

# QUALITY HIGH-FREQUENCY DATA COLLECTION IN MALAWI:

PILOTING THE CHILD  
DEVELOPMENT STUDY



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CCWD  
CENTER FOR CHILD WELL-BEING  
& DEVELOPMENT



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## Acronyms

CCWD	Center for Child Well-being and Development
COMREC	College of Medicine Research and Ethics Committee
ECG	electrocardiography
EEG	electroencephalography
HSA	Health Surveillance Assistant
IVR	Interactive voice response
UNICEF	United Nations Children’s Fund
WASH	Water, sanitation and hygiene

# Preamble

This report was produced by the Child Development Study research team, keeping in view the list of deliverables defined in section 12 of the Project Document annexed to the three-year contract signed by the National Committee for UNICEF in Switzerland and Liechtenstein, and the Department of Economics at the University of Zurich, on 17 December 2019.

The report covers the period from 1 January 2020 to 31 December 2020, during which the following overarching deliverables were expected:

- Agreements with technology vendors and data collection firms
- Data generation

The Child Development Study made considerable progress against these deliverables.

With respect to the first deliverable, the team tested and validated several options. These will be explored over three fronts: technology vendors, research organizations, and academic partnerships.

The pilot phase in the field provided a useful opportunity to test several technologies and relationships with key partners. It emerged, for example, that one vendor, Pickcells, was unsuitable for this study. The devices it provided did not work properly, and some information was never delivered to the team. This is the main reason the leadership team of the Child Development Study put an end to this collaboration. On the other hand, the team found in Mawi and Interaxon valuable tech partners. The tests with ECG pads (Mawi) and EEG headbands (Interaxon/Muse) proved to be effective and the agreements with these two commercial firms have been confirmed. Both companies will accompany the researchers through the next phases of the study and provide key hardware to collect biomarker data. Mawi also supported the study with additional software. A tailored dashboard was conceived to support data collection and visualize data in aggregate form. This dashboard is now hosting data coming from other sources, including, for example, the EEG data generated by the Interaxon/Muse devices and short surveys administered to caregivers.

During 2020, the team found a strong partner in the Institute for Scientific Interchange (ISI) based in Torino, Italy. This research group works at the frontier of the field of complexity science. Mainly comprising social and data scientists, ISI has longstanding experience with the study of social networks in real life through the engineering of proximity sensors and their application to various contexts. More, the group is at the forefront of the COVID-19 response, developing participatory surveillance tools (<https://www.influweb.it/>) and directly supporting the Italian government. Two scientists from this network will take growing responsibilities within the scientific leadership team of the Child Development Study.

In Malawi, the relationship with the College of Medicine was strengthened during 2020. A formal agreement has been signed so that this organization will lead field data collection, and will create a local team of young researchers to lead operations in the field. To this end, a doctoral student is about to be hired and at least two other research assistants will be brought on board in 2021. Moreover, the study needs to have a strong policy presence in Malawi which this institution is ready to cultivate.

The study developed strong ties with academic researchers in child development. In 2020, these included Michelle Bosquet from Harvard / Boston Children's Hospital, and Ting Liao from the Stevens

Institute of Technology, both in the United States. The study can now rely on six different universities and 10 scientists to steer its scientific agenda.

The second overarching deliverable relates to data generation. Despite the COVID-19 outbreak, the project was able to collect pilot data between the end of 2019 and the beginning of 2020. This data was valuable to run preliminary analyses during the second and third quarters of 2020. The report presented below explains in detail the nature of the data that the study collected and the preliminary conclusions we can draw from it. The data collected in this phase was written up in three working papers, which have been submitted for publication to peer-reviewed journals. One of them has been already accepted for publication.

Finally, section 12 of the Project Document annexed to the three-year contract listed several detailed KPIs, without reference to specific years of implementation. We report against all of these in the table below, with an indication of progress made using a traffic light system.

Research Outputs	Detailed Breakdown of Deliverables and KPIs	Progress
		2020
Face-to-face survey data	• Sub-agreement with data firm (or with NSO or CSR)	
	• Enumerator training manual per round of data collection	
	• Validated face-to-face survey module for children's cognitive and non-cognitive development, adapted for different age groups	
	• Yearly reports on data quality (high-frequency check, back-check, spot check) per round	
	• Yearly anonymized data sets including aggregated face-to-face data	
Mobile survey data	• Sub-agreement with mobile survey firm	
	• Manual describing the architecture of the mobile (SMS/IVR) system and its performance	
	• Validated mobile survey instruments to track different dimensions of child and youth development, adapted for different age groups	
	• Yearly anonymized data sets including aggregated mobile-based data	

Biomarker data	<ul style="list-style-type: none"> <li>• Catalogue of tech firms and their offerings</li> </ul>	
	<ul style="list-style-type: none"> <li>• Test report on the piloting activities involving wearables</li> </ul>	
	<ul style="list-style-type: none"> <li>• Training manuals, covering both HSAs and Community Watchers, describing the way in which biomarkers have to be collected and data transmitted to the server</li> </ul>	
	<ul style="list-style-type: none"> <li>• Report summarizing and justifying the set of wearable technologies to be used in the study</li> </ul>	
	<ul style="list-style-type: none"> <li>• Internal note on ethical considerations and acceptability of the wearable devices</li> </ul>	
	<ul style="list-style-type: none"> <li>• Access to data at the frequency and level of aggregating to be determined in agreement with UNICEF</li> </ul>	
Nudges and alerts triggered by Early Warning System	<ul style="list-style-type: none"> <li>• Application program interface (API) that integrates readings from different wearable devices</li> </ul>	
	<ul style="list-style-type: none"> <li>• Open-access codes to prediction model and early warning system</li> </ul>	
	<ul style="list-style-type: none"> <li>• Statistics on nudges sent to participants over the course of the project</li> </ul>	
	<ul style="list-style-type: none"> <li>• Statistics on alerts sent to HSAs and participants over the course of the project</li> </ul>	
Scientific papers	<ul style="list-style-type: none"> <li>• At least 3 publications in high-quality peer-reviewed scientific journals within 3 years of project completion</li> </ul>	
Reports	<ul style="list-style-type: none"> <li>• Yearly reports summarizing activities, main findings, and lessons learned</li> </ul>	
	<ul style="list-style-type: none"> <li>• Bi-yearly financial reports</li> </ul>	
	<ul style="list-style-type: none"> <li>• Final narrative report, including the main findings of the project and recommendations for the next steps</li> </ul>	
	<ul style="list-style-type: none"> <li>• Policy notes, including 'nuts and bolts' of wearables for child development</li> </ul>	
Dissemination of results	<ul style="list-style-type: none"> <li>• Inception workshop in Lilongwe</li> <li>• Intermediate workshop after 18 months</li> <li>• Research symposium in Lilongwe at project completion</li> </ul>	

# Executive summary

Decision-makers need quality data to take informed decisions. In Malawi as in many other developing countries, however, the availability of high quality data on child development, collected at high frequency, remains a challenge.

The Child Development Study is a platform for generating ground-breaking data to study children and adolescents in Malawi. Through a partnership between the College of Medicine at the University of Malawi, the Center for Child Well-being and Development (CCWD) at the University of Zurich and the United Nations Children's Fund (UNICEF), the study is exploring novel and low-cost ways of deploying technologies to collect precise, high-frequency data.

The study began with a pilot in 2019–2020, which tested the use of wearable devices to collect biomarkers on heart rates and brain performance; sensors and mobile phone communication to test behaviour change “nudges” and phone surveys on child health; as well as by face-to-face interviews. The aim was to find out the quality of data which could be obtained using these methods, and how the instruments could be improved for the study.

## Findings

Using three layers of data collection, researchers collected quality data accurately, cost effectively and at high frequency.

A layered approach offers a promising way to meet the overarching goal of the study: to collect data accurately, cost effectively and at high frequency. Once deployed at scale, researchers will be able to investigate child development and identify sudden shocks and general trends to help decision-makers respond in a timely and appropriate manner.

In the first data collection layer, the child wore wearable devices in weekly sessions under the supervision of her or his parents and community health workers or trained volunteers. This yielded data on the child's brain waves (electroencephalogram or EEG) and heart rate (electrocardiogram or ECG). While dependent on careful training, this achieved a high degree of accuracy and the potential to provide a wealth of information.<sup>1</sup> Only 2 per cent of parents reported discomfort with technology in health clinics, and none when the technology was used in the home. Children reported some discomfort, and care is required in taking the technology to scale.

In the second data collection layer, parents received weekly robocall surveys on key aspects of child health and wellbeing. This was an efficient means of collecting precise data at high frequency, and of understanding trends and patterns. Local patterns of mobile phone ownership and use suggest that careful tracking will be required to ensure that data are collected from the right respondent.

The third data collection layer comprised conventional face-to-face interviews conducted weekly and at other specific moments. This generated complementary data, which was useful to validate the other data sources.

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<sup>1</sup> Although the study is still in its inception phase, the signals collected through the devices have been judged to be of high quality by the experts involved by the team. Daniel Robles from Alberta University checked EEG data and Mawi experts, who specialize in this field, checked ECG data.

## Data collection with smart lanterns and facial coding was flawed

Smart lanterns were intended to monitor the child's home environment by collecting data on environmental variables such as temperature and air pollution. However, in real-life conditions, the lanterns could not be recharged effectively and data collection was limited.

Similarly, it was found that the use of facial coding to analyse emotions experienced by children did not collect data of sufficiently high quality.

## The effects of mobile nudges can be measured using sensors

Sensors which measured the duration and frequency of contact were worn by both children and their caregivers. Using these devices, contacts within and between households were measured before and after caregivers were sent "nudges" – short text messages urging them to take actions beneficial to children, such as washing hands with soap. The data collected provided preliminary evidence that caregivers comply with nudges when the content is carefully developed to induce the desired behaviour. Moreover, information shared via text message spreads, with delays, within the village.

## People tolerate the use of technology for data collection

A survey conducted at the conclusion of the pilot broadly showed that the population tolerates data collection using these technologies and that data collection at health clinics does not lead to longer waiting times. All parents reported they were provided complete and accurate information, though only 76 per cent recalled that they were informed that data would be fully anonymized. Only 4 per cent said that they hoped to earn rewards through participation, suggesting that the study incentive structure does not create flaws. About 28 per cent felt that non-participants were appreciative of their participation in the study, pointing to village dynamics that will be taken into account during scale up. Children reported mixed views on data collection, and care will be required to create an environment in which they feel comfortable.

To ensure full alignment with international standards, national conventions and ethical guidelines, a comprehensive legal and ethical framework has been developed.



## Recommendations

- **District authorities should be involved at an early stage** to ensure local buy-in, connect with communities and facilitate roll-out. **Early engagement with the College of Medicine Research and Ethics Committee (COMREC)** is also required to achieve validation and approval of the full study.
- **The collaboration with the College of Medicine, University of Malawi should be strengthened.** A collaborative research agreement for the Child Development Study has been signed between the college and CCWD.
- **A field team of research assistants should be developed to conduct activities efficiently.** In particular, intensive training of community volunteers is key to guarantee data quality when the study is at scale.
- **There is an opportunity to refocus the study to support COVID-19 surveillance.** The piloted technologies can potentially be used to monitor the spread of communicable diseases and analyse contact patterns. Nudges can also provide behaviour change messages to limit the spread of disease.
- **Technologies will be optimized and vendors reconsidered where appropriate.** The pilot suggested that smart lanterns and facial coding applications are ineffective in the context of the study and will not be used. Instead, the tested technologies will be refined and optimized to respond to real-life conditions, with enhanced training for Health Surveillance Assistants (HSAs) and community volunteers.
- **The data collection software and hardware will be reconsidered.** Software that can integrate face-to-face data collection with biomarker data, as well as with other sources of information, will streamline processes in the field. Similarly, solar power banks to recharge data collection tablets will enhance flexibility in the field.
- **The roll-out of the study will be staggered.** The pilot demonstrated the need for in-depth training for field staff, and showed that, for the time being, the field team can implement operations in a limited number of villages at a time. Conditional on approvals by district authorities and COMREC, implementation will begin in five villages and progressively expand to 30 and later on to 180 villages.
- **Mobile nudges will undergo further pre-testing.** While the pilot phase showed that nudges work well, this is dependent on the content of the messages. Extensive pre-testing will be required to assess how nudges can achieve the desired effects.
- **Richer ECG and EEG data will be collected.** During the pilot phase, biomarker data was collected from children at rest. This data will be enriched by collecting data while children are gently stimulated using images or objects.
- **Data on additional biomarkers will be collected.** Further biomarkers will be added such as respiratory rate. The tools will be tested in the early stages of roll-out.

# Introduction

Decision-makers need quality data to take informed decisions. In Malawi as in many other developing countries, however, the availability of high quality data on child development, collected at sufficiently high frequency, remains a major challenge. While household surveys (such as the Demographic and Household Survey, and the Multiple Indicator Cluster Survey) have made available substantial data on the situation of children and adolescents, they provide, at best, snapshots taken at infrequent intervals. This makes it difficult to see problems clearly and to design appropriate solutions. In such situations, decision-making can be like driving through a dense fog in the middle of the night. Decision-makers need more data, and they need it more often.

The Child Development Study is a platform for scientists, researchers and policymakers to generate ground-breaking data to study children and adolescents in Malawi. It is exploring novel and low-cost ways of deploying technologies to collect data, which are not currently available, on children in resource-poor environments and in developing countries such as Malawi. In addition to testing and implementing new means of data generation, the study has developed the first-ever ethics and data protection framework of its kind to protect study participants. This document represents the constitution of the Child Development Study and will have new versions, as the study evolves and new challenges are tackled.

Through a partnership between the College of Medicine at the University of Malawi, the Center for Child Well-being and Development (CCWD) at the University of Zurich and the United Nations Children's Fund (UNICEF), the study brings together researchers from different disciplines and areas of expertise to develop ideas, using the data infrastructure of the Child Development Study, and to explore pathways into policymaking. Collaborations with key ministries and local authorities provide a pathway to channel study recommendations and infrastructure to public bodies.

## Piloting the Child Development Study

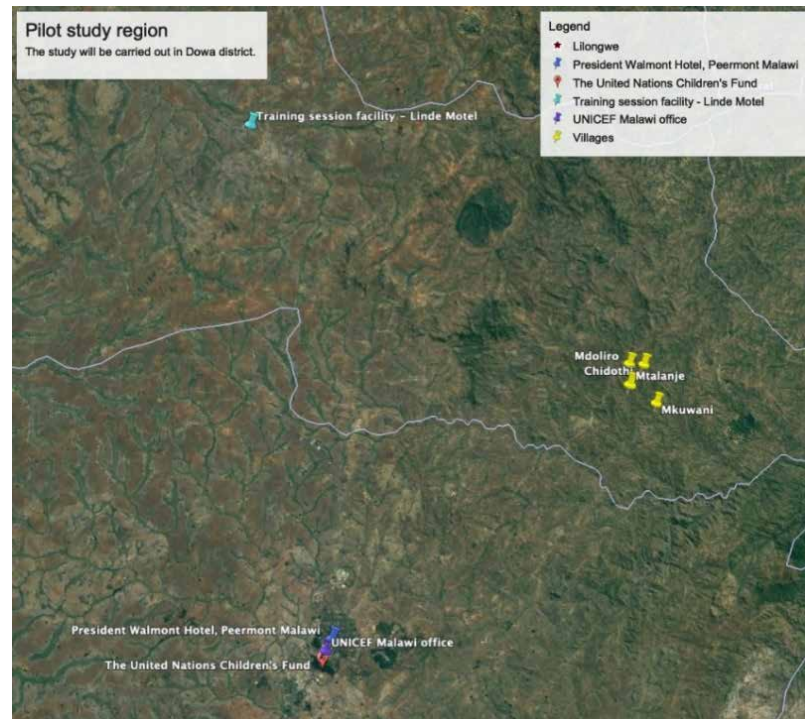


The Child Development Study began with a pilot phase to test its new modes of data collection. This was an important means of assessing the viability of these modes in real-life conditions, evaluating the technologies used, and understanding how people in communities understand and accept new, non-invasive modes of data collection.

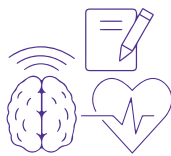
The pilot investigated the use of wearable devices, sensors, mobile phone text messaging and robocalls. Survey instruments were also tested. The aim was to find out the quality of data which could be obtained using these methods, and how the instruments could be improved for the study.

The pilot was conducted in four villages – Mdoliro, Chidothi, Mtalanje and Mkuwani – located in Dowa district, in the Central Region of the Malawi.

Figure 1: The first phase was conducted in Dowa District, Central Region, Malawi



## Measuring key biomarkers



Using wearable technology devices, key biomarkers – brain waves, and heart rate and variability – were collected weekly from sampled children aged 0–5 years in their homes by a locally-recruited community watcher. Community watchers are local volunteers who help the village community health workers, known as Health Surveillance Assistants (HSA) with their work, and are well known to every villager. HSAs also collected biomarker data whenever a sick child was taken to the village clinic. In total, 82 sessions of data collection were performed in the four villages.

Thus, the pilot also tested the feasibility of delegating data collection through wearable devices to HSAs, who have basic training in community health, as well as community volunteers who generally require extensive training to use the devices.

Hand pads were used to collect data on heart rate and variability (electrocardiogram or ECG). Children were instructed to hold the pads in their hands with their thumbs resting on a metal electrode for three minutes. For young children, with smaller hands, clips were used to connect the child's wrist to the electrodes.

Data on brain waves (electroencephalography or EEG) data was collected using headbands placed on the child's head, with two electrodes in contact with the skin, for five minutes. The headband was adjustable to fit the size of the head, and for smaller children could be affixed using a piece of cloth.

ECG and EEG data was stored on a password-secured tablet computer and later uploaded to the cloud.

## Smart lanterns and facial coding



Smart lanterns were used to collect data about environmental variables such as temperature, humidity, and air pollution. These were intended to be kept in the room where the child slept. However, the lanterns were operational only for a few days, as the solar battery could not be fully charged in field conditions.

The study team also intended to collect facial coding data by shooting a 4–5 second video of a child's face and then use an algorithm to detect and analyse emotions. However, the selected application did not perform as expected.

## Mobile phone and face-to-face surveys



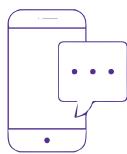
Data collection was supplemented with individual surveys. Using interactive voice response (IVR) technology, popularly known as robocalls, to mobile phones, the study team administered weekly surveys to caregivers.

In total 3,531 calls were sent over five weeks, with a pickup rate of 65 per cent, a completion rate at pickup of 26 per cent and a completion rate after answering the consent question of 59 per cent. These asked questions related to children's medical symptoms, nutrition, water and sanitation, early stimulation and child development

While the biomarker data was being collected from children, HSAs conducted face-to-face surveys using tablet computers. Unfortunately, the data collected by the application was not exploitable because of technical issues. Nevertheless, this was an important opportunity to test the collection of weekly data on children's condition in combination with the biomarker data collection.

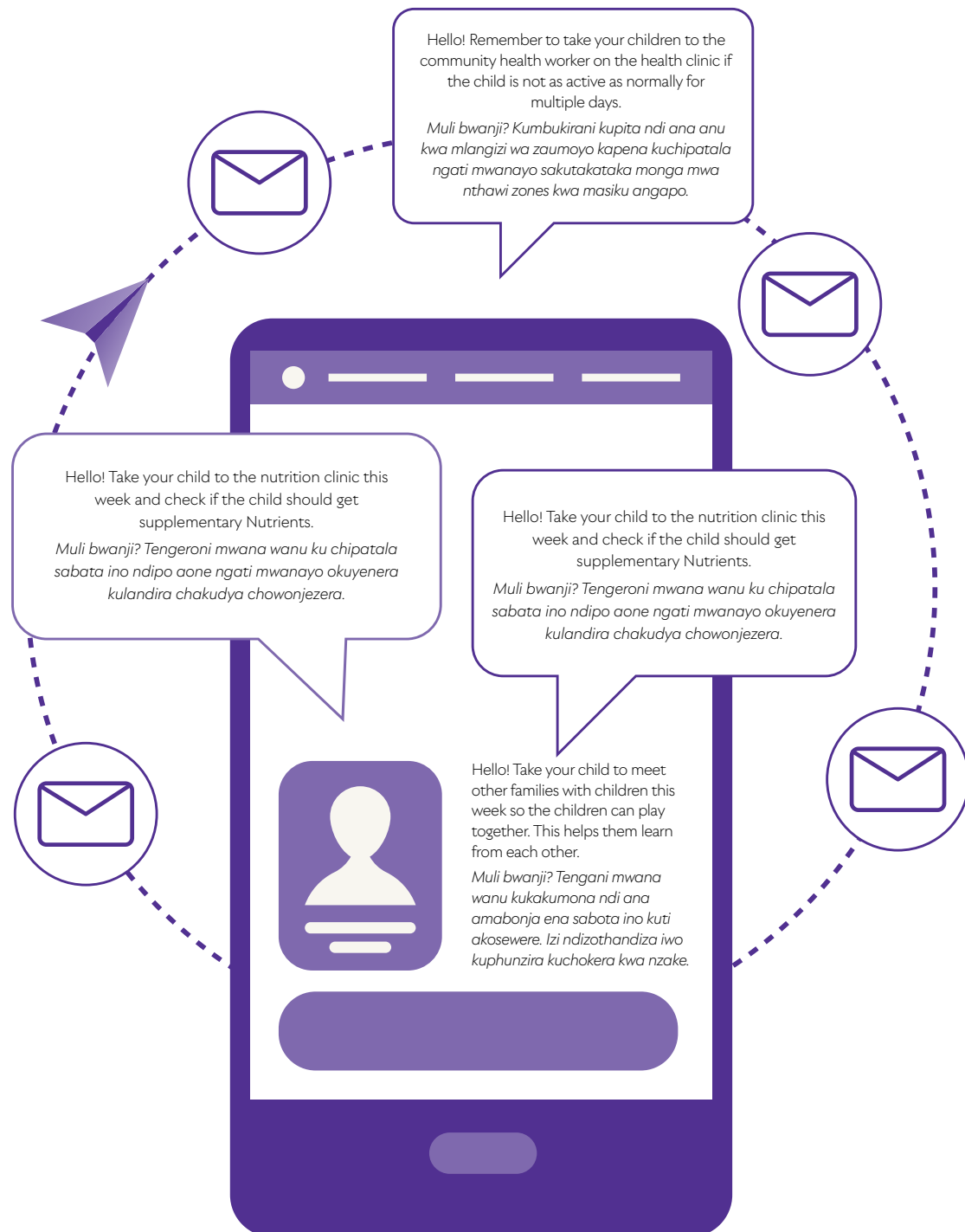
The symptoms reported in weekly surveys, combined with EEG and ECG data collected using wearables, will allow the study team to predict the probability of different disorders.

## Mobile phone nudges

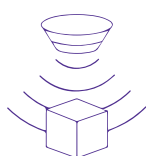


The study team also tested mobile phone "nudges" – messages sent by text message aiming to create new habits and induce behaviour change. These messages were sent to half of the study participants in each village.

Figure 2: Encouragement messages or “nudges” were sent by text to selected caregivers



## Proximity sensors



Proximity sensors were worn by the child and his or her caregiver. A total of 100 sensors were available, limiting the pilot to a single village.

Study participants were asked to wear the bag containing the sensor on the front of their chest throughout the day. The sensors recorded the number and duration of each contact between people wearing sensors, where a contact was recorded

only when two people were face-to-face and no more than 1–2 metres apart. Thus, sensors record only active interactions between participants, for example when a caregiver holds the child. The study will make sure that data from proximity sensors can be associated to other layers of data and thus also give information about the quality of contacts.

In total, 94 participants from 47 families (one child and one caregiver from each family) were selected to wear sensors.

*Figure 3: The proximity sensors registered contact when two sensors faced each other about 1–2 metres apart*



Sensors were also placed at the door of the village clinic to detect if a study participant approached, but these provided only limited data.

The sensors were used to detect contacts within and between household members following a mobile phone nudge. Some households with proximity sensors were not sent nudges, but their contacts were monitored to assess the impact of nudges sent in the wider community.

## End-line survey



At the end of the pilot, a detailed face-to-face end-line survey was administered by trained external enumerators. This included questions that intended to understand if the new data collection methods were acceptable to participants, and if they were comfortable with the data confidentiality arrangements.

## Findings

The pilot phase confirmed and validated the use of innovative technologies to collect high-quality data in Malawi, a country where data is scarce, especially on child development.

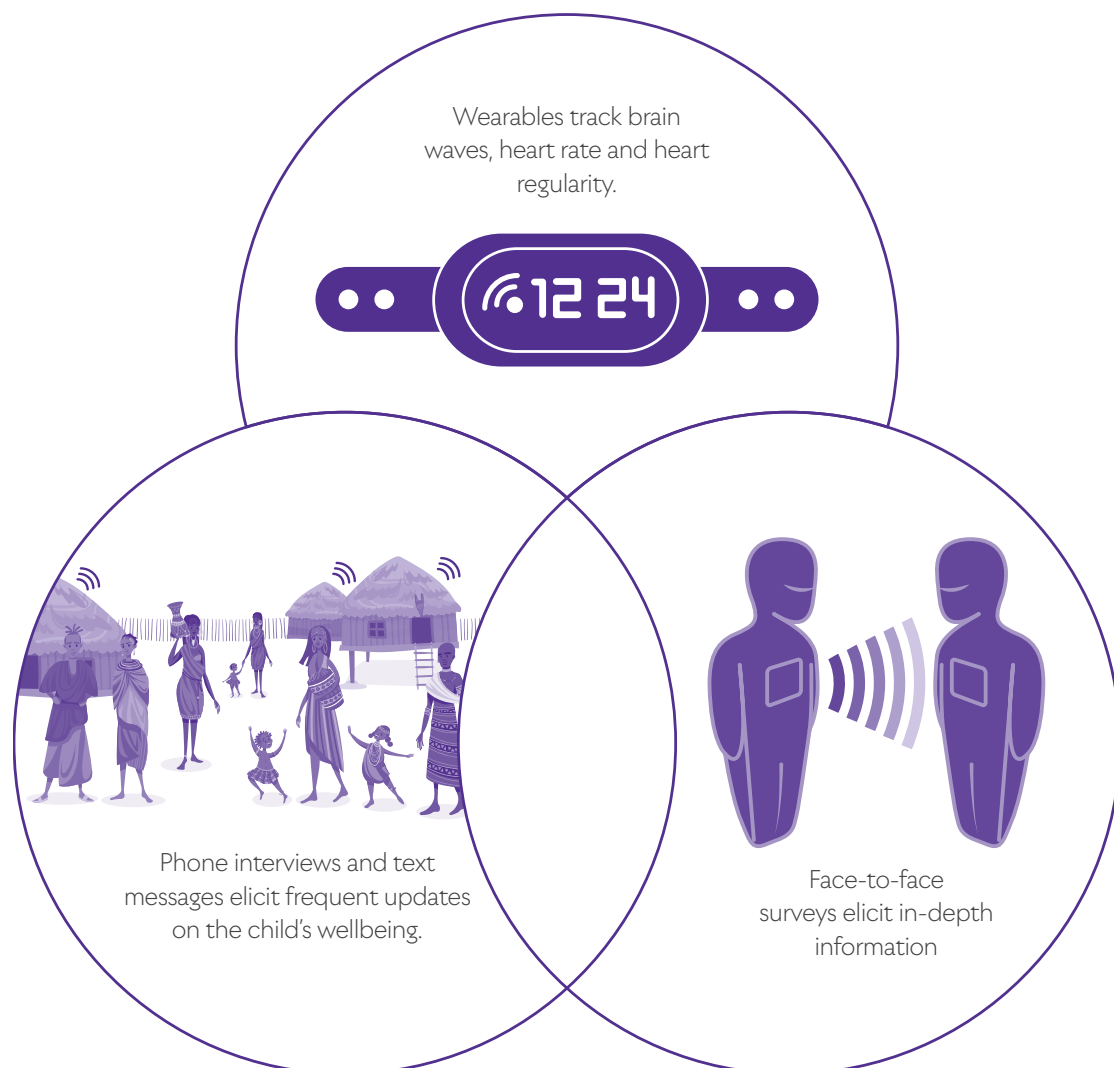
It provided insights on how best to optimize tools used in the pilot for future implementation. In particular, it shed light on the use of three data layers to collect high-frequency data: technologies worn by the child to collect biomarkers, mobile interviews and text messages, and face-to-face surveys adapted to local contexts.

Some of these data streams are well known in Malawi, while others are innovative, such as the collection of biomarkers (such as EEG and ECG) that are not usually collected by the health system. The project also introduces the concept of high-frequency data collection (e.g. weekly), which is not commonly done in Malawi.

The study also assessed acceptance of the technology by participants and found no barriers to the large-scale use of these tools. However, two data collection modes failed to provide data of sufficient quality and will be omitted from the remainder of the study.

Using three layers of data collection, researchers collected quality data accurately, cost effectively and at high frequency

Figure 4: Three layers of data collection



The three layers of data collection were found to be a viable means of collecting quality data, and offer a promising way forward to meet the overarching goal of the study: to collect data accurately, cost effectively and at high frequency. Deploying this at scale will enable the study team to investigate aspects of child development and identify both sudden shocks and general trends to help decision-makers respond in a timely and appropriate manner.

## Wearable devices



In the first layer of data collection, the child wore wearable devices at weekly sessions under the supervision of her or his parents and an HSA or a community volunteer. This allowed the collection of high-quality data on two critical biomarkers for assessing a child's development: EEG using headbands to measure brain waves, and ECG using hand pads to measure heart rate and variability. Data was collected weekly over the course of five weeks from children below five years of age.

This study was the first ever attempt to collect reliable and systematic data using such devices in the context of Malawi. It achieved a high degree of accuracy and the potential to provide a wealth of information, even in a relatively short period of time and with a small sample.

### Lessons for large-scale deployment

Although the volunteers involved had no prior experience with the technologies, careful training ensured they were able to use it successfully. Such training will be critical for the smooth implementation of the main study.

The experience of participants with these new technologies was generally positive. Only 2 per cent of caregivers reported feeling uncomfortable when the technologies were used in their homes, because they were concerned about the outcome of the study. However, none of the caregivers reported discomfort when data were collected at the clinic.

The experience of children was more nuanced and at-scale implementation will require care to ensure a pleasant environment. While 39 per cent and 44 per cent of children reported feeling excitement about ECG and EEG respectively, 51 per cent and 47 per cent were neutral and 41 per cent and 33 per cent were worried.<sup>2</sup> While working with community enumerators and HSAs – figures who are known and trusted in the community – probably enhanced acceptance and reduced reluctance, this approach will need to be validated repeatedly in future phases of the study.

## Mobile phone surveys



The second layer of data collection entailed the use of mobile phones by caregivers. Through robocalls<sup>3</sup> or IVR, surveys, caregivers were asked weekly to respond to questions related to their child's wellbeing. In the four villages sampled during the pilot, 55–80 per cent of participants owned a mobile phone.

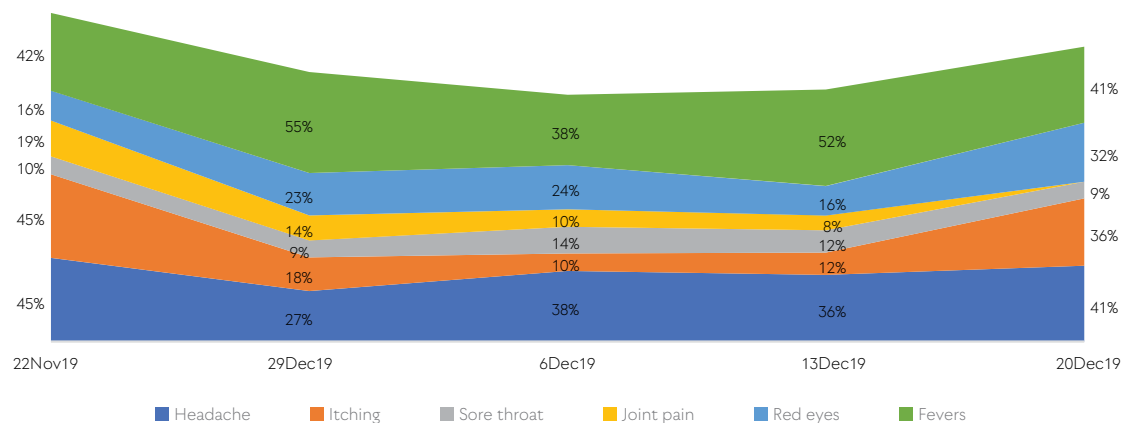
Robocalls were an efficient means of collecting data on children's symptoms at high frequency, and enabled their evolution to be monitored over time. For instance, as Figure 5 shows, during the five weeks of data collection in a single village (sample of 21–31 respondents every week), the incidence of fever was high throughout.

<sup>2</sup> The figures do not add up to 100 per cent as the questionnaire allowed multiple answers.

<sup>3</sup> A robocall is a phone call that uses a computerized autodialer to deliver a pre-recorded message. Robocalls are often associated with marketing campaigns, but can also be used for public-service or emergency announcements. Some robocalls use personalized audio messages to simulate an actual personal phone call.

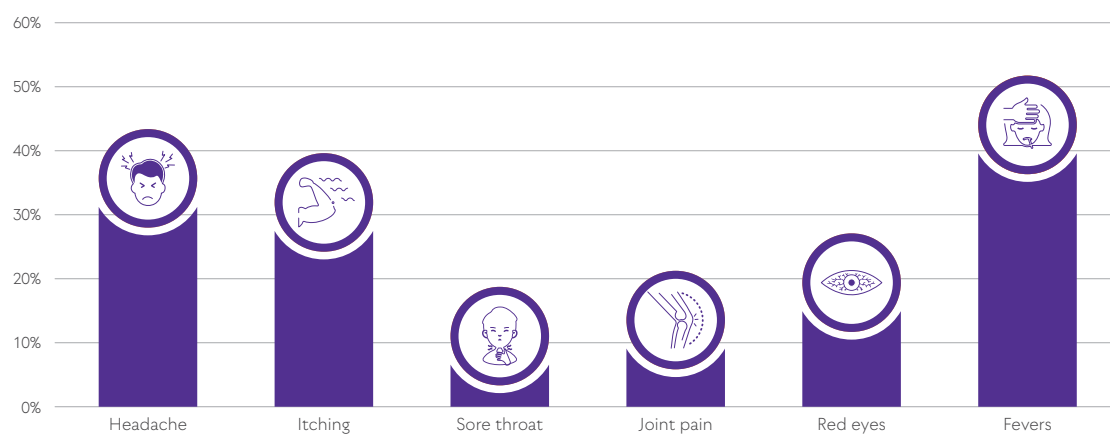


Figure 5: Data on children's medical symptoms can be elicited weekly through mobile surveys



This data collection method also generated precise data, as the error bars in Figure 6 show. The 90 per cent confidence margins of error are relatively small (5–10 per cent).<sup>4</sup>

Figure 6: Symptoms are captured with precision by mobile surveys

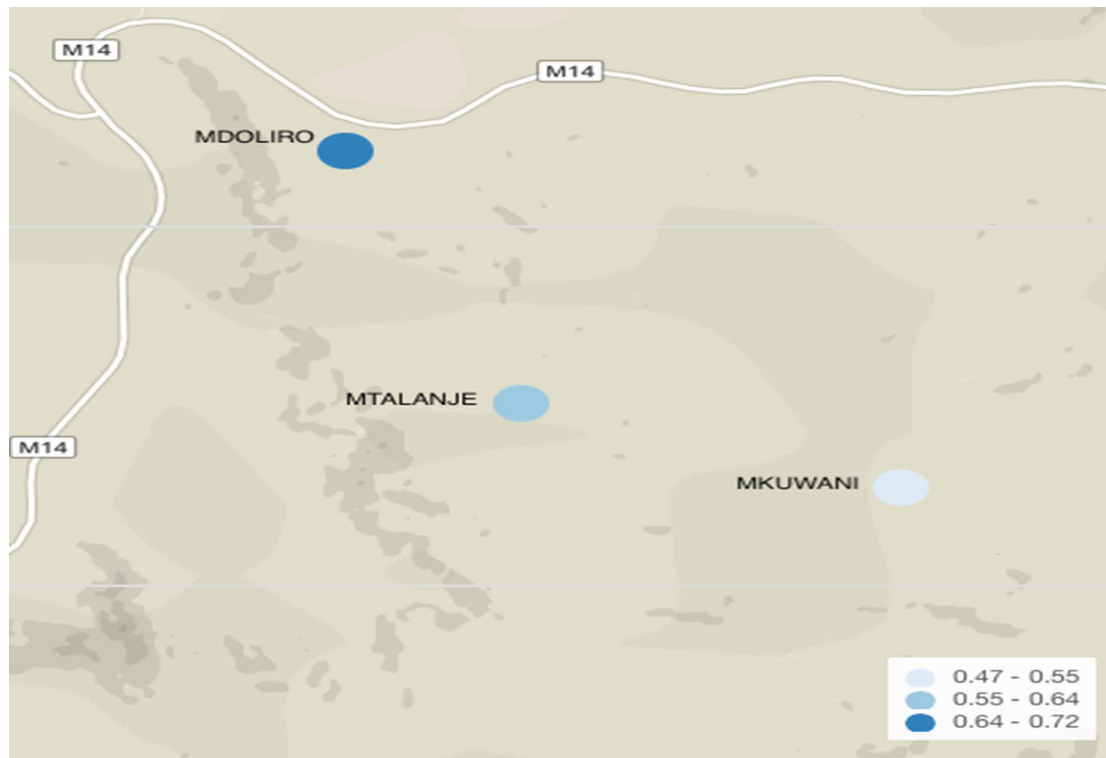


Robocall surveys also enabled researchers to understand other kinds of patterns. As Figure 7 shows, in Mdoliro village a critically high proportion of respondents reported potential low caloric intake for their children.<sup>5</sup>

4 Confidence margins of error describe precision, not accuracy. The margin of error indicates by how many percentage points the results may differ from the real population value. For example, a 90 per cent confidence interval with a 5 per cent margin of error means that if the data collection were to be repeated, 90 per cent of the time the result would be within five percentage points of the real value.

5 Considering the epidemiological setting that those children are exposed to in Malawi, it would not be uncommon to identify clinical outcomes related to Malaria and Pneumonia - where those symptoms may play a role. Moreover, the syndromic approach we proposed in the CDS is not considering an individual-level outcome. However, identifying syndromic clusters at the community level would drive the intervention to signal that an alteration of the epidemiological pattern was affected. We maintain that the suggested symptoms are essential and have been considered in a more extensive study. The results presented in the report came from the mobile survey, which has a limitation in terms of the number of questions that can be administered (i.e. 12 questions). In the future, we will rotate different surveys considering seasonal aspects and disease incidence. We made progress on the syndromic approach's final proposal, which includes diarrhea, vomiting, bleeding, among others. Please see the attached document. Finally, we will continue to involve colleagues at the College of Medicine in discussions about the Malawian context's current epidemiological priorities.

Figure 7: Responses to mobile surveys can be used to understand spatial patterns related to malnutrition



Proportion of respondents who answered "yes" to the question "Over the last 7 days, have you struggled to provide food to your child?"

#### Lessons for large-scale deployment

Some constraints rooted in local phone usage patterns must be mitigated when the study is scaled up. Following local custom, fathers are usually the owners of household mobile phones and may spend extended periods in different houses. They, and the phone, may not be therefore in the company of the child participating to the study. Additionally, caregivers who do not own a phone might give a relative's or neighbour's phone number. Thus, careful tracking will be required to ensure that data are collected from the correct respondent. The study team will develop check-questions to ensure that the same respondent is interviewed over time.

#### Face-to-face surveys



Face-to-face surveying is by far the most widely used method for data collection in developing contexts, but entails higher costs and lower frequency than the other two data collection methods. During the pilot, HSAs completed weekly tablet-based surveys and conducted tests to monitor morbidity and malnutrition among children. These are not possible with mobile phone surveys, and were found to be essential means of generating complementary data and validating the other data sources.

#### Data collection with smart lanterns and facial coding was flawed



During the pilot, two further methods of data collections were investigated: to assess home environments using smart lanterns, and children's facial expressions to detect their emotions. These methods posed technical challenges that cannot be overcome in the short term. For now, they are judged to be inappropriate for deployment at scale in Malawi.

## Smart lanterns



Smart lanterns were piloted as a means of monitoring the home environment. However, these lanterns only recorded data for a few days and then stopped as their batteries ran out of charge. Although solar powered, the energy required to recharge the power banks was not consistent enough for the lanterns to work continuously. Since the required quality of data could not be achieved, and no suitable alternative products were available, the study team decided to put this method on standby.

## Facial coding



This method required HSAs and volunteers to shoot a short video of the child's face. The video itself was not recorded or stored, but was directly analysed by an algorithm to detect the relative locations of facial features and to identify which of the seven universal emotions (anger, fear, disgust, happiness, sadness, surprise and contempt) the child was expressing. This information was meant to be stored and available only to the study team. It was found that this method did not collect reliable data of sufficiently high quality and was abandoned for the next phase of the study.

## The effects of mobile nudges can be measured using sensors



Mobile phones were also used to deliver information: to send messages to study participants and encourage changes in habits, particularly for hygiene or social behaviours. This is especially useful in the context of a contagious communicable disease such as the COVID-19 pandemic, as it can induce behaviour change to prevent the spread of the disease.

During the pilot, the use of mobile phones for real-time programme evaluation was tested and confirmed by analysing how social contacts reacted in response to nudges sent via text message. These social contacts were monitored using small sensors that participants were instructed to wear during the day.

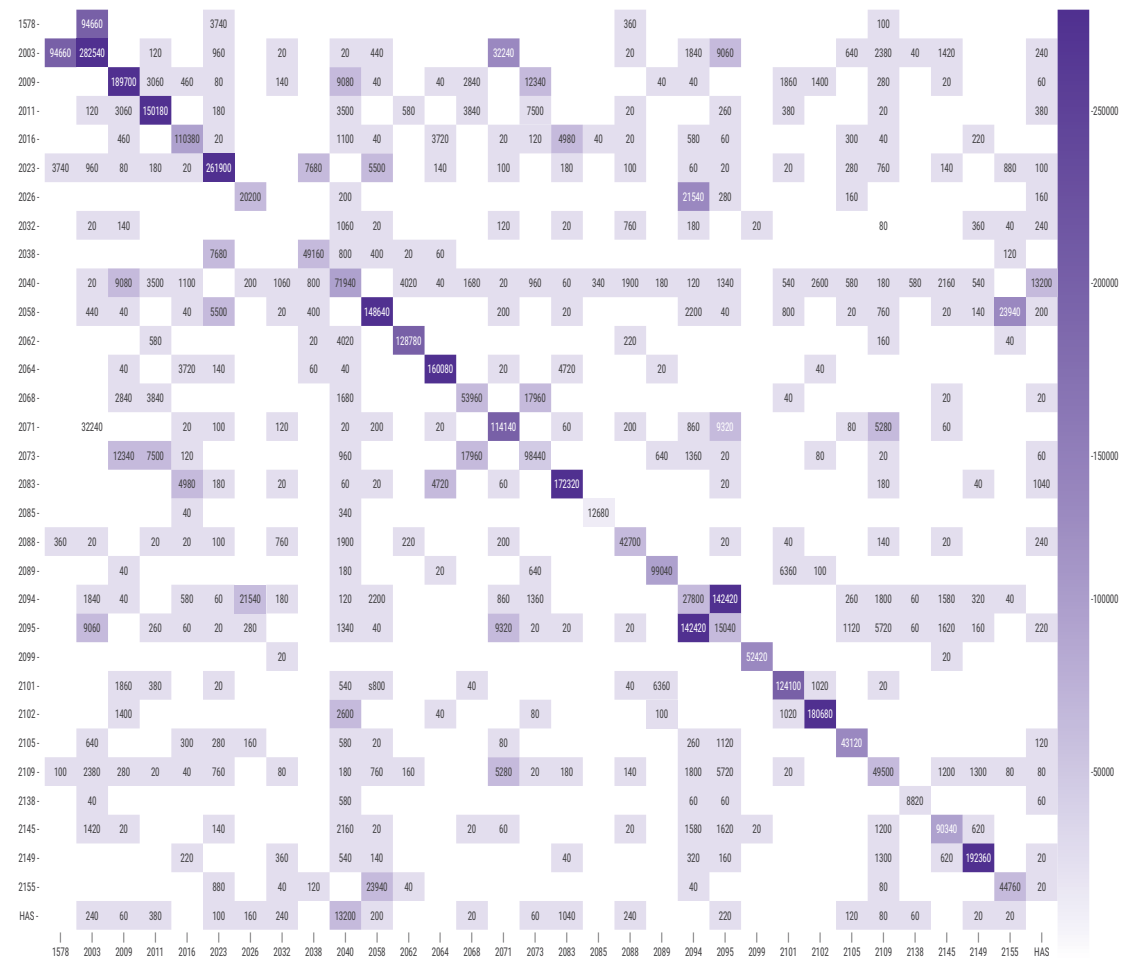
## Intensity of contact between child and caregiver



Figure 8 shows all social contacts within and between households recorded using sensors during the pilot. The left-hand vertical axis and the horizontal axis give anonymized household numbers, thus contacts within households correspond to the diagonal of the matrix. Conversely, the rest of the matrix shows the contacts among members of different households. The darker the colour of an interaction, the longer its duration, i.e. the more intense or high quality it is.

As the figure shows, most interactions happen within households, between the caregiver and the child. This matrix only provides an overview of all contacts that happened within the village in which sensors were deployed, as a subsample of 99 participants were selected to wear sensors. Nevertheless, it is clear that sensors work well to collect data on social contacts.

Figure 8: Social interactions within and between households were recorded by sensors, with the intensity [duration] of contact denoted by colour



## Response to nudges



The sensors enabled the study team to investigate how study participants reacted to mobile nudges via text message and robocalls.

The nudges were in the form of short messages in the Chichewa language, encouraging participants to engage in positive activities such as handwashing, visiting health or nutrition clinics, or meeting other families for children to play together.

Figure 9 shows that the **number** of contacts in the orange “nudge group” spiked after two separate nudges: when study participants were informed about handwashing with soap before eating and encouraged to relay this to other families; and when they were encouraged to meet other families so children could play together. Following both nudges, there was also an increase in the number of contacts in the blue control group. The second nudge (related to meeting other families) saw a less strong increase, which is consistent with messaging encouraging social contacts. This provides preliminary evidence that caregivers comply with encouragement messages.

The second chart in Figure 9 shows that the **quality** of the relationship between the caregiver and the child responds to nudges, as measured by the duration of daily contacts. In the orange nudge group, contact duration spiked on days that nudges were sent to participants, especially for the nudges on handwashing and playing with other children. In the control group, spikes were delayed by a day following these nudges. This is a preliminary indication that information shared via text message might be spreading, with some delay, within the village.

*Figure 9: Number and quality [duration] of contacts between caregiver and child for participants who received a nudge by text message [orange] and those who did not receive a nudge [blue]*



## People tolerate the use of technology for data collection



The deployment of these technologies in Malawi faces legal and ethical concerns mainly related to data ownership and the acceptance by the population of the data collection methods.

All the tools deployed were new to the rural population, and some risked appearing intrusive to study participants, such as the headbands that children had to wear for three minutes to collect EEG data. To this end, the study team surveyed 237 participating caregivers at the end of the pilot about their experience with the study tools. The survey broadly showed that the population tolerates data collection.

**Data privacy:** All surveyed parents reported they were provided complete and accurate information about the study, but only 76 per cent recalled that the data would be fully anonymized and 8 per cent stated that their answers would be kept secret and only read by authorized people.

**Reasons for participation:** All participants reported that their main reason to participate in the study was to learn about their child's health and development, while 28 per cent said that they also wanted to learn about health in the community. Only 4 per cent said that they wanted to earn rewards by participating in the study, suggesting that the study incentive structure does not create flaws.

**Effects on health services:** There were concerns that data collection at health clinics would crowd out resources from HSAs and lead to longer waiting times. This appeared, however, not to be the case. Less than 1 per cent of respondents said that there was more waiting at the clinic. Moreover, no one reported feeling uncomfortable with the use of devices at the clinic. However, about 2 per cent of surveyed parents reported feeling discomfort with data collection at home, as they were afraid about the outcome.

**Perceptions of non-participants:** Survey respondents were asked how they thought people who did not participate perceived them. This is important to take into account as negative outcomes may occur if participants and non-participants change behaviours in response to the perceptions of the other group. About a third of respondents said that they felt non-participants were discouraging (32 per cent), contemptuous (35 per cent) or jealous (39 per cent), while 25 per cent felt non-participants were neutral and 28 per cent felt they were appreciative. These results are in line with village social dynamics which will be taken into consideration when the study is scaled up.<sup>6</sup>

**Children's perceptions:** Around half of children reported feeling neutral towards EEG and ECG data collection using wearables, while around a third also reported feeling worried or excited. These findings suggest that the study team must work with HSAs and volunteers to create an environment in which children feel comfortable with data collection. It is also likely that children will feel increasingly comfortable as the study progresses and its procedures become more familiar.

Most parents also reported dedicating more care and attention to their children. This is a positive finding, as the study aims to induce beneficial parenting habits. However, this may be due to the so-called Hawthorne effect, i.e. the inclination of study participants to change or improve behaviours being evaluated because they are being studied. The study team will examine and validate this trend based on future study activities.

Although the results of the pilot are preliminary, they provide useful evidence to help optimize novel technologies, and their deployment at scale. Overall, a critical element seems to be the inclusion of local HSAs and community volunteers to facilitate the acceptability of the data collection methods and devices.

**Legal and ethical framework:** To ensure full alignment with international standards, national conventions and ethical guidelines, the Child Development Study has developed a comprehensive legal and ethical framework under the supervision of Professor Noelle Vokinger at the University of Zurich. The framework considers legal and ethical principles in a field that is still partly uncharted. This document represents the constitution of the Child Development Study and will have new versions as the study evolves.

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<sup>6</sup> One sub-component of the study will look at this issue from an anthropological perspective. One or two students from University of Zurich are planning to spend few months in selected villages to study more deeply the perceptions of participants and non-participants.

# Recommendations

## Involve district authorities and the ethics committee at an early stage



To work and collect data in the areas where the Child Development Study will take place, it is of primary importance to inform and cooperate with district authorities. The rollout strategy depends on the approval of district authorities to connect with communities, including village chiefs and potential participants. The pilot has proven the role played by local authorities in facilitating study operations on the ground, as well as in formally authorizing the course of the study.

Since the study will be conducted in multiple districts, the study team is prepared to engage with district health management teams and district executive committees in the selected districts, and to work closely with UNICEF Malawi.

While ethics approval was obtained for the pilot from the College of Medicine Research and Ethics Committee (COMREC) at the University of Malawi, validation and approval of the implementation of the full study must be obtained in the first part of 2021. The College of Medicine team, led by Professor John Phuka, is in charge of this important matter.

## Strengthen collaboration with the College of Medicine, University of Malawi



The College of Medicine, University of Malawi, is a key partner for research, thanks to its knowledge and long-lasting experience in leading research in Malawi. The college will provide essential insights to drive research questions and analyse outcomes. In addition, it will facilitate liaison with district hospitals at the sensitization stage as these institutions are known and trusted in local communities. A collaborative research agreement for the Child Development Study has been signed between the College of Medicine and the University of Zurich.

## Build a field team of research assistants



The field team for the pilot was very limited, and consisted of a single research assistant supervised by Professor John Phuka at the College of Medicine, University of Malawi. The research assistant was responsible for organizing and supervising all field activities, from the selection and training of volunteers and HSAs, to deploying enumerators with the necessary material for effective data collection. As the study goes to scale, however, a larger team is required to ensure that activities are conducted efficiently and the necessary training is provided. In particular, community volunteer, who do not have medical expertise, require careful training to guarantee data quality at scale.

To this end, the study team will work closely with the College of Medicine, University of Malawi, and possibly with the research organization Innovations for Poverty Action, to recruit additional research assistants and build a strong team to support field activities. The research assistants will be trained and deployed in the study districts to ensure that quality standards are met by training the people involved in data collection.

All research assistants will be under the direct supervision of Professor Phuka and another Associate Researcher at the College of Medicine. The University of Zurich team will visit the country for short-term field visits.

## Leverage the study to support COVID-19 surveillance<sup>7</sup>



Malawi has not escaped the global COVID-19 crisis. In this new epidemiological context, the systems put in place for the Child Development Study become interesting tools for participatory surveillance.

For example, weekly mobile phone surveys can track symptoms even without face-to-face data collection. Sensors can track contact patterns, while nudges can encourage social distancing and handwashing to prevent the disease from spreading. The Digital Health Department at the Ministry of Health is working on similar surveillance systems, and bridges may be developed between the appropriate ministerial bodies and relevant components of the Child Development Study.

The study team is prepared to work with the College of Medicine, University of Malawi, to set up a meaningful digital disease surveillance mechanism that can also generate knowledge on COVID-19. The team will test a novel digital surveillance system powered by the data generated by the study. This epidemiologic surveillance effort should be deployed under the leadership of the Public Health Institute of Malawi and the Quality and Digital Health Department of the Ministry of Health, the bodies responsible for national COVID-19 surveillance.

## Optimize technologies and reconsider vendors as appropriate



Most of the vendors and providers of data collection technologies tested in the pilot will remain the same for the next phase of the study, other than smart lanterns and facial coding applications which were found to be ineffective. Although the team initially investigated the possibility of finding new vendors offering alternative products to generate the data these were intended to collect, it was decided to suspend this strand of the study.

Instead, the team will optimize the other data sources used. In particular, mobile surveys will be improved to increase response rates, and wearable technologies will be optimized to fit young children and babies.

The deployment of sensors will also be improved to respond to technical issues encountered during the pilot. For example, some participants wore the sensors inside their clothing instead of outside. When this is rolled out, field teams will need to be trained to clearly emphasize the need to wear the sensors outside.

Moreover, sensors were packaged in white fabric bags which participants cleaned regularly, by removing the sensor and washing the bags, potentially affecting the quality of data. This may be addressed simply by changing the colour of the bags to black, which will not stain easily. The team is also testing the possibility of putting the sensors in a protective plastic case without reducing data quality, analysing what is available on the market, and communicating with experimental laboratories at the University of Zurich to develop 3D-printed cases to make the sensors less fragile and more usable.

<sup>7</sup> We agree that at the beginning of the pandemic COVID in kids was an unknown matter, but recent pieces of evidence confirm that clinical manifestations in children are strategic, showing essential findings that we should consider in the context of CDS.



The team will also use fixed sensors at key sites (such as health and nutrition sensors, and handwashing facilities) to track the frequency at which participants visit these locations.

To take the study to scale, the team is in discussion with vendors to deploy larger stocks and provide equipment maintenance over time. The processes and instruction manuals used by field teams will also be improved to avoid technical issues.

## Reconsider data collection software and hardware

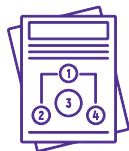


The study team is increasingly focusing on short sessions for face-to-face data collection just before and after data collection using wearable technologies. This will require data collection software that is compatible with the applications used to collect ECG and EEG data. The face-to-face data collection tool used in the pilot, Survey CTO, is not optimal for this integration, and an alternative software, Jotform, is being tested.

Software that can integrate face-to-face interviews with medical tests such as the Malaria Rapid Diagnostic Test or mid-upper arm circumference measurement to assess the nutritional status of children, is also under consideration. The study team is working with the College of Medicine at the University of Malawi to select the appropriate software.

The study team is also investigating the use of chargeable solar power banks for data collection tablets. This will enable greater flexibility on where to charge them, and allow surveyors to complete other tasks while the tablets are charged.

## Stagger the roll-out of the study



Through much of 2020, the Child Development Study was on hold due to the global COVID-19 pandemic. Once field activities resume, the study will implement a staggered roll-out.

The pilot phase demonstrated the need for in-depth preparation and training for field agents, and suggested that the field team will be able to implement operations in five villages at a time. Thus, spacing the start of deployment and ensuring the right amount of supervision at the right time is imperative.

Conditional on approvals by district authorities and COMREC, implementation will begin in five villages and progressively expand to 30 villages, and then to 180 villages.

The Roger Federer Foundation (RFF) was added as a core partner for the roll-out phase of CDS, through their School Readiness Initiative (SRI). The expansion of CDS will focus on the villages served by ECD centers and SRI staff, such that we can leverage the combination of ECD services, local infrastructure for data collection (as every staff member is equipped with a tablet and trained to use it), and weekly home visits in the context of SRI. SRI covers nearly 900 villages across Malawi. We estimate RFF's in-kind contribution to CDS to be in the order of 700'000 CHF.

## Further pre-test mobile nudges



The nudges in the study will target health-seeking, hygiene and parenting behaviours. The pilot showed that such nudges work well, depending on the quality of the messages.

For example, one message was not correctly understood because of the terminology it used: the nudge referred to the “nutrition clinic”, which may not be the term used in that community. In some cases, messages did not always reach the intended individuals as mobile phones are often shared by several household members.

Tailoring messages to the context is critical to ensure impact. Given this, the study team will extensively pre-test how the population responds to nudges, ensuring that they have the desired effect. This will occur in the early stages of the study.

## Collect richer ECG and EEG data



The pilot confirmed that collecting ECG and EEG data at high frequency is possible. This was the first ever attempt to do so in a developing context.

During the pilot, biomarker data was collected from children at rest. This gives valuable information on the health status of the child. This measurement will be continued, however the study team will add also collect EEG and ECG data collection while the child is gently stimulated using images or objects that spark a reaction.

This will greatly enrich the data collected, represent a major improvement to the Child Development Study protocol, and offer unprecedented data on child development. Subsequent phases of the study will be dedicated to further improve the data collection process and its analysis.

## Collect additional biomarkers



The Child Development Study collects a combination of biomarkers that, together, can create an accurate proxy of the condition of a child. With acute respiratory infections the leading cause of death among children below five in developing countries, collecting further biomarkers can help avoid many deaths with low-cost treatments provided in time.

To this end, in consultation with experts on ECG data,<sup>8</sup> the study team decided to selectively introduce a new biomarker, respiratory rate, on a subsample of the study participants (e.g. around 200 participants). This measures the rhythm and form of respiration and can give valuable data on acute respiratory infections, especially pneumonia, bronchitis and bronchiolitis.

The tools deployed to measure respiratory rate is a chest-band that will be tested in the early stages of roll-out to ensure that their implementation is both feasible and yields high-quality data.

<sup>8</sup> In particular, the study team acknowledges the inputs of Dr Michelle Bosquet Enlow (Harvard University), a member of the study's Scientific Leadership Team.

# Resources

## Personnel

Human resources costs related to the UNICEF CH grant totalled approximately CHF 155,000 up to December 2020. These included a fundraising manager, a research manager, two postdoctoral students and two research assistants holding master's degrees.

Given the complexity of the activities required for the projects, with fieldwork in remote rural areas of Malawi and interactions with governmental and international agencies, the research manager dedicated 50 per cent of his time to supporting this project. The research manager was responsible for dealing with field protocol conception, field supervision, stakeholder management, and dissemination of research findings. Each postdoctoral student dedicated 70–80 per cent of their time to the project. One postdoctoral student (Onicio Leal-Neto) is an expert in technology, epidemiology and in combining the two for digital disease detection and early warning systems, with substantial previous experience in Brazil and the United States. The second postdoctoral student (Simon Hänni) focused on the behavioural economics dimensions of the project, and has large prior experience with randomized control trials in Malawi. During the course of 2020, Simon Hänni left CCWD. The plan to replace him is under discussion. The compensation for the principal investigator is covered by the UZH Department of Economics.

In addition, the support of two master's student, employed at 20 per cent of their time, was required, in addition to a fundraising manager based in Zurich, dedicated at 50 per cent of his time to raising funds for the remaining budgetary needs of the project, and to the administrative management of the grants.

## Travel

Since fieldwork was still possible at the beginning of 2020, piloting, survey supervision, and extensive collaboration with local stakeholders and partners across different regions took place. Our research team was in Malawi during the first quarter of the year and one last field trip was also possible in December 2020. The cost of travel by the research team, including flights, accommodation, local expenses and field excursions to villages and communities during 2020, totalled approximately CHF 12,000.

## Data collection

Our extensive collaboration with the College of Medicine of the University of Malawi is paramount to make sure that the considerable field operations of the project are carefully supervised and monitored by local agents and researchers who are knowledgeable about the local context. A cost-reimbursement subaward was established by the Collaborative Research Agreement to cover human resources (such as a full-time research associate based in Malawi), travel expenses and data collection expenses. The amount currently obligated for expenditure under this subaward is CHF 62,700 based on the sub-awardee budget incorporated to the contract.

## Subcontracting costs

A subcontract with Professor Kerstin Noëlle Vokinger was also established. Her Academic Chair supported CCWD with legal and ethical issues. Professor Vokinger is an assistant professor at the Faculty of Law and DSI professor at the University of Zurich. She studied law and medicine in parallel

at the University of Zurich and received her doctorate in biomedical ethics and law. After being admitted to the bar, she completed a master of laws degree (LLM) at Harvard Law School (Cambridge, United States). The support brought by Professor Vokinger during 2020 was compensated with approximately CHF 16,000.

## Available resources

At the end of 2020, subcontracts to specific vendors related to the technological development of key applications for the project were ready to be signed. Due to the COVID-19 outbreak, some components necessary to hardware fabrication and coming from China could not be delivered in time, and the manufacture of those applications and their respective payments were postponed.

In January 2021, with supplies normalized, CCWD paid approximately CHF 73,000 to Bitmanufactory Ltd. for an order of 3,000 proximity sensors and eight data extractors. Additionally, a payment of approximately CHF 92,000 will be made by the end of February to MAWI manufactory for the customized engineering and production of 300 ECG sensors.

Year 1 budget		Resources spent in 2020	
<i>All figures are in CHF unless otherwise stated</i>		<i>All figures are in CHF unless otherwise stated</i>	
	Year 1		Year 2020
<i>Budget Plan</i>		<i>Spending</i>	
Human resources	277,455	Human resources	155,559
Travel	45,800	Travel	11,275
Data collection	307,200	Data collection	62,700
Monitoring and system creation	141,000	Sub-contracting costs	16,582
Equipment	368,100	Other sources of direct costs	20,803
Conference and events	19,000	<b>TOTAL</b>	<b>266,919</b>
Software development and maintenance	55,600		
<b>Subtotal</b>	<b>1,214,155</b>		
Overheads (5%)	60,708		
<b>TOTAL</b>	<b>1,274,863</b>		
	<b>Year 1</b>		
<b>REQUESTED FROM UNICEF CH</b>	<b>497,800</b>		

**Year 2 budget**

*All figures are in CHF unless otherwise stated*

	Year 2
<i>Budget plan</i>	
Human resources	283,004
Travel	46,716
Data collection	227,664
Monitoring and system creation	125,460
Equipment	41,962
Conference and events	14,280
Software development and maintenance	15,912
<b>Subtotal</b>	<b>754,998</b>
Overheads (5%)	37,750
<b>TOTAL</b>	<b>792,748</b>
	Year 2
<b>REQUESTED FROM UNICEF CH</b>	<b>499,756</b>

**2021 costs outlook**

*All figures are in CHF unless otherwise stated*

	Year 2021
<i>Spending in Jan/Feb 2021</i>	
Proximity sensors – Bitmanufactory	73,000
ECG sensors – MAWI	92,000
Human resources	23,756
<b>Expected Spending</b>	
Human resources	197,268
Travel	33,720
Data collection	200,100
Sub-contracting costs	143,750
Equipment	112,460
Software development and maintenance	107,000
<b>TOTAL</b>	<b>983,054</b>

## Next steps

The study team is exploring the following projects for the next phase of the Child Development Study:

- Combining proximity sensors and mobile nudges to understand networks in villages
- Conducting an ethnographic study on the use of digital health in a Malawian community
- COVID-19 monitoring based on crowdsourced data
- Developing an ethics and legal framework for research on child development and wearables
- Using behaviour change communication on handwashing to reduce morbidity and improve child wellbeing
- Studying how children react to stimuli using tablet-based EEG and ECG devices.

## Leadership team and research products

The Child Development Study is steered by a scientific leadership team to ensure the research that emerges is of the highest standard. The team comprises:

- Chair: Guilherme Lichand (University of Zurich)
- Child development and nutrition: John Phuka (University of Malawi)
- ECG data: Michelle Bosquet Enlow (Harvard University)
- Social impacts of new technologies: Annuska Derks (University of Zurich)
- User experience of wearable technologies: Ting Liao (Stevens Institute of Technology),
- Proximity sensors: Daniela Paolotti (Institute for Scientific Interchange Foundation)
- EEG data: Daniel Robles (University of Alberta)
- Legal and ethical issues related to data privacy and ownership: Kerstin Volkingher (University of Zurich)
- University of Zurich postdoctoral researchers: Simon Hänni (economic impacts of UNICEF programmes using high frequency data); Onicio Leal-Neto (digital disease detection and early-warning systems).

All scientific articles will be published in open access and will likely have at least one Malawian co-author. Scientists at the College of Medicine, University of Malawi are also participating in the study and developing their own streams of research. A doctoral researcher at the College of Medicine will develop a new stream of research within the Child Development Study under the supervision of Professor John Phuka.

- O Leal-Neto, S Hänni, J Phuka, L Ozella, D Paolotti, C Cattuto, D Robles, G Lichand. "Using wearable devices and mobile surveys for child and youth development in Malawi: An implementation study of high-frequency data collection based in multi-modal approach." [Approved by JMIR]
- L Ozella, S Hänni, G Lichand, D Paolotti, O Leal-Neto, J Phuka, M Tizzoni, C Cattuto. "High resolution proximity of children and adolescents for social networks understanding in poor settings." [Under preparation]
- G Lichand, K Volkingher, O Leal-Neto, S Hänni, L Ozella, D Paolotti, C Cattuto, J Phuka. "Child and Youth Development Study: A research protocol for mixed data collection methods and ethical framework." [Under preparation]



## Contact

College of Medicine, University of Malawi. [www.medcol.mw](http://www.medcol.mw)

UNICEF Malawi. [www.unicef.org/malawi](http://www.unicef.org/malawi)

Center for Child Well-being and Development. [www.ccwd.uzh.ch/](http://www.ccwd.uzh.ch/)

University of Zurich, Department of Economics. [www.econ.uzh.ch/en.html](http://www.econ.uzh.ch/en.html)



University of  
Zurich

Department of Economics



CCWD  
CENTER FOR CHILD WELL-BEING  
& DEVELOPMENT

