WAAA! The conception and rapid development of a wearable for good technology

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WAAA! The conception and rapid development of a wearable for good product

Worldwide, 1 million babies die on the day they are born and one third of all births take place without the assistance of a skilled healthcare worker (UNICEF, 2018). This case study describes the conception and development of a Wearable, Anytime, Anywhere, APGAR designed to address neonatal mortality. WAAA! was originally conceived as a part of a six hour academic innovation challenge. The event brought together impromptu teams with the brief to develop an innovation that would address maternal and/or infant wellbeing. The WAAA! team synthesized their disciplinary expertise in design, business, engineering, computer gaming and public health to conceive a soft patch surveillance system that specifically monitored APGAR signs. The WAAA! team became a finalist in UNICEF's Wearables for Good challenge. A two-week development and mentoring programme in conjunction with Philips, IDEO, ARM and Apple advanced the raw idea into a comprehensive system, service and product solution consisting of APGAR education materials, a gateway communication unit and two-part wearable.

Keywords: SDGs, APGAR, UNICEF, neonatal mortality, frugal innovation

Subject classifications: 130: Design practice & 200: International issues in design

Introduction

This paper describes the rapid conception and development of a wearable for good technology designed to reduce neonatal mortality. It demonstrates three important points for further consideration: the value of time-limited open innovation competitions to catalyze academic engagement with sustainable development goal challenges, the value and effectiveness within interdisciplinary collaboration and a need to prioritize *satisfice* solutions (Simon, 1956). This study traces an intense programme of applied research and development consisting of two phases: the first a rapid meeting lasting six hours followed by 14 day period of development.

Background

The Honeypot was a two-year initiative introduced at the University of Huddersfield in 2014 and funded by the Royal Academy of Engineers. The primary objective of Honeypot was to foster entrepreneurship and stimulate interdisciplinary working between art, design and engineering students. An online platform provided a secure environment where communities of students were able to spin-in specific competencies and skills to advance personal projects. Equally, the platform also provided opportunities for enterprise-minded students to respond to designated challenges whereby the best ideas received seed funding to advance the development of their concept. To expand the reach and impact of Honeypot, a six-hour innovation challenge involving academics from art, design, engineering and business was held on 7th July 2015. On the day teams were randomly formed. The theme of challenge that was revealed on the day called for interventions and innovations that could improve the health and wellbeing of new mothers' and their babies- in six hours. The team that is the focus of this paper combined their disciplinary expertise in serious games, health and well-being, global healthcare innovation, and sustainable communities and social enterprise. The team identified three key drivers that would steer our critical thinking and approach on the day:

global challenges, frugal innovation and the application of wearable technologies that supported the self-management of health. A collective literature review quickly identified influential statistics and strategies:

- Over one million babies die on the day they are born (Save the Children, 2013)
- Sustainable Development Goal 3.1- to reduce the global maternal mortality ratio to less than 70 per 100,000 live births by 2030
- Sustainable Development Goal 3.2- to end preventable deaths of newborns and children under 5 years of age
- UNICEF's Committed to Child Survival-A Promise Renewed (2014a) and Every Newborn Vision (2015) both articulated a need to end of preventable newborn deaths due to inadequate/ non-existent care or the dearth of resources.

After a further period of investigation, market analysis and discussion, it was agreed that a Wearable, Anytime, Anywhere, APGAR device (WAAA!) could be a promising conceptual solution to these challenges. Conceived in 1952 by Virginia Apgar, the APGAR observation tool is used throughout the world to quickly assess the health of a newborn child and to determine if immediate medical care is required. APGAR is an acronym for Appearance, Pulse, Grimace, Activity and Respiratory. These simple assessment parameters are applied one to five minutes after birth. Kayemba Nalwadda et al (2013) suggests that despite its widespread use there is great variability in its application that can lead to incorrect assumptions or neonatal danger signs being missed by Community Health Workers (CHW) or Volunteer Health Teams (VHT). Strange and Scheerlinck (2014) suggest inconsistencies in medical training is a key factor that results in misdiagnoses. The mounting scientific evidence pointed towards a need for a more objective, reliable and systematic method of applying the

APGAR method. The proposed intervention was for a system solution that effectively provided a birth attendant by proxy in locations where access to a healthcare professional is limited. A wearable soft patch sensor technology would to identify warning signs associated with poor pulse and respiration, while new APGAR education materials improved techniques for the surveillance of grimace, appearance and activity. The detection of a usual rhythm pattern by the wearable sensors would trigger a SMS text message alert to be sent directly to the mobile phone of a community health worker to prompt an immediate response. **[FIGURE 1 PLACE NEAR HERE]** A two-minute explanatory film was produced to support a competitive pitch to the challenge's judging panel that included individuals from the University's senior management team and Stefan Gabriel, Vice President for Innovation at 3M. On the day, the WAAA! team's innovation was judged to be the overall winner and secured £10,000 prize fund to support the advancement of the research and the project.

UNICEF's Wearables for Good Challenge

Unknowingly, the WAAA! discovered shortly after the conclusion of the University internal challenge that UNICEF had launched a global Wearables for Good Challenge in conjunction with the UK's leading technology company ARM, and the global design consultancy-Frog Design. This call to action posed a familiar question, 'Can innovative, affordable solutions make wearables and sensor technology a game-changer for women and children across the world?' Framed around UNICEF's strategic pillars, the challenge called for cost-effective, low-powered, rugged and durable and scalable solutions that specifically responded to the themes of: alert/ response; diagnosis/ treatment / referral; behaviour change and data collection/ data insight. The competition was structured into three distinct phases: phase one consisted of an initial application phase to determine ten finalists; phase two involved an intensive development/ mentoring phase lasting two weeks; and a final business incubation phase for the two winning teams lasting four months. This was a fortuitous opportunity to test the originality of the WAA! concept and thinking through an international peer-review process.

Phase one

An initial application form requested entrants to clearly articulate the strategic fit and the context of the submitted idea, the feasibility of the technology underpinning the idea and to identify its key hardware and software components. These considerations were used to inform a scorecard assessment process to filter submitted ideas down to a top ten. Given the time constraints of the Honeypot challenge, we recognised the inherent shortcomings and omissions were recognised in our original concept. To strengthen our application and to refine our thinking, a comprehensive review of the wearable market was undertaken, a detailed technical investigation and completed case studies reviews to identify the barriers that humanitarian innovations encounter that influence their traction, adoption and implementation at scale. Findings determined with greater precision the necessary system requirements, technologies and components to support the design and development of a feasible solution for a low-economic country context. Entry materials now articulated a WAAA! system that incorporated proven, low-cost and low power, commercially available wireless network technologies- including sensor patches, an XBee radio and gateway devices and a basic mobile phone. The following commercialization issues were identified:

- Clinical efficacy: data quality, reliability and calibration
- Cost, usability, practicality of device
- Data security: privacy and ownership
- Conformity with manufacturing and product standards as described by the Global Harmonisation Task Force

In late August 2015, UNICEF announced that WAAA! had been selected as one of ten finalists to progress to a Phase 2. A 12-week application window had attracted 1853 registrations from 65 countries, which resulted in 250 entries being submitted from 46 countries. Geographically, the selected project teams resided in Vietman, USA, India, South Korea, East Africa, Nigeria, and Netherlands. Uniquely, WAAA! was only UK representative. The ten finalists proposed wearable devices that spanned a range of thematic issues: record keeping, medical histories, tracking of medication; risk assessment tools; body surveillance/ monitors; compliance of hand washing and the purification of water. A deeper interrogation of these products revealed that their market and technological readiness was significantly more advanced than ours and that the WAAA! team were only academic team to reach the final. **[FIGURE 2 PLACE NEAR HERE]**

Phase Two: week one

It must be noted that the timing of the two-week development phase was not ideal as it coincided precisely with the first two-weeks of scheduled teaching in semester one. The coaches designated to support us in this phase were Quirine van Voorst, Director of Group Strategy at Philips, Adam Reineck Global Design Director at IDEO and mentors from Apple and ARM. Given the brevity of this phase, and the distance we needed to travel to deliver a compelling and competitive submission, additional specialist academic expertise was recruited to the team to support aspects of electronics and embedded systems and the production of final assets that included physical prototypes, film and animations, Systems thinking guided hierarchal methodological approach to maximise the robustness of our final deliverables: strategic, system, service and product. Activities in week one concentrated on determining our strategy, system architecture and service design, while the week two focused upon the design, usability, and technical feasibility of system technologies.

The strategy was deliberately grounded in a real contextual need. In Africa only half of births take place without the assistance of skilled health personnel (WHO, 2018). The Government of Uganda and Ministry of Health set renewed national targets to address the challenge associated with one midwife per 7000 births with the ambition to improve the percentage of postnatal care for mothers within 48 hours from 33% to 70%; and the percentage of postnatal care for newborn within 48 hours from 11% to 70% (Republic of Uganda, 2013). This validated our proposition for ‘birth attendant by proxy’ technology that could improve health outcomes in a context where personnel and resources are limited. In this context, the primary and secondary benefits of such an intervention were perceived to be:

- Improved survival rates
- Enhanced understanding (volunteer health teams (VHT), community health workers (CHW), parents) of new born health signs and checks
- Timely alerts, intervention and support
- Parental peace of mind
- Prompt and increased birth registration
- Data collection resulting in better informed public health and resource allocation decisions

To support the development of an appropriate system/ service architecture a series of in-depth reviews were undertaken. These investigated CHW and VHT infrastructures: strategies, operation, training, costs to ensure to ensure alignment within existing in-country VHT and CHW networks and practices (Pathfinder, 2015; The Earth Institute, n.d.). In addition to this, detailed case studies scrutinized UNICEF's own innovation programmes that led to the successful deployment of MobiStation, BackPack Plus, U-Report and Arida. These initiatives, together with a review of We Care Solar's Solar Suitcase project, yielded valuable insights to the operational challenges experienced by stakeholders, providers and end users. These proven models provided the WAAA! team with a roadmap for implementation would informs our future decision-making -thereby de-risking the potential failure of our final outcomes (UNICEF 2011; Frog, 2013; UNICEF Supply Division, 2014; We Care Solar, 2014; UNICEF, 2015). Our findings arising from this body of work also served to establish to a service blueprint that articulated the system components, the points of interaction and clarified the beneficiaries arising from its moments of need, use and impact. **[FIGURE 3 PLACE NEAR HERE]**

Phase Two: week two

The focus of work in week two centred upon the design, development and technical resolution of a gateway unit and wearable, together with the production of assets that included prototype devices, a business model canvas, project animations and studio photography. Drawing upon the University's partnership with 3M, key personnel with responsibilities for corporate research, healthcare market and electronics and embedded systems were consulted. It quickly became apparent that the high consumable costs associated with a soft patch sensor solution and the use of skin-kind adhesives would deter future stakeholders. Armed with this knowledge the team discarded its original typology in favour of a reusable solution. The team's on-going activities was also steered by the universal principles of acceptability, appropriate, accessibility and availability as used by United Nation's Committee on Economic and Social Council to assess projects and their minimum standards of health service delivery (United Nations, 2000). The acquisition of geographically appropriate anthropometric data guided a two-day programme of iterative 2D and 3D development that explored a range of attachment configurations for the wearable device. The optimal solution was an expandable silicone band that secured a robust product unit that encapsulated both sensor circuitry and radio communication technologies that performed the following tasks:

- Monitor ECG signals and determine heart rate
- Monitor expansion of the chest cavity to determine respiratory effort
- Sample heart rate and respiratory effort at the interval required by the APGAR protocol and determine whether they remain in safe limits
- Wirelessly connect to the ‘gateway’ unit in the event of an alert condition
- Maintain a low power, dormant state to save power at all other times.

The design of our two-part wearable promote new behaviours, improved infection control practices as the band was designed to be detached and washed, while prolonging its longevity and sustainability as the separable sensor unit to be ungraded or replaced if it became faulty (Howitt et al, 2012) **[FIGURE 4 PLACE NEAR HERE]**

Working in harmony with the wearable, a‘gateway’ unit provided a bridge between the sensor and a cellular network to allow alert conditions to be communicated to a VHT or CHW via a SMS text message. **[FIGURE 5 PLACE NEAR HERE]**

Our technical analysis identified that the data payload available in a text message is low but sufficient to supply a timestamp, location, alert type and sensor data (heart or respiratory effort rate). Additionally, the ‘gateway’ could respond to incoming texts sent by a health worker to cancel false alarms. The system was also engineered to operate across a five-day deployment period with an active monitoring service provided for three consecutive days- the time when newborns are at most risk. As part of our final project assets, the team conducted both a market and cost analyses. Our research identified a potential market size of 1,300,000 CHWs worldwide with 890,000 located in India and 83,000 in Uganda- the target country for our intervention. Our route to impact strategy proposed a two-stage process. A first stage suggested the development of small-scale pilot in partnership with UNICEF's Innovation Lab located in Uganda. To support this pilot, 100 first generation prototype units would be constructed, evaluated and tested. The use of additive manufacturing technologies and off the shelf OEM components minimized initial costs and engineering effort, to deliver a unit price of $134.31- equivalent to $3.31 per birth. Speculatively, a second-generation system was costed to facilitate the scaling up of a successful pilot. A fully engineered solution comprising of bespoke hardware and software to support such a product launch could deliver a unit cost of $29.37- $0.32 per birth.

A comprehensive asset pack was submitted on the 14th September 2015 for a final round of judging. A judging panel led by UNICEF, ARM and Frog also consisted of leading technologists, design and media experts from around the world. A scorecard process evaluated the finalists' submission materials against five performance criteria: feasibility; design; innovation in their focus area; business potential and overall potential. Our project animations can be accessed at: https://vimeo.com/141251827 and https://vimeo.com/142363565

The winners of UNICEF's first wearables for good challenge was announced in Helsinki on the 12th November at Slush 2015- the world's leading start-up event for global tech.

entrepreneurs. The first award winner was SoaPen, a wearable soap-crayon that when applied stimulated good hand hygiene practices among school children aged three to six. Khushi Baby was announced as the second award winner- a data-storing necklace device worn by infants that kept a digital record of their medical history such as immunization records.

Discussion

From the team's perspective, success can be measured by our own collective achievement which have since been corroborated by UNICEF and the team's mentors. The group came together as individuals; worked collectively and effectively as a team on an unfamiliar challenge and were able to accelerate a raw idea into an advanced level of feasibility, design and technical completeness in a very compressed timeframe. While innovation sandpits are an excellent way to promote interdisciplinary work, they are also valuable forums for building long-term professional alliances and allow participants to travel outside their traditional disciplines and patterns of thinking. The time constraint is a crucial factor too. The six-hour timeframe the group was originally confronted with was a catalyst for legitimacy; cutting out unnecessary preambles and more importantly it was a stimulus for risk-taking. For my non-creative colleagues, it introduced a different way of working while also developing numerous transferable skills that have since been applied within new roles and projects to address aged-old problems.

The project outcome serves as a timely exemplar to those seeking to engage with global healthcare challenges and social innovation. While strategic thinking and early consideration of scale and implementation is advisable from the outset, even if these de-risking ingredients are present, they do not necessarily guarantee traction with future stakeholders. On reflection, two factors prejudiced our good judgement during an intense phase of development. Firstly, the persuasive influence of UNICEF's sponsoring partner

ARM- a world-leading semiconductor IP company that touches 70% of the global population with its technologies. Clearly to become a top ten finalist, the choice of geographically appropriate technologies and low-cost platforms must have resonated with the reviewers. However, the team became unconsciously married to this approach during our development phase because of this relationship - after all a wearable implies a technological solution? The second factor was time. The pressure of delivery encouraged risk-taking but also blinded the team in an equal measure. An obvious factor was missed - the high development and investment costs associated with bringing such a product to market. APGAR education opposed to a technological system would deliver the greatest impact to the end user.

A *satisfice* solution was demanded with the foresight to sacrifice technology in favour of an educational solution that challenged our preconceived ideas of a wearable. Inspired by Mandela (2003) who articulated that 'education is the most powerful weapon which you can use to change the world' has become our new strategy moving forward- an APGAR aid that educates expectant parents of the risks and signs associated with newborns in distress.

Disclosure statement

No potential conflicts of interest are known.

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Figure captions

Figure 1. Original WAAA! concept visualisation

Figure 2. Screenshot of UNICEF's wearables for good challenge finalists

Figure 3. WAAA! system components, points of interaction and beneficiaries

Figure 4. 3D CAD visualization of a two-part wearable design

Figure 5. WAAA! system components: gateway unit and two-part wearable