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Health Literacy and Cell Phone Usage in text4baby: What do they tell us about the design of mhealth programs?

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# Health Literacy and Cell Phone Usage in text4baby: What do they tell us about the design of mhealth programs?

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## Abstract

Health Literacy and Cell Phone Usage in text4baby: What do they tell us about the design of mhealth programs?

By Elisabeth Poorman

**Background:** Text4baby provides educational text messages to pregnant and postpartum women that are aimed primarily at low health literacy populations.

**Objective:** To examine the health behaviors and cell phone usage patterns of a text4baby target population and the associations with health literacy.

**Methods:** Pregnant and postpartum women were recruited from two clinics in Atlanta. Women were asked about their demographics, selected pregnancy or postpartum health behaviors, and cell phone usage patterns. Health literacy skills were measured with the Newest Vital Sign. Multivariable logistic regression was used to examine health behaviors and cell usage patterns by health literacy classification, controlling for commonly accepted confounders.

**Results:** Four hundred sixty-eight women were recruited, and 445 completed the Newest Vital Sign. Of these, 22% had inadequate health literacy, 50% had intermediate health literacy, and 28% had adequate health literacy skills. Lower health literacy was significantly associated with smoking, not receiving a flu shot, not consistently keeping

appointments, not taking a daily vitamin during pregnancy, and not putting their infant in a car seat consistently ($p<0.05$). The majority of our sample received nine or more text messages a day (69.4%), one in four participants (24.6%) had changed their number within the last six months, and 7.0% shared a cell phone. Those with limited health literacy were more likely to share a cell phone than those with adequate health literacy (OR 2.57, 95% CI: 1.79, 3.69).

**Conclusion:** Text4baby messages should be appropriate for low health literacy levels, especially as this population has a higher prevalence of targeted unhealthy behaviors. Behaviors associated with low health literacy may require more frequent messages and supplemental information delivery. Text4baby and other mhealth programs aimed at low health literacy populations should also be aware of the different ways that these populations use their cell phones, including sharing cell phones, which may mean participants will not receive messages or have special privacy concerns; frequently changing cell phone numbers which could lead to higher drop-off rates; and the penetrance of text messages in a population that receives many messages daily.

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**Table of Contents**

**Background**

Poor pregnancy outcomes, including low birth weight and preterm birth, continue to be a problem in the US, particularly for minority women and those with few resources (1). Low birth weight and preterm births have remained relatively constant since 1980, with improvements in infant mortality attributable primarily to advanced health care interventions for preterm infants as opposed to increased utilization of preventive services. Infant mortality remains high in the United States when compared with other industrialized countries, with a rate of 6.42/1,000 live births between 2008 and 2009 (2).

Unhealthy behaviors in the prenatal period, including smoking, alcohol use, and poor diet, are linked to poor pregnancy outcomes (1). Conversely, proactive healthy behaviors in the preconception and prenatal period, such as vitamin use, influenza vaccine, and regular prenatal care lead to improved outcomes (1, 3). While behavior modification has had limited success in modifying poor pregnancy outcomes, the combined effect of a multi-pronged behavior intervention has the possibility to have a significant impact on poor pregnancy outcomes (4). Ideally, these interventions would be targeted to women who have the greatest potential to benefit. Women at higher risk of poor outcomes, however, have traditionally been the most difficult to reach.

The recent explosion of new technologies offers novel opportunities for counseling and behavior change for these historically underserved groups. Text messaging is unique among newer technologies as it is widely used across income and educational strata. According to the Pew Research Center's Global Attitudes Project, a survey of 21 representative countries found that 85% of those surveyed owned a cell phone, and of those, 75% reported regularly using text messaging (5). Significantly, text messaging was more common in the poorest nations surveyed. In the US, 73% of cell

phone owners use text messaging. In a separate Pew Research Center survey of Americans, the groups who sent the most text messages were young (18-24 years), earned less than $30,000 a year, and had less than a high school education (6).

Text messaging is thus a potentially powerful avenue for reaching low-resource populations, and has led to the creation of mobile health interventions, known as mhealth programs. Few programs, however, have focused directly on maternal and infant health. The subject of this present study, text4baby, sends educational messages to pregnant and postpartum women with the goal of promoting healthy, preventative behaviors. The program was created by a public-private partnership overseen by the National Healthy Mothers, Healthy Babies Coalition. Text4baby developed a series of messages from evidence-based guidelines from the American College of Obstetrics and Gynecology and the Bright Futures Guidelines for Infants, Children, and Adolescents. Participants in the text4baby program receive one free educational message three times a week timed to their gestational age or birthdate.

Prior to conducting the analysis for this thesis, a systematic review of the literature was undertaken to identify studies of text messaging that may be applied to the promotion of maternal and infant health (see Appendix). Articles were retrieved from five databases. Articles from peer-reviewed journals published before June 2012 were included if they were experimental or quasi-experimental studies of behaviors endorsed either by the American College of Obstetrics and Gynecology, the American Pediatrics Association, or the United States Preventive Services Task Force; included reproductive age women (12 to 50 years) or infants up to two years of age; and were available in English. Qualitative studies of text messaging specific to pregnant women were also

included. Studies were compared and contrasted by key variables, including: design, time-period, study population, and results. Forty-eight articles were included, 30 of which were randomized controlled trials. Only nine studies included more than two hundred participants. Six specifically targeted pregnant or postpartum women, and one specifically targeted infant health.

All seven studies that targeted text4baby's population are of populations smaller than the study we present here. Text4baby, therefore, is unique in its scope and target population: pregnant and postpartum women, available nationally. As a result, there are many questions that have not been answered by previous studies about the unique nature of this population, and the ideal design of the text4baby program.

Text4baby's educational messages were refined in focus groups at community centers in six cities across the country and are aimed at women with low health literacy (7). This target population therefore likely overlaps with the group most likely to text: young, less educated, and low-income women. Defined as "the degree to which individuals can obtain, process, and understand basic health information and services needed to make appropriate health decisions," health literacy has emerged as a marker of existing knowledge, the ability to process new health information, and a strong predictor of health behaviors (8). Some studies have indicated that it is a stronger predictor of outcomes than education alone (9). Targeting women with low health literacy for health education could potentially have the greatest impact, empowering women at high risk for poor pregnancy outcomes to make healthy decisions for themselves and their children (10).

The effect of health literacy on outcomes may be mediated by higher rates of unhealthy behaviors. A 2011 meta-analysis conducted for the Agency for Healthcare Research and Quality found that low health literacy is associated with lower acceptance of influenza vaccine and decreased ability to interpret health messages (11). Other studies have found that women with low health literacy are less likely to breastfeed (12), plan their pregnancy (13), and to be insured (14). These associations are not consistent across all studies, suggesting that other factors, such as attitudes and cultural beliefs about medicine, may mediate the effect of health literacy on health behaviors (15). More information is needed about how the prevalence of these behaviors varies with health literacy and how to best support behavior change in these populations.

In addition to differences in health behaviors, successful mhealth education requires intimate knowledge of the way that target populations use their cell phones. Though women who are likely to have low health literacy have adopted text messaging, they may use it in different ways. Younger cell phone users in the US are more likely to share a cell phone, for instance, and lower income cell phone users are more likely to use prepaid cell phone plans (6). Those with prepaid plans are in turn less likely to use text messaging, and to change their numbers frequently. Americans with higher education are more likely to look for health information on their phones, as are ethnic minorities (16).

Since text message is a written medium, health literacy may influence the type of messages that users send and receive, and their understanding and use of these messages. So far, however, this relationship has not been explored directly. Further, as the measurement of health literacy incorporates math literacy and executive planning, women with low health literacy may also be less likely to have stable cell phone plans.

Most prepaid plans, for instance, do not require the user to read and interpret a complicated contract, and therefore may be more appealing to those with lower health literacy skills. As a result, women with low health literacy may use prepaid plans at a higher rate, affecting the receipt of messages, the number of messages they receive, and the stability of their cell phone numbers.

Health literacy, therefore, may affect important characteristics of text4baby's target population: the prevalence of unhealthy behaviors, and the way that the population uses cell phones. Delivering health education via text message requires knowledge of the prevalence of different health behaviors in the population and those associated with low health literacy in order to customize messages to the targeted population. Moreover, mhealth program designers should take into account the unique ways that this population uses their cell phones to deliver messages effectively. This paper examines the prevalence of unhealthy behaviors in a group of pregnant and postpartum women enrolled in text4baby, and their relationship with health literacy skills. This study also examines the relationship between cell phone usage characteristics and health literacy skills. Understanding these relationships is key to maximizing the benefit of text4baby for a low health literacy population.

## Methods

### *Setting*

The text4baby health literacy evaluation was conducted in two Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) Clinics in Metro Atlanta as part of a broader evaluation of text4baby.

### *Study population*

Women were recruited from nutrition classes, which are a requirement of receiving WIC support, at the two WIC clinics. Interviewers attended all classes during the study collection period, and either approached all women in the class if the class was small, or randomly selected participants using numbered slips of paper, creating a stratified random sample. Women who were willing to participate were eligible for the study if they: 1) were the biological mother of a child under 10 months old (postpartum) OR were currently pregnant; 2) had a working cell phone; 3) could receive text messages; 4) had not been enrolled in text4baby previously; and 5) spoke English. Those who qualified to participate were consented orally with both the Emory consent and HIPAA agreement forms. Recruitment procedures have been described previously in more detail (17).

### *Data Collection*

Participants were read an in-person survey by a trained interview pregnant or postpartum baseline survey, to ensure comprehension, which took approximately ten to fifteen minutes. Data was collected at three points: baseline, two weeks, and two-to-six month follow-up. This paper analyzes baseline data.

### *Measures*

At the baseline interview, women self-reported all demographic, behavioral, and cell usage data. The primary outcomes were current behaviors and cell usage. Women were asked if they currently smoked (possible answers "no," "some days," or "every day"); if they had rules about smoking in the house ("no," "no one is allowed to smoke in the house," or "people are allowed to smoke in some rooms sometimes"); how often they felt "down-hearted or blue," ("all of the time," "most of the time," "some of the time," "a little of the time," "none of the time"); if they had had an alcoholic drink in the past thirty days ("yes," "no," or "don't know"). Pregnant women were asked how many days a week they participated in physical activity for thirty minutes or more ("less then one day a week", "one to two days," "three to four days," or "five a more," or that they were advised against exercise by a health professional"); if they had a seasonal flu shot in the last year ("yes," "no," "don't know"); how often they kept their appointments and ("always," "nearly always," "sometimes," "seldom," and "never"); and how often they took a multivitamin in the past week ("I did not take any vitamins at all"; "1-3 times a week," "4-6 times a week," "daily"). Postpartum participants were asked if they were currently breastfeeding, and if not, if they breastfed at any point after birth; and how often they put their baby in a car seat ("always," "nearly always," "sometimes," "never" and "don't have a car"). All answers were collapsed into healthy and unhealthy behaviors; for instance, those who smoked sometimes or always versus those who did not smoke. These collapsed categories are presented in the results.

The other outcomes were cell phone usage patterns. Women were asked the average number of text messages they received per day ("less than 2 per day;" "3 to 5 per day;" "6 to 8 per day;" "9 or more per day"). Answers were recoded into "9 or more per

day" versus all others. Women were also asked if they currently shared a cell phone ("yes" or "no"). Finally, women were asked how many phone numbers they had had in the past six months ("1, 2, 3, 4, 5, >6"). They were classified into more than one versus one cell phone number.

The primary predictor was health literacy. This was measured during the final portion of the baseline survey using the Newest Vital Sign (NVS) assessment (18). The NVS is a six-question instrument that asks respondents to interpret an ice cream label, and incorporates both reading literacy and numeracy skills. In the original paper on this health literacy metric, the creators of the NVS found that those with a score less than two were likely to have inadequate health literacy, and those with a score of four or greater were likely to have adequate health literacy when measured against the Test of Functional Health Literacy in Adults. Women were divided into three health literacy categories: 0-1 for limited health literacy, 2-3 for intermediate health literacy, and 4-6 for adequate health literacy (18).

Demographics were included as covariates. Participants were also asked: the highest level of education completed ("less than $12^{th}$ grade, high school/GED, technical/vocational training," "some college," "associate's," "bachelor's," "graduate/professional degree,"); their race/ethnicity ("black/African, white/Caucasian, Hispanic/Latino, Native Hawaiian, Asian/Asian-American, American Indian/Alaskan Native"); what their current household income was ("less than $10,000," "$10,001-$20,000," "$20,001 to $30,000e," "More than $30,000); what their current employment status was ("employed full-time," "employed part-time," "currently unemployed," "volunteer," or "student"); and their current marital status ("single/never married,"

"single/living with a partner," "married," "separated," "divorced," and "widowed"). Education levels were reclassified as having less than high school, high school or GED, or beyond high school. Ethnicity was reclassified as black versus all others. Income was reclassified as less than $10,000, $10,001 to $20,000, and more than $20,000. Employment was reclassified as any current employment versus all others. Marital status was reclassified as living with a partner and married versus all others.

**Data analysis**

Sample weights were assigned to each observation to reflect the entire population of the two clinics; survey methods are described elsewhere (17). Participants' characteristics were summarized by means and standard deviations in the case of normally distributed data, and by medians and the interquartile range in the case of skewed data. The distribution of the primary variable of interest, the Newest Vital Sign (NVS), was graphed to assess its distribution. The distribution of demographics was then calculated for these health literacy categories, reporting unweighted numbers for the number of observations and weighted numbers for summary statistics.

The prevalence of all health behaviors that could be dichotomized into healthy or unhealthy behaviors as defined by the American College of Obstetrics and Gynecology, the American Academy of Pediatrics, or the United States Preventive Services Task Force were quantified for the entire study population and by the three health literacy categories. Adjusted odds ratios for the association of health literacy categories and those health behaviors that were significantly associated with literacy were calculated, controlling for income and education, which are the most commonly controlled confounders in the literature (11).

The distribution of three cell phone usage characteristics—sharing a cell phone, changing cell phone numbers, and the number of text messages received in a day—was then calculated for the entire study population and by health literacy categories. Finally, a predictive model of these usage patterns was created using the health literacy category as the primary predictor, controlling for the most common confounders identified in the literature: age, education, race, income, employment status, and marital status (11). Cell usage categories were plotted as outcomes of the only continuous predictor, age, to determine if it represented a true logistical function. Multicollinearity and other model diagnostics were performed. Logistic regression was used to create our final model, using weighted sampling and an alpha level of .05 as a cut-off for statistical significance. All analyses were completed using SAS v. survey procedures (SAS Institute, Cary, NC, USA).

## Results

### *Baseline characteristics*

A baseline survey was read to 468 women, and 445 completed the NVS who were included in the analysis. Participants had an estimated median age of 25 (Table 1). Almost all (92.3%) of study participants were African American; 57.3% had twelve or fewer years of schooling, and 81.1% had a household income under $20,000. Slightly more than half (56.7%) of participants were unemployed or students, and 29.7% were married or living with a partner. The NVS scores were normally distributed, with 22% having limited health literacy, 50% intermediate health literacy, and 28% adequate health literacy.

Higher health literacy was significantly associated with older age, higher education, higher income, and being employed (Table 1). Those in the lowest health literacy category were more likely to have an income less than $10,000, and those in the highest health literacy category were least likely to have completed less than high school. Marital status did not differ significantly between health literacy categories.

### *Health literacy and health behaviors*

The prevalence of many unhealthy behaviors was significantly associated with low health literacy (Table 2). Of those with inadequate health literacy, 19.8% reported currently smoking, compared to 15.8% of those with marginal health literacy and 8.8% of those with adequate health literacy ($p<0.01$). Pregnant women with inadequate health literacy were also more likely to report not consistently keeping their appointments (16.8%), compared to those with marginal (6.9%) and adequate (2.1%) health literacy skills ($p=0.03$). They were also less likely to have taken a vitamin every day during the

thirty days prior to the baseline interview than those with marginal or adequate health literacy (45.1% versus 29.3% and 15.4%, respectively; $p<0.01$).

After controlling for income and education, allowing smoking in the house, not receiving a flu shot, not taking a vitamin daily during pregnancy, and never breastfeeding in the postpartum population continued to vary by health literacy category (Table 3). However, only daily vitamin intake was significantly and consistently associated with lower health literacy across all categories (limited versus intermediate aOR 2.2, 95% CI 1.4, 3.6; limited versus adequate aOR 3.6, 95% CI 1.6, 8.5).

***Health literacy and cell phone usage characteristics***

Overall, 7.0% of the sample reported sharing a cell phone, and 24.6% had changed their cell phone number at least once in the six months prior to enrollment (Table 4). Sharing a cell phone and having more than one cell phone in the past six months were more common among those with in the lowest NVS scores. Over 90% of the sample received two or more texts a day, and the majority (65.8%) received nine or more texts daily. Only sharing a cell phone was significantly associated with health literacy when other confounders were uncontrolled.

Since the sample was all female and >90% black, these variables were not included as potential confounders in the model. Marital status was also excluded, since previous literature has not indicated it as a confounder and it was not significantly associated with health literacy in our sample. All other demographic variables were left in as potential confounders in the final models. For sharing a cell phone, NVS score remained predictive in the presence of all potential confounders, with those in the lowest vital sign category with 2.57 times the odds of sharing a cell phone than those with

intermediate health literacy (95% CI 1.79, 3.69), and 1.67 times the of those with adequate health literacy (95% CI 1.06, 2.63; Table 5). Income level was also a significant predictor of sharing a cell phone: those with a household income less than $10,000 had 2.16 times the odds of sharing a cell phone than those with a household income between $10,000 and $20,000 (95% CI 1.18, 3.97), and 4.24 the odds of sharing a cell phone than those with a household income over $20,000 (95% CI 1.48, 12.19).

Health literacy was not predictive of having changed cell phone numbers at least once in the previous six months after controlling for confounders (Table 6). Age was predictive of changing cell phone numbers, with the youngest (ages 18-22) with 1.50 times the odds of changing their cell phone in the previous six months than those in the middle age group (95% CI 1.12, 2.00), and 1.75 times the odds of changing their cell phone than those in the oldest age group (95% CI 1.20, 2.55). Those with less than high school compared to those with some college or more had 1.75 times the odds of changing their number in the previous six months (95% CI 1.19, 2.58). Those who were employed had 0.72 times the odds of changing their number at least once in the previous six months (95% CI 0.58, 0.89).

Health literacy was also not predictive of receiving nine or more text messages a day after controlling for confounders (Table 7). Age, however, was associated with the number of texts received, with the youngest mothers having 1.87 times the odds of the middle age group (95% CI 1.37, 2.55), and 5.06 times the odds of the oldest age group (95% CI 3.79, 6.76) to receive nine or more messages a day. The lowest income group had 1.41 times the odds of receiving nine or more messages a day compared to the

middle income group (95% CI 1.08, 1.85), and 0.61 times the odds of the highest income group to receive nine or more messages a day (95% CI 0.45, 0.81).

**Discussion**

In this study population, lower health literacy was significantly associated with a variety of unhealthy behaviors that are known to have a negative impact on maternal and infant health. This is consistent with several studies that have found a similar association with low health literacy and certain unhealthy behaviors, including smoking and not receiving an influenza vaccine (11). Fewer studies, however, have looked directly at the target population of text4baby, pregnant and postpartum women. Therefore, our study reaffirms this relationship in this specific population and the need to adapt these important health behaviors in text4baby's messages for low health literacy populations. Importantly, daily prenatal vitamin intake was mediated by health literacy in our sample even after controlling for confounders, making this an important target for future mhealth programs aimed at lower health literacy levels.

Given the higher prevalence of unhealthy behaviors amongst the lowest health literacy groups, it is important that future analyses of text4baby examine the relative impact of the program at different literacy levels. Though the developers have written messages that are meant to accommodate lower health literacy levels, the messages may need to be simplified further. Supplemental information delivery, which several studies have found to be effective, may be incorporated in the future, especially using smart phone platforms. These supplemental delivery methods include using videos, icons, and verbal narratives (11).

This study is also one of the first to examine directly how people enrolled in an mhealth program use their cell phones, and how these patterns of usage are related to health literacy and demographic variables. Our analysis shows that those with low health

literacy are more likely to share a cell phone, as are those with lower income. The youngest group (ages 18-22) was the most likely to have changed their cell phone number at least once in the previous 6 months, as were the unemployed. The youngest participants were also the most likely to receive nine or more text messages a day. These findings are largely consistent with national surveys of text messaging. Our findings are also supported by data that the youngest Americans are more likely to share a cell phone (6). Though we did not find data on cell phone number instability, low income populations are more likely to use prepaid cell phone cards, and therefore more likely to experience service disruptions (5).

To determine the effectiveness of text4baby, researchers will need to determine if rates of knowledge acquisition and behavior change differ depending on health literacy skills. Text4baby continues to be promising in this population given that it incorporates a few core features of effective communication with low health literacy populations, namely presenting important information by itself and using limited numeracy in messages (11). It is possible that text message may not be the most effective medium to reach those with low health literacy, or that supplemental learning aides will be necessary to effect change in this population. The Agency for Healthcare Research and Quality, for instance, found in their systematic review that those with low health literacy benefit from visual aides and videos. Given the rapid expansion of smartphones, which are now available on many prepaid plans, text4baby could explore the advantages of these expanded platforms.

Several mhealth interventions have successfully improved health behaviors known to impact maternal and infant health (10-14). Mhealth programs have rarely,

however, examined directly the ways that participants use their cell phones, or the ways that these usage patterns may affect the design, measurement, or retention of these programs. After we systematically searched the literature, we found thirty randomized controlled trials of text message behavioral interventions relevant to maternal and infant health. Of the nine that included more than 200 participants, only four had more than 80% follow-up: one of these provided cell phones to participants (19); one had participants text their interest and consent to researchers, demonstrating their interest and comfort with the medium (20); and one scheduled follow-up interviews with high school during school hours (21). The last is distinguished in its design by the personalization of messages to participants' baseline information, and the integration of the program into their care (22). One pilot study of text message reminders for parents in a low-income urban clinic found that 19 of 48 participants changed their number at seven-month contact, and were thus lost-to-follow-up (23). It is possible that this is one factor to a drop-off in participation, a common problem in large-scale mhealth programs. Determining what leads to successful retention in these programs is essential to designing an intervention that can be evaluated and scaled up beyond a pilot study. As of yet, very little data is available on what leads to drop-off and how it might be prevented.

There are six main limitations of our research. First, health behaviors were self-reported, and therefore may not represent the true behavior of the baseline population, especially for socially undesirable behaviors. For instance, only four participants indicated that they drank during pregnancy. Secondly, there were few events, and therefore not enough events to control for multiple confounders. We also did not ask participants for more information about their cell phone usage patterns, particularly

whether they used prepaid cell phone cards or had long-term service plans. In large-scale surveys, these plans are more common among low-income populations, and therefore were likely common in our study sample. This may be an important factor in the usage patterns we found. Fourth, the relationship between health literacy and other predictors with these cell phone usage characteristics may have been underestimated in this population, as it was primarily a low literacy population and fairly homogenous with respect to demographic variables. Fifth, we do not have data on how long participants continued to receive text4baby messages after enrollment, and therefore cannot infer how these different usage patterns would affect retention or receipt of messages. Finally, our use of women from two urban clinics may not be generalizable to the whole population, and cell phone usage may vary by region.

Despite the noted limitations, there are at least three strengths of this study. First, this study provides clues as to the ideal design of mhealth programs, particularly for low health literacy and low resource populations in urban centers. As preliminary data and surveys indicate that the ways that people use their cell phones is not uniform, this is particularly important for programs like text4baby that are aimed at large and diverse populations. Second, the study population is similar to the ideal target population of text4baby, with significant health burdens and low health literacy. Finally, we are able to demonstrate that each of these usage characteristics are likely related to demographic variables, especially age and income level, even after controlling for potential confounders.

One implication of this study is that mhealth participants should be asked about how they use their cell phone to ensure that they receive messages. If targeting those with

low health literacy or other groups who may be more likely to share a cell phone, designers of mhealth programs should consider how they will determine that the intended recipient actually read the message, and how they will ensure privacy of the participant. Programs could build in ways to determine that the intended recipient had read the message by: using the name of the recipient, having them text back, providing a free cell phone to recipient, or sending password-protected messages. In promoting retention, program designers should consider if their participants are likely to change their numbers often, especially if their target group is young, unemployed, or has less than some college education. Finally, the appropriateness of text messaging as a means of targeting low socio-economic and health literate populations is reaffirmed by our study, as the majority of participants receive more than nine messages a day. This, however, means that text4baby and similar mhealth programs must rise above the noise of other messages that enrollees receive in a given day.

Future studies of text4baby should find ways to determine that the intended recipient has received the message. They should also measure retention directly to determine what infrastructural barriers may lead to drop-off. Finally, participants should be asked directly about how they use their cell phones and ways that text4baby could more effectively address the needs of its target population. Addressing these infrastructural issues is an important step in refining the design of these programs and measuring their impact.

**References**


1. Berkowitz GS, Papiernik E. Epidemiology of preterm birth. *Epidemiologic reviews* 1993;15(2):414-43.
2. Kochanek K, Xu J, Murphy S, et al. Deaths: Preliminary Data for 2009. *National Vital Statistics Reports*: U.S. Department of Health and Human Services, 2011.
3. Kotelchuck M. The Adequacy of Prenatal Care Utilization Index: Its US Distribution and Association with Low Birthweight. *American Journal of Public Health* 1994;84(9):1486-8.
4. Savitz D, Harmon Q, Siega-Riz AM, et al. Behavioral Influences on Preterm Birth: Integrated Analysis of the Pregnancy, Infection, and Nutrition Study. *Maternal and Child Health Journal* 2012;16(6):1151-63.
5. Kohut A, Wilke R, Horrowitz J, et al. Global Digital Communication: Texting, Social Netowrking Popular Worldwide. *Global Attitudes Project*: Pew Research Center, 2011.
6. Smith A. Americans and text messaging. *Pew Internet and American Life Project*: Pew Research Center, 2011.
7. Whitaker R, Matoff-Stepp S, Meehan J, et al. Text4baby: Development and implementation of a national text messaging health information service. *American Journal of Public Health*;102:2207-13.
8. Gazmararian J, Curran J, Parker R, et al. Public Health Literacy in America: An Ethical Imperative. *American Journal of Preventive Medicine* 2005;28(3):317-22.
9. Baker D, Parker R, Williams M, et al. The Relationship of Patient Reading Ability to Self-Reported Health and Use of Health Services. *American Journal of Public Health* 1997;87(6):1027-30.
10. Endres L, Sharp L, Haney E, et al. Health Literacy and Pregnancy Preparedness in Pregestational Diabetes. *Diabetes Care* 2004;27(2).
11. Berkman N, Sheridan S, Donahue K, et al. Health Literacy Interventions and Outcomes: An Updated Systematic Review. Research Triangle, North Carolina, 2011.
12. Kaufman H, Skipper B, Small L, et al. Effect of Literacy on Breast-feeding Outcome. *Southern Medical Journal* 2001;94(3):293-6.
13. Endres L, Sharp L, Haney E, et al. Health Literacy and Pregnancy Preparedness in Pregestational Diabetes. *Diabetes Care* 2004;27:331-4.
14. Sanders L, Shaw J, Guez G, et al. Health Literacy and Child Health Promotion: Implications for Research, Clinical Care, and Public Policy. *Pediatrics* 2009;124(Supplement 3):S306-S12.
15. Shaw S, Huebner C, Armin J, et al. The Role of Culture in Health LIteracy Screening and Management. *The Journal of Immigrant and Minority Health* 2008;11:460-7.
16. Fox S, Duggan M. Mobile Health 2012. *Pew Internet and American Life Project*: Pew Research Center, 2012.

17. Gazmararian J, Yang B, Elon L, et al. Successful Enrollment in Text4Baby More Likely With Higher Health Literacy. *J Health Commun* 2012;17(Supplement 3):303-11.
18. Weiss B, Mays M, Martz W. Quick Assessment of Literacy in Primary Care: The Newest Vital Sign. *Annals of Family Medicine* 2005;3(6).
19. Pop-Eleches C, Thirumurthy H, Habyarimana JP, et al. Mobile phone technologies improve adherence to antiretroviral treatment in a resource-limited setting: a randomized controlled trial of text message reminders. *Aids* 2011.
20. Free C, Knight R, Robertson S, et al. Smoking cessation support delivered via mobile phone text messaging (txt2stop): a single-blind, randomised trial. *Lancet* 2011;378(9785):49-55.
21. Whittaker R, Merry S, Stasiak K, et al. MEMO--a mobile phone depression prevention intervention for adolescents: development process and postprogram findings on acceptability from a randomized controlled trial. *Journal of Medical Internet Research* 2012;14(1):e13.
22. Naughton F. Randomized Controlled Trial Evaluation of a Tailored Leaflet and SMS Text Message Self-Help Intervention for Pregnant Smokers. *Nicotine & Tobacco Research* 2012;14(5):569-77.
23. Ahlers-Schmidt C, Chesser A, Nguyen T, et al. Feasibility of a randomized controlled trial to evaluate Text Reminders for Immunization Compliance in Kids (TRICKs). *Vaccine* 2012;30(35):5305-9.