with obese type 2 diabetes. *IJMI*. 2008.
25. Kummervold PE, Holthe H. Communicating textual health information to the mobile phones of visually-impaired users. *Journal of telemedicine and telecare*. 2008 Jun 1;14(4):186-9.
26. Lee HY, Koopmeiners JS, Rhee TG, et al. Mobile phone text messaging intervention for cervical cancer screening: changes in knowledge and behavior pre-post intervention. *JMIR*. 2014;16(8):e196.
27. Leong KC, Chen WS, Leong KW, et al. The use of text messaging to improve attendance in primary care: a randomized controlled trial. *Family practice*. 2006 Dec 1;23(6):699-705.
28. Lester RT, Ritvo P, Mills EJ, et al. Effects of a mobile phone short message service on antiretroviral treatment adherence in Kenya (WelTel Kenya1): a randomised trial. *The Lancet*. 2010 Dec 3;376(9755):1838-45.
29. Levine D. Using technology to promote youth sexual health. *Texting 4 Health*. 2007:61-9.
30. Liptak GS, Benzoni LB, Mruzek DW, et al. Disparities in diagnosis and access to health services for children with autism: data from the National Survey of Children's Health. *JDBP*. 2008 Jun 1;29(3):152-60.
31. Ngabo F, Nguimfack J, Nwaigwe F, et al. Designing and Implementing an Innovative SMS-based alert system (Rap-idSMS-MCH) to monitor pregnancy and reduce maternal and child deaths in Rwanda. *PAMJ*. 2012;13(31).
32. Park S, Jeong H, Zimmerman J. ENSURE: Support for Parents in Managing their Children's Health. the Proceedings of Design and Emotion. 2008.
33. Parker RM, Dmitrieva E, Frolov S, et al. Text4baby in the United States and Russia: an opportunity for understanding how mHealth affects maternal and child health. *Journal of health communication*. 2012;17:30-6.
34. Patrick K, Raab F, Adams M, Dillon L. mDiet: A personalized approach to weight management using text messaging. *Texting 4 Health*. 2009:35-48.
35. Perrier T, Dell N, DeRenzi B, et al. Engaging pregnant women in Kenya with a hybrid computer-human SMS communication system. CHI 2015 Apr 18 (pp. 1429-1438). ACM.
36. Sharp H, Jenny P, Rogers Y. Interaction design: beyond human-computer interaction.
37. Rodgers A, Corbett T, Bramley D, et al. Do u smoke after txt? Results of a randomised trial of smoking cessation using mobile phone text messaging. *Tobacco control*. 2005 Aug 1;14(4):255-61.
38. Strandbygaard U, Thomsen SF, Backer V. A daily SMS reminder increases adherence to asthma treatment: a three-month follow-up study. *Respiratory medicine*. 2010 Feb 28;104(2):166-71.
39. Suh H, Porter JR, Hiniker A, Kientz JA. @ BabySteps: design and evaluation of a system for using twitter for tracking children's developmental milestones. CHI 2014 (pp. 2279-2288). ACM.
40. Uhrig JD, Lewis MA, Bann CM, et al. Addressing HIV knowledge, risk reduction, social support, and patient involvement using SMS: results of a proof-of-concept study. *JHC*. 2012 ;17(sup1):128-45.
41. Vilella A, et al. The role of mobile phones in improving vaccination rates in travelers. *Preventive medicine*. 2004.
42. Yun TJ, Jeong HY, Hill TD, et al. Using SMS to provide continuous assessment and improve health outcomes for children with asthma. IHI 2012 (pp. 621-630). ACM.