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Abstract. The challenging family and work environments affect health of women as well as their pregnancies in developing countries like India. Some of these pregnancies occur too early and may lead to health complications at the time of child birth. A preterm birth of infants is a significant public health issue and there are several problems faced by mothers and their families. These problems include absence of messaging / calling service in emergency, lack of communication channel with physicians, no platform for experience sharing, poor understanding about infant growth tracking, induced mental stress and shattered confidence. This paper discusses about a paper prototype design of proposed app for mothers of preterm infants. A paper prototype for this app is designed based on correlated literature survey as well as peer Android app review. This prototype design include several facilities for 'Save Our Souls' (SOS), user guide, growth tracking, experience sharing and mother's health monitoring, improving their work engagement and communication with assigned physician(s). In future, this app will provide a user guide in local Indian languages along with experience sharing option for mothers.

Keywords: Mother, Preterm Infant, Android App, Paper Prototype, Neonatal ICU

1 Introduction

The world human population has reached around 7.5 billion by end of 2017. The global population growth amounts to about 83 million or 1.1% per year [23]. India is the second-most populated country in the world and supports over 1.3 billion people, which is around 18% of the world's population. In 2017, a crude birth rate for India was 18.8 births per thousand population [4]. Since the total size of the population is already huge, there is urgency for speedy achievement of demographic transition from high birth rate to low birth rate, resulting in lower population growth. The effects of

the high population growth in India include unemployment, malnutrition, high poverty level, inequitable distribution of income, over-strained infrastructure, over-stretched health and educational services [2] Such challenging environment affects health of women as well as their pregnancies. Some of the pregnancies occur too early, too late or too frequently and it may lead to illness and complications at the time of child birth.

A preterm birth of infants is a significant public health problem across the globe because of the related neonatal mortality during first 28 days of life, as well as short-term and long-term morbidity or disability in later life. The term - 'Preterm' for babies is defined as the infants born alive before 37 completed weeks or fewer than 259 days of gestation period [9][14]. Table 1 depicts the categories of infants based on the related gestational age (in weeks), which is a duration of conception to birth for an infant [20]. Generally, a full term human pregnancy lasts about 40 weeks and preterm infants have premature birth.

Table 1. Categories of infants based on gestational age

Category of infants	**Gestational age (in Weeks)**
Extreme **Preterm**	< 28 0/7
Very **Preterm**	28-32 6/7
Moderate **Preterm**	32-33 6/7
Late **Preterm**	34-36 6/7
Preterm	< 37 0/7
Early term	37-38 6/7

According to World Health Organization (WHO), every year about 15 million babies are born prematurely around the world and that is, more than 1 in 10 of all babies born globally. Almost 1 million children die each year due to complications of preterm birth [5]. The rate of preterm births ranges from 5% to 18% of babies born all over the world [18]. In India, out of 27 million babies born every year, 3.5 million (about 13 %) babies born are preterm [12].

The mothers of preterm infants experience significant psychological distress, with elevated levels of depression or anxiety. The study of maternal-infant bonding reveals that contact with infant is fundamentally important for the development of self-confidence, security or sentimental emotional stability of the mother [9]. With improved infant care and related healthcare services in Neonatal Intensive Care Unit (NICU), the survival rate of preterm infants has been increased. The quality of early maternal-infant relation is an important factor with potential for long-term negative

effects on the mother and her preterm infant. To reduce the gap between NICU and the parents, there is a need for an android application, which can track the growth of infant and can provide an information support to the mother of preterm infant.

This paper provides an overview about the **initial design process and a paper prototype developed for Android application** designed for mothers of preterm infants. Along with this research work, there is a plan of developing a user persona for Indian mothers of preterm infants. This mother's persona is being developed through field studies and interviews of selected mothers as well as physicians in local hospitals and NICUs. Such persona is based on philosophy of **Human Work Interaction Design (HWID)** and is expected to provide insights about mothers of preterm infants in the form of their attributes, work habits and challenges faced during patient care. This mother's persona along with a paper prototype design for related Android app will provide a solid foundation for actual design of Android app for mothers of preterm infants.

2 Literature Survey

The literature surveys in healthcare domain and related with mobile apps are vast and varied. This section discusses few of these related research articles, which are helpful in prototype design of a proposed Android app for mothers of preterm infants.

The aim of the study by Mbwele et al. has been to assess mothers' experience, perception and satisfaction of neonatal care in the hospitals of Kilimanjaro region of Tanzania. This cross-sectional study has employed qualitative and quantitative approaches involving semi-structured interviews of 112 mothers from 14 healthcare facilities [14]. Several reasons such as shortage of food supply, cost of medical care, impoliteness of staff, care for husband and other children, domestic responsibilities, and lack of transportation facility have developed a reluctance of mothers to attend medical services. Other complaints from mothers included **foul language, irregular doctor examinations, nurses in a hurry, little opportunities in asking questions and delay of medical care.** This study has highlighted important aspect – need for communication between patient and a physician. Therefore, a physician is included as a vital medical user and a mother is provided with several **communication channels such as appointment booking option, messaging service for advice and messaging / calling facility in case of emergency**. The proposed app also provides growth tracking facility for infants and also the user guide, which can help in reducing stress level of mothers of preterm infants.

In an Iranian study, Heidari et al. have attempted to investigate about socio-cultural factors of Iranian parents with hospitalized preterm infants in NICU.This article has revealed that the parents of hospitalized infants in Iran experienced **stress-induced physical and emotional problems, shattered confidence in their parental**

role, challenges related with family dynamics, shame as a social stigma, and job or income loss [8].This study makes one aware about the mental state of the mothers of hospitalized preterm infants and several problems faced by parents in their social life. Thus, the study has pointed out the emotional problems of the mothers and their need for support. The proposed Android app provides several experience sharing options to support the mothers of preterm infants. These options include **forums, videos, reports and physician recommendations.** Such experience sharing options can help mothers understand the challenging situation better and effectively to deal with their traumatic experiences.

Hayes et al. have described the design process and principles used in the development of Estrellita, a mobile capture tool to support parents of preterm infants in homes to track health data [7]. This article has emphasized on two vital aspects in application design - healthcare and parenting concerns. It has highlighted several design principles for such apps - **supporting flexibility and clinical adherence in data collection, enabling parent empowerment through education and/or reflection, and supporting communication through data sharing.** The proposed app supports infant growth tracking facility based on infant data collected from or entered by mother and monitored by connected physician and/or a nurse. The mother is empowered by providing user guide and experience sharing facility. **The user guide has components such as Frequently Asked Questions (FAQs), medical terms and NICU equipment list, supporting flexibility through content in multiple languages**; at least few of European and Indian languages apart from English. A physician is included as a vital medical user and can use **data sharing or communication service for advice** and messaging / calling facility in case of emergency.

The objective of the study on **infant growth tracking** by Riddle et al. is to provide gender-specific preterm infant growth curves that can be incorporated with WHO growth standards to continuously track weight, head circumference and body length of infant from 22ndweek of gestation through 2 years of age [21]. Intrauterine growth charts are used to monitor the growth of preterm infants in the NICU. The case studies involving infants from United States of America (USA), Australia, Italy, Israel, Turkey, Sweden and United Kingdom (UK) are considered for comparison in this research article. During study of infant growth tracking, the gender-specific percentiles for **birth weight, head circumference and body length values** are also compared. The **age-adjustment calculator** for infants, **user-preferred measurement units** and **value ranges of growth tracking parameters** with Indian context will be provided in proposed app.

3 Android App Review

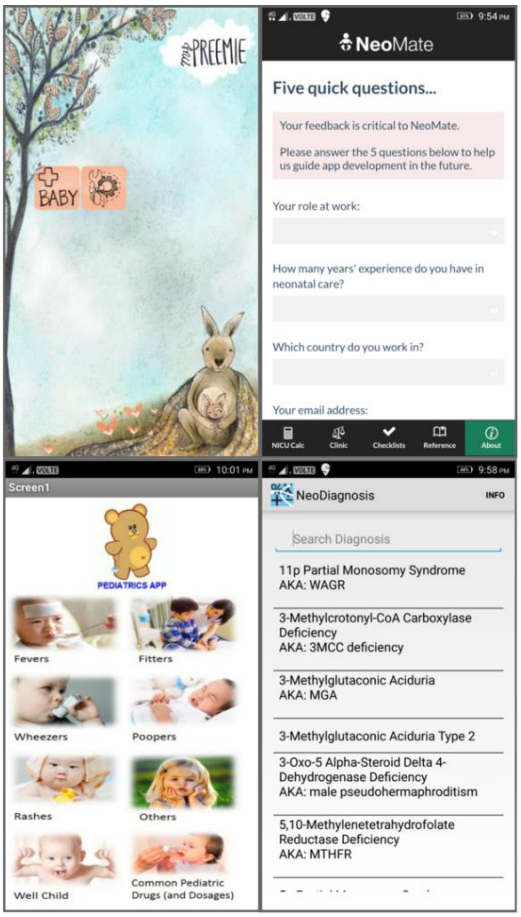


Fig. 1. Sample Screenshots for selected Android apps

A systematic review has been conducted for currently available Android apps related with neonatology and pediatrics used mainly by mothers of infants and other medical users. **There are seven Android apps for mothers of infants available in 'English' language, mostly developed in USA.** Fig. 1 depicts sample screenshots of four Android apps. The app review is focused on seven identified Android apps and aimed to provide interesting insights into functionalities and other design aspects. To examine such aspects of selected Android apps, an expert-based review is conducted by authors. The team of authors includes an active physician too. During the review process, the authors have put themselves in the role of potential users i.e. mainly

mothers to assess the mobile apps in terms of their functionalities as well as other design aspects.

Table 2. Details of Android apps used by mothers based on design considerations and user acceptance parameters

App Name	Major Function	Mother's Health Option	Targeted Users	SOS Button	App Downloads Thousands	User Rating Max. 5
Ovia Parenting	Growth Tracking	No	Mother & Caregiver	Yes	100	4.7
Neomate	NICU Calculator	No	Mother	No	50	4.4
NeoDiagnosis	Diagnosis Search	No	Nurse	No	01	4.2
Pediatrics	Drug Dose Calculator	No	Mother & Paediatrician	No	10	4.6
Mypreemie	Growth Tracking	No	Mother	Yes	10	4.4
Preemie Adj. Age Tracker	Adj. Age Calculator	No	Mother & Caregiver	No	01	3.8
Connect2NICU	Growth Tracking	Yes	Mother	Yes	01	4.5

Table 2 depicts details of apps used by mothers based on design considerations and user acceptance parameters. Major design aspects considered in selected apps include **mother's health option, targeted users, 'Save Our Souls' (SOS) button, app downloads and user rating**. There are three calculators – adjusted age calculator, drug dose calculator and NICU calculator, apart from a major function of growth tracking. An adjusted age is preterm infant's chronological age minus the number of weeks infant is born early. An adjusted age calculator helps in calculating this age for the infant. Due to lack of proper brain development, preterm infants are often at elevated risk for health issues with learning, communication, emotional regulation, and social bonding [17]. Therefore, **physicians often consider adjusted age in assessment of infant's growth and development.** Drug doses are part of regulated administration in NICU and usually expressed as a quantity per unit of time. **A drug dose calculator helps in normalizing the drug dose according to neonatal age and body weight.** Such normalized drug dose is required for infant's safety and well-being [11]. The NICU calculator provides calculations for different types of drugs based on body weight of infant. It also provides calculations for **intubation tube, oxygenation index, intravenous fluids and central line size** along with information on when to start cooling treatment for infant [15]. The vital observations from entries in table 2 are provided as follows:

- Most of the apps (6 out of 7 apps) are designed mainly for mothers of preterm infants; but these **apps don't provide much support for mother's health (1 out of 7 apps) directly.**

- **Most of the apps (4 out of 7 apps) have included caregivers such as physicians and/or nurses in patient care of mothers and their preterm infants.** One of the apps has included specialist physicians such as pediatricians to support these mothers.
- **Some of the apps (3 out of 7 apps) provide SOS button for making emergency contacts.**
- **All apps have at least one thousand downloads.** Few of these apps (2 out of 7 apps) have more than 50 thousand downloads.
- **Average user rating for the apps is 4.4 / 5.0** and most of the apps (6 out of 7 apps) have user rating of at least 4.2.
- **The single-functionality apps** such as NeoDiagnosis and Preemie Adjusted Age Tracker **have comparatively less number of downloads (just over one thousand).** The average user ratings for these apps are around 4.0 / 5.0 lesser than average user rating of all apps - 4.4.

Table 3. Details of Android apps used by mothers based on major functionalities

App Name	Growth Tracking	Adj. Age Calculator	Drug Dose Calculator	Diagnosis Search	User Guide	Term Illustrations
Ovia Parenting	Yes	No	Yes	No	Yes	No
Neomate	No	Yes	Yes	No	No	Yes
NeoDiagnosis	No	No	No	Yes	Yes	Yes
Pediatrics	Yes	No	No	Yes	Yes	Yes
Mypreemie	Yes	Yes	Yes	No	No	Yes
Preemie Adj. Age Tracker	No	No	Yes	No	No	No
Connect2NICU	Yes	Yes	No	No	Yes	Yes

Table 3 depicts details of apps used mainly by mothers based on major functionalities. All entries in the table 3 are either 'Yes' or 'No', indicating presence or absence of that functionality in related app. Major functionalities observed in these selected apps include **growth tracking, adjusted age calculator, drug dose calculator, diagnosis search, user guide and term illustrations.**

The preterm infants are more vulnerable to infections than other term babies and therefore, their health as well as growth needs to be continuously monitored. **A growth tracking record helps physician as well as mother to keep infant development diary incorporating head size and body length, track a weight gain, log infant feeds and share growth progress with physician and parents.** An adjusted age calculator and drug dose calculator are also vital functions in infant care and they are explained in earlier part of this section. A diagnosis search is a facility

allowing the detection of any subjective evidence of an ailment or medical condition. Such **diagnosis search may be run by the mother based on known symptoms, with the assistance of medical personnel if required.** The user guide is a technical communication document intended to give assistance to medical users using the mobile app. This **guide helps the user to know how to use the application functions and details along with the step-by-step guidance to perform specific tasks.** A function - Term illustrations is a facility provided to medical users, who want to refer or understand the medical terminologies related with neonatal care. It offers concise and easily accessible information searching for descriptions of the related medical terms. Important trends observed with entries in table 3 are listed below:

- **Most of the apps (4 out of 7 apps) provide the infant growth tracking facility, which is vital functionality** in reducing the stress levels among mothers of preterm infants.
- **Most of the apps (5 out of 7 apps) have provided calculator facility for adjusted age and/or drug dose.**
- **User guide and Term illustrations** are important facilities for mothers as well as other medical users. **They are provided in most of the apps (6 out of 7 apps)**.
- **Diagnosis search is provided by only two apps**; mainly for physicians or pediatricians.
- **There are two single-functionality apps -** NeoDiagnosis and Preemie Adjusted Age Tracker - that **focus on only one particular function such as diagnosis search and adjusted age calculation** respectively.

4 Paper Prototype Design for Mobile App

A prototype is an experimental model of an idea. It can be considered as an attempt of a designer to present his/her idea in front of the world. A paper prototype is a low-fidelity option in mobile app design [19]. Such paper prototype is proposed for eye-free Android app for visually impaired users by Sagale et al. [22]. A similar paper prototype design is proposed in this paper for Android mobile app for mothers of preterm infants.

The proposed mobile app starts with user login process either using Facebook / Google login or user registration option. If the user is a mother of preterm infant, she is redirected to SOS Setup in which she needs to provide the default contacts required in case of any emergency. A menu screen provides the user with three major options - **Growth Tracking, User Guide and Experience Sharing.** Each of these options has

few more options, which are presented later in this section. A physician needs to track health of mother continuously and is connected to the mother via the option - **Mother's Health.** App Settings option is also provided to the user for control of settings related with **Font, Language and Security**. A physician performs two main functionalities in the app - to track infant's growth as well as mother's health, and validate the infant body parameters. Physicians may communicate with the mothers on weekly basis via any method of appointment, by calling or messaging mechanism. They can also recommend mothers with consolidated reports of other mothers and some informative articles for reference. This section presents the major screenshots in paper prototype along with related design considerations for proposed mother's app.

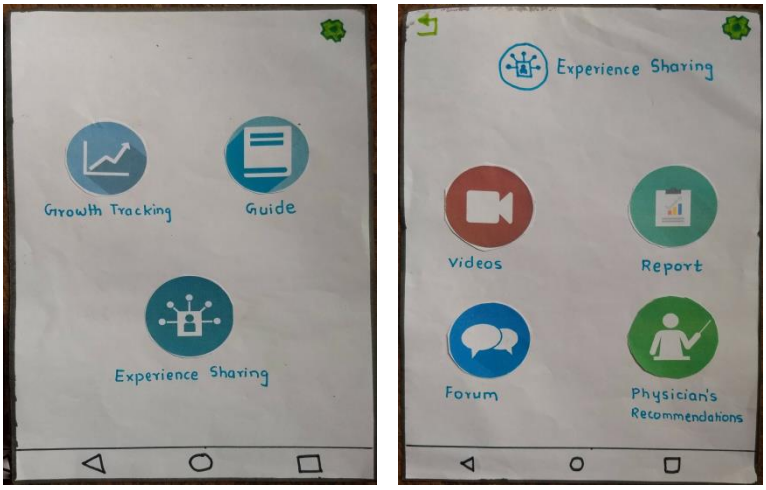
(a) (b)

Fig. 2. Screenshots for (a) User Login and (b) SOS Setup

The screenshots for **User Login** and **SOS Setup** are depicted in Fig. 2. In User Login, user can complete login process either using **Facebook / Google login or User Registration option** as seen in Fig. 2 (a). There is a User Registration option, through which mother or medical users can complete user registration process and then, can proceed to use the app though own login. The user login process considers three major types of users - **mother, physician and even nurse**, observed in mobile app review in section 3.

A screenshot for SOS Setup is depicted in Fig. 2 (b). It has been included in app design since several mobile apps studied have **SOS button / option for signaling of extreme distress or an emergency condition [7, 14]** as depicted in Table 2. It can be used by mothers to contact the concerned **physician, husband or other family member.** The proposed app stores emergency contact numbers of the physician(s) or other family member(s) collected from the mother during SOS setup process. These

contacts can be changed as per her preference. In case of any emergency, a mother needs to touch the SOS option, which notifies the related contact persons via different modes like vibration, blinking, notification, alarm and even a call**.** Such notification can even be supported with real-time safety information using the Google Maps to detect location of emergency and also, to provide a suitable map route of where to go and how to get to the location of emergency. Thus, **SOS button / option provides a useful messaging service in emergency to the mother.**



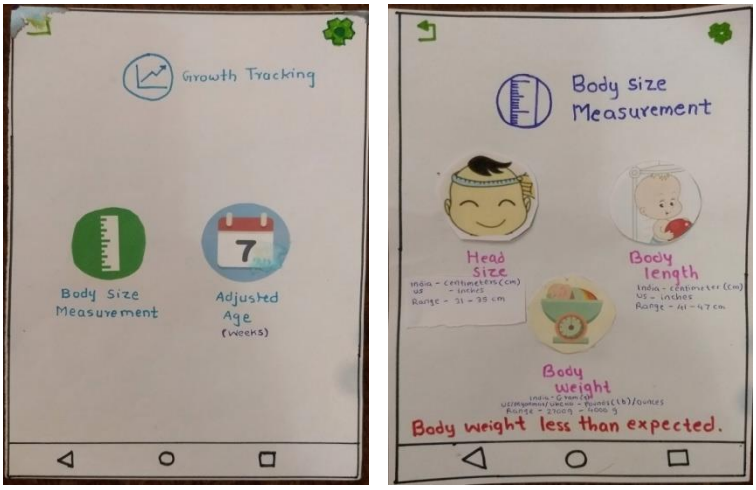
(a) (b)

Fig. 3. Screenshots for (a) Menu and (b) Experience Sharing option

A screenshot for Menu option is depicted in Fig. 3 (a). This main menu has three vital options which are **Growth Tracking, User Guide and Experience Sharing**. The growth tracking process involves monitoring of infant's growth through supervision of body measurements with due consideration to adjusted age of the infant. A user guide includes information about Medical Terms and Equipment used in NICU along with related FAQs for mothers, medical users and other family members with multilingual support. These options are also discussed in details later in this section.

An Experience Sharing option contains facilities for sharing especially the experiences of the mothers. These facilities include **Videos, Reports, Forums and Physician Recommendations.** A mother and family of a preterm infant are required to deal with mainly stress-induced emotional problems as revealed by literature survey. The parents' confidence may be shattered and few other challenges are created related with family dynamics [8]. In order to change their mindset and help them to deal with their emotional traumatic experience, a thoughtful learning strategy needs to be incorporated in proposed app design. Such experiences are personal, but

there is a lot of social learning that can be derived from similar experiences of other members of society. The mothers and family members can learn through videos, reports and online community groups. **Forums targeting online community groups of mothers help them bounce ideas off each other, share care tips and get answers to their queries** [16]. Videos are also a powerful mode of experience sharing and learning. They should essentially relay on what the infant's family has done or accomplished, and how the mother talks about her own past experiences. **The physician often recommends the mother some consolidated information or reports from medical journals, articles, news, and blogs, which can help her resolve issues or concerns, to improve communication among physicians and patients.**



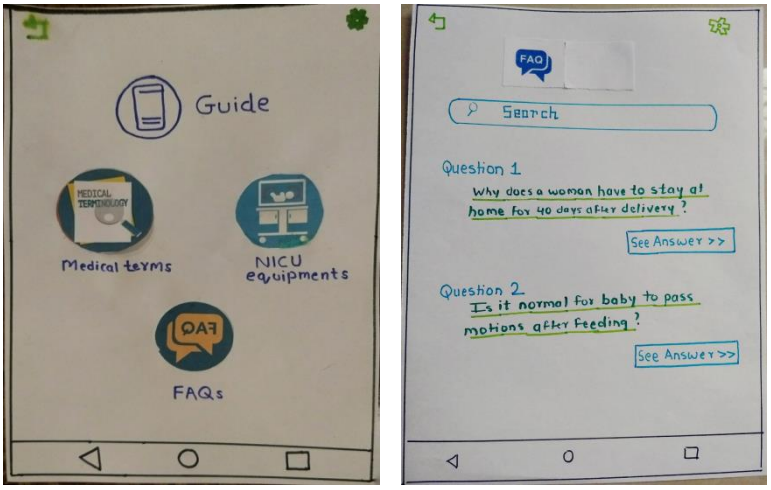
(a) (b)

Fig. 4. Screenshots for (a) Growth Tracking and (b) Body Size Measurements

The screenshots for Growth Tracking and related Body Size Measurements of infant are depicted in Fig. 4 - (a) and (b) respectively. The Growth Tracking option focuses on **growth monitoring of infant through supervision of body measurements as well as adjusted age of the infant.** The literature survey also reiterates the need of growth tracking functionality in the app for improved communication with mother and also, for reducing their stress level [9].

The body measurements of infant have three significant parameters such as **Head Size, Body Length and Body Weight.** It is essential to know the gestational age-adjusted measurements as there is a significant relationship of preterm birth with neonatal complications, mortality and developmental delay [10,21]. These measurements can be entered periodically into the proposed app either by NICU nurse or mother of preterm infant and may be closely monitored and verified by the physician. The default value ranges for each of body parameters and user-preferred

measurement units are also depicted in Fig. 4 (b). For example, a head circumference normally measured in cm (in India) or inches (in USA). The amount of increase in head circumference helps in identification of high-risk infants [21].

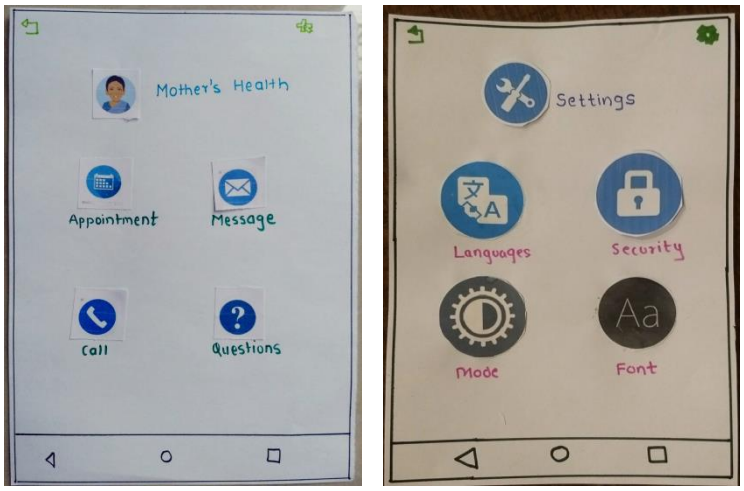


(a) (b)

Fig. 5. Screenshots for (a) User Guide and (b) FAQs

A Fig. 5 depicts the screenshots for User Guide and related FAQs in Fig. 5 (a) and (b) respectively. The User Guide is really crucial function as highlighted in both literature survey as well as app review. Generally, a User Guide / manual is a technical communication document intended to give assistance to intended app users. It may even include instructions and step-by-step guidance on how to perform related task [1,3]. This guide is desired to be in users' language and with possible multilingual support. A proposed User Guide has options for **Medical Terms, NICU Equipment and FAQs** for helping mothers and her family members as suggested by Hayes et al. [7] and these options are depicted in Fig. 5 (a). The definitions and explanations of Medical Terms assist especially the mothers to understand the medical context related to preterm births, pediatrics and NICU. These terms include the terminologies such as **preemie, neonatology, adjusted age, induced preterm infant** and others. The Equipment used in NICU for infant care include **incubator, lung ventilator, multi-parameter monitor, radiant warmer** and other devices. An introduction along with images of these devices under Equipment option help the mothers and other family members in accepting and even appreciating the infant care in NICU to reduce their stress. Mothers can take benefits from FAQs by exploration of related answers whenever required. The FAQs can be explored using a search bar where user can enter keywords and the app displays related FAQs in a list format as

seen in fig 5 (b). The FAQ's can be updated periodically as per physicians' recommendations and feedback from mothers.



(a) (b)

Fig. 6. Screenshots for (a) Mother's Health and (b) App Settings options

A screenshot for Mother's Health is depicted in Fig.6 (a). It has been included in proposed app since such option has not been provided in most of the related apps as seen in table 2. A physician can track Mother's Health and can connect to the mother via this functionality. It includes **Appointment, Call, Message and Questions.** The option - **Questions**, provides a personal channel to the mother for asking specific queries to related physician as discussed in Mbwele et al. [14].

App Settings screenshot has options for settings related with **Languages, Security, Mode and Font** as seen in Fig. 6 (b). These are commonly used setting options in most of the apps. A Language function can offer multi-lingual support to the mothers as well as other users. Selecting preferred language overcomes language barrier and helps mothers to get desired guidance and support effectively [6]. A **day-night mode and adjustable font size** helps to reduce the eyestrain of the users.

5 Conclusions and Future Work

The proposed app for mothers of preterm infants is quite interesting and useful Android app. A paper prototype for this app is designed based on allied literature survey as well as mobile app review. This prototype design includes several functionalities to support mothers, family members as well as physicians. It has

options for SOS, User Guide, Growth Tracking, Experience Sharing and Mother's Health. Thus, the proposed app is designed with main intention of helping mothers in getting answers to their queries along with improved communication with assigned physician(s). **The development of proposed Android app for mothers will improve the work engagement through automation and will also, in reducing the mental stress faced by mothers as well as by their families.**

In future, the proposed app will be developed with initial focus on user guide as well as growth tracking option, and its first version will be available on Google Play Store by later 2018. There is also a plan of providing a user guide in at least one Indian language along with English. **The availability of local language support in the app will impart health education to even more number of mothers of preterm infants and help them in taking care of infants more effectively.** This app will be tested through usability testing method with selected mothers and physicians in real-life work environment of hospitals and NICUs. The option of physician's recommendations along with experience sharing will also be incorporated in the app in subsequent versions.

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