Integrated diagnostic device for children under five for emerging markets

Master Thesis report 2017

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Executive summary

Low and Middle Income Countries (LMICs) face major issues throughout the continuum of primary healthcare for child care (0-5 years). Altogether more than 10 million children die each year in developing countries before they reach their fifth birthday. WHO and UNICEF created an Integrated Management of Childhood Illness (IMCI) strategy to tackle this global issue. However, IMCI implementation has not been able to scale up due to numerous issues. This design aims to improve the usability and scalability issues of this strategy at user level across India and Kenya.

Context Variation by Design approach is used to focus on usability and scalability. First, insights from different contexts are studied to find shared or opposing requirements. From this study, a creative solution space is formulated. India and Kenya contexts are studied first to create the first solution space which indicated a large number of insights being similar. Hence, Kenya was considered to be the focus context and opposing insights are used as guidelines for scalability.
Similarly, two user scenarios were studied- low expertise and high expertise. The user solution space was defined which led to identification of problems and insights on workflow. The main problems of lack of data driven dialogue for adaptation of IMCI to regional morbidity profile, lack of planning in peripheral systems, lack of continuous trainings and high cognitive load of IMCI workflow are identified throughout the research phase.

The proposed product system is broken down into two main parts- smartphone app and physical device. Various concepts are explored with sketching, mock-ups and prototyping.

The final design thus composed of a workflow support application and a spot check device. The main features of the app are screening and training. The application reduces the cognitive load on the user by guiding the health worker and recording the information from the caretaker. At the end of the screening, an appointment and consultation is made possible through SMS service within the app. The data from the screening process is used to gather data for the adaptation process at the systemic level. The app also provides training with a gamified version of scenario based training.
The spot check device is used with the workflow in order to improve the outcome of IMCI with diagnostic information. The device provides measurement of four vitals- temperature, respiration rate, oxygen saturation and heart rate. The device consists of display device and a probe.

Glossary

Workflow: A workflow consists of an orchestrated and repeatable pattern of activity enabled by the systematic organization of resources into processes that transform materials, provide services, or process information.

Neonate: an infant less than four weeks old

Infant: a very young child or baby.

IMCI: Integrated Management of Childhood Illness of IMCI is a systematic approach to children's health

Morbidity profile: Distribution of diseases in a given population

ASHA: Accredited Social Health Activist are community health workers instituted by the government of India's Ministry of Health and Family Welfare

CHW: Community Health Worker

Health worker: Any medical professional including the community health worker

Caretaker: The person who takes care of the child. Usually the mother.

Medical supply chain: The sequence of processes involved in the production and distribution of medication

Introduction

Integrated Management of Childhood Illness (IMCI)

A brief description of IMCI strategy and challenges

1.1 The global problem-childhood illness

Low and Middle Income Countries (LMICs) face major issues throughout the continuum of primary healthcare for child care (0-5 years). Altogether more than 10 million children die each year in developing countries before they reach their fifth birthday. Seven in ten of these deaths are due to acute respiratory infections (mostly pneumonia), diarrhoea, measles, malaria, or malnutrition—and often to a combination of these conditions (figure 1).

There have been many efforts to improve child healthcare by countries worldwide. However, failure to coordinate on child health guidance and implementation has made such efforts ineffective and inefficient. Fragmentation of global child health efforts urgently needs to be resolved since they place a large burden on countries[1].

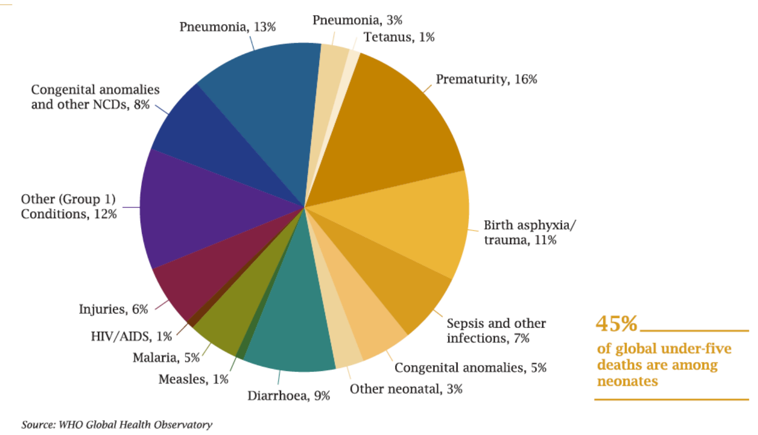


Figure 1: Causes of death among neonates and children under five globally

1. Introduction. (2016). In Towards a Grand Convergence for Child Survival and Health (p. 8). World Health Organisation . doi:November 2016 http://apps.who.int/iris/bitstream/10665/251855/1/WHO-MCA-16.04-eng.pdf?ua=1

1.2 What is IMCI?

Providing quality care to sick children is a serious global challenge. In response to this challenge, WHO and UNICEF developed a strategy known as Integrated Management of Childhood Illness (IMCI).

"The objectives are to reduce deaths, the frequency and severity of illness and disability and to contribute to improved growth and development of child."

IMCI strategy consists of following three components:
1. improving health worker skills
2. strengthening health systems
3. improving family and community practices

The clinical guidelines, which are based on expert clinical opinion and research results, are designed for the management of sick children aged 1 week up to 5 years. They promote evidence-based assessment and management, using a syndromic approach that supports the rational, effective and affordable use of drugs. They include methods for assessing signs that indicate severe disease; assessing a child's nutrition, immunisation, and feeding; teaching parents how to care for a child at home; counselling parents to solve feeding problems; and advising parents about when to return to a health facility[1]. The guidelines are implemented at user level through trainings sessions and chart booklet (see figure 2) to be used while performing the assessment. The targeted users are Community Health Workers from communities to nurses and doctors at health facilities.

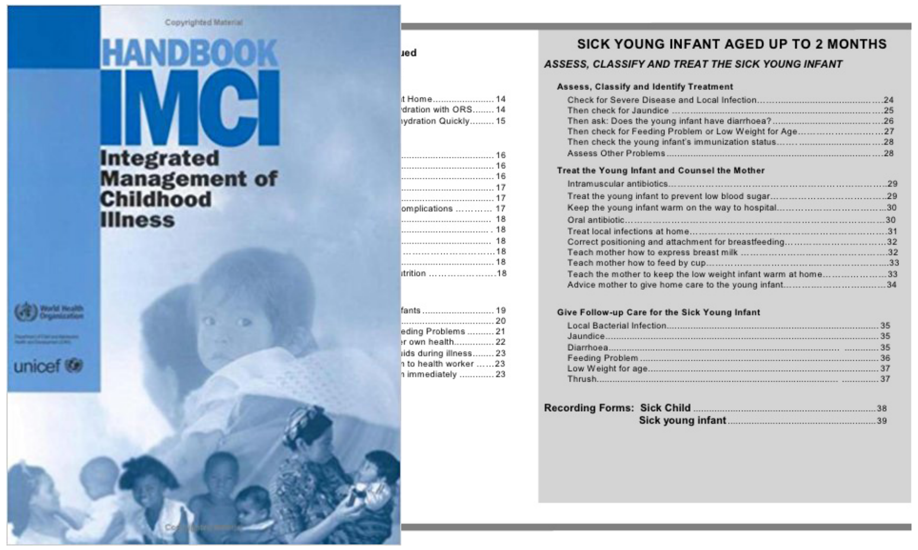


Figure 2: IMCI handbook used by the health workers

1. Integrated Management of Childhood Illness (IMCI). (n.d.). Retrieved August 04, 2017, from http://www.who.int/maternal_child_adolescent/topics/child/imci/en/

1.3 Challenges with IMCI

IMCI implementation has not been able to scale up due to number of challenges. Two types of challenges are focussed in this project- systemic and user level.

1.3.1 Systemic challenges:

First systemic challenge is adaptation of the IMCI to regional morbidity profile. The district teams face this challenge while implementing continuous training, monitoring of the health workers and gathering population health data. Adaptation suffers from poorly-functioning health system at operational level due to lack of resources. They were identified as a major constraint to scaling up IMCI[1]. Specific weaknesses included lack of work staff, lack of supportive supervision, financing and lack of logistics support[2].

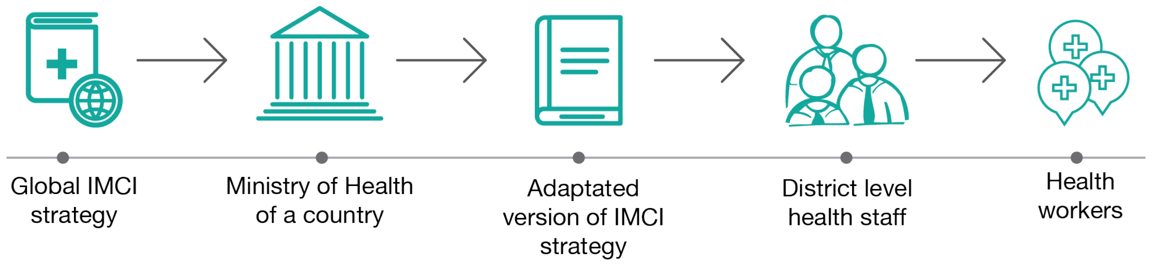


Figure 3: A process diagram of adaptation of IMCI strategy

Second systemic challenge is to improve the dialogue and collaborative problem-solving between health care staff at district level, and political authorities. Experimental and quasi-experimental studies in Kenya and Vietnam suggest that the effect of health committees is best achieved via improved dialogue[2].

> " Targeting child health packages by child mortality burden alone was found to be inadequately granular, as a "one-size-fits-all" strategy cannot serve the differing needs of dense urban areas, remote rural areas, and emergency contexts, where delivery channels are vastly different "
>
> - World Health Organization (2016)

1. Shah, D., & Sachdev, H. P. S. (1999). Evaluation of the WHO/UNICEF algorithm for integrated management of childhood illness between the age of two months to five years. Indian pediatrics, 36, 767-778.
2. Introduction. (2016). In Towards a Grand Convergence for Child Survival and Health (p. 8, 36). World Health Organisation . doi:November 2016 http://apps.who.int/iris/bitstream/10665/251855/1/WHO-MCA-16.04-eng.pdf?ua=1

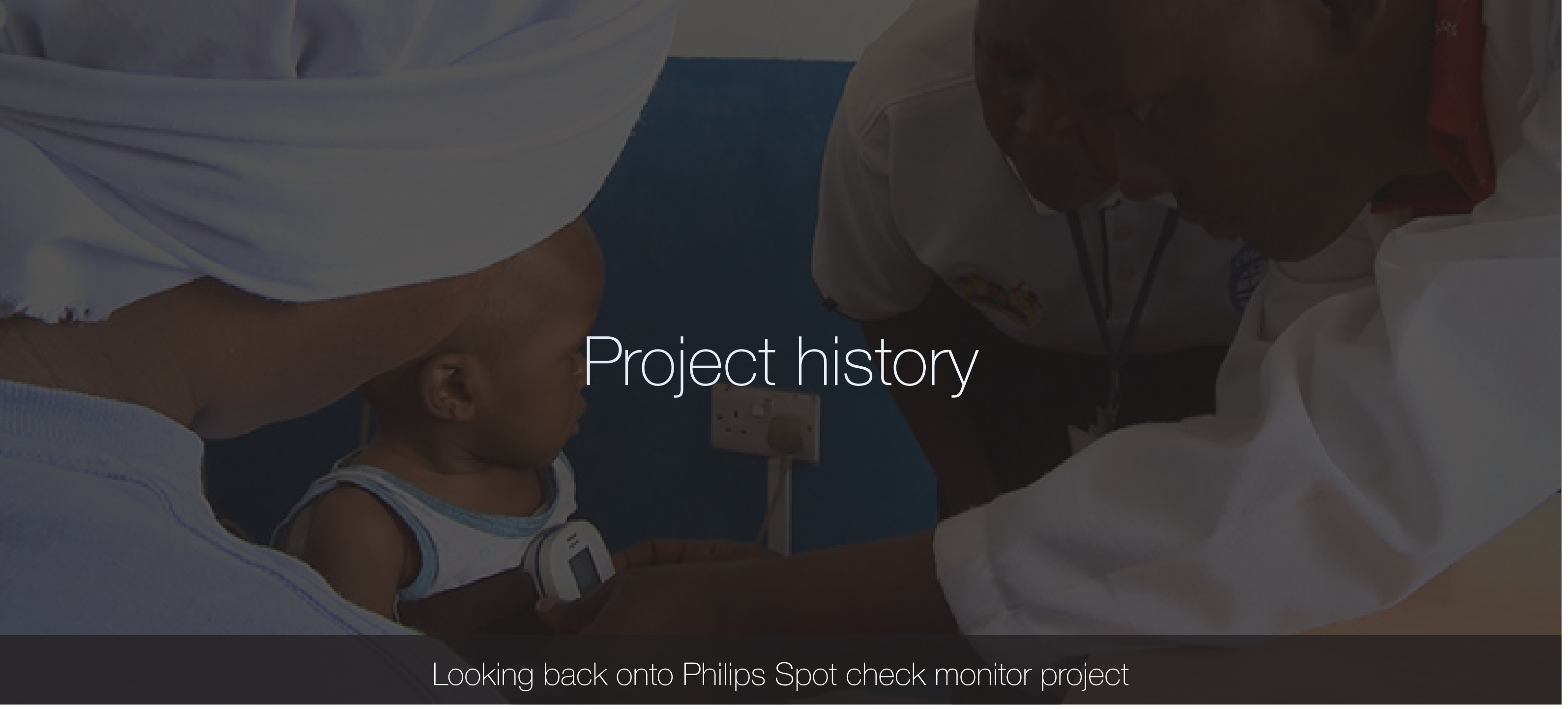
1.3.2 User level challenges:

The first user level challenge is related to usability of the IMCI guidelines. Research has shown that many health workers do not adhere to IMCI workflow, particularly for the management of severe illness[1]. Implications of systemic challenges are also visible at user level. On top of problems associated with usability of IMCI booklet (demanding high cognitive effort), lack of medical equipments, training, and organisational factors are also highlighted in various researches[2].

The second user level challenge is the training of health workers. Current training approaches are too costly and not effective enough: there is a need to promote improved pre-service training accompanied by regular supervision, clinical mentoring and updates through on-site visits.

Figure 4: An overview of the challenges

1. Naimoli10. JF, Rowe AK, Lyaghfouri A, Larbi R, Lamrani LA. Effect of the Integrated Management of Childhood Illness strategy on health care quality in Morocco. Int J Qual Health Care 2006;18:134-44. PMID:16423842 doi:10.1093/intqhc/mzi097 || Centers16. for Disease Control and Prevention. Health worker performance after training in Integrated Management of Childhood Illness – Western Province, Kenya, 1996-1997. MMWR Morb Mortal Wkly Rep 1998;47:998-1001. PMID:9843326 || Pariyo14. GW, Gouws E, Bryce J, Burnham G, Uganda IMCI Impact Study Team. Improving facility-based care for sick children in Uganda: training is not enough. Health Policy Plan 2005;20 Suppl 1;i58-68. PMID:16306071 doi:10.1093/heapol/czi051
2. Cabana22. MD, Rand CS, Powe NR, Wu AW, Wilson MH, Abboud P, et al. Why don't physicians follow clinical practice guidelines? A framework for improvement. JAMA 1999;282:1458-65. PMID:10535437 doi:10.1001/jama.282.15.1458 || Rowe23. AK, de Savigny D, Lanata C, Victora CG. How can we achieve and maintain high-quality performance of health care workers in low-resource settings? Lancet 2005;366:1026-35. PMID:16168785 doi:10.1016/S0140-6736(05)67028-6



Project history

Looking back onto Philips Spot check monitor project

Philips has been working on this project since last 2 years (started in 2015). The project was initiated by Philips research and funded by Gates foundation, and Royal Philips. The short term goal of Philips is to develop products which provide integrated care for children under five age, and then adapt the products for maternal healthcare in the long run. This project will be the first integrated device for complete child healthcare and second in generation.

2.1 First generation

The first generation device, ChARM was designed and implemented in India and Kenya in 2015. ChARM is a low-cost diagnostic device used to measure breath counts in children under 5 age, which is used in diagnosing Pneumonia. Breath counts are measured using an accelerometer sensors which are placed in a small housing. This housing is secured around the lower chest using a belt.

Figure 5: First generation devie-ChARM developed by Philips research

2.2 Second generation

The outcome of this project is expected to lead to the next generation device which will have added functions of measuring SpO2, Hear rate, and Temperature. These functions fulfil all the requirements in terms of diagnostic information to carry out a complete IMCI diagnosis.

On top of device, the next generation will also provide workflow support through a smartphone app. This app is intended to improve the usability of IMCI and also cater to other scalability issues.

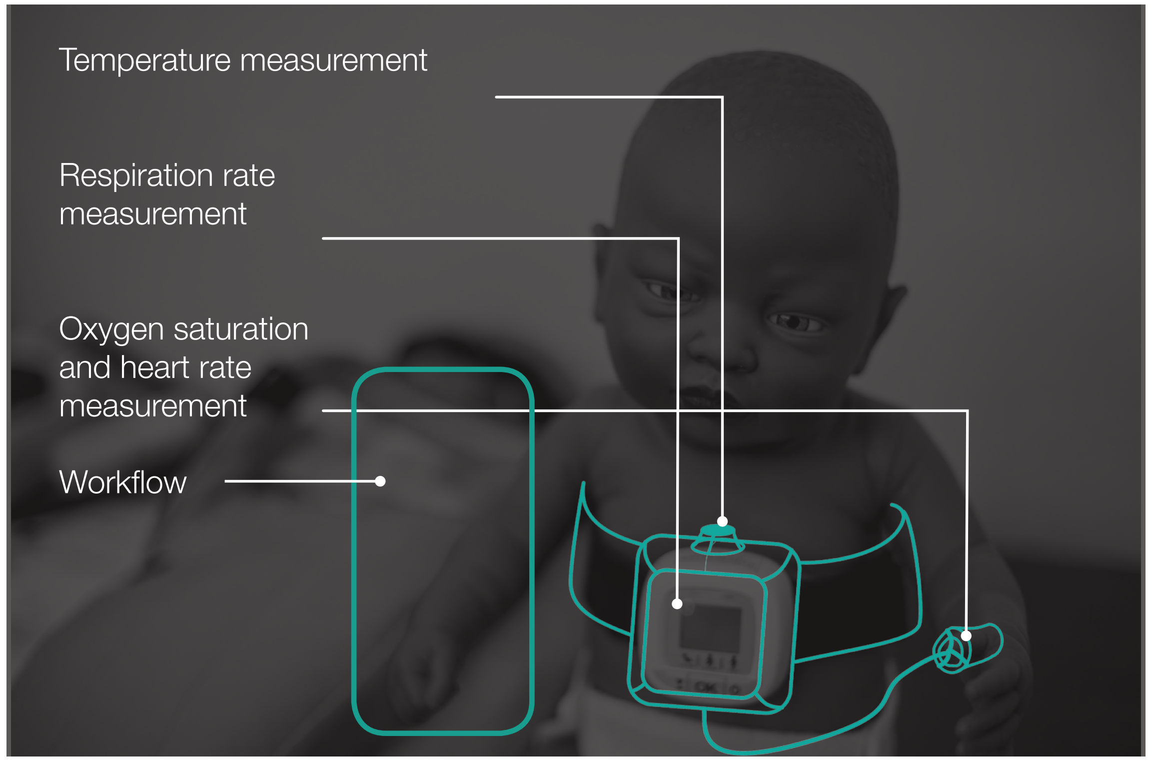
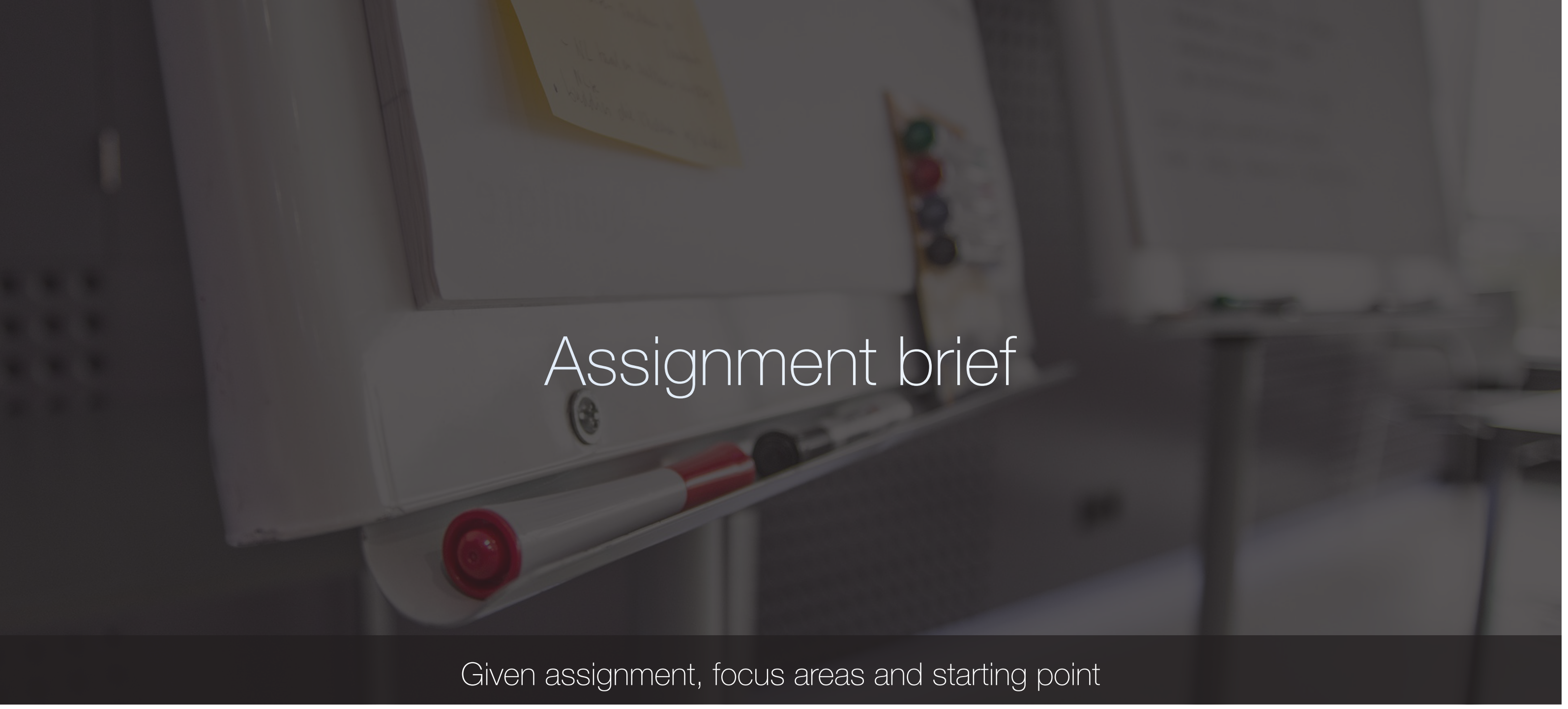


Figure 6: Proposed idea of second generation ChARM device

2.2 Future generations

The major vision of the project is to provide integrated child and maternal care. The future generations will provide care for children under 5 and also extend care to pregnant women as well. These extensions of the functions will be made in stages, by first adapting the SpO2 sensor for the pregnant women and then include the blood pressure function as the final stage. Please refer to Appendix A for the complete product system roadmap (APPENDIX A).



Philips envisions a product system comprising a device and smartphone application which can improve the adherence of IMCI workflow. The low-cost device is intended to provide all the diagnostic information to make a reliable IMCI diagnosis whereas the smartphone app can solve problems related to usability issues with IMCI booklet, training, and organisational factors at software level. The target markets for Philips are India and Kenya with this project. The nature of the assignment is explorative and an conceptual product system is expected as the deliverable. The design of the product system will be focussed on scalability and usability.

> The assignment is to design an **integrated** diagnostic **product system** for **child illness under five** aimed at **India and Kenya**

3.1 Scalability

Scalability is defined as capability of the product system to adapt to variations in context. Context is composed of the user, physical environment, technical infrastructure, institutions and culture. Four types of scalabilities will be explored during the project, which are summarised in the following table.
The second focus of the project is usability of the product system for the target users. Usability is defined as the ease of use which comprises of effectiveness, efficiency and learnability. Usability is already an identified problem with current IMCI implementation and will most likely cause higher cognitive load with the introduction new product system. Thus, it is important to consider the combined usability problems from current situation and future situations while designing the product system.

Scalability aspects	Description
User	ability to handle variations in education and role of the user (from community level health worker to health facility level doctor)
Functional	ability to change the product system by adding, changing, removing functionality at minimal effort (from previous generations to future generations)
Geographical	ability to maintain performance, usefulness, usability at various geographical places (India and Kenya)

Table 1: Scalability, focus of the project

After the need is identified, focus on scalability during the design process is desired mainly from technological and business perspectives. It enables the company to maintain product performance and usability, reducing the necessity to redesign while scaling up[1].

In order to focus on the scalability aspect, context variation by design approach is taken. This approach will be elaborated more in detail in next section.

3.2 Usability

In order to focus on usability aspect, user research backed up with cognitive theories are studied. User research is directed to gain subjective insights directly from target users whereas cognitive theories help in generating insights which may lead to more objective, hence scalable concepts.

It is important to note that scalability affects the usability and vice versa. For example, change in priority on guidance or time varies with user aspect of scalability and influences the efficiency aspect of usability at the same time.

Usability aspects	Description
Effectiveness	ability of the user to complete the task or achieve some particular goal with the product
Efficiency	amount of efforts user require to complete the tasks
Learnability	ability of the user to learn both during the first use and recurring use

Table 2: Usability, focus of the project

1. Bondi, A. B. (2000). Characteristics of scalability and their impact on performance. Proceedings of the second international workshop on Software and performance - WOSP 00. doi:10.1145/350391.350432

3.3 Starting point

This project started officially in April 2017. At this point, Philips envisioned a product system comprising of a device and smartphone application. The team was exploring various embodiment ideas for the next generation device. The main focus was to finalise the design of the SpO2 probe and then device. My role in the team was to research and conceptualise the product system and was given the complete responsibility of designing the smartphone application. Parallely, I learnt and assisted the team in designing the device and the probe.

Requirements on physical device:
1. The requirements on the physical device consisting of spot check monitor and probe were already decided by the design team through prototyping. These requirements were as follows:
2. The probe should function for all the finger sizes from neonates to infants
3. Temperature sensor should be integrated into the spot-check monitor for intuitive use
4. The design should be similar to ChARM in order to reduce the efforts (human resources) while adding new functionalities
5. The design should be easy to adapt to future generations at minimal efforts
6. The device should be compatible (charge and run) with locally available source of electricity

Wishes:
1. The device should function independent of smartphone in order to scale up scenarios where smartphone is not available
2. The device should be easy to clean and store

Approach and design process

Defining the approach to tackle the challenges

A combination of human centred design (HCD) and Context Variation by Design (CVD) approaches are taken due to focus areas- usability and scalability. HCD provides a holistic approach to design whereas CVD helps designers to deal with scalability in multiple contexts early on in the process.

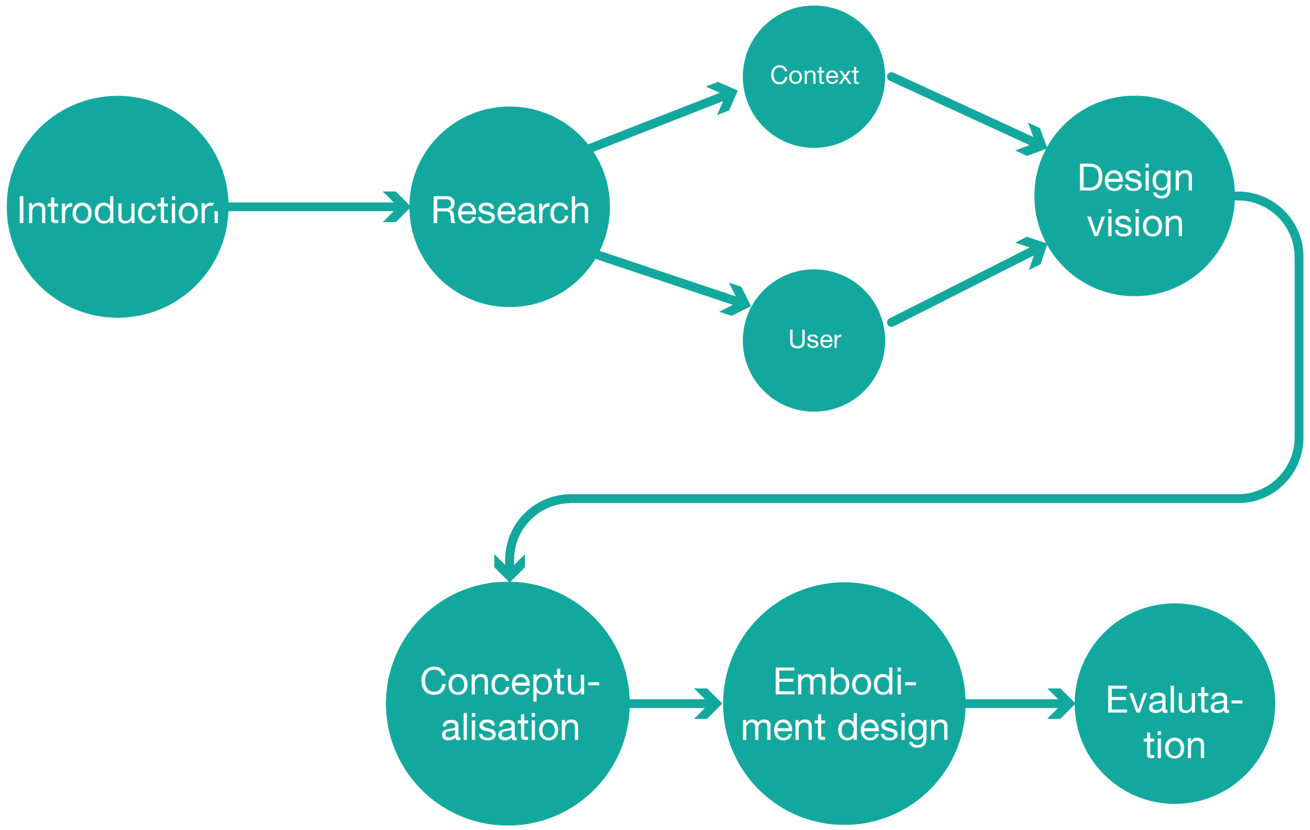
In order to tackle scalability challenges at systemic level (macro-context) and user level (micro-context), CVD will be used both to research & analyse context and users. Within the context research, (mono-) insights from India and Kenya will be separately collected which are relevant for this project. Letting these insights interact can lead to overlapping or conflicting requirements. This interaction of insights is expected to form a rich contextual Solution Space regardless of degree of overlapping or conflict. Within user research, same approach will be applied at user level. First the user scenarios will be created using expert interviews and literature study. Mono-insights will be generated using cultural probe for every scenario. Interactions with the mono-insights will lead to second rich user Solution Space.

There are two rich solution space- context and user, which will be used at conceptualisation phase. The creative tension within the solution space is expected to boost creativity especially keeping scalability in mind.

There are three possibilities for a concept:
1. Product adapted to one context, but informed and enriched by insights from other context(s).
2. Product adapted to one context, with a clear advice about the steps to the solution for the other context(s).
3. Product that can be implemented in more contexts, but with variation; for example with adding modularity.

All the three possibilities are open at this point, a decision on this will be made after the research phase. An overview of the design process is explained on next page.

Figure 7: Approach of the project & structure



Research

Context research

Gaining insights on India and Kenya contexts

The design of medical devices has failed to deliver effective and efficient products to low-resource settings (LRSs). Challenges in understanding the context of use of products in LRSs have been reported as potential causes of failed designs[1]. Accurate collection of user requirements and contextual information has proven to be highly valuable in medical device design[2].

Only considering the physical environment as context has not ensured a good contextually fit design. Thus a holistic approach to researching the context is used by first defining the context based on Contextual framework by Clara et. al. for designing medical devices in LRSs[3].

5.1 Definition of context

Contextual framework by Clara et. al. is meant for various types of medical devices. Since the idea of product system is already present (see project history, pg.15), the framework is adapted to make it more relevant for project.

Three main contextual factors were selected to be relevant for project- Physical environment, Systems and structures, Society (originally called- 'individual' in framework). Technical factors like availability of electricity, storage, etc. are incorporated into physical environment. Systems and structures category was reduced in scope to focus only on insights from public and private healthcare sector.

Thus, following the context factors, various insights are collected based on previous field studies, literature research and personal experiences (for more details on methodology, refer to appendix A-2). Since, all the insights collected were not all scientific, they are rated on a scale of 5 (detailed version is explained in appendix A-3). Next section presents an overview of contexts and insights collected.

1. Free, M. (2004). Achieving appropriate design and widespread use of health care technologies in the developing world. International Journal of Gynaecology and Obstetrics, 1(85), S3-13
2. Martin, J. L., Clark, D. J., Morgan, S. P., Crowe, J. A., & Murphy, E. (2012). A user-centred approach to requirements elicitation in medical device development: A case study from an industry perspective. Applied Ergonomics, 43(1), 184-190
3. Aranda Jan, C. B., Jagtap, S., & Moultrie, J. (2016). Towards a framework for holistic contextual design for low-resource settings

Physical environment

Storage systems
Do they use backpacks or they keep devices in shelf?
Are they moving or static?

Electricity (type and availability)
What type of electricity is available?
What are the issues associated with it?

Phones (type and availability)
What kind of phones do they use?
Are they familiar with using smartphones?

Density of health facilities
How are the health facilities distributed?
Where are they concentrated and how is the accessibility?

Systems & structures

Public healthcare
What is the percentage share of health facilities and workforce?
What kind of financing system is used?
Are the services free?

Private healthcare
What are the incentives for patients?
What benefits are given to workforce?

Society & culture

Languages
Which languages are used in daily conversations?
Which language is used on medicines?

Literacy and education
What are the literacy levels?
How is it distributed across age and gender?

Cultural hierarchy
Is religion a major part of their culture?
Which reliagions are followed the most?
How are they affecting their daily life?

Economic stratification
How is society divided on basis of income?
How much of population belog to above divisions?

Figure 8: Context framework, defining context

5.2 India

India is a country in South-Asia, second most populous and seventh largest country in the world. Indian economy is world's seventh largest by nominal GDP and is considered to be world's fastest growing economy. India still faces challenges like poverty with 29.8% of population living below poverty line[1]. The private healthcare is the major provider in both urban and rural areas providing service to 70% and 63% households respectively. Caste system (hereditary groups) embodies most of the social stratification. Patriarchal joint families are usually found in rural parts of India. Although Hindi and English are spoken, local languages are widely used in rural areas.

Figure 9: An impression of Indian context

Physical environment

The environment varies a lot from coast, to plateau, to plains and to mountains. India has three prominent seasons everywhere-summer, winter and rainy. Majority of the population relies on grid electricity. Second most reliable electricity source is micro-grids. But they also suffer from stealing and poor maintenance leading to load-shedding. It is interesting to note that micro-grid suffers a lot from stealing as people do not wish to pay for them. India's smartphone penetration is lower than Kenya and also growing at smaller pace.

Systems and structures

Medical expenses are mostly paid by patients and families themselves. The idea of insurance is not very popular and most of insurance buyers are from urban areas. A large number of money is borrowed by money-lenders in rural areas for emergent healthcare services. The public healthcare mostly operate in rural areas and suffers from reluctance of medical professionals to work in rural areas. Hence, it is usually filled with unmotivated interns who are required to spend time in rural areas under their curriculum.

Society

Economic inequality in India is lesser than Kenya but most of rural areas are concentrated with low income population. Hinduism is the largest religion, but it is also largely divided into smaller castes (communal groups based on ancient professions). Caste system is mainly observed in rural areas and its effects are often seen in settlement areas, communal festivals, administrations. Language in rural areas is highly specific to region. Although Hindi and English are spoken widely (mainly in North India), but still large population at district level cannot speak or understand Hindi or English (for example south India).

5.2.1 Mono-insights from India

Approximately 10 insights per context were selected in order to create a good solution space at the same time taking into account limited project timeline. An overview of the mono-insights from India context is presented with following infographic. A detailed version of the same is attached in the APPENDIX D Mono-insights from context research.

Grid electricity: Approximately 30% (77 million households) of the households in India live without access to electricity. Another 20 million households, are considered under-served, receiving less than 4 hours of grid power per day

Private healthcare: The private healthcare sector is responsible for the majority of healthcare in India. Most healthcare expenses are paid out of pocket by patients and their families, rather than through insurance. private medical sector remains the primary source of health care for 70% of households in urban areas and 63% of households in rural areas

Literacy: Six Indian states account for about 70% of all illiterates in India: Uttar Pradesh, Bihar, Madhya Pradesh, Rajasthan, Andhra Pradesh and West Bengal. Bihar is the least literate state in India, with a literacy of 63.82%

Health worker density: Bihar had the lowest density of 53.7 per lakh whereas Mizoram had the highest density of all health workers of 771.7 per lakh population

Smartphone: Smartphone uptake inis about 30% in 2016. It grew by 13% in 2016

Language: About 41% of the population speak Hindi or its sub-ordinate forms. It is also one of the language used by central government in official communications. English is spoken by 12.18% of the population. Which is also the language used for all the medicine labels, brochures, etc. Although they are the minority, but very specific to the state and region in India

5.3 Kenya

Kenya is a country in East Africa lying on the equator. Kenya is usually classified as an emerging market and it is the largest nation in East and Central Africa on the basis of Gross Domestic Product (GDP). The private health sector is larger and more easily accessible than both the public and the non-profit health sectors in terms of facilities and personnel. Kenya has a young population, with 73% of residents aged below 30 years because of rapid population growth. There are an estimated 47 different ethnic communities and all of them have their own languages. Two official languages Swahili and English are used in varying degrees of fluency for communication with other populations. English is widely spoken in commerce, schooling and government.

Although Kenya is making lots of progress, it suffers from extreme economic inequality which is evident from GINI coefficient of 47.7 (0 is complete equality and 100 is complete inequality), which ranks Kenya at 147th position in list of 187 countries[1].

Figure 10: An impression of Kenyan context

Physical environment

Concerning the physical environmental factors- geographical conditions, storage, electricity and availability & type of phones are studied. Depending on the region, there is varying amount of dust in the air which might settle on medical equipments. Community health workers are usually provided with back-packs which have basic medical equipments like thermometer, IMCI booklet and reporting notebook. Although grid electricity is present, it suffers from irregular supply. On the other hand, solar house systems are more and more adopted but mainly targeted towards lighting. Smartphone penetration in Kenya is increasing rapidly due to introduction of cheap phones from Chinese manufacturers but this is widely distributed across population.

1. *Human Development Reports. (n.d.). Retrieved August 09, 2017, from http://hdr.undp.org/en/content/income-gini-coefficient*

Systems and structures

The private healthcare sector has been growing largely due to three main reasons-lack of accessibility of public health services, introduction of patient fees (public health services were free in past) and policy reforms encouraging private health service providers. The new systems of working are introduced recently where healthcare professionals can work in public as well as private facilities.

Society

The economic inequality is very high and high-income population is present mostly in three main cities- Nairobi, Mombasa and Kisumu. Most of the poor population in concentrated in rural areas and slums in cities.
Christianity is the major religion with 82% of population, which has large influence on the administration, education and community gatherings. Second largest religion is Islam at 11% of population who are concentrated in specific regions. Research on healthcare seeking behaviour indicates that parents differentiate between going to a hospital or to traditional healers, depending upon the complaints and duration of illness of their children. Fathers are found to make the ultimate decisions regarding health-seeking behaviour[1].

5.3.1 Mono-insights from Kenya

Approximately 10 insights per context were selected in order to create a good solution space at the same time taking into account limited project timeline. An overview of the mono-insights from India context is presented with following infographic. A detailed version of the same is attached in the APPENDIX D Mono-insights from context research.

Grid electricity: 36% of total population and 12.6% of rural population is have access to electricity (as of 2014), which has been increasing steadily

Smartphone: Smartphone uptake in Kenya is 44% in 2016. Social media dominates with 58% followed by search engines at 39%. Behind search engines is email at 30% followed by video at 25%

Literacy: about 19% of female population above 15 years of age have no education. Most literate population is living in urban areas and are men

Health workforce: Majority of them are in private. Almost 75% doctors and 66% nurses and clinical officers work in private sector

Private healthcare: Potential factors contributing to its growth include the lack of quality public health services, the introduction of user fees in the public facilities and health sector reforms that eased the licensing and regulation of private healthcare providers and allowed public sector staff to work in the private sector as well

1. *Abubakar, A., Van Baar, A., Fischer, R., Bomu, G., Gona, J. K., & Newton, C. R. (2013). Socio-Cultural Determinants of Health-Seeking Behaviour on the Kenyan Coast: A Qualitative Study. PLoS ONE, 8(11), e71998. http://doi.org/10.1371/journal.pone.0071998*

5.4 Context solution space

The context solution space is created by letting the mono-insights from India and Kenya interact with each other. Various types of interactions are possible here- the insights can be combined with each other if they are similar, or they can be translated from one context to other or they might raise some interesting new ideas. In this chapter, the interaction between the mono-insights are described to create the context solution space.

1. Electricity: Both India and Kenya rely on grid electricity for the majority of the households. But The second most common source is different- micro-grids for India and SHS for Kenya. It was also discussed that reluctance of rural Indian people to pay for electricity. A conjecture can be made here saying that- tangible form of source of electricity might be the reason for this. Micro-grid can still be easily perceived as grid electricity and the household is not aware from where and how much electricity they get. On the other hand, SHS in Kenya shows at tangible level the source of electricity creating a perception of owning that energy, hence, willingness to pay. Hence, tangible form of electricity may be through batteries might create a perception of ownership and increase the chances of paying for running the product system.

2. Smartphone availability: Penetration of smartphones is higher in Kenya than in India. The growth of smartphone penetration is also growing by about same rate in India and Kenya. Various reasons could be increase in basic income and availability of cheaper smartphones. But it may be safe to assume that people in Kenya are more likely to be familiar with smartphone due to high penetration.

3. Public healthcare: India and Kenya seem to be similar when it comes to public healthcare. Both are transitioning towards more privatisation with introduction of new reforms. However, the reluctance of working in rural areas and low motivation is certainly present in India and may be present in Kenya as well. Mono-insights from lowest-level health workers in Kenya suggest they are motivated to work despite not being paid by the government. A presumption can be made here that features that motivate the health workers can be used with facility workers in public health facilities to increase their motivation.

4. Private healthcare: Private health facilities and services are growing both in India and Kenya due to the poor access to public services and new reforms.

5. Payment of health services: Similar insights were collected for India and Kenya where money is borrowed to pay for emergent cases. But informal money lenders are popular in India whereas subsidiary companies (of banks etc.) provide fast money through mobile money in Kenya. This presents a unique opportunity for Indian context, to mediate the money lending through mobile money (which is also slowly becomes popular means of money transfer) on top of existing cultural system of money-lenders.

6. Society: Although major religions in India and Kenya are different, both suffer from caste- and ethnic- based groups at community level. the difference is, in India, the caste system implies groups that may not be willing to work, talk, etc. whereas ethnic subdivisions in Kenya might be speaking different languages and have different believes on health behaviour. Hence, the barriers created due to such divisions vary from not willing to interact in India, to not able to interact in Kenya.

7. Lowest level health worker: Variations in gender while selecting the health worker and payment varies for India and Kenya. ASHA workers in India are only women, whereas CHWs in Kenya can be male or female. ASHA workers work on performance based payments whereas CHWs in Kenya work voluntarily. This leads to interesting ideas on how to motivate ASHA workers and how CHWs might earn taking cues from India's financing model.

8. Language: Although there are widely spoken languages, which are also used for administration, labels on medical supplies, etc. at regional level, they are most likely not being used for both contexts. If the language is being used, it is important that they are regionally suited for the intended context.

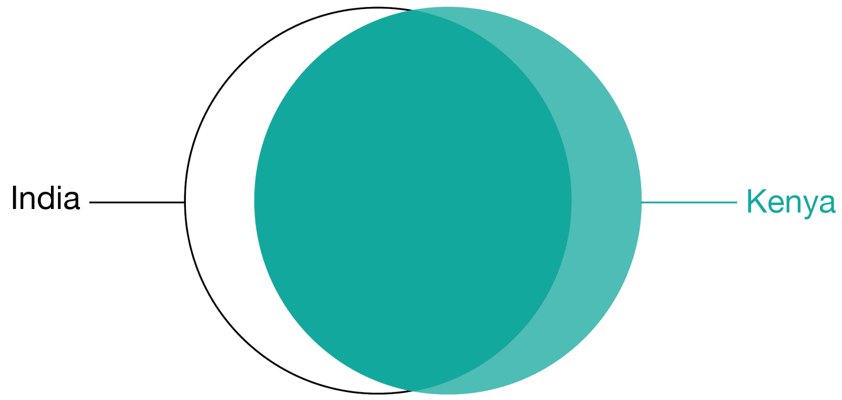


Figure 11: Context solution space

It is clear from contextual solution space (figure 11) that most of the insights are similar for India and Kenya. Hence, focusing on one context but enriching the insights from other context might be more efficient for the project.

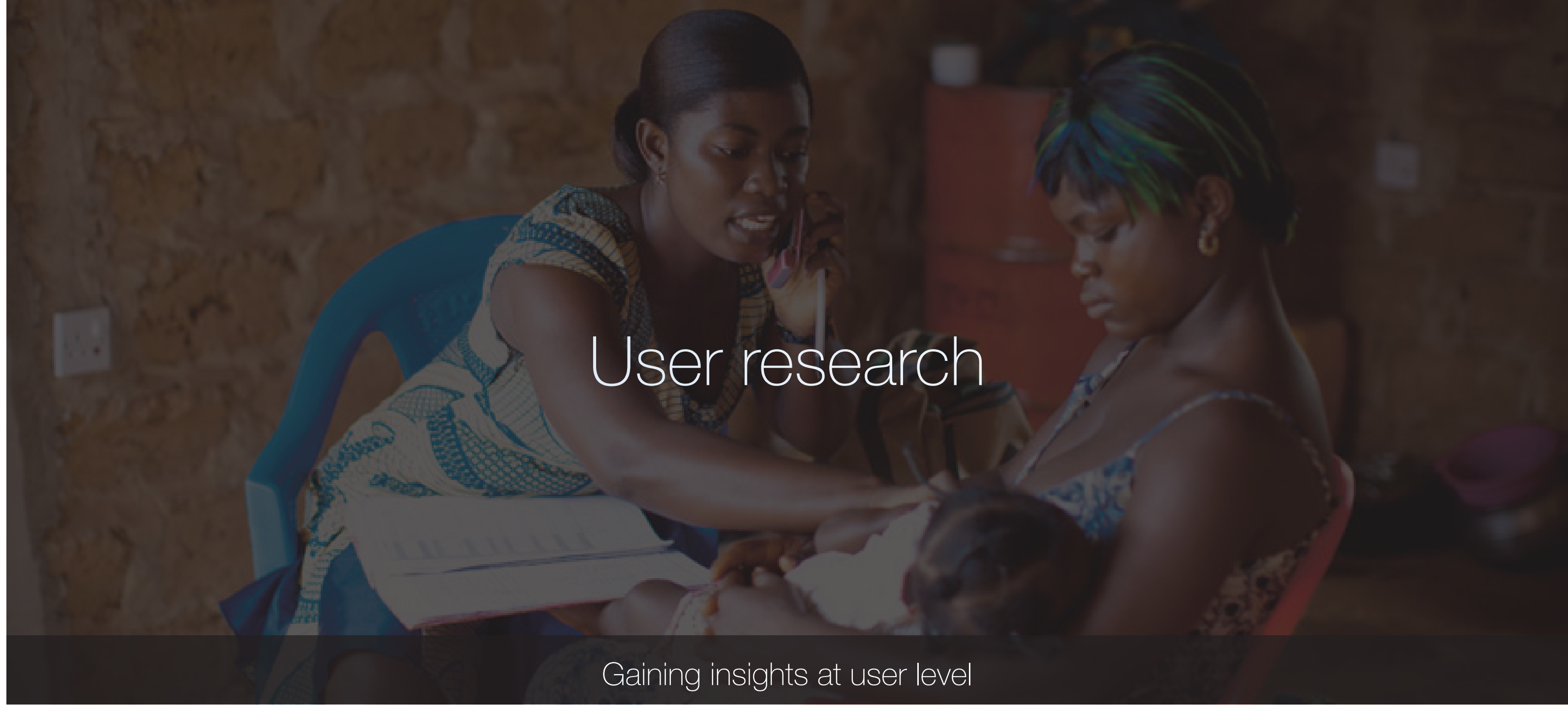
Although the insights are similar for India and Kenya, some insights from Kenya are much more favourable to design in terms of faster implementation. Insights like willingness to pay for electricity, higher smartphone penetration, mobile money infrastructure, motivated CHWs provide a better launchpad for the final design in shorter time. This is one of the desires of the company to implement the design faster, hence, a decision is made to focus on Kenya from this point onwards. Moreover, local resources and contacts in Kenya is also one of the factors which will aid the research and evaluation of the project. Thus, providing detailed insights on design in later stages.

5.5 Conclusion

Research indicates study of context is very important to design successful medical products for Low resource settings. Hence, a holistic definition is used to collect insights from all the contextual factors categorised into physical environment, systems & structures, and society. Using this definition, desk research was conducted in order to gather insights regarding India and Kenya. This research is used in using CVD approach to create contextual solution space.

Mono-insights from the research were collected for India and Kenya. interaction between the mono-insights led to creation of contextual solution space which indicated the contexts are very similar. Due to high overlap, the design will be focussed on one context but enriched by insights from other context. Due to favourable conditions for faster implementation, Kenya was chosen to be the focus context.

The insights and contextual solution space thus created is more inclined towards the scalability focus area of the project. Enriched insights from the India while focussing on Kenya would help in scaling up from Kenya to India much more informed and predictable. However, in order to deep-dive into usability focus area of the project, user research is necessary. The next chapter explain the collection of mono-insights from various user interaction scenarios which lead to user solution space which is focussed on usability focus area.



6.1 IMCI workflow

As described in introduction chapter, IMCI was introduced by WHO and UNICEF to reduce child deaths, the frequency and severity of illness and disability and to contribute to improved growth and development. In this chapter, the workflow which is an implication of IMCI at the user level will be studied along with the barriers to follow it. Major barriers reported by WHO reports point towards usability of the IMCI workflow and implications of systemic challenges on the workflow. These systemic challenges are seen with peripheral systems that are important for the workflow. Peripheral systems like medication supply, referrals impact the workflow in terms of effectiveness and efficiency.

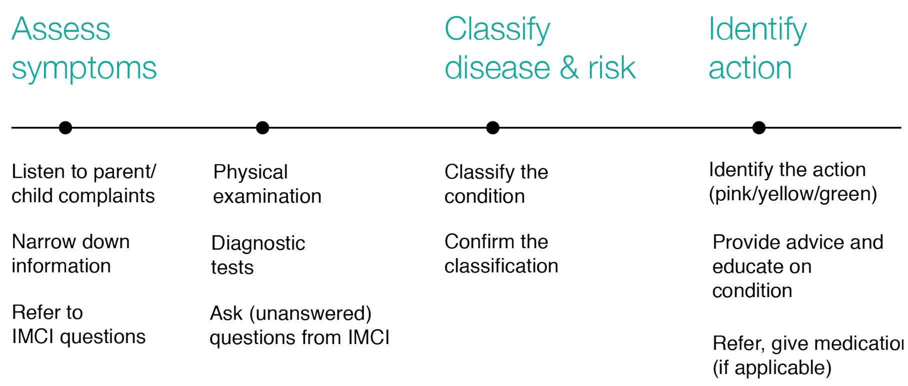


Figure 12:IMCI workflow, ideal version

Figure 12 shows a generic workflow and its peripheral systems along with their intersection points. This workflow is derived from WHO reports, charts and studies. The user research is conducted to first validate the derived workflow and then identify the barriers. User research set-up and methodology is described more in details in following section

6.2 Research set-up

As described in introduction chapter, IMCI was introduced by WHO and UNICEF to reduce child deaths, the frequency and severity of illness and disability and to contribute to improved growth and development. In this chapter, the workflow which is an implication of IMCI at the user level will be studied along with the barriers to follow it for user. Major barriers reported by WHO point towards usability of the IMCI booklet and implications of systemic challenges on the workflow.

6.2.1 Research objective

1. To create the workflow model of actual IMCI process in practice and to understand the barriers and opportunities within the workflow
2. To create personas in order to make foundation for the designer to empathise with the user
3. To formulate user interaction scenarios and collect mono-insights in order to create user solution space.

6.2.2 Research methodology

Three main data collection points were utilised- literature study, expert interviews and cultural probe. First, series of expert interviews were conducted to validate the workflow and identify some barriers. Using the results, a cultural probe was given to the users (CHWs, nurses and clinical officers) which was followed up by interviews. Their aim of cultural probe is to reveal users' personal perspectives to enrich design. The sequence of data collection helped in scoping down the data desired from the users which helped in gaining more detailed data from the users. The results are presented though workflow in practice, personas and mono-insights for various user interaction scenarios. For detailed results please refer to APPENDIX E.

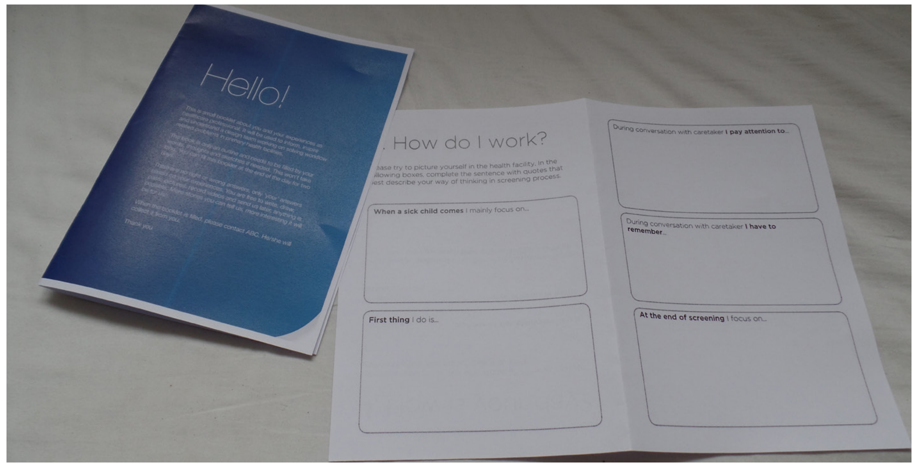


Figure 13: Cultural probes used for user research

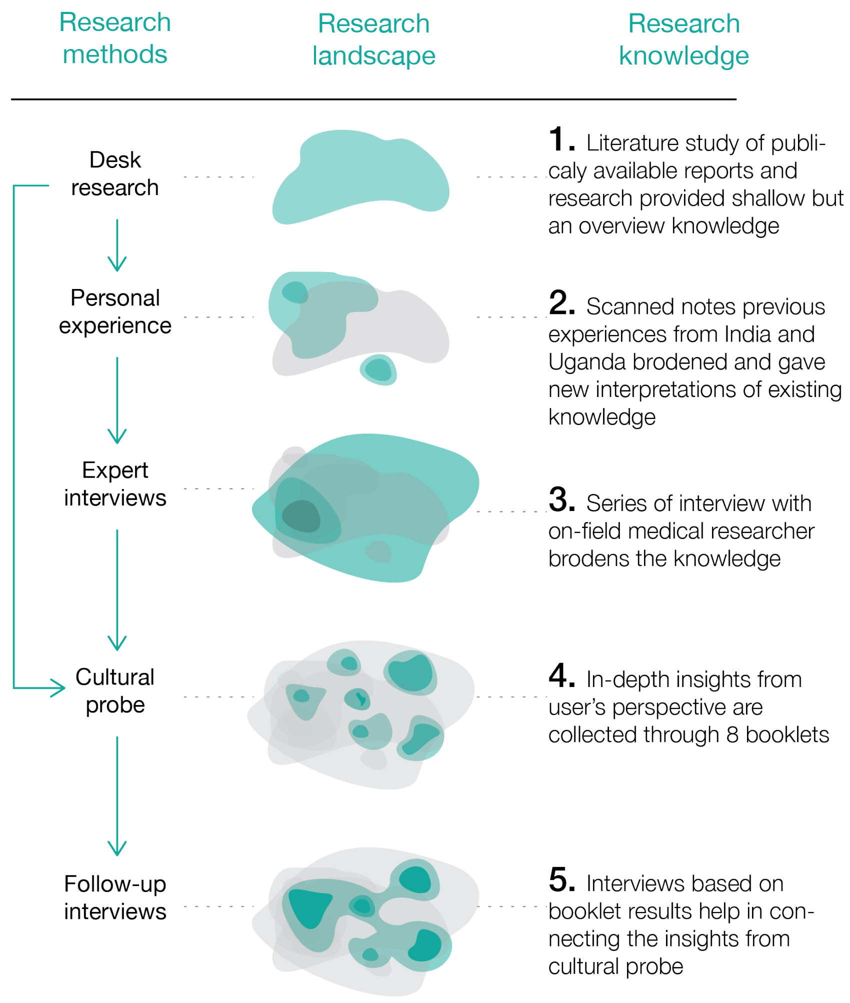


Figure 14: An impression of collection of user insights

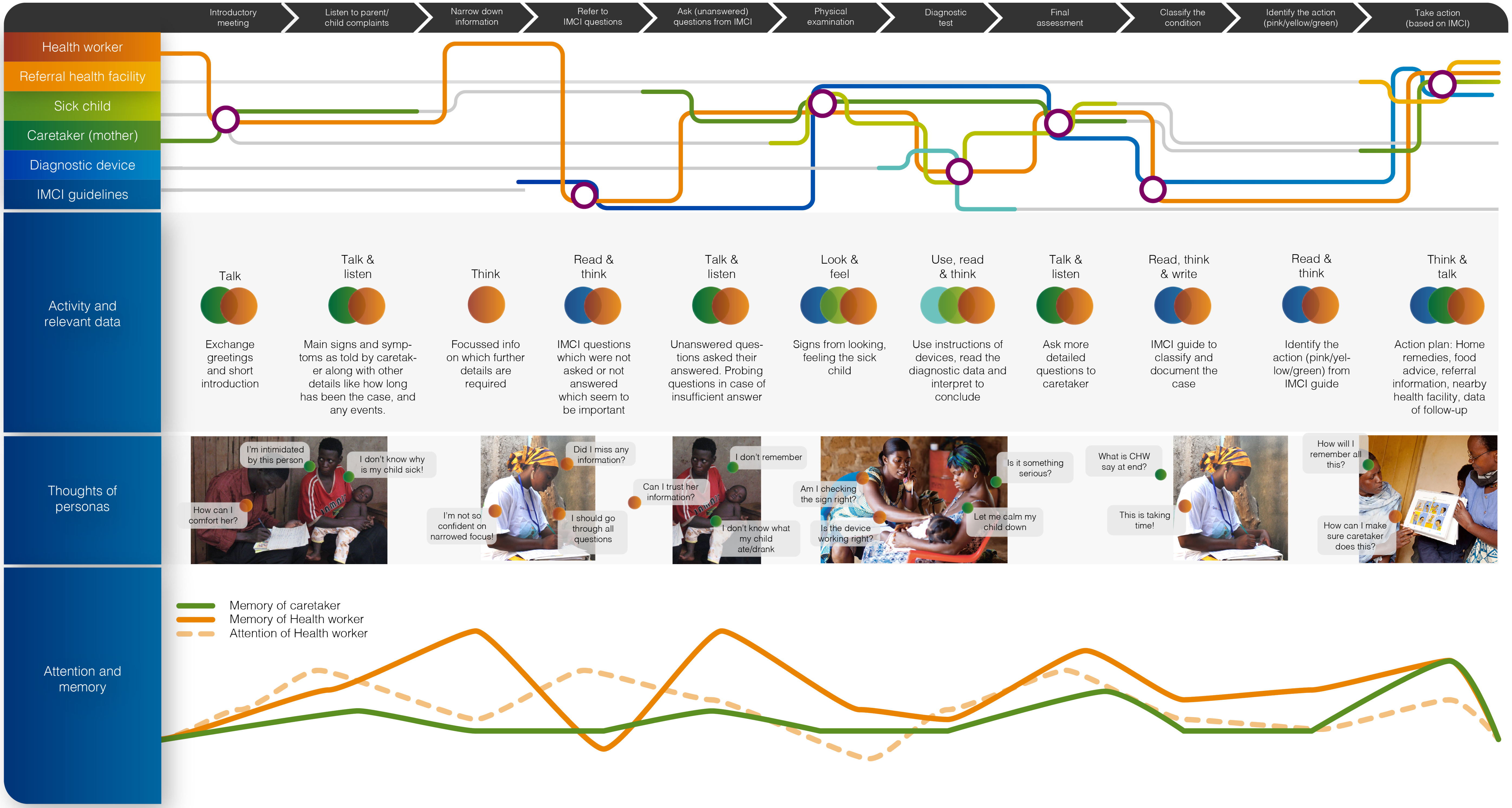
6.3 Workflow in practice

It is evident from the expert interviews and cultural probe that the sequential nature of proposed IMCI workflow is not followed. The actual workflow is carried out in a haphazard manner depending on the situation. The actual workflow is carried out in a adapted format on the field. It may be influenced by the user, the conversation with caretaker, how emergent the case is, etc.

Cognitive walkthrough exercise was carried out with the expert which helped highlight the perceived use of memory and attention of the user throughout the workflow. This helps in gaining insights on the parts of the workflow which demand high cognitive load. An overview of the results to validate and gain insights on current workflow is shown in figure 15.

There are two possibilities here- adapt the rigid IMCI workflow into a much more modular one or structure the current workflow in practice. A structured workflow helps the user to be more in control and have a holistic understanding of the case (by not missing out parts). Moreover, the second possibility is considered favourable for stakeholders like Philips, WHO, and Ministry of Health for training, reporting and monitoring purposes.

Figure 15: insights on actual workflow followed in field



6.4 Barriers to IMCI workflow

Three types of usability barriers were discovered from the research- peripheral systems barrier, cognitive barriers, socio-cultural barriers. All the barriers are associated with effectiveness, efficiency and learnability of the IMCI usability.

6.4.1 Planning in peripheral systems

Two of the barriers related to referrals and availability of medication directly impact the effectiveness of the IMCI workflow. Moreover, they also contribute to socio-cultural barriers which are described in later section.

The first barrier was low reliability on referrals. Health workers reported the worst part about their jobs was seeing the caretaker had taken the sick child to higher health facility with referral spending lot of money but the facility was not operation or the doctor was not available. This delay in seeking referrals might result in child developing complications on top of wastage of valuable money for the caretaker. Moreover, such incidents demotivate the caretaker to take the referrals and visit higher facility in future as well.
Another aspect of referrals was delivery of information from the first screening. This information is very beneficial for further diagnosis and treatment in higher health facility. This barrier was observed for both health worker and the caretaker. The health worker wanted to confirm that the information about his/her screening, assessment, decisions were given, so that those are not repeated and next step is taken by higher health facility. The caretaker wanted the health worker to go with them, may be because she was not confident on what information to give at higher health facility.Planning and delivery of information seems to be a planning barrier in the referral system.

The second barrier is lack of medications with the health worker. CHWs receive the stock medications from their associated health facility. The health facilities received them directly through regional warehouse. This barrier can be reduced to more independent issues like, lack of finances, and lack of planning. In the scope of this project, lack of planing is selected as the barrier. Lack of finances is classified as managerial but essential issue.

6.4.2 High cognitive load

Cognitive load is measured by identifying the use of memory and attention in the screening process. It was noted that the health workers needs to listen and process lot of information from the caretaker regarding the symptoms and any measures taken. This information is not stored anywhere, hence usually the health worker rely on their memory. Five out of nine health workers said, they have to pay attention towards behaviour of child, behaviour of caretaker towards the child while doing the screening. This information from behaviour is used to create a perception of caretaker and ask more detailed questions, provide final advice along with treatments.

The health workers are required to remember key points from their trainings and information from the caretaker. It is difficult to recall key points from the trainings since they are not implemented often. Almost all the CHWs desired said, continuous training would help. Four out of five CHWs said that they learn the most from other CHW experiences.
High cognitive load during the workflow seems to be causing due to high demand on memory and attention during the process and lack of continuous trainings. This impacts the efficiency and learnability aspect of usability of the IMCI workflow.

6.4.3 Socio-cultural barriers

Two related barriers were identified with caretakers Most of the problems noted at start of process were related to non-cooperation by the caregivers (6/10 responses). It was elaborated by saying that the importance of questions like on history, duration of condition, was not understood by caregiver.

This barrier could be linked to the caretaker, the content of advice or the health worker. It is interesting for the project to frame it from content and delivery perspective by saying, the content of advice and delivery of advice from health worker is not persuasive enough for caretaker to co-operate and comply with IMCI process and results. It results in lower effectiveness aspect of the usability.

6.4.4 Conclusion-barriers identified

Three types of barriers were identified at user level- barriers with peripheral systems, high cognitive load and socio-cultural barriers. Lack of planning and delivery of information in referral system was identified as barrier for effective use of IMCI workflow. Lack of planning for stock medications results in lack of medication with health workers, this also affected the effectiveness of IMCI workflow.

High cognitive load was caused due to high demand on memory to remember the key points from training and information from the caretaker during the process. Along with this, attention was divided between looking at behaviour of the caretaker with sick child which influenced the questions and advice health worker used. One of the causes was also linked to lack of continuous training. This affected the efficiency and learnability of IMCI process.

Non-cooperation of caretaker because the advice at the end of IMCI was identified as last barrier. It resulted in the caretaker not following the advice, or taking the sick child to referral facility. The barrier was framed as the content and delivery of the content of advice from health worker was not convincing enough for the caretaker. This affected the effectiveness of the IMCI workflow.

6.5 Personas & scenarios

Two personas of lowly-educated (community health worker), and highly-educated (clinical officer) were created from the suer research to assist the designer while designing. Details about the personas are shown in the figure16.

Figure 16: Personas

Community Health worker (CHW)

“ I had been chosen by elders of the community. I have always loved serving other community members

Goals & motivation: To educate the community about preventive care, screening and triaging sick patients.
“Giving community hope and interact with people. I love when they call me doctor”

Wishes: to have good relation with the community.
“Is seeing good response from the community”

Best part about job:
“Learning new things about community and giving related health education”

Key qualities:
Social and communication skills
Emotional support attitude

Clinical officer

“ I have studied rigorously for 5 years to treat sick people. I love seeing improvements in my patients because of my treatment

Goals & motivation: To see patient, treat them and help recover faster.
“Giving community hope and interact with people. I love when they call me doctor”

Wishes: identifying every problem of the patient easily.
“I wish the caretaker tells me everything on her own”

Best part about job:
“Seeing my patients smile after recovering”

Key qualities:
Problem solving mindset
Clinical eye
Fast thinking
Proactive

After exploring the barriers and creating the personas, all the insights gathered are collected into two main user interaction scenarios- low expertise scenario and high expertise scenario. The purpose of the user scenarios is to consolidate main insights from user research in a more holistic form. This would enable providing context to mono-insights and creation of more informed solution space. Low expertise scenario is representation of possible scenarios where lowly educated health worker (CHW) is using the IMCI guidelines. A high expertise scenario is representation of possible scenario where highly educated health worker (clinical officer) is using IMCI guidelines. Both the scenarios can be found in APPENDIX H.

Mono-insights regarding the two scenarios are collected in three categories- best part of the workflow, worst part, wishes/improvements.

6.6 Mono-insights

6.6.1 CHW (low expertise scenario)

1. The best part in the workflow for the CHW is the community sees her/him as ‘doctor’. The CHWs like to talk to the community and educate them. They focus on rapport building by engaging in social discussions in the community.
2. The worst part of the workflow is non-cooperation of caretaker, difficulty using IMCI, and knowing caretaker going to facility with referral but facility is not open or clinical officer is not available. Non-cooperation issues are generally noted during the process, and not considering the advice/referral at the end of the process. IMCI guide demands the CHW to remember the information from caretaker and key points from training. This leads to difficulty in using the guide. Lack of planning with referrals causes wastage of financial resources which also hamper the trust of caretaker in health system.
3. The CHW wishes to have more trainings and communicate to the community better. Continuous trainings help learn about handling caretakers, diseases, etc. from listening to other CHW experiences. CHW also desire to reach out to more people faster to provide information which is especially helpful for example during certain seasons, when there is an outbreak of a particular disease.

6.6.2 Clinical officer (high expertise scenario)

1. The best part for a clinical officer is knowing that the sick child they treated got well after the treatment when the caretaker comes for a review.
2. The worst part of the workflow is non-cooperation of the caretaker, and that most of the cases are emergent Sometimes the caretakers don’t tell all the problems and also deny their mistakes when the clinical officer asks them for example, regarding the food they gave to their children. They are also shy in revealing all the information to clinical officer and (s)he has to keep probing. In order to gauge this, the clinical officer usually pays attention towards the behaviour of caretaker and towards the child. Most of the sick children seek emergent care at the facility. These cases can be handled at CHW level as well if the action is taken by the caretaker.

3. The clinical officer wishes that IMCI should be upgraded to included care for advanced cases. Alternatively (s)he wishes to improve the assessment by consulting to a specialist in case of such situations.

6.7 User solution space

The interaction between the mono-insights from the two scenarios are studied in this section to create the user solution space. This solution space is categorised in the same manner as mono-insights. This solution space will be focussed on usability focus area of the project.

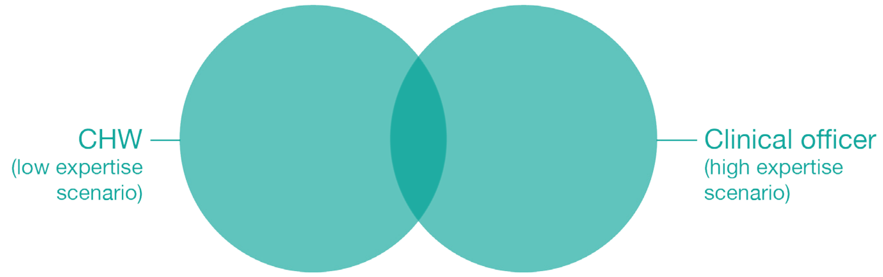


Figure 17: User solution space

1. The best part for the CHW is when people refer to her/him as 'doctor'. Considering that a CHW is unpaid and volunteers based on only motivation to serve the community, this feeling seems to be important. CHW seems to feel like a clinical officer. This leads to interesting ideations, on how this can be achieved by examining the clinical officer. One of the CHW mentioned that she talks to caretaker and checks for signs on child simultaneously. This is a kind of behaviour that might instil the feeling of doctor for CHW as well as caretaker. This might cause the caretaker to cooperate in the workflow actively.

2. The worst part of the workflow is common for a CHW and clinical officer regarding non-cooperation of the caretaker. And both use similar techniques of assessing the behaviour during the process to gauge the co-operation on top of their questions. But, while a clinical officer can explain the important of every step, CHW might need to refer or undergo more trainings.

3. A CHW wishes continuous trainings especially with fellow CHWs whereas the clinical officer seeks consultation in case of special cases. This difference in wishes ignites an idea to provide consultation for the CHW when they give an advice to the caretaker. This can reduce the number of emergent cases at the facility which is one of worst parts in high expertise scenario.

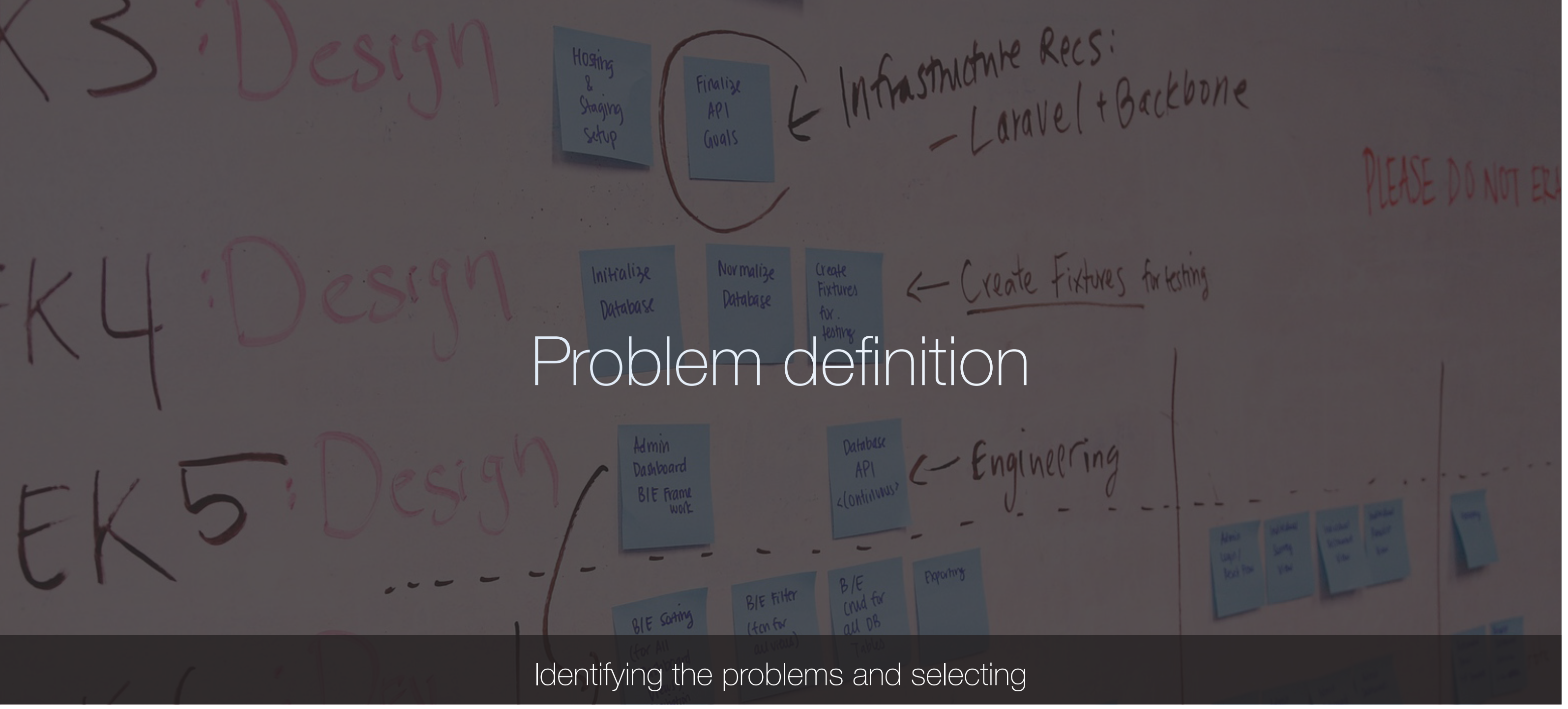
6.8 Conclusion

In this chapter, the user research was conducted in order to validate the prescribed IMCI workflow with actual practice workflow. Then, barriers to adapt the prescribed workflow are identified using expert interviews, cultural probes followed by user interviews to gain user's perspective. Personas were created using the results from cultural probe. Using the same results together with the personas, user interactions scenarios were created to collect mono-insights of the scenarios and create a user solution space.

The actual IMCI workflow was found to be different that prescribed one. Due to dependencies on the health worker, situation, and caretaker, the sub-tasks within the workflow were adapted accordingly. It was decided that, actual workflow should be more structured with the ideal workflow being the prescribed workflow. This becomes one of the main requirements to improve the usability.

The barriers identified were categorised into three groups- barriers with peripheral systems, cognitive load and socio-cultural barriers. Peripheral systems that influence effectiveness of IMCI workflow are referral system and stock medication supply system. Planning and delivery of information were identified as main barriers in the peripheral systems. High cognitive load was indicated due to large amount of information to be remembered while using the IMCI guide. The cognitive load affects the efficiency of IMCI process. Continuous trainings are considered important to use IMCI effectively and efficiently. This is a sign of low-learnability of the workflow itself. Non-cooperation of the caretaker during and after the workflow was identified as socio-cultural barrier. This affects the efficiency of IMCI process as well.
The personas were extended into two scenarios- low expertise and high expertise scenarios. These scenarios are representation (in story form) of all the insights in a holistic form supported by context. This lead to collection of mono-insights highlighting the best, worst and wishes regarding IMCI workflow. The solution space thus created, was mostly dominant from opposing insights. It helped in igniting creative tension which lead to ideas on how CHW can avoid non-cooperation from caretaker, by taking actions like a clinical officer. Another idea was providing consultation to CHW from associated clinical officer, this can reduce the referrals with more informed advice and treatment.

Design vision



Problem definition

Identifying the problems and selecting

7.1 Problems identified

Four main challenges were identified with IMCI literature study (please see Introduction- Challenges with IMCI) at systemic level and user level. To recap, adaptation was the main challenge at the systemic level which suffered due to lack of resources to adapt the global IMCI to regional morbidity profile and lack of dialogue between the health staff at district level and political authorities at ministry of health. At user level, usability of IMCI due to high cognitive load and lack of continuous training was identified as two challenges. More sub-problems were identified at both systemic and user level throughout the research. All the problems are ranked on estimated severity and frequency of occurrence in figure 19.

7.2 Problems selected

Three main problems were selected based on this chart- lack of dialogue for adaptation of IMCI to regional morbidity profile, lack of continuous trainings and high cognitive load of IMCI workflow. These problems ranked high in estimated severity and frequency. Other problems might be related to the selected problems, hence, they are not completely discarded but simply not focussed upon.

Figure 18: Problems selected

High cognitive load of IMCI workflow
due to high demands on memory and attention

Planning in peripheral systems
in referral support and medication supply chain

Lack of follow-up trainings
due to lack of budget, and human resources

Lack of data-driven dialogue in adaptation process
between the ministry and district health staff

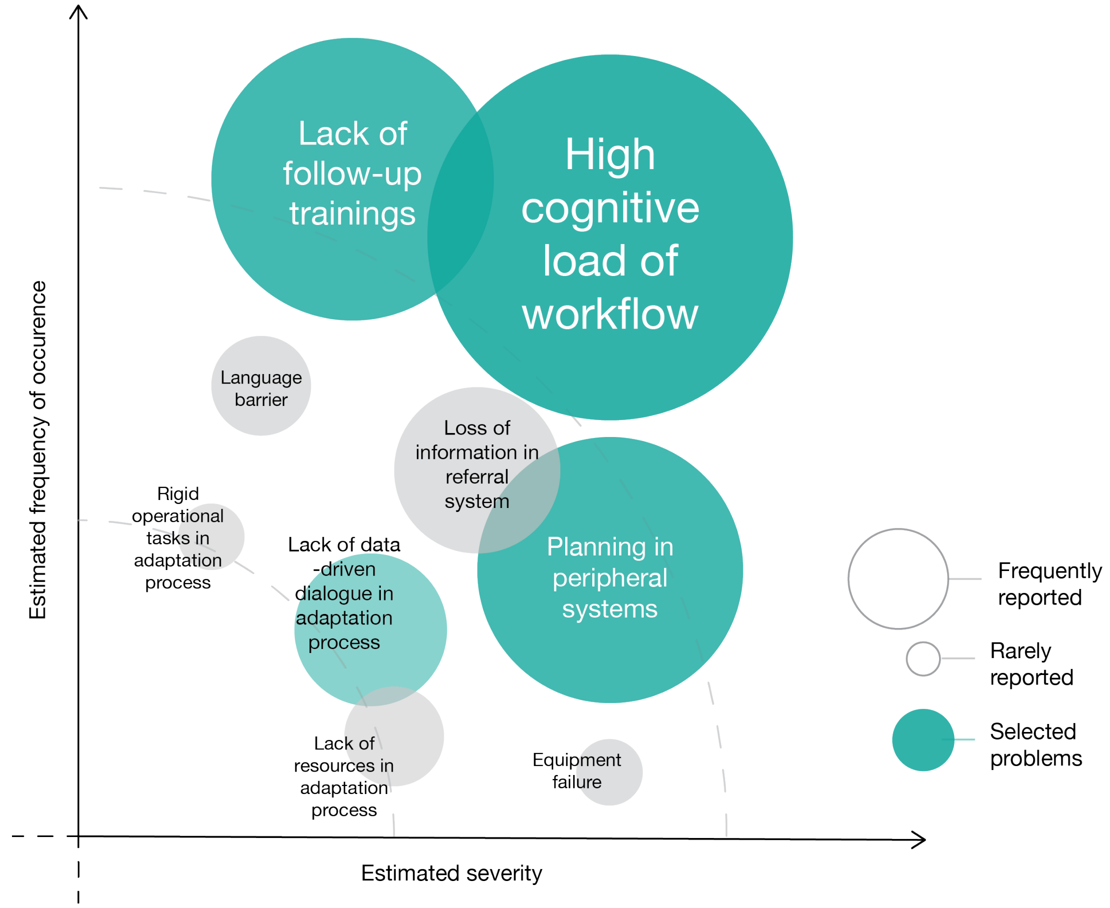


Figure 19: Problem definition

These problems along with the insights from the research are then translated into list of requirements for the product system. In order to do this, the product system is defined in terms of the smartphone application and physical device. An effort is made to incorporate other problems as well by classifying them into list of wishes.

The scope of the project was defined (see APPENDIX I). Defining a scope is a profitable inventory method to spark creativity and to limit the divergent solutions to be relevant to the project. The scope is divided into four quadrants- what, how, when, and who, each again divided into user and systemic level. Main problems identified are taken as starting point while defining the scope supported by insights generated through research.

Requirements & wishes

Setting the boundaries for creativity

Considering the two focus areas- scalability and usability of the project, context research and user research were conducted to gain insights for designing the next generation product system. The results of the these researches especially the solution spaces, are converted into requirements for the design. Since the parts of the next generation product system are already known, the requirements are categorised according to the parts.

8.1 Overall product system

Goal:

To create a product system which is easy to scale and use to reduce and manage childhood illness based on IMCI guidelines

Requirements:

1. The design should help in adaptation (to local morbidity profile) by gathering data for providing data-driven decision making dialogue between the district health staff and ministry of health
2. The product system should adapt itself to reduce the cognitive load on the user by reducing number of tasks for the user
3. The product system should be integrated on the existing healthcare system

8.2 Smartphone application

Goal:

To create a detailed smartphone application prototype to improve the usability and scalability of IMCI workflow

Requirements:

1. The app should reduce the dependency on user’s memory during the IMCI workflow by recording the important information
2. The app should guide the user into a more structured workflow
3. The app should provide key information to the user on demand easily
4. It should help in planning and delivery of information with the referral and medication supply systems
5. The app should cater to low and high expertise personas by adapting the workflow
6. It should provide continuous training and monitoring of skill sets through training content and experiences from other CHWs
7. It should help create a good perception (similar to doctor) for the CHW in the perspective of caretaker
8. The app should provide clear indication of when to use the physical device and provide information to rectify any irregularities while measuring the vitals

Wishes:

9. The app should motivate the user to volunteer for betterment of the community
10. App should be available in local languages with an option of switching languages to nearby local languages

8.3 Physical device

Goal:

To create a concept of physical device to be used along with smartphone application and to collect diagnostic information during the IMCI workflow

Requirements:

1. The probe should function for all the finger sizes from neonates to infants
2. Temperature sensor should be integrated into the spot-check monitor for intuitive use
3. The design should be similar to ChARM in order to reduce the efforts (human resources) while adding new functionalities
4. The design should be easy to adapt to future generations at minimal efforts
5. The device should be compatible (charge and run) with locally available source of electricity.
6. The device should provide clear indication of tasks in order to complete measuring the vitals reliably

Wishes:

7. The device should function independent of smartphone in order to scale up scenarios where smartphone is not available
8. The device should be easy to clean and store
9. Tangible form of electricity should be preferred in form of batteries in order to gain sense of ownership of electricity

Vision of product system

Foreseeing the end

9.1 Vision statement

A design vision was developed deriving knowledge from problems, scope and parts of next generation product system. The purpose of the vision is to consolidate all the information and to provide an overview and guidance for concept generation.

The vision is defined as- “An adaptable product system that reduces the cognitive load on the health worker by facilitating the IMCI workflow to improve the effectiveness and efficiency of the screening process and planning in its peripheral systems. The product system is composed of physical device to measure diagnostic data for improved efficiency and smartphone application to train the user; provide guidance and reduce use of memory during the workflow and permit planning within referral and medication supply system”

9.2 Envisioned impact

The primary desired effect is defined as increase in effectiveness and efficiency of the workflow. At systemic level, the introduction of data points from the field would improve the dialogue between the health staff at district level and ministry of health. It might automate and organise some operational tasks within adaptation process, it might lead to new tasks.

Similarly at peripheral systems level, the planning and delivery of information will increase the effectiveness of referrals and availability of medications, but it adds extra tasks for the health worker and higher health facility. Considering that clinical officers like to reduce to emergent cases, they might be willing to do the extra tasks if any. Moreover, the designer will also consider reducing the generation of extra tasks for optimising the solution.

At user level, the product system will introduce much desired training to the health workers. It will reduce the cognitive load during the workflow. Although, extra tasks will be created at the end of the workflow in case of referrals and requesting medications. But considering that they can plan it ahead to avoid not able to help patient, they might not see this as a barrier.

1. Regional level
Ministryof Health, District health staff

Gather population health data for adaptation of IMCI strategy to suit local needs

2. Peripheral system level
Referral facility

Plan referral appointments and manage stock medication supply to CHWs

3. User level
Health worker with smartphone app and physical device

Improve IMCI workflow usability and execute follow-up trainings
Create next generation diagnostic device for reliable IMCI screening

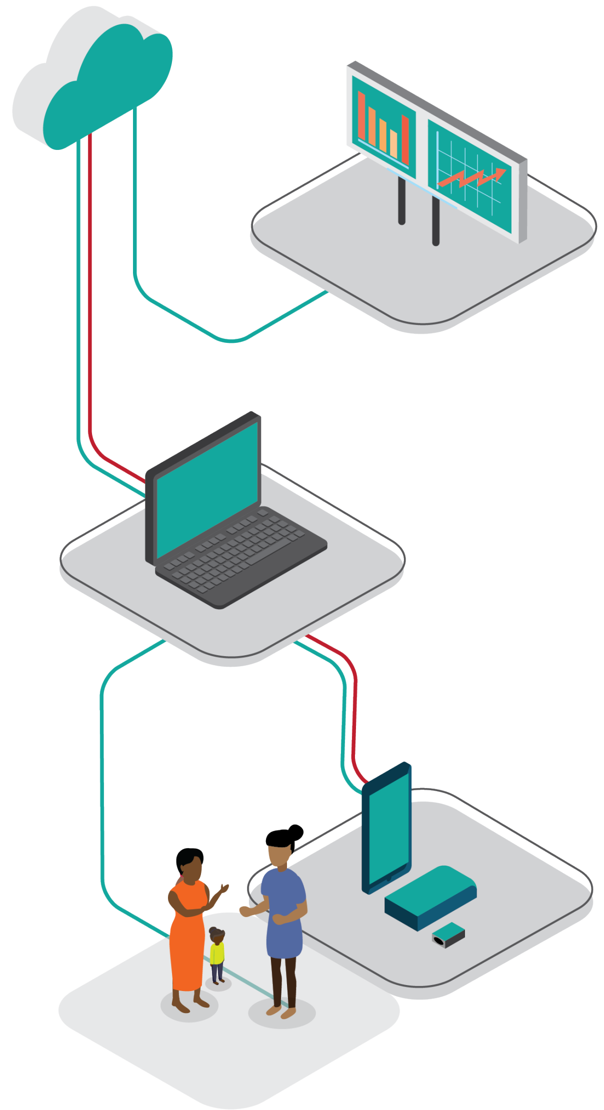
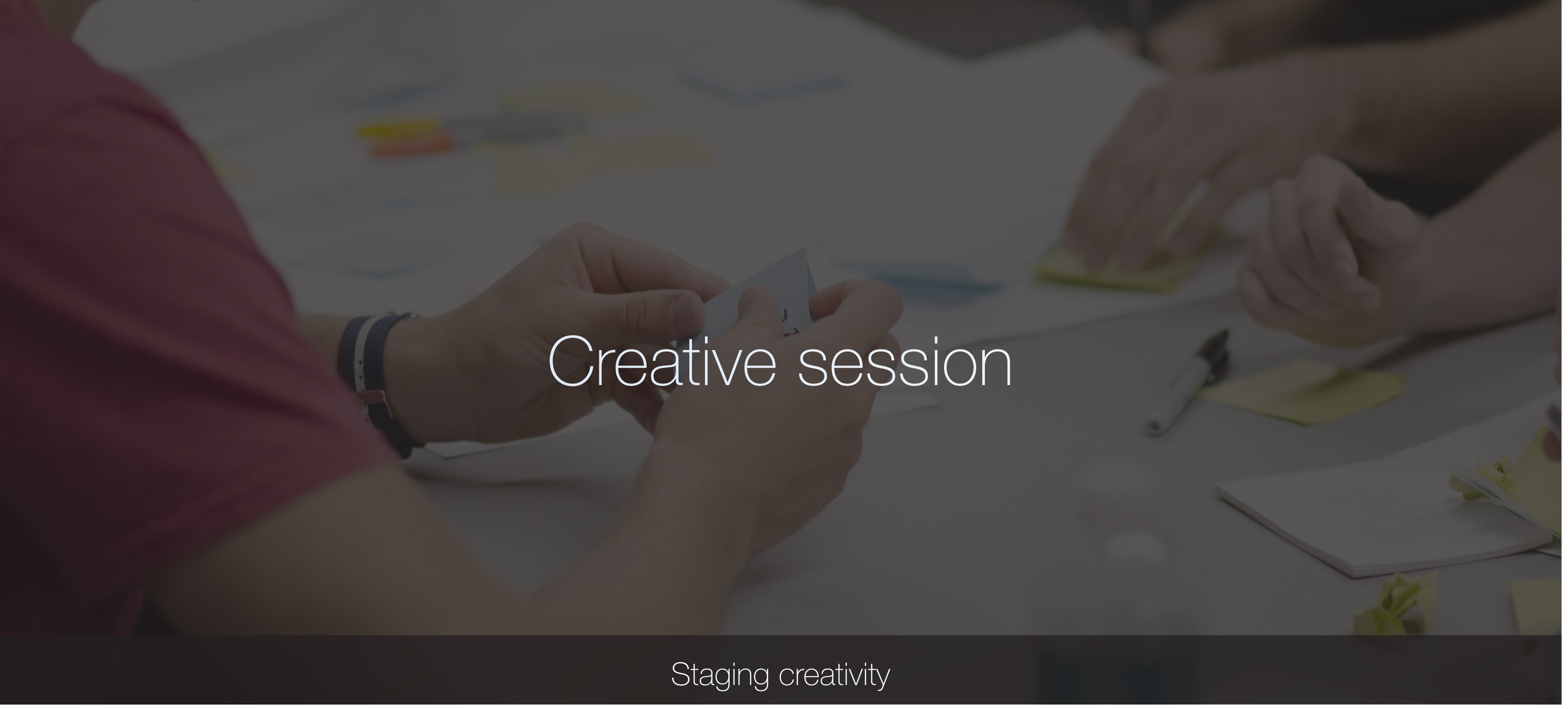


Figure 20: Design vision of product system

Conceptualisation



Creative session

Staging creativity

10.1 Session set-up

The creative phase of the project was kickstarted by creative brainstorming session. Considerable amount of time has been spent by the designer on research and analysis. Although, uncontrollably certain ideas were generated implicitly or explicitly, it is considered as bias and an obstacle to creativity. Hence, in order to generate spontaneous ideas from outside perspective over the defined problems and research, a session is held.

The creative session was started with a brief overview of IMCI and project. The problems were presented along with the scope while explaining the workflow research. In order to provide insights from research, mono-insights were presented regarding both context and user. An interactive Q&A was conducted which cleared some doubts and also kick-started bouncing ideas.

Brain-writing and sketching exercises were done with the participants on pre-defined “How to’s”. The how to’s are divided into mainly two parts- smartphone application and Physical device.

Smartphone application:

How to provide training in interesting manner?
How to reduce use of memory during the workflow for user?
How to plan referral visits with minimal addition of tasks?
How to make user perceive like a doctor in caretaker’s perspective?
How to collect data that would help in identifying local morbidity profile?
How to implement the adaptations into the smartphone application?

Physical device:

How to integrate probe and temperature sensor in ChARM design?
How to make the functions easy to recognise for the user?
How to use the device together with smartphone?
How to reduce design changes in future generations?

All the ideas were ranked and clustered based on personal preference, usefulness, perceived scalability and usability. The results of the session are described in next section.

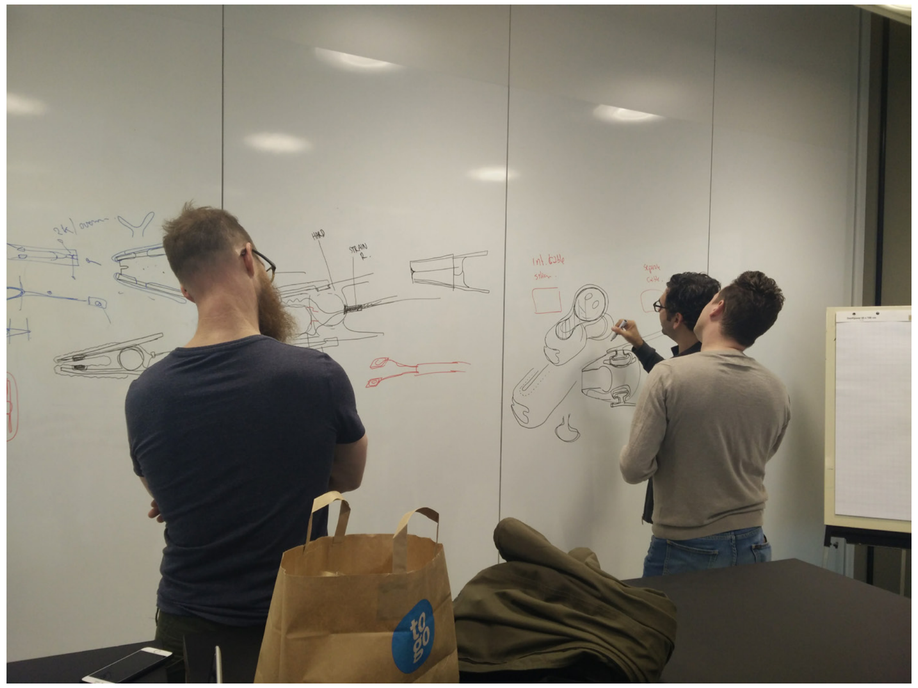


Figure 21: Creative session in progress (up), and outcome of session (down)

Concept directions

Dvergent solutions

11.1 Smartphone application

All the ideas regarding smartphone application were clustered into four groups- adaptability, training, workflow and planning. A concept direction was created by combining all the groups. Two concept directions are created as shown below.

Concept #A1

Visual mode of guidance is given through step-by-step tasks to do. Cumulative summary os selected answers is shown at every stage.

Concept #A2

Auditory mode of guidance is given through step-by-step tasks to do. User can focus on looks of symptoms and talk/ listen at same time.

Visual guidance #A1

Advantages

Easy to shift from current IMCI usage, since the screening will be similar. Hence, it will have more acceptance. Summary would help in training from the experiences.

Disadvantages

Adaptation will need significant amount of screening results, hence, it will take more time.

Impact on identified problems

Results of the screening data is used for adaptaion. This data will aid predictive analysis and uncertainty analysis

SMS / call based planning and referal support. Chat based support for consultations in case of remote locations

Objective questins help the user follow the tasks. The summary of answers is shown at every step for reference

Gamification of the training. User is portrayed as hero who can educate and treat children in virtual village by completing training content

Auditory guidance #A2

Advantages

More focus is given to looking for symptoms and assessing behaviour of caretaker. Scenario based training will enhance learnings from other CHWs. Adaptation is accelerated due to pre-defined modules at administrative level.

Disadvantages

Caretaker's perception of user might affect negatively since user may seem not knowledegeble. Automated planning would require constant system updates at facility level.

Impact on identified problems

Predefined actionable modules are defined by ministry for adaptation. The workflow and training is affected by these modules. They are released othrough internet

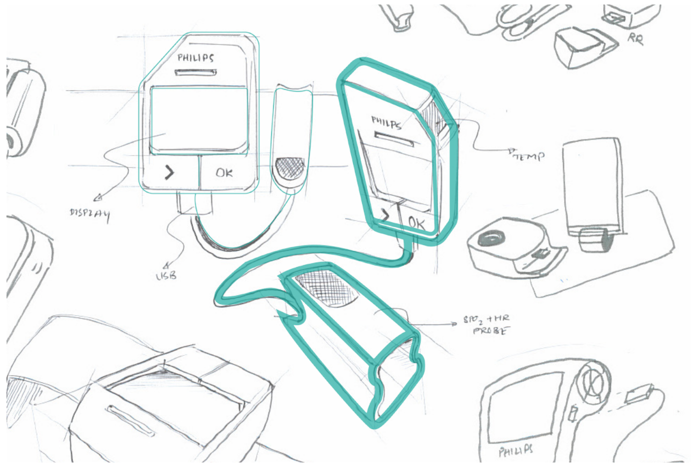
Automated planning of referral appointmentts at the end of screening process

The user listens to tasks and performs while listening. Then user speaks the findings which app records and caretaker also confirms. Makes user feel like doctor.

Scenario based training- training scenarios promote open ended discussions among CHWs during monthly meetings

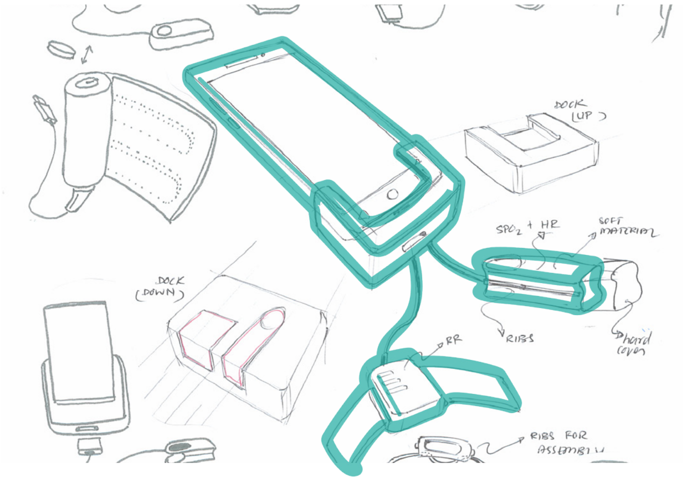
11.2 Physical device

Three main concept directions were created on the basis of how integrated, and specialised the cluster of ideas are. One concept direction sketch for every direction was created in order to capture basic idea of cluster.



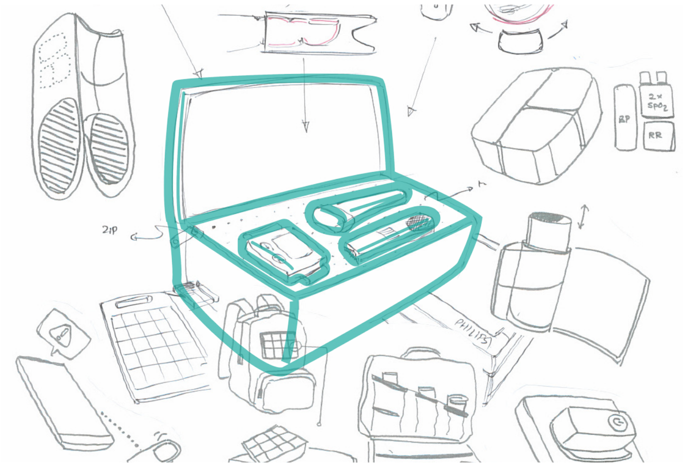
Concept #P1

Semi-integrated physical device with temp. and respiration rate forming one part and probe as an extension. This is the most closest to existing design of ChARM device.



Concept #P2

Smartphone add-on concept. All the other functions are extensions of the add-on as probes. The smartphone helps during workflow as well as power probe and display results directly.



Concept #P3

Suitcase concept incorporates all the diagnostic devices seperately. It has inbuilt solar charging unit. All the devices function independently.

11.3 Concept direction selection

Two types of evaluation were performed on both- smartphone app and physical device. The first preliminary evaluation was done keeping in mind scalability and usability using harris profile. The second and final weighted criteria evaluation was done considering more holistic perspective of estimated feasibility, desirability and viability.

Preliminary evaluation- focus areas

The first evaluation was done using harris profile to check the estimated usability and scalability of the concept directions. For more details, please check appendix G-concept direction selection.

Final evaluation- holistic criteria

In this evaluation, the results from preliminary evaluations were challenged and a more holistic evaluation was done considering technical feasibility, user desirability and economical viability. The criteria were brainstormed for desirability, feasibility and viability and the weightage was decided by calculating the importance of each with other. This weightage was then used to evaluate the concepts for both app and the device. For more details, please check appendix G-concept direction selection.

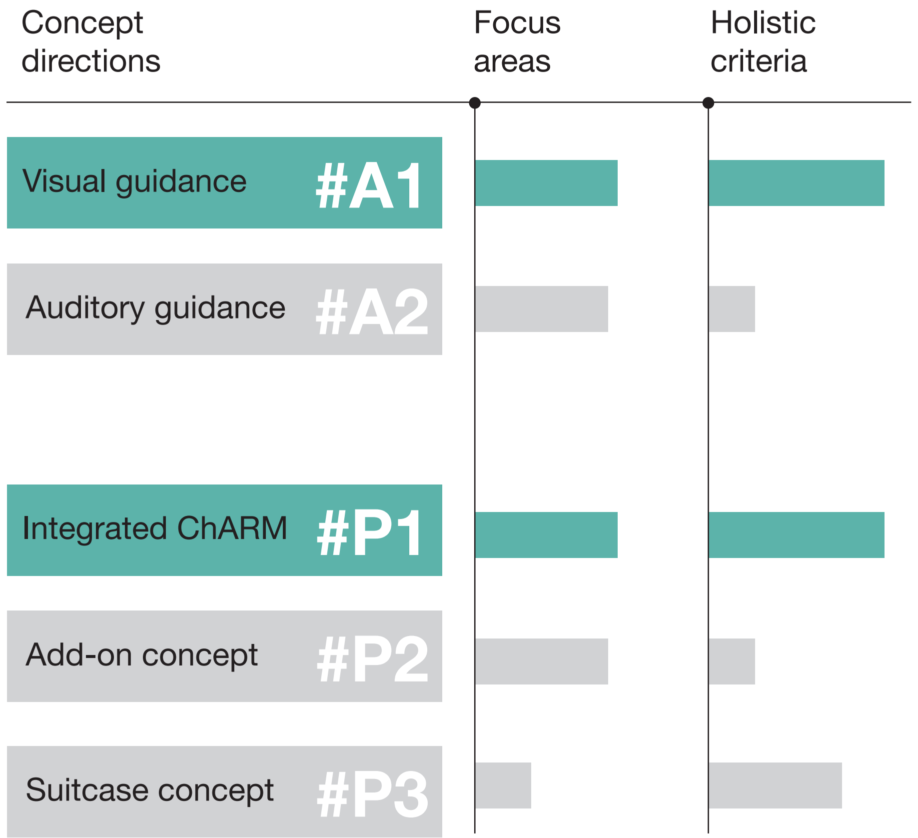


Figure 22: Evaluationf of the concepts

11.4 Final concept direction

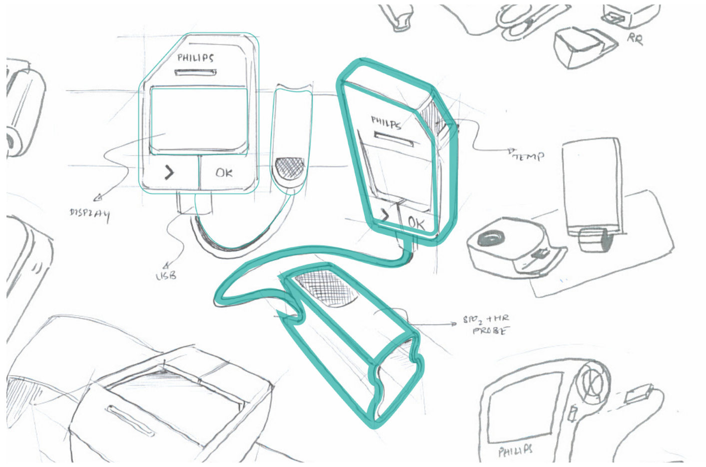
Combination of first and second evaluation resulted in clear winner- the first concept direction for both smartphone app (concept #A1) and physical device (concept #P1). But some aspects of the rejected concept directions could be incorporated into concept #A1, at the same time enhancing the existing aspects of itself.

For the smartphone app, the idea of actionable modules for adaptability, scenario based training from concept #A2 are interesting and could be incorporated into concept #A1. These ideas can enhance the existing ideas of using screening outcome data and gamification within scenarios.

For the physical device, the ideas from concept #P3 on usability of individual functions can in incorporated into concept #P1. The ideas related to guidance of using device and estimated cost of manufacturing from concept #P2 are also considered to be incorporated into concept #P1.

Concept #A1

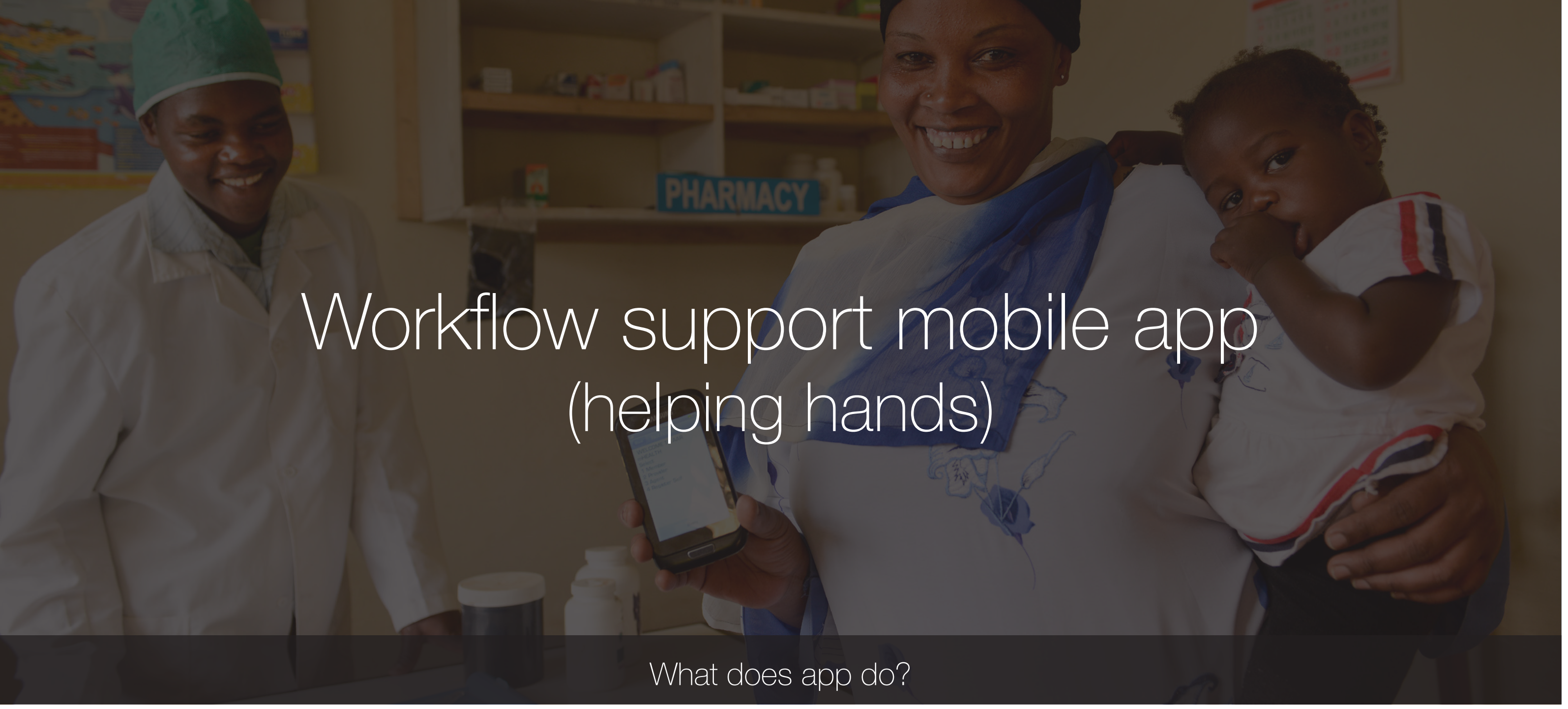
Visual mode of guidance is given through step-by-step tasks to do. Cumulative summary os selected answers is shown at every stage.



Concept #P1

Semi-integrated physical device with temp. and respiration rate forming one part and probe as an extension. This is the most closest to existing design of ChARM device.

Embodiment design



Workflow support mobile app (helping hands)

What does app do?

In order to realise the vision and concept direction into a concrete embodiment, first, an app flow is created. App flow provides all the basic functionalities of the application and their interrelations. Taking app flow as foundation, low-fidelity paper prototypes are created. This is validated with the users in Kenya in the field. Feedback on the low-fidelity prototypes is carried towards making the final design.

12.1 Low-fidelity prototyping

Based on the app flow, sketches of application screens were created. These sketches were mainly targeted to create a coherent application to use. The aesthetics of the prototype was kept sketchy in order to focus more on the basic idea of the application and features only. An interactive version of the application was validated with the users.

Figure 23: Paper prototypes of smartphone application

12.2 User validation

Low-fidelity prototypes are mainly used to validate the idea and features with the users. Hence, with an expectation of gaining validation of the basic idea, user validation was done. This user validation was conducted by Philips employees in Kenya. The user interview results are attached in APPENDIX J.

Desirability

“ It seems more reliable, and will reduce revisits of patients and hence the workload as well ”

Most of the users liked the basic idea of screening feature said it was simple to use. Clinical officers although desired more advanced support like differential diagnosis in handling rare conditions which are not covered in IMCI.

Training

“ The training modules are clear but the storyline is not clear and hence not relatable ”
“ It looks useful and should be available to both clinical officers and CHWs as all are updated on the trainings ”

The training feature was well received for implementation using smartphone app but the storyline was not relatable.

Screening

“ Should list common symptoms based on region ”
“ Will make screening easy, as I won’t miss any data during the process”

The screening feature was appreciated for recording the information, and thus reducing the cognitive load. Additional recommendations were given such as- symptoms should be region specific which is also being considered at conceptual level in the project.

Impact on work

“ Will make screening faster and better. Also improvement in quality and reduced time in managing the patient ”
“ Caretaker will have positive impression of me while using the app. It will help caretakers to be specific too ”

Users felt the app will increase the reliability and reduce time of screening process. They also felt the decision making process will be easier. With regards to any change in perception of user, they responded positively. They think, the app will create an impression that CHW can do better diagnosis.

Problems they envision in daily use

" What if the app crashes, can data still be retrieved? "
" It may take longer time to manage patients "

Most of the users were worried about what will happen to data and process if the app crashes. They also recommended to keep the app standalone (not connected to internet all the time). Although the screening time will reduce, the users thought they would take more time to manage patients i.e. to input their name, address, etc. for the first time due to typing.

12.3 Final design

All the learnings from the user validation is taken into account while creating the final design. The app is given a working title-"helping hands". Helping hands is a smartphone application which provides the health workers with integrated workflow support. With features ranging from training the health worker through a gamified training modules, guidance during the screening process to assisting in planing tasks to ensure the users provide effective care to their patients. The following sections provide a brief overview of the features.

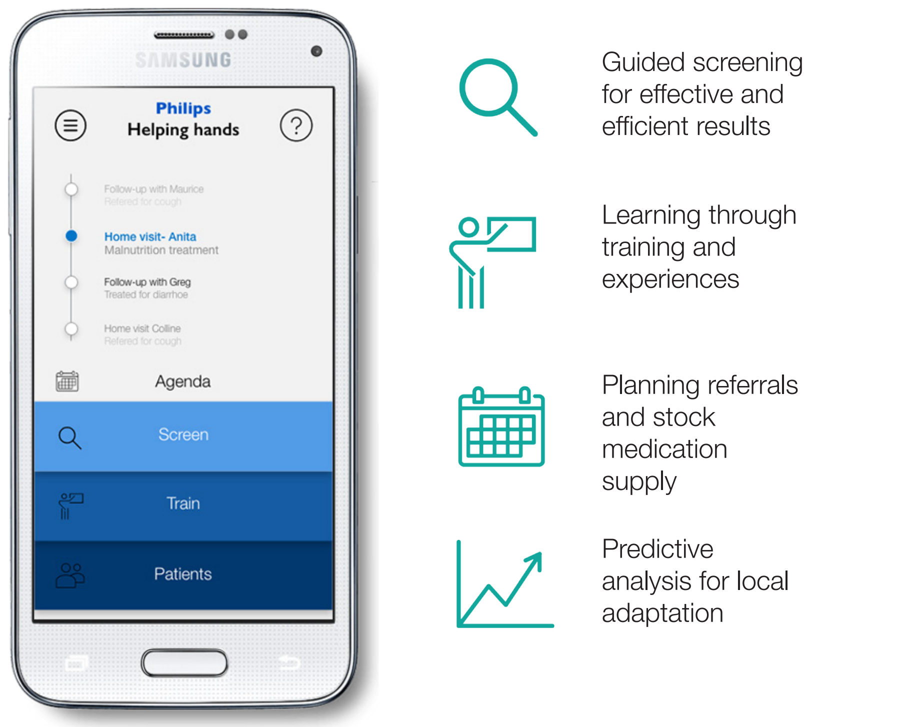


Figure 24: Final app and its main features

12.3.1 Screening workflow

The screening feature provides workflow support during the screening by guiding the user through entire steps, recording important information from caretaker, and providing the summary of the process in real-time. The summary is intended to train the user through experiences. More information on every step is also made available if required.

The screening feature also encloses sub-feature called journal. If in case the user is confused or wants to reflect on a particular case. (S)he can save the case at the end of screening. The summary of the case is saved for future reference. This is especially beneficial to stimulate discussions among CHWs during their monthly meetings.

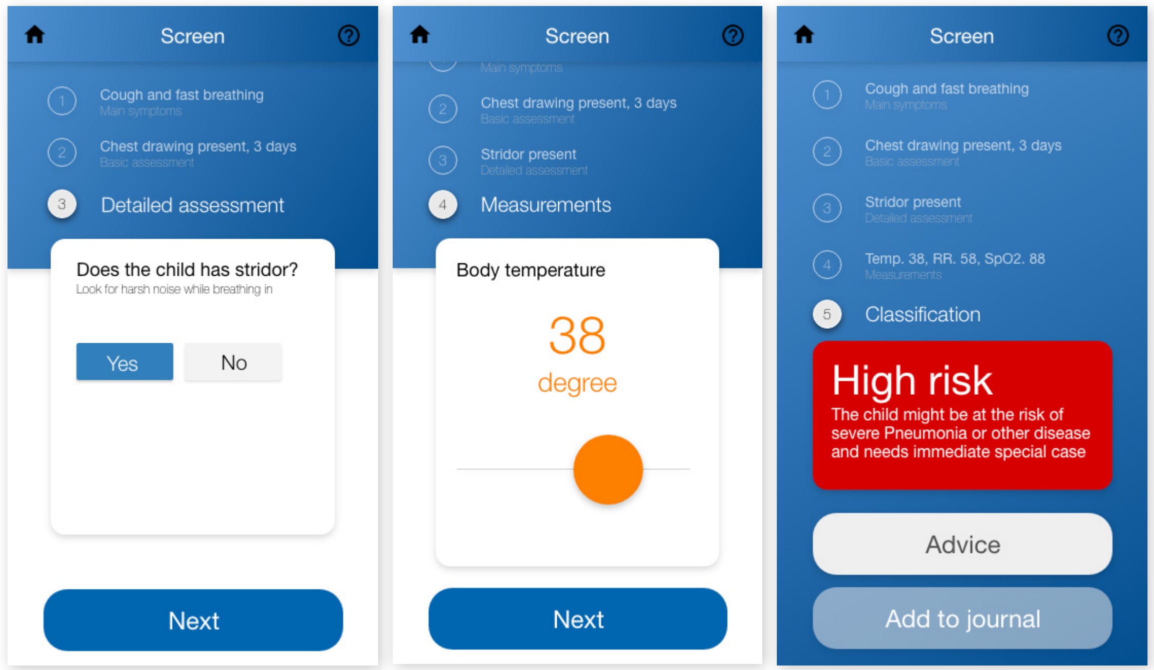


Figure 25: Guidance during the IMCI workflow

12.3.2 Training

Gamified version of training modules are intended to motivate the user into sustained completion of trainings. Training modules are scenario based i.e. questions and content is built around a scenario. This helps in associating real life experiences to training better. The training modules are linked to journal and adaptations made at system level. In this way, the training feature tries to replace the real-life training session.

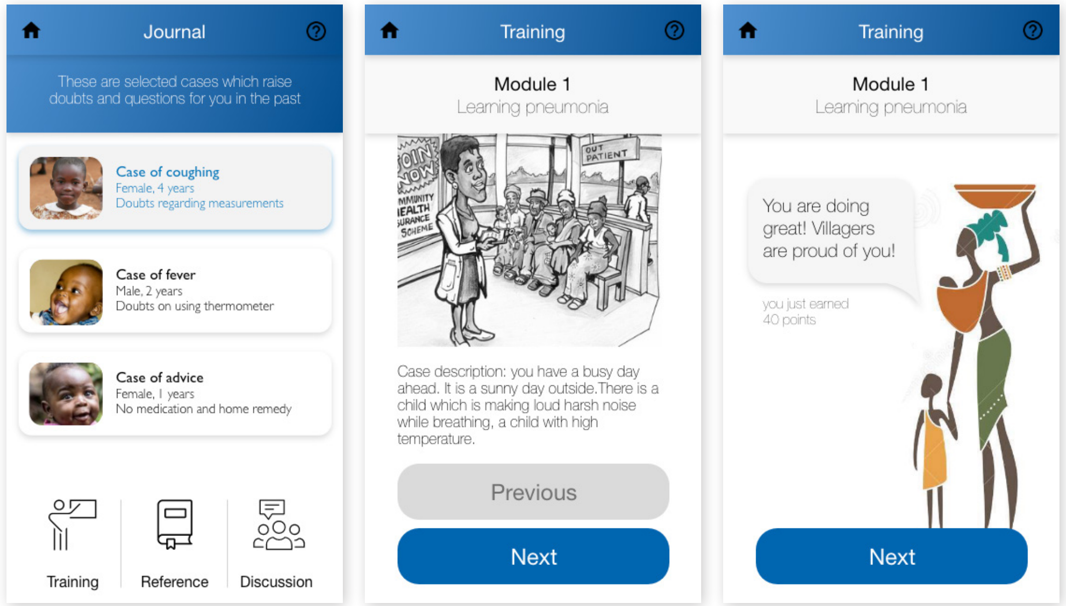


Figure 26: Training feature screens

12.3.3 Referral planning & consultation

At the end of screening, the user is given an option to plan the referral appointment and in some cases also seek remote consultation through SMS. The information regarding the patient and the summary of the screening is sent to caretaker as well as referral facility through SMS.

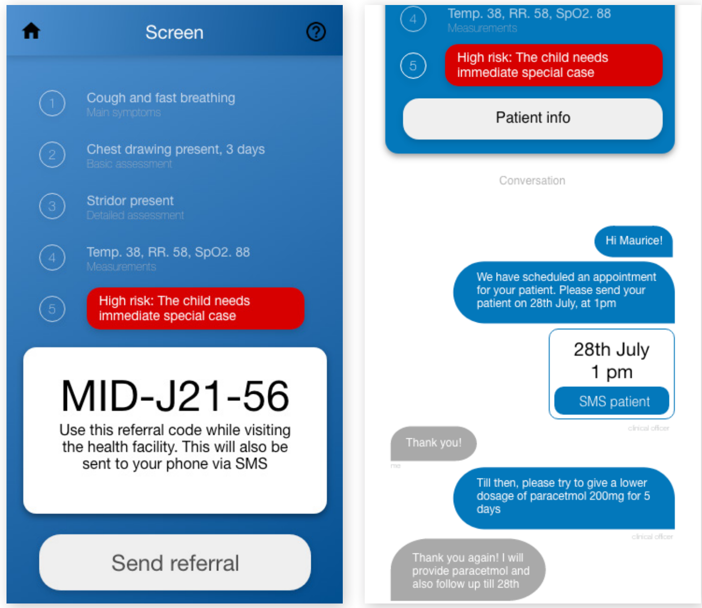


Figure 27: Referral support screens

12.3.4 Stock medications

In order to record medications available with health worker, the app records the use of medications from the treatment suggested at the end of screening process. Based on the consumption, the app provides a prediction of availability of medication in stock. This helps in raising early requests for medication supply from the warehouse.

12.3.5 Statistics

Important statistics regarding patients, training, referrals and symptoms are collected and visualised for the health worker to evaluate. For every such statistic, a prediction for next week is also provided which helps the user prepare and plan ahead.

These statistics are also made available to the Ministry of Health on regular basis. This helps track the population health at systemic level directly from the user level. The data from 3 weeks is stored on the smartphone. The past data is weekly transferred to the cloud to be used by Ministry.

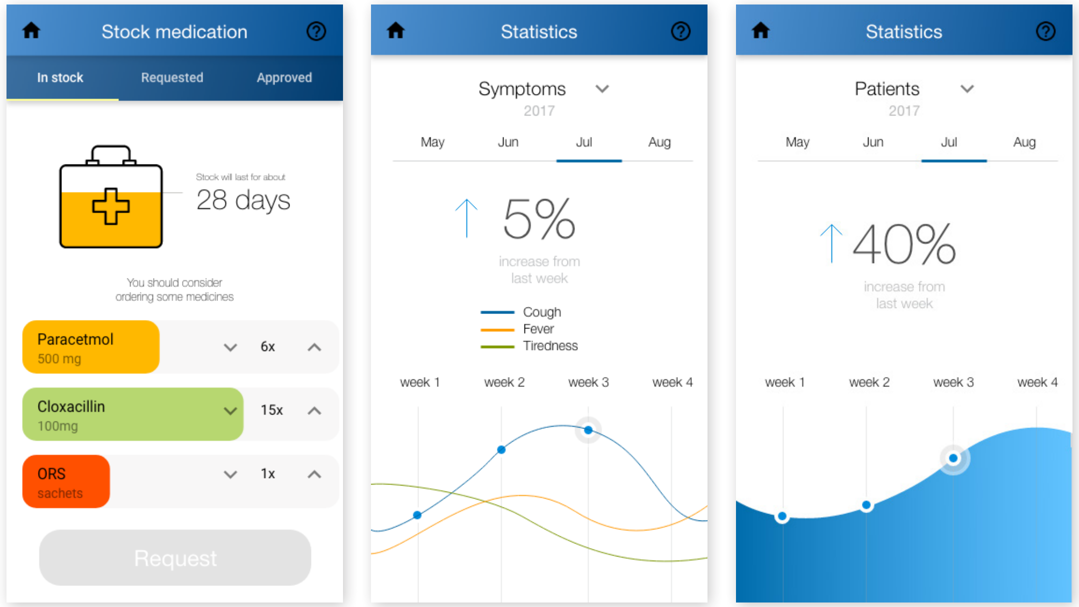
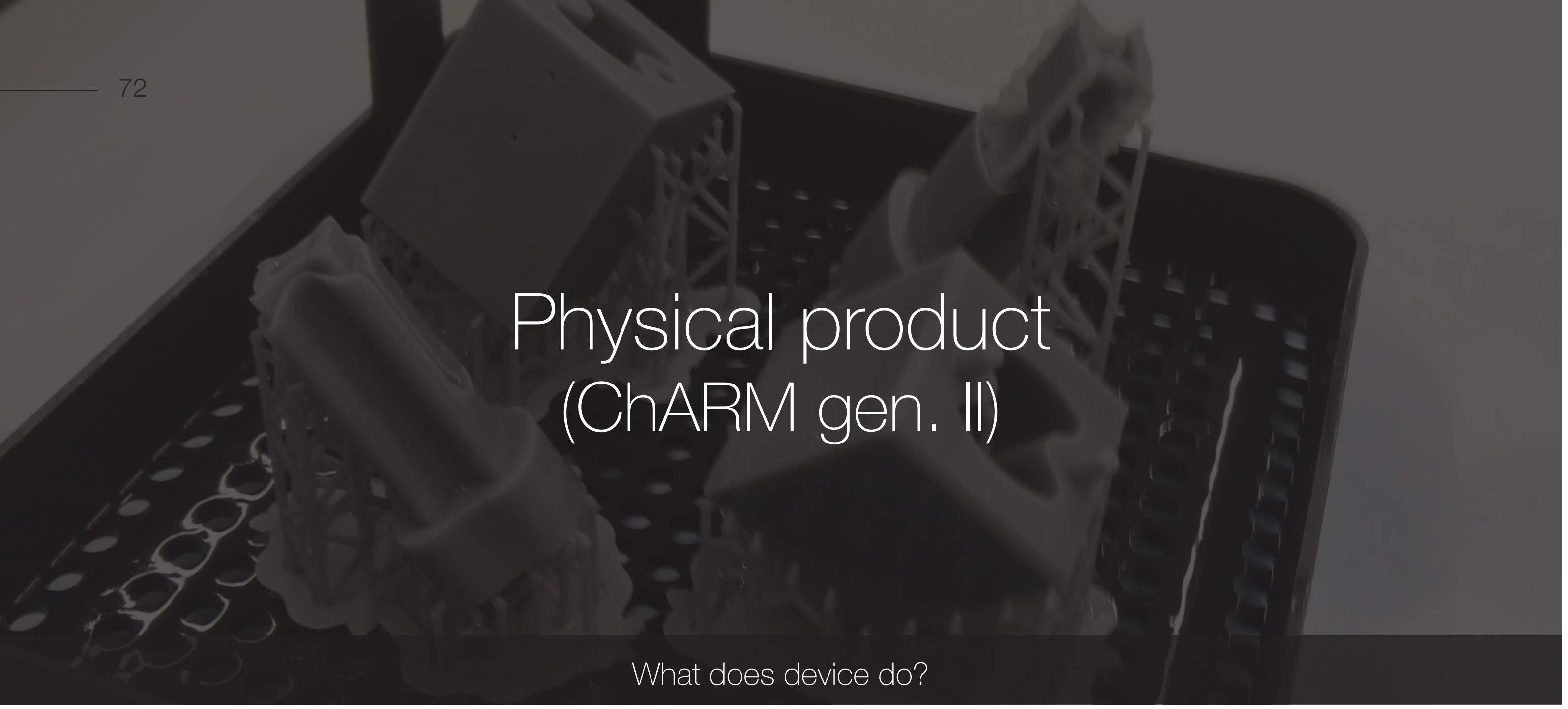


Figure 28: Planning stock medication (left), screens showing important stats (right)



Physical product
(ChARM gen. II)

What does device do?

ChARM gen. II is an integrated spot-check device with four vital measuring functions into one device. These vitals help improve the outcome of the IMCI workflow thus increasing its specificity. The physical device consists of probe for measuring SpO2 & hear rate and display device for measuring temperature & respiration rate.

More detailed description of the parts are highlighted in subsequent sections.

13.1 Probe design

The main innovation can be seen in the design of the probe which is designed for all finger sizes ranging from 5mm to 12mm diameter. A novel use of soft materials to design the mechanism for accommodating all finger sizes at the same time ensuring simple, robust and low-cost design is the highlight of the probe design.

The probe consists of two sensors (emitter and receiver) which are placed on diametrically opposite ends. The absorption of waves which are emitted by emitter is measured by receiver which provides the oxygen saturation level in the bloodstream. A successful and reliable position to measure is at the tip of the finger.

13.1.1 Embodiment ideations and process

The main requirements on the probe were one design for all fingers on top of robustness and durability on the opening mechanism. This mechanism had constraints on the pressure it exerted on the fingers. The challenge in embodiment of the probe was evaluating if it opens enough for all finger sizes. The ideations were done with sketching, scaled-up mock-ups. Later, in order to test this, CAD simulations and prototyping were used.

A fast paced iterative process of sketching, simulating the mechanism, prototyping was used to improve the final concept incrementally. This resulted in the final design as shown in figure 29.

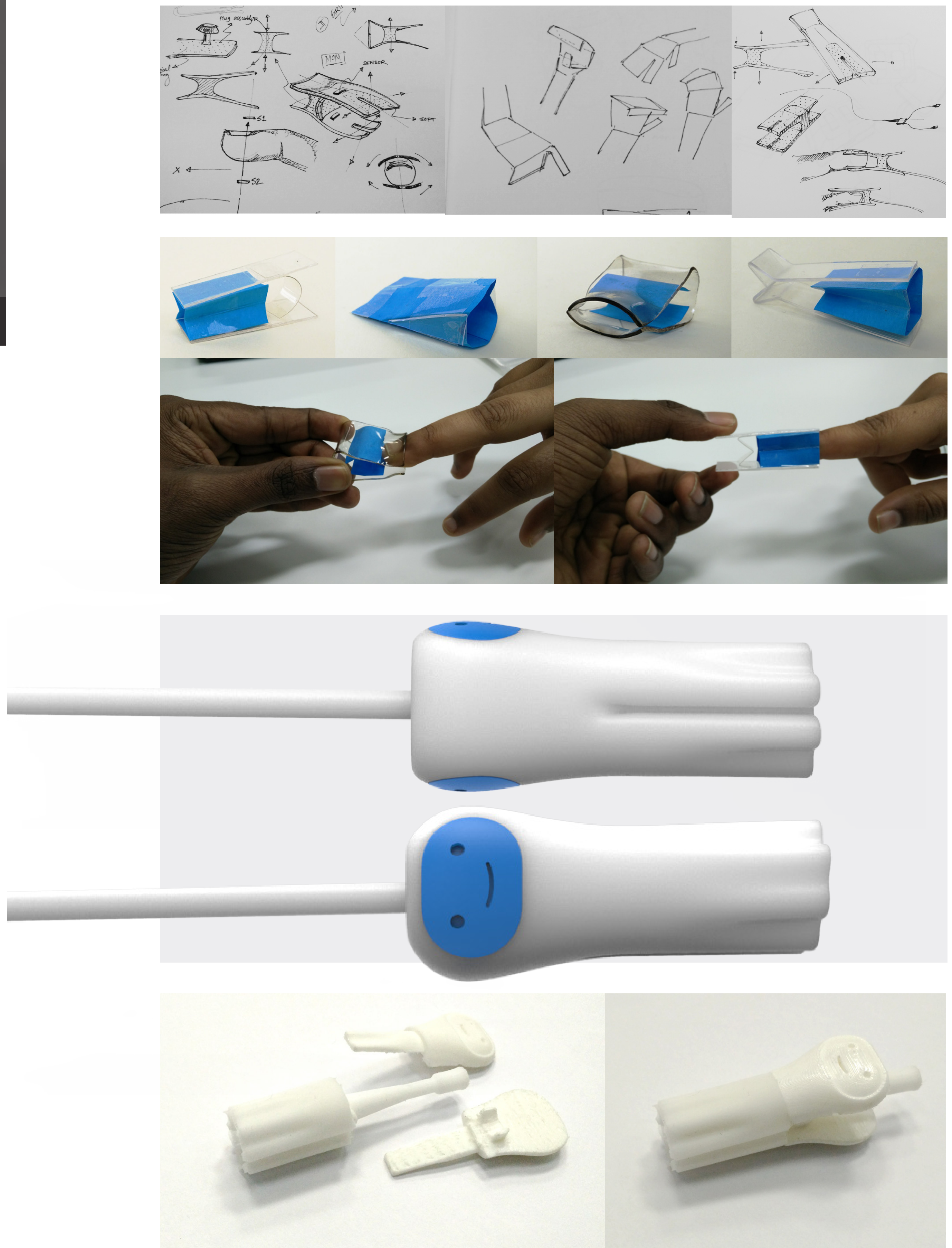


Figure 29: (Top to bottom) Embodiment process showing sketching, mock-ups and role play exercise, CAD modelling, Prototyping

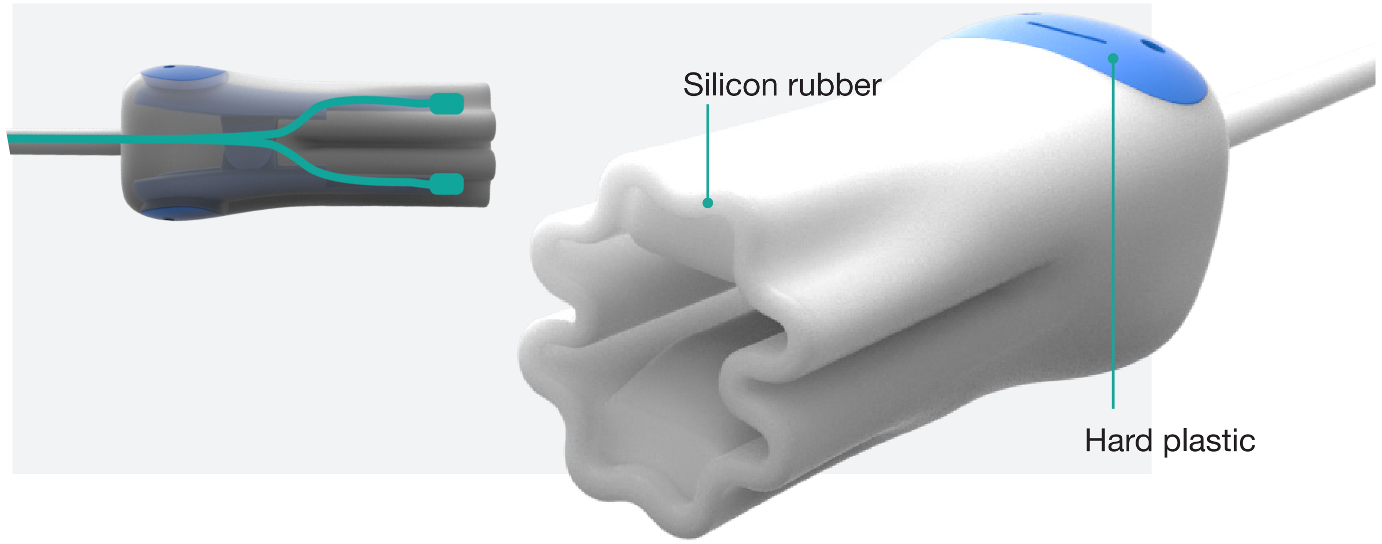


Figure 30: (Left) sensor positioning inside the probe, (right) materials used

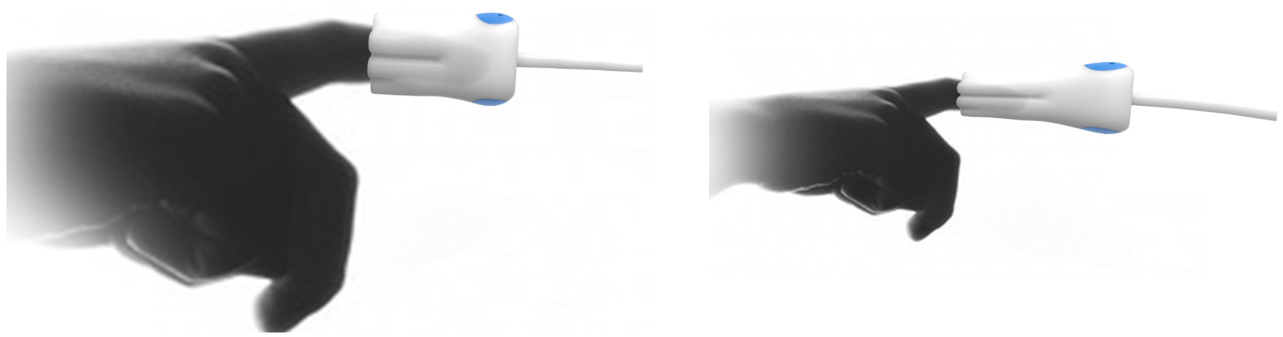


Figure 31: Usage of the probe in infants (left) and neonates (right)

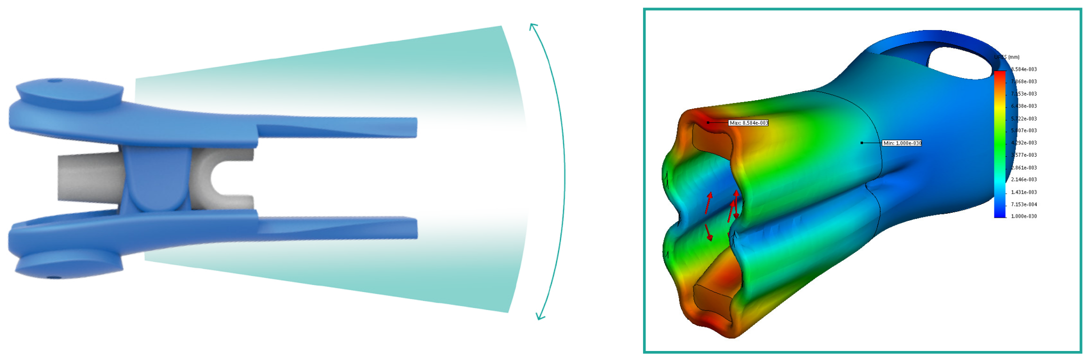


Figure 32: Workinf spectrum of probe (left), simulations to check threshold pressure (right)

13.1.2 Detailing- DFA and DFM

The working prototype was then engineered from Design for Assembly (DFA) and Design for Manufacturing (DFM) perspectives. DFA was done at the CAD level and by studying existing probe designs. Two concepts for DFA were proposed at the end. This proposal will be given to the product manufacturer to evaluate and decide which is feasible. An evaluation of the advantages and dis-advantages of two assemblies is given in figure 33.

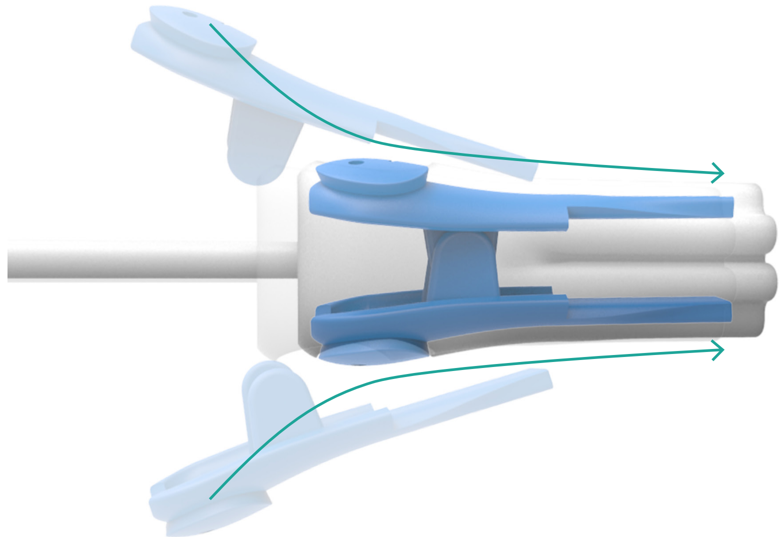


Figure 33: Assembly procedure of the probe

During the prototyping phase, 3D printed moulds were created and soft material prototypes were made using injection moulding technique. This helped in creating functional prototypes and simultaneously evaluate manufacturing feasibility. Injection moulding of soft material and hard material is proposed to reduce the cost for producing approximately 1000 parts.

Figure 34: Moulds created for prototyping soft part of probe and to check feasibility og manufacturing

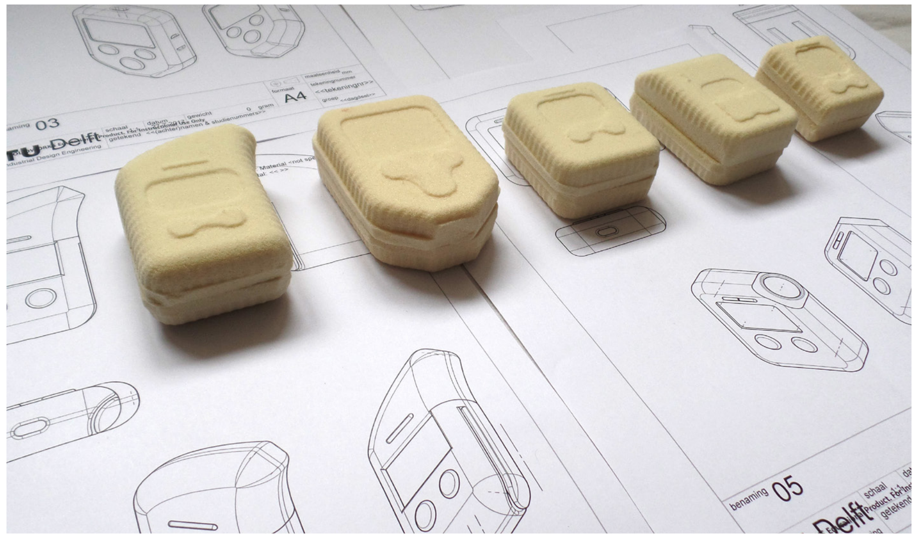
13.2 Display device

As discussed earlier in this section, the display device provides two vital measurements- respiration rate (RR) and temperature. To measure RR, the device is strapped around the belly of the sick child with a belt. The accelerometers within the device measure the belly movements which is used to count the respiration rate. To measure temperature, the device is pointed at the forehead, infrared temperature sensors in device collect the temperature. The display device also displays the readings and helps the user in choosing which functions they want to use. In case of any disturbance while measuring, the display is used to warn the user.

13.2.1 Embodiment ideations and process

First sketching is done based on the concept direction sketches from previous phase. These sketches are then translated into basic CAD models which were used to create foam models. These foam models were then used to perform role play and usability evaluations were done. Using a morphological chart (figure 35) a final CAD model is created.

Figure 35: Morphological chart used on foam models



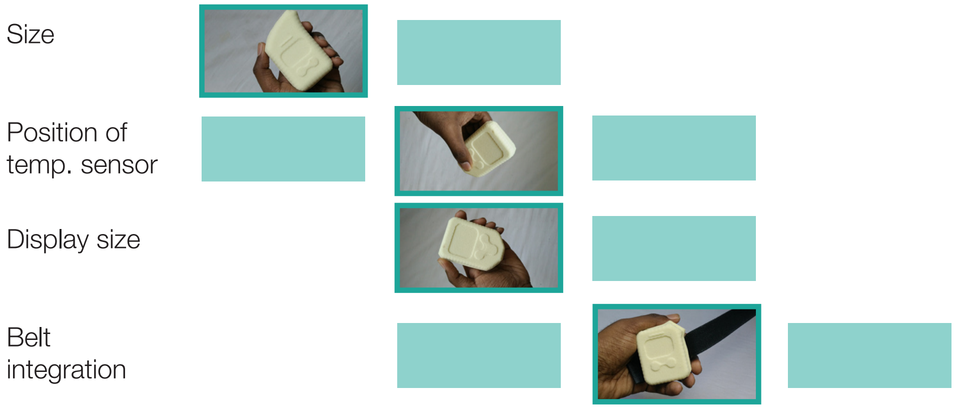


Figure 36: Final design (left), temperature sensor (right)

Figure 37: Belt assembly (left), Ddsplay and notification light (right)

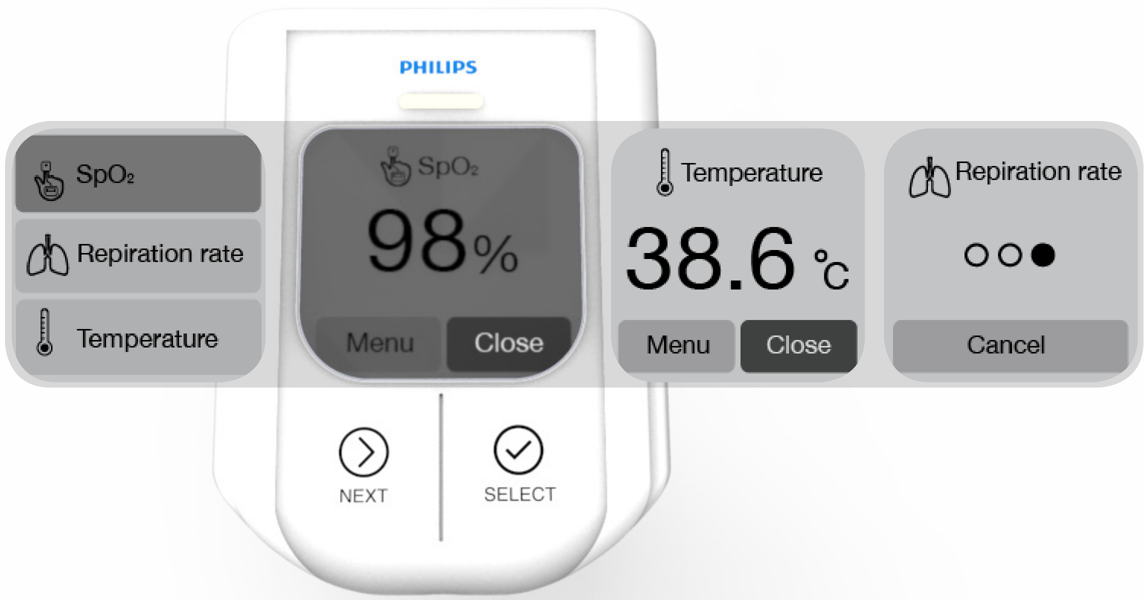


Figure 38: Display screens on the device

13.2.2 Detailing

Considering the previous and future generations (see introduction pg.17), context solution space- internal components were defined for ease of scalability. Main design choices on the components are described as follows. The display is changed from segmented to pixel based display (used in Kindle readers) which provides more freedom for UI designers to give more information in same display size. This helps in providing more information when probe is adapted for adults, BP monitor is included in future generations. AA batteries were used considering the insight from context solution space. These batteries provide tangible form of electricity removing the reliance on grid electricity at the same time making the user responsible for buying the batteries. This is expected to help when the device is introduced in India.

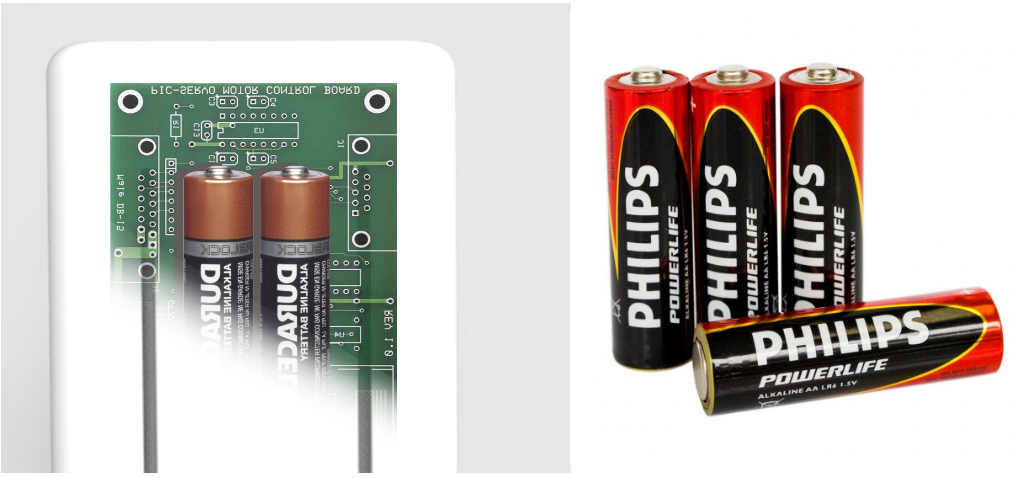


Figure 39: Batteries used inside the device

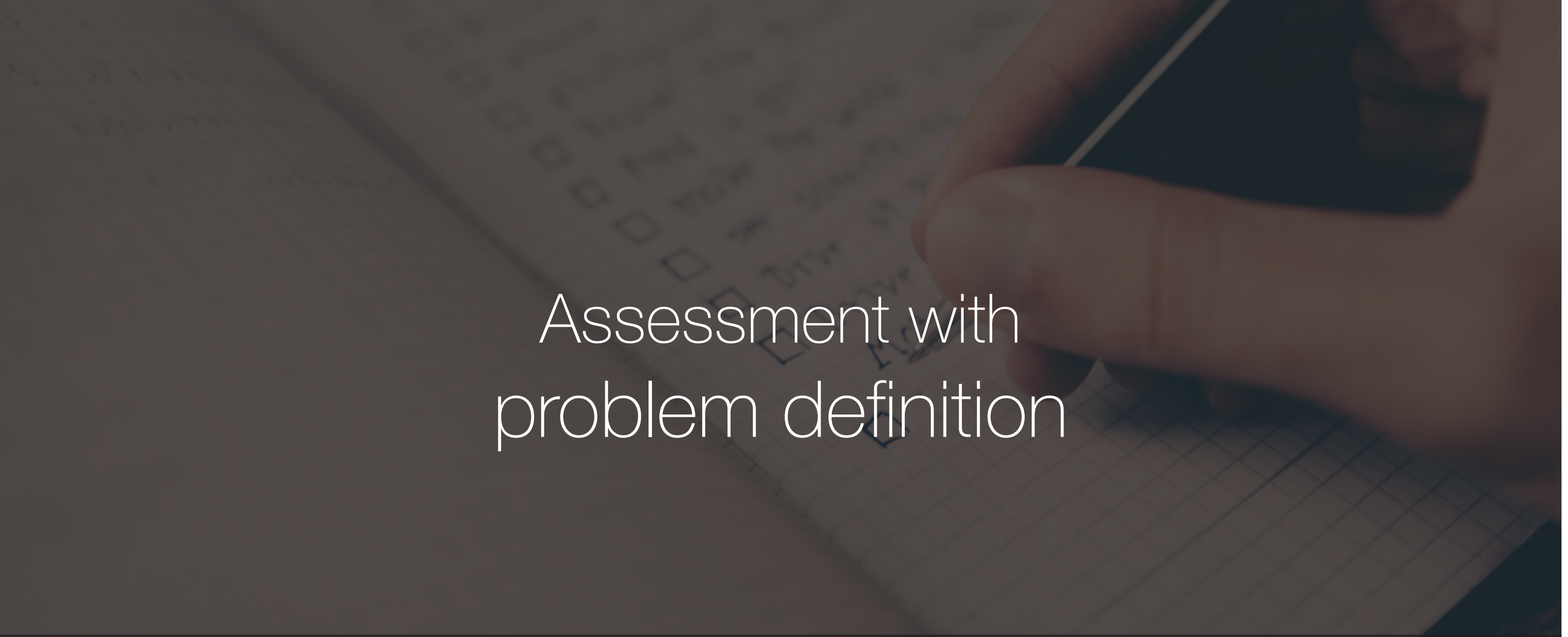
Figure 40: Display (pixel based) screen

13.3 Integration of ChARM gen. II and Helping hands app

The app and device are integrated at two steps- during screening process and training. During the screening process, the app guides the user on which measurements need to be done for that particular case. The measurements from the device are then recorded in the app. This ensures, a stable measurement is taken and checked twice before recording. Secondly, the training feature is used to help the user to learn how to use the device, what could go wrong during measurements and how to mitigate the mistakes.

Figure 41: Recording the measurements into the app

Evaluation



Assessment with problem definition

How does the design solve the problem?

Four main problems were selected to be solved- lack of data driven dialogue for adaptation of IMCI to regional morbidity profile, lack of planning in peripheral systems, lack of continuous trainings and high cognitive load of IMCI workflow. In this section, the final design is assessed on these problems and an estimated impact is discussed in the end.

14.1 Lack of data-driven dialogue for adaptation of IMCI

In order to provide data for the dialogue, the statistics from the screening process is used. This provides raw data directly from the field to the Ministry of Health and Regional health staff. The predictive analytics at the user level with the app also provides a collective prediction of population health data.

Although this does not ensure that the dialogue for adaptation will be done, but this app definitely provides data in order to support the adaptation process from the field. This data can be combined with clinical reports on population health from district staff to foresee requirements for adaptation at user level.

14.2 Lack of planning in peripheral systems

The app provides direct connection of the health worker with the referral facility. At the end of the screening process, if a referral is needed, an appointment is given by the referral facility which is conveyed to the health worker and the caretaker with an SMS. At the same time, information of the patient and summary of screening process is given to the facility.

The app provides a feature to record the current stock medications and usage for the user. Based on the usage, the app also provides a prediction on how many days the medications will last. Using this prediction, the user gets alerts to raise request for the medications this reducing the delay in medical supply chain.

14.3 Lack of continuous trainings

One of the main features of the app is scenario based training. The training modules are structured with gamified approach which motivate the user to complete the trainings. The scenarios help in connecting the training on app to real life situations on dealing with caretakers, knowledge on the tasks, knowledge of the disease, etc.

The screening feature also provides a journal where all the rare, interesting, cases for the user can be saved. These cases are used to facilitate the discussions during the monthly meetings. This feature was based on existing discussions (derived from cultural probe, see APPENDIX E), the app is used here only to support and encourage learnings through discussions among CHWs about their experiences.

14.4 High cognitive load of IMCI workflow

High cognitive load as caused due to high demand on memory and attention during the workflow. A comparison of estimated usage of memory and attention is made with and without the app in figure 42.

It is clearly visible that recording of information during the workflow and also reducing the effort to find more information helps reduce the cognitive load. This was also evident from the user validation of the low-fidelity prototypes when users mentioned that the app- “Will make screening easy, as I won’t miss any data during the process”.

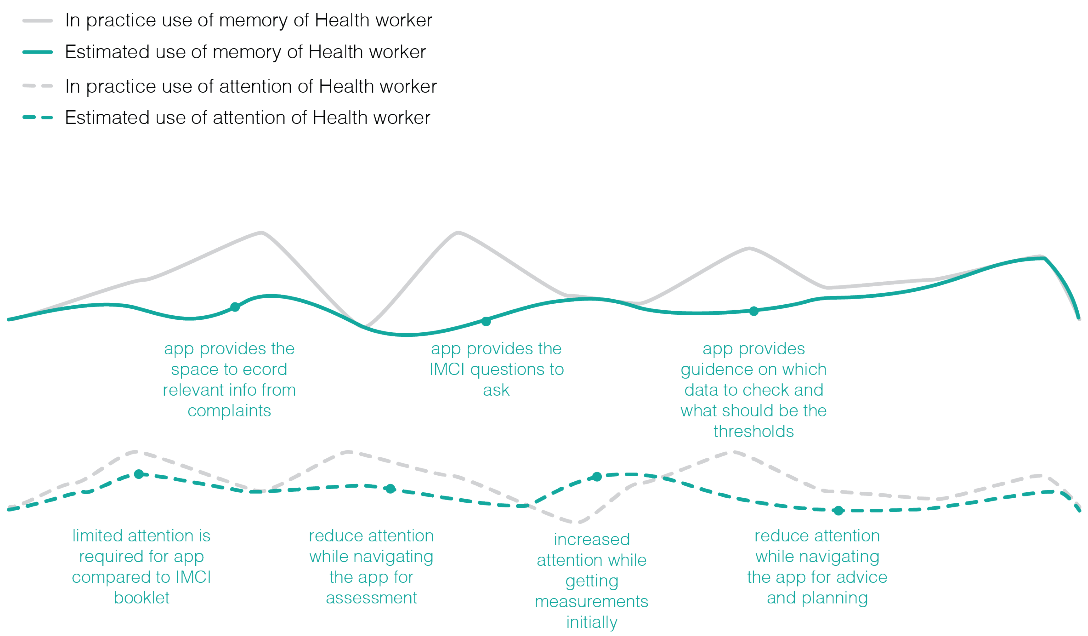


Figure 42: Impact of the design on the cognitive load of health worker

Assessment with focus areas

How is the design usable and scalable?

Four main problems were selected to be solved- lack of data driven dialogue for adaptation of IMCI to regional morbidity profile, lack of planning in peripheral systems, lack of continuous trainings and high cognitive load of IMCI workflow. In this section, the final design is assessed on these problems and an estimated impact is discussed in the end.

15.1 Usability evaluation

Usability of the app and the device is presented in this section. For the app main results from the user validation is used whereas for the device, results from roleplaying exercise from the foam models and probe prototypes are used to assess usability.

15.1.1 Smartphone app

The low-fidelity prototype of app was tested with the CHWs and clinical officers in the field. The results of this user validation is the main source of usability evaluation. The final evaluation of the usability hence is to a large extent, an extrapolation of the user validation. The results of the user validation is presented in APPENDIX J.

Usability aspects	Quotes from user validation
Effectiveness	“...I won’t miss any data during the process” “...integration with CHWs will enable referral and knowledge support.” “I can do more home visits. It will enhance my judgement as it will summarise the visit.”
Efficiency	“Will make screening faster and better”
Learnability	“It is simple to use, and understand.” “The app may take time in the beginning to get used to.”

Most of the users said that the app will make their workflow effective since they won’t miss any information from the caretaker. They also mentioned that this will enhance their judgement due to the summary of the case. Planning and consultation for the referral system was also appreciated by both clinical officers and CHWs.

Most of the user felt that the app will make their workflow faster and better. Time can be a good objective parameter to evaluate efficiency along with how much improvement is there on rational judgment within the workflow.

Regarding learnability, some of the users said that the app is simple to use and understand where as few said that the app might need some time in beginning to learn how to use it.

15.1.2 Physical device

Usability of the device was mainly improved with the use of use cues using colour, form and anatomy of the device. The geometric form of the temperature sensor is kept circular compared to cuboidal form of the rest of the device. It is also highlighted with the blue coloured strip around the housing. This helps in recognising the orientation and thus the position of handling the device intuitively while measuring temperature.

The orientation of the probe is made clear with use of blue colour hard plastic. This is also a cue for identifying the place to hold. Since the probe is meant to be used only on children, the aesthetics is kept child-friendly. It can be used to calm the child in case (s)he is crying. The dimensions of the probe is kept to position the sensors at the tip of the finger already.

15.2 Scalability evaluation

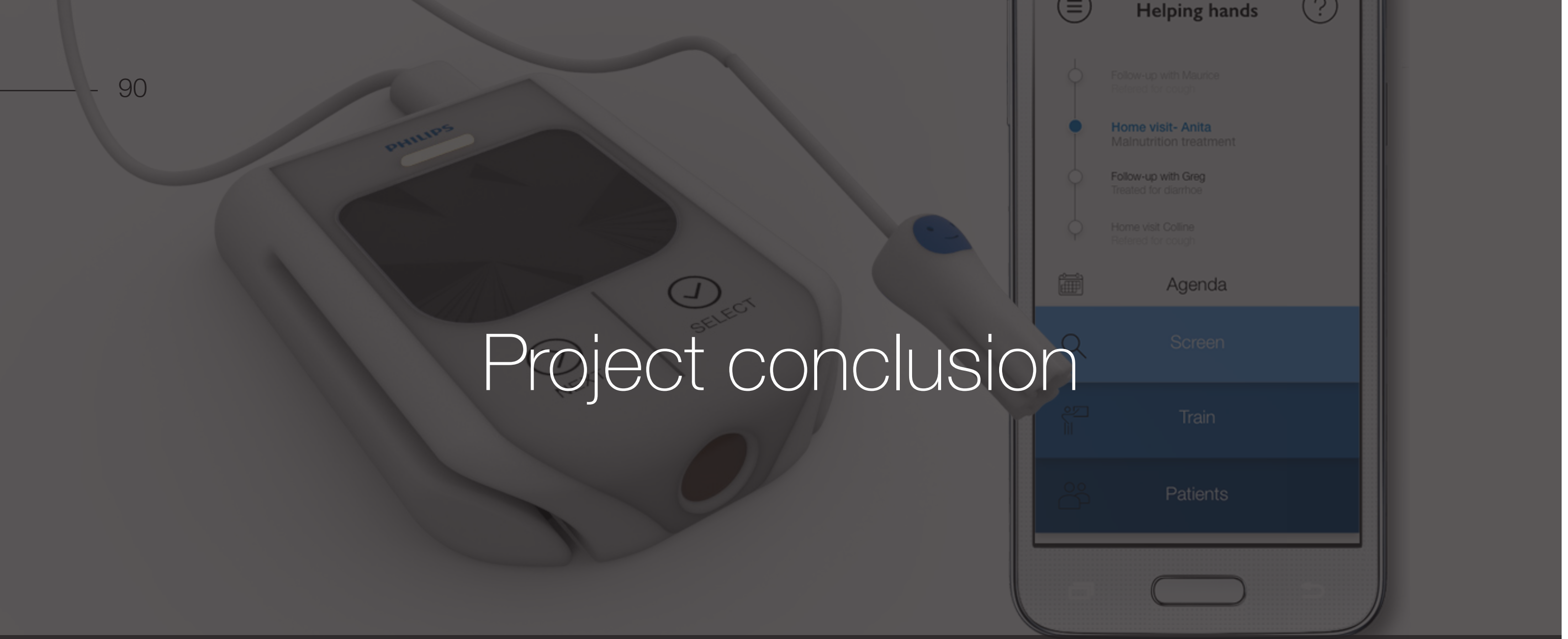
Scalability of the product system is mainly focused on the device than app. The app is important to be scaled up from user aspect whereas for the device, functional and geographical scalability is important.

Scalability of the app with the user can be seen from the user validation results. Both the users- clinical officers and CHWs found the app desirable. Although the clinical officers desired more advanced decision support system on top of IMCI algorithm. This was the only big difference on the responses between the two user groups.

At a functional level, efforts in reducing the changes from ChARM design and foreseeing changes due to future generations were made. The form of the ChARM was retained with small addition of temperature sensor on the corner. In order to use any locally available belt, the strap to hold the belt was redesigned. Considering the future generations, the display type was changed from segmented to pixel based in order to present more information when more probes are incorporated into the device. Insights from context solution space were used to incorporate geographical scalability especially on electricity usage. Batteries were selected to provide electricity due to variations in grid electricity output (the sockets are different). Another reason for use of batteries was because it is a tangible form of electricity. This might make the user buy the battery on their own and feel the ownership of the device. This is also expected to make the user take care of the device in terms of its storage, handling and maintenance.

Scalability aspects	Description
User	ability to handle variations in education and role of the user (from community level health worker to health facility level doctor)
Functional	ability to change the product system by adding, changing, removing functionality at minimal effort (from previous generations to future generations)
Geographical	ability to maintain performance, usefulness, usability at various geographical places (India and Kenya)

Conclusion & Recommendations



Project conclusion

What do we have finally?

The project started off from the global challenge of child mortality and challenges of proper implementation of IMCI workflow to tackle it. Both systemic and user level challenges were identified but focus was mainly on user level challenges while being aware of systemic challenges in this project. While studying the challenges and finding solutions, focus was kept on usability and scalability. A human centred design approach was used with a CVD approach. CVD approach helped in embedding scalability within the project research.

Research on the context and user helped in identifying the main problems of lack of data driven dialogue for adaptation of IMCI to regional morbidity profile, lack of planning in peripheral systems, lack of continuous trainings and high cognitive load of IMCI workflow.

The proposed product system was broken down into two main parts- smartphone app and physical device. Various concepts were explored with sketching, mock-ups and prototyping.

The final design thus composed of a workflow support application and a spot check device. The main features of the app were screening and training. The application as reduced the cognitive load on the user by guiding the health worker and recording the information from the caretaker. At the end of the screening, an appointment and consultation is made possible through SMS service within the app.The training was made possible with a gamified version of scenario based training. The data from the screening process is used to gather data for the adaptation process at the systemic level.

The spot check device is used with the workflow in order to improve the outcomes. The device provides measurement of four vitals- temperature, respiration rate, oxygen saturation and heart rate. The device consists of display device and a probe. The main highlight of the device is the design of probe. It uses a novel mechanism which makes it possible to fit for all finger sizes.

16.1 Expected impact

The impact of the product system was envisioned in chapter design vision. With the final design, an estimate of the impact at user and systemic level assessed. The highest impact is expected to be at the user level. The product system is expected to improve the IMCI workflow, introduce trainings for the health workers. This can lead to higher specificity of IMCI outcomes and hence better treatment of diseases. Due to reduction in time of workflow, the number of patient visits might increase.

At the referral facility level, the design might lead to reduction in patient visits but at the same time introduce an additional task of consulting remotely and planning the appointments. At the ministry level, the design would help gather population health data from the field directly. But additional efforts would be needed to analyse it in order to incorporate it into adaptation process.

1. Regional level
Raw data analysis

Population health data from field is available
Increase in analysis of raw data

2. Peripheral system level
Increase in managerial tasks

Reduction in patient visits thus lower workload
Increase in organisational tasks
Introduction to referral consultation through SMS

3. User level
Highest impact

Improved management of diseases through specific IMCI outcomes
Increase in patient visits
CHWs and Clinical officers better equiped with knowledge in handling cases

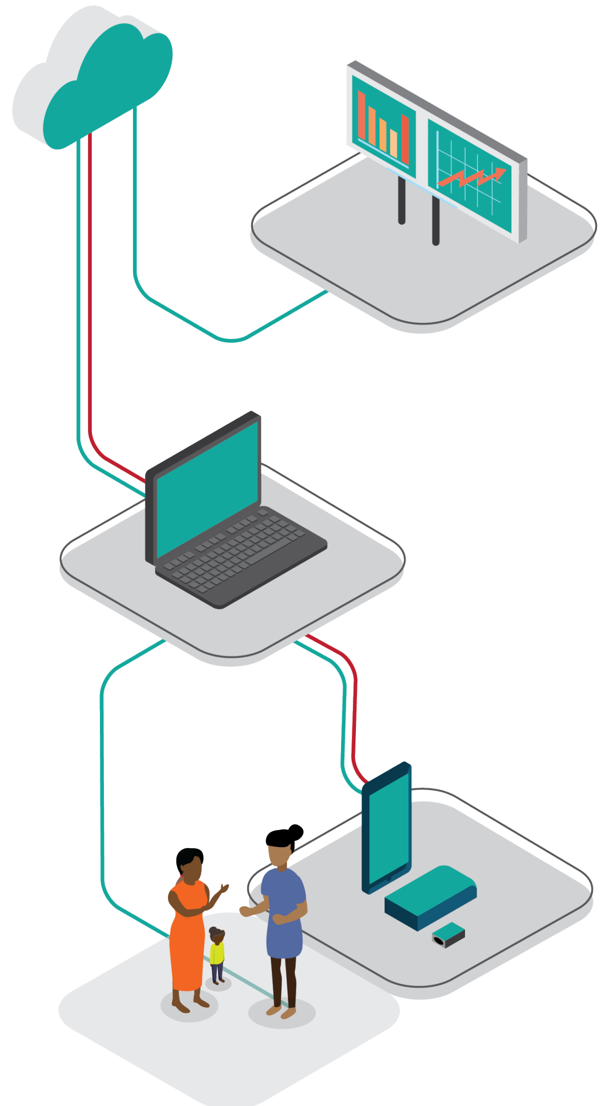


Figure 43: Impact of the design on healthcare system

Recommendations

What needs to be done next?

The proposed design has numerous parts and aspects for every part. Due to limited timeframe of the project, not all of them were dealt with deserved importance. The strengths and weakness of the parts are identified from the final design. These are recommended to be taken ahead during continuation of the project.

17.1 Strengths of project

The research with the CVD mindset has certainly expanded the viewpoints of the designer in the project. The solution spaces for the context and user insights were considered both beneficial for the final design. But more importantly, guidelines for scalability of the product system can be envisioned based on the solution spaces.

The aim of the final design (especially with app) was to identify existing practices and use the smartphone app to mediate the workflow practices to gradually adapt and adhere to IMCI guidelines. In order to achieve this, the users were involved at two touch-points in the project- for user research and user validation of concept app. The need for the final design can be justified along with the features identified. The guidance during the workflow was well received along with training feature by CHWs and Clinical officers.

The design of the probe is one of the highlights of the project. The final probe design provides an interesting mechanism using soft silicon and hard plastic to provide a reliable measurement. The novelty of the design being its scalability to different finger sizes in children without any adaptation. The one design for all finger sizes between 5 to 12 mm diameter helps in improving the usability (by reducing tasks since there is only one probe to use) as well as cost.

17.2 Weakness of project

Considering the vision, the final design only provides a detailed outcome at user level with the app and the physical device. Hence, one of the biggest weakness of the project is detailed designs at referral facility level, ministry level and the service which connects all the three levels.

Since the focus of the project was given mainly to usability and scalability, less importance was given to more holistic criteria- technical feasibility, financial viability. They were briefly used to evaluate the concept directions. Technical feasibility was dealt through expert talks within Philips throughout the project. An estimate of the financial viability was kept in mind (the complete product should cost approx. 150 euros) but a detailed assessment of the final design was not made.

17.3 Takeaways for Philips

The final design can be considered high scalable and usable across users with different expertise. The final design is validated with the users- CHWs and Clinical officers through user research and concept validation. Although, this design was well received by the CHWs whereas the clinical officers desired to have more advanced algorithms instead of only IMCI algorithm. Considering the impact of the product system, it seems that the final design will favour CHWs more through referral consultation, journals and stock medication planning. This will introduce more tasks at referral facility and medication supply chain. At the same time, introduction of new tasks might lead to ease of other tasks. for example, the workload at referral facility might reduce due to referral consultation through app. Therefore, it is recommended to study the introduction of new tasks at referral facility level due to the final design by creating a service blueprint.

The final design can be considered high scalable across functionality and geographical contexts of Kenya and India as well. The final design of the physical device has emerged out of various sketching ideations and models overlaying previous product ChARM. The future generations of the product system were also studied in order to reduce the redesign efforts in later generations. The form, size of the product were kept the same but validated for usability through foam models. Aspects such as displays and temperature sensor position were decided envisioning changes in future generations. Other design decisions like use of batteries and use of icons were consequence of contextual solution space which unites the insights from India and Kenya.

The probe design was a novel outcome for measuring SpO2 for all finger sizes in children under 5. The design combines the strengths of soft silicon and hard plastic to open and position the sensors for reliable measurement. It would be interesting to explore the same concept to scale up to include larger finger sizes especially considering maternal care is incorporated in future generations.

During the project, it was noted that a similar application exist for maternal care call MOM. Inspirations from this application could be considered for further improvements in final design. Possibilities of integration with other Philips programme should be considered like MOM, Philips backpack initiative and CLCs. This might lead to lower costs, for example, the smartphone which runs the MOM app can be used to run Helping hands (final design) as well.

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