

Worlds apart: a socio-material exploration of mHealth in rural areas of developing countries

A socio-material exploration of mHealth

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Abstract

Purpose – The implementation of mobile health (mHealth) in developing countries seems to be stuck in a pattern of successive pilot studies that struggle for mainstream implementation. This study addresses the research question: what existing health-related structures, properties and practices are presented by rural areas of developing countries that might inhibit the implementation of mHealth initiatives?

Design/methodology/approach – This study was conducted using a socio-material approach, based on an exploratory case study in West Africa. Interviews and participant observation were used to gather data. A thematic analysis identified important social and material agencies, practices and imbrications which may limit the effectiveness of mHealth apps in the region.

Findings – Findings show that, while urban healthcare is highly structured, best practice-led, rural healthcare relies on peer-based knowledge sharing, and community support. This has implications for the enacted materiality of mobile technologies. While urban actors see mHealth as a tool for automation and the enforcement of responsible healthcare best practice, rural actors see mHealth as a tool for greater interconnectivity and independent, decentralised care.

Research limitations/implications – This study has two significant limitations. First, the study focussed on a region where technology-enabled guideline-driven treatment is the main mHealth concern. Second, consistent with the exploratory nature of this study, the qualitative methodology and the single-case design, the study makes no claim to statistical generalisability.

Originality/value – To the authors' knowledge, this is the first study to adopt a socio-material view that considers existing structures and practices that may influence the widespread adoption and assimilation of a new mHealth app. This helps identify contextual challenges that are limiting the potential of mHealth to improve outcomes in rural areas of developing countries.

Keywords Healthcare, Developing countries, Mobile technology, Socio-materiality, Practice, mHealth, Rural healthcare workers

Paper type Research paper

Introduction

Continuous improvements in wireless technologies and mobile devices have extended the reach of digital systems (Barnes, 2002; Zhang and Adipat, 2005; Lin and Bhattacharjee, 2010; Chun *et al.*, 2013; Ying *et al.*, 2018). This has allowed organisations across a range of domains to explore new products, services and user/consumer channels (Lu *et al.*, 2005; Scornavacca

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and Barnes, 2008; Chen *et al.*, 2012). One of the most profound changes has been the use of these technologies in mobile health (mHealth) initiatives; initiatives that extend health services to poorer areas that are often neglected by traditional systems, notably people living in rural areas of developing countries (Chetley *et al.*, 2006; Kahn *et al.*, 2010; Aryee, 2014).

Mobile technologies have diffused through developing countries far quicker than many expected (Kahn *et al.*, 2010; Furuholt and Matotay, 2011). This is largely because mobile technologies do not require the same level of individual investment or supporting infrastructure (Asangansi and Braa, 2010; Furuholt and Matotay, 2011). Mobile technologies do more than allowing users to make calls and receive multimedia messages; they also provide access to the web. The use of mobile technologies has become engrained in the day-to-day life of many people in developing countries (Asangansi and Braa, 2010; Mwakaje, 2010). Thus, it is logical that healthcare delivery should build upon these technologies to extend care services into isolated rural areas of developing countries (Braa *et al.*, 2004; Avgerou, 2008; Kahn *et al.*, 2010). This lessens the burden on individuals to travel to urban centres for care (Chetley *et al.*, 2006; Robertson *et al.*, 2009) and provides an information channel between healthcare workers in rural and urban centres (Chetley *et al.*, 2006; Kay *et al.*, 2011).

Despite the potential of new mHealth systems, they seem to be stuck in a pattern of successive pilot studies that struggle for mainstream implementation (Chib *et al.*, 2015; Béland and Ridde, 2016; Grindle, 2017; Alam *et al.*, 2020). The reasons for the underwhelming implementation of pilot systems are typically because designers do not understand the full situation outside the context of the pilot, which can result in unforeseen incompatibilities with existing technical infrastructure (Chetley *et al.*, 2006) or with the existing social norms and practices (Wagner *et al.*, 2010). This suggests these pilot studies are developed within a “bubble” that hides some of the complexities and interdependencies of the true environment. Indeed, local contexts are often represented as blank canvases upon which mHealth should be introduced without any great difficulty (Oudshoorn, 2012). Frequently, local perceptions and experiences are minimised to matters of user acceptance, usability and feasibility of a specific mHealth technology or “app”, as part of a broader investigation of local barriers to the adoption of such an intervention (Haberer *et al.*, 2010; Palazuelos *et al.*, 2013; Agarwal *et al.*, 2015; Duclos *et al.*, 2017). Yet, wider complexities and interdependencies are key to the eventual integration of new technologies and practices (Orlikowski, 2000; Avgerou, 2001, 2002; Setia *et al.*, 2011; Leonardi, 2012, 2013). Thus, this study asks *what existing health-related structures, properties and practices are presented by rural areas of developing countries that might inhibit the implementation of mHealth initiatives?* This study addresses this question using a socio-material perspective.

Socio-materiality has been heralded as a useful approach to extend traditional theorising and offer new and interesting insights into emergent practices in complex sociotechnical systems (Leonardi, 2011, 2013). We apply this perspective to explore a rural area of Nigeria in the early stage of exposure to new mHealth technologies. An immersive study of this context demonstrates how existing material and social agencies may impact the implementation of mHealth in this area. The rest of the article is structured as follows. The next section reviews existing literature on mHealth in rural areas of developing countries, showing a lack of holistic socio-technical analysis and implementation-focus. We then introduce socio-materiality and discuss the unique analytical perspective it affords. Following this, the research methodology is outlined based on an exploratory case study in Enugu State, Nigeria. Finally, a thematic description of the findings is presented under the analytical headings of social, material, practice and imbrication, following the key concepts which inform the

socio-materiality lens deployed, that is, the substantialist point of view by [Leonardi \(2011, 2012\)](#). The article concludes with discussions and summary.

mHealth in rural areas of developing countries

We began by performing a systematic literature review to examine the different streams of research that are common for mHealth in developing countries. This systematic review searched each of the leading academic publication sources that typically publish mHealth research, namely the AIS Electronic Library (AISeL); Science Direct and Web Science; JSTOR; Academic Search Complete and Scopus; OCLC FirstSearch; Google Scholar; and PubMed/MEDLINE. These publication sources were searched using an evolving set of search terms relating to mobile healthcare, specifically “mHealth”, “m-Health”, “mHealth Care”, “mHealthcare”, “Mobile Health Care” and “Mobile Healthcare”. This resulted in an initial set of 329 papers. Papers published before 2010 were then excluded ($N = 68$), as the rapid evolution of mobile technologies makes it difficult to compare devices before this period. We further removed studies that did not focus on developing countries ($N = 63$), that focussed on non-health goals ($N = 36$), that were not peer-reviewed ($N = 21$), that used obscure or non-mobile technologies ($N = 20$) and that were not written in English ($N = 12$). This presented a final set of 108 papers.

The sampled research focussed on three dominant streams. The first stream focusses on the improvements in healthcare enabled by mHealth tools. In rural communities, local healthcare workers are often the first and only point of contact with the healthcare system for community members ([Agarwal et al., 2015](#)). Therefore, the ability to improve healthcare interactions between rural healthcare workers and community members is crucial ([Akter and Ray, 2010](#)). Several studies have focussed on general improvements in scope, efficiency and quality ([DeRenzi et al., 2012](#); [Florez-Arango et al., 2011](#); [Varshney, 2014](#)). Other studies have focussed on training for rural healthcare workers (e.g. [Chib et al., 2015](#); [Littman-Quinn et al., 2013](#); [Littman-Quinn et al., 2011](#)) and balancing new tools with competing demands for attention and multiple priorities (e.g. [Chang et al., 2011](#); [Selke et al., 2010](#)).

The second stream is more technology-focussed, highlighting the ability of different individuals to make sense of modern technologies at an interaction and interface level. Several studies have focussed on usability and the need to design mHealth interfaces that can be used as easily and effectively as possible (e.g. [Chib, 2010](#); [Vélez et al., 2014](#); [Zargaran et al., 2014](#)). Other studies have taken a slightly different approach, focussing on the reduction of errors, particularly data recording and data entry (e.g. [Brown, 2015](#); [DeRenzi et al., 2012](#); [Rajput et al., 2012](#); [Sadasivam et al., 2012](#); [Zhang et al., 2012](#)).

The third stream focusses on the process of change management around the introduction of new mHealth processes. Examples include remote clinical check-ups (e.g. [Blaya et al., 2010](#); [Hall et al., 2014](#); [Hufnagel, 2012](#)), remote tracking of treatment and medication adherence (e.g. [Chandra et al., 2014](#); [Haberer et al., 2010](#); [Smith et al., 2012](#)), remote dissemination of health information for chronic diseases (e.g. [Kumar et al., 2013](#); [Madon et al., 2014](#)), remote assistance in the treatment of patients with mental disorders (e.g. [Brian and Ben-Zeev, 2014](#); [Knoble and Bhusal, 2015](#); [Li et al., 2014](#)) and participatory community healthcare reporting (e.g. [Boulos et al., 2011](#); [Freifeld et al., 2010](#)).

These studies provide many valuable insights for mHealth in developing countries. Yet, they are collectively characterised by one noteworthy trend. Of the 108 sampled articles, 13 were purely conceptual in nature, that is, they did not actually develop or evaluate tools, and 78 relied on controlled pilot deployments for evaluation, that is, there was no evaluation of widespread implementation, *ex ante* or *ex post*. Only 17 developed and evaluated a mHealth tool in a study that did not limit participation to sampled users and areas (six in African countries, seven in Asia and the Middle East and four that combined countries). Thus, the vast majority of mHealth studies chose to avoid engaging with contextual issues that might

impact the eventual implementation, meaning the roll-out of these tools likely faces significant unresolved challenges.

As an example of a valuable and promising pilot study that requires further contextual consideration, consider [Littman-Quinn et al. \(2011\)](#). Those authors developed a system that coupled a camera-enabled mobile phone and an application called ClickDiagnostics. This system was used in Botswana to send digital referrals from remote areas to a specialist in a central hospital, so connecting people in resource-poor areas with remote specialists. Yet the ability to scale this system is not obvious, as the number and capacity of those specialists are limited. Neither is the long-term effect of likely delays obvious for the willingness of remote participants to send pictures.

Another example was a study by [Knoble and Bhusal \(2015\)](#) that developed a diagnostic application called e-algo to aid remote clinical diagnosis in Nepal. Analysis of that project suggested patients were more confident when healthcare workers used e-algo in their patient care. This raises questions about the shifting power dynamics embedded in this new system and the potential delegitimising of healthcare workers. Such emerging changes often produce shifting balances of resources that can transform early enthusiasm into subsequent resistance ([Feldman, 2004](#)).

As a third example, [Ngabo et al. \(2012\)](#) developed a mobile phone SMS-based system known as RapidSMS-MCH. This system allowed community health workers to track maternal and child health records remotely in their community in Musanze, Northern Rwanda. This system has obvious practical benefits, yet also introduces the potential (or perceived potential) for intrusive monitoring practices, not only among patients but also among local healthcare workers administering treatment. Transparency is notoriously challenging to balance with the sensibilities of healthcare workers when implementing systems, many of who distrust scrutiny from others outside their profession or context ([Doolin, 2004](#)). This suggests that significant contextual barriers to implementation may remain for the RapidSMS-MCH system.

A socio-material view of mHealth in developing countries

Socio-materiality [1] proposes that *technology*, *people* and *process* are mutually generative and interdependent in practice ([Orlikowski, 2007](#); [Orlikowski and Scott, 2008](#)). Socio-materiality argues the use of material artefacts is shaped by social processes, understood and used within a social context, and social action is made possible by the use of material artefacts ([Leonardi, 2012, 2013](#)). Socio-materiality therefore describes what happens when humans (social) and things (material) interact in practice without ignoring the impact of either of them on one another ([Leonardi et al., 2012](#); [Leonardi, 2013](#); [Orlikowski and Scott, 2008](#)). This allows socio-materiality to overcome the shortcomings associated with treating the social at the expense of the material or vice versa ([Orlikowski and Scott, 2008](#); [Leonardi et al., 2012](#)).

Conceptually, socio-materiality prefers to discuss “materiality” rather than “technology”, since the latter creates the impression there are some objects, artefacts or devices out there that independently do things, and ignores that these objects, artefacts or devices only come to reality when manifested in practice ([Suchman, 2007](#); [Leonardi et al., 2012](#)). Instead, “materiality” is understood to be the fashioning of physical or digital materials into useful forms that endure across time and space ([Leonardi et al., 2012](#)). This means that we cannot drop specific types of hardware or software into different contexts and expect it to behave similarly ([Linderoth and Pellegrino, 2005](#); [Orlikowski and Iacono, 2001](#); [Orlikowski, 2007](#)). Equally, we cannot expect software or hardware to be completely passive and amorphous. Rather, each object contains some essential building blocks of eventual form. This quality is referred to as *material agency*, that is, “the way the object acts when humans provoke it” ([Leonardi, 2013: 70](#)). *Material agency* is therefore a construction that relies partly on

materiality and partly on a user's perceptions of whether that materiality affords the capabilities or constraints needed to achieve some objectives (Leonardi, 2011, 2012, 2013). Thus, the *material agency* of some artefact affords a wide range of potential uses and actions, the nature of which depends on the context in which it is enacted (Leonardi, 2011, 2013).

Socio-materiality also prefers the term "social" to "people", as the former is better equipped to capture the variety of social structures involved in a system, including individuals, groups, institutions, norms and perceptions (Orlikowski and Scott, 2008; Barad, 2003). *Social agency* therefore describes how diverse social actors interact differently with varied *material* artefacts, as they align these artefacts with different institutional structures and environmental properties (Ulmer and Pallud, 2014; Efendioglu *et al.*, 2005). Just as artefacts have some *material agency* that affords some possible uses and actions, so human actors have *social agency* that identifies and adapts uses and actions to take advantage of those possibilities (Yates and Orlikowski, 1992; Leonardi, 2013). Following this, as humans pursue different goals, they perceive technology (e.g. mHealth tools) as affording different possibilities or limitations depending on how they are enabled or constrained by the *social agencies* of their surrounding context (Leonardi, 2011, 2013).

The next important concept for socio-materiality is the concept of *practice*, which refers to the space in which the social and the material come together as a performance (Leonardi, 2011, 2012). These *practices* are part of a socially fashioned ecosystem in which multiple interdependent *practices* are co-operatively "negotiated" (Leonardi, 2012). Therefore, *practice* is a collective activity. While *social* and *material agencies* exist in a way that transcends any one specific use or goal, it is in *practice* where abstract possibilities and these two agencies become realised (Orlikowski, 2005). Thus, observable systems are considered systems of *practices*, co-constituted by the available *social* and *material agencies* under pressure to meet various needs and produce desired outcomes (Leonardi, 2007; Feldman and Orlikowski, 2011). This means designers must understand the range of *practices* if they are to understand the possibilities afforded by relevant *social* and *material agencies* and vice versa. Typical mHealth systems include *practices* that non-native developers may find intuitive, for example, end-user training (Medhanyie *et al.*, 2015; Sanner *et al.*, 2014), and also some that may not be obvious without local knowledge, for example, the sharing of phones and SIM cards among multiple rural users (Bullen, 2013; Manda and Herstad, 2015). Hence, the *social* and *material agencies* in local systems may be only partially understood unless a more extensive exploration of *practices* is performed.

Socio-materiality brings together these notions of *practice*, *social agency* and *material agency* with the concept of *imbrication*. *Imbrication* refers to the emergence of structure and routine over time, as systems gradually accumulate *practices* and *social* and *material agencies* become more tightly intertwined (Leonardi, 2011). *Imbrication* explains the process of "organisation and technology mutually shaping nature", in which "the structure between individuals . . . , and technologies . . . evolve as a socio-material creation" (Ulmer and Pallud, 2014, p. 4). This is important to make sense of decreasing flexibility and adaptation of core structures over time, as layers of *imbrication* embed layers of interdependent *practices* and expectations into a system (Tyre and Orlikowski, 1994). Disrupting these embedded *practices* usually requires some key changes in the technologies, individuals or expectations that constitute a system, at which time new *material* and *social agencies* are introduced that must be reconciled with prevailing structures (Thomas and Bostrom, 2010). An example of *imbrication* in mHealth for developing countries is how historic *social agencies* for confidence and cooperation have been enacted in *practice* by *material agencies* for service reliability and efficiency. These result in varying continuous use intentions that constrain where and how a mHealth system will be used in the future (for a detailed discussion, see Akter *et al.*, 2013). The use of mHealth in developing countries is therefore based on the accumulated *imbrication* of *material agencies* from mobile technologies and *social agencies* for personal and commercial

purposes (Donner and Escobari, 2010). This means new mHealth projects must build on the historic precedents laid out by previous mHealth projects in developing countries, as these have likely *imbricated* some existing *material* and *social agencies among* participants (Kenny *et al.*, 2017).

Method

This study adopts an exploratory case-study approach (Yin, 2013) using the socio-material perspective as a guiding theoretical lens. A case study approach was selected because case studies permit the exploration and understanding of complex, loosely bounded contexts (Feagin *et al.*, 1991; Zainal, 2007). This resonates with the needs of our study, as the empirical boundaries of exploration are not clearly pre-defined. Additionally, case studies can be useful in capturing the emergent properties of rapidly changing environments (Feagin *et al.*, 1991; Noor, 2008) and engaging with the subtle complexities of real-life situations (Zainal, 2007; Yin, 2013). Case studies help to answer “why” and “how” questions (Yin, 2013), which is especially valuable in situations where designers and developers have limited ability to control the influence of context.

The selected case took place in the Nsukka Local Government Area in Enugu State (Appendix 2), Nigeria. Nigeria is a developing country with an estimated population of more than 198m (NPopC, 2017) and divided into 36 states and the Federal Capital Territory, Abuja. The rate of under-fives mortality in Nigeria is the eighth highest in the world (Adewemimo *et al.*, 2017). United Nations Children’s Fund (UNICEF) and the World Health Organisation (WHO) presented a set of standard operating procedures (SOPs) for healthcare workers in rural areas of developing countries to assess, classify and treat seriously ill children (UNICEF-WHO, 2012, 2015). Despite the introduction of these SOPs, about 14 of every 1,000 live births in Enugu result in mortality, many of which are attributed to preventable medical causes (Okeibunor *et al.*, 2010). Nsukka Local Government Area is one of the 17 local governments in Enugu State, with an area of 1,810 km² and a population of 309,633 (NPopC, 2018; Ozor *et al.*, 2015). An especially large proportion of the population are believed to live in abject poverty (Ataguba *et al.*, 2011), and maternal mortality rates have been estimated at over three deaths per 100 live births (Okeibunor *et al.*, 2010).

This study coincided with the introduction of an mHealth App in Nsukka to support the diagnosis and treatment of children under 5 years old in the rural community. Specifically, this app was designed to assess, classify and treat sick children under 5 years in the community for diseases such as malaria, cholera and diarrhoea using smart devices (e.g. phones and tablets) at the point of care. To do this, the app used a clinical guideline decision support rule engine with embedded classification and treatment rules to help assess sick children. This rule engine was based on existing WHO and UNICEF iCCM (electronic integrated Community Case Management) guidelines (UNICEF-WHO, 2012, 2015) for Nigeria. The research team worked with collaborators on the ground in Enugu who were developing and evaluating the prototype Android app alongside a rural healthcare worker mHealth training programme in March 2017. Appendix 3 presents more details.

This case was interesting for two main reasons. First, poverty has traditionally been high in Nsukka, and there have been few attempts to reform the infrastructure to date. This is important, as the lack of previous projects in Nsukka lowers the likelihood of propensity biases, whereby researchers are drawn to the rural contexts that are most amenable to mHealth (Abebe *et al.*, 2013; Sankaranarayanan and Sallach, 2014). Second, the app was not yet in widespread use at the time of study, though discussions and demonstrations had begun with local stakeholders. This created a natural transitional period for the region that helped

bring *practices* and *agencies* to light before the system has had a chance to resolve tensions and re-establish equilibrium (Jasperson *et al.*, 2005).

We present a single-case analysis of the context surrounding the introduction of a new mHealth app. Consistent with our research question, we extend our analysis beyond the actual app in question, primarily focussing on the surrounding social and material circumstances that must accommodate and enact this new app. We select a single case design for three complementary reasons. First, the researchers were involved in an ongoing funded practical project in the area that provided unusual levels of immersion and access, not least because one of the researchers is from the area under study, so understands the culture and local dialect. The researchers were not actively developing the app. Rather, they were providing support in the form of planning, requirements gathering and user training. This type of opportunistic sampling provides empirical reach and richness that is difficult to engineer by any other means (Patton, 1990). Second, a single-case design helps to bring the researchers closer to the empirical matter under investigation, allowing the data to “talk back” in a way that increases those researchers’ sensitivity to emerging variables and demands re-inspection of pre-existing biases (Ragin, 1992; Flyvbjerg, 2006). This means a single-case design offers the greatest depth to explore an opportunistically sampled case, as it encourages the researchers to follow interesting emerging empirical insights and capture subtle quirks that may be hidden or treated as “noise” if using other methods. Third, where a sufficiently rich case can be studied, a single-case analysis helps the researchers to provide a less-reductive description of the phenomena under study (Darke *et al.*, 1998; Patton, 2005). This maximises the value of the opportunistic sampling approach. Readers are presented with greater empirical detail that may add nuance when making connections with other research.

Data collection

Data were collected between 2nd and 23rd September 2016 and between 25th February and 25th March 2017. Data were gathered at the headquarters of Enugu State’s civil service, Ministry of Health (MoH), Parklane Teaching Hospital Enugu State University of Science and Technology (ESUT), Nsukka Local Government Headquarters, Nsukka, Health Centres in the rural communities (Plate 1) and a university in the North-West Europe with experience in mHealth projects in rural areas of Africa. Prior to data gathering, ethical approval was



Plate 1.
Edem-Ani health
centre in Edem-Ani
Community, Nsukka,
Enugu State

obtained in both the primary host institution of the researchers and a local university in Nigeria involved with recent mHealth initiatives.

Interviews and participant observation provided the most important sources of data (Structured Interview Guide at [Appendix 4](#)). We focussed on individuals that occupy key roles, participate in key binding policy decisions, have the actual power to make changes and have the important political relational power with other systems ([Knoke, 1994](#)) in the Enugu State healthcare system. Specifically, the authors engaged with four key groups of stakeholders that are involved in rural healthcare delivery in the Nsukka Local Government Area (1) Parents/Guardians (PGs) – mothers/guardians to the children under the age of 5 in the target community whose primary tasks among others is to take care of their children’s health in their homes; (2) Rural HealthCare Workers (RHCWs) – trained healthcare workers working in the healthcare centres located in the rural communities; (3) Developers – responsible for developing, building and maintaining the mHealth system; and (4) Facilitators – individuals or bodies that expedite or enable the development, implementation and delivery of mHealth processes, for example, the public health ministry ([Yepes et al., 2016](#); [Mavhu et al., 2017](#)).

Data gathering involved interviews (e.g. [Plate 2](#)), participant observation, document/records (e.g. [Plate 3](#)), field notes and photographs (e.g. [Plates 4–6](#)) from clinics in the rural communities. Coupled with document/records, 53 photographs and observational and reflective field notes, thirty-two (32) interviews were conducted, with seven PGs, seven RHCWs, six Developers and six Facilitators (A subset of the participants were interviewed more than once over the course of two visits). Interviews were conducted in Igbo or English and recorded (with informed consent) for analysis. All recordings were transcribed verbatim into English, along with the written notes from the interviews. Participant observation involved visiting different stakeholder groups and shadowing individuals as they performed healthcare-related tasks. The two separate visits lasted a combined 7 weeks in total (some additional participant observations were also performed separately for Developers based in Europe). In Enugu, the researchers also observed the work areas and habits of RHCWs and Parents/Guardians by visiting rural communities and accompanying individuals to healthcare centres. One researcher further visited a range of related areas that emerged as important locations during observation, such as local pharmacies and community events where individuals often discussed health-related issues, including local Church services.



Plate 2.
Interviewing one of the
RHCWs at the health
premises

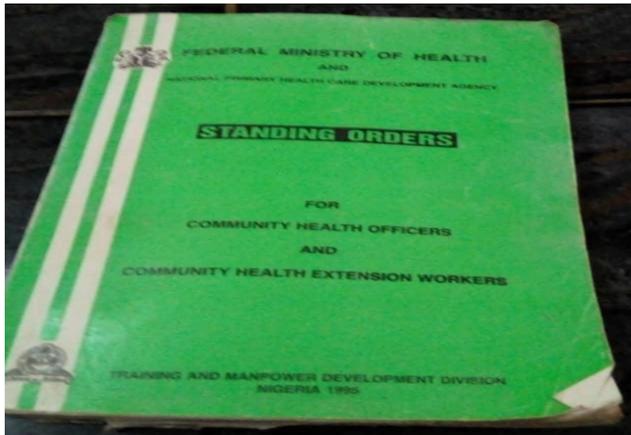


Plate 3.
Standing operating
procedure (SOP) in a
rural healthcare centre

The focus of the interviews, observational work and field notes was to ascertain the socio-material factors that influence the widespread adoption and assimilation of mHealth technologies. Hence, the interviews and observations were semi-structured and evolving in nature, focussing on understanding and explaining healthcare *practices* relevant to the proposed mHealth tool, the individuals and groups involved, the different materials used (e.g. paper guidelines, utilities and material resources) and how each of these things had changed over time. RHCWs were interviewed at the community health clinics where they performed their duties, and Developers and Facilitators were interviewed in their offices and workplaces.

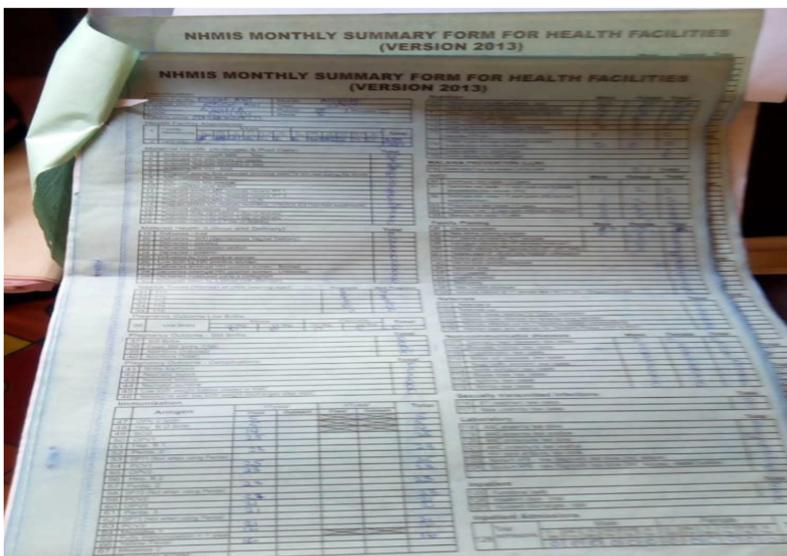


Plate 4.
Paper-based
summary forms

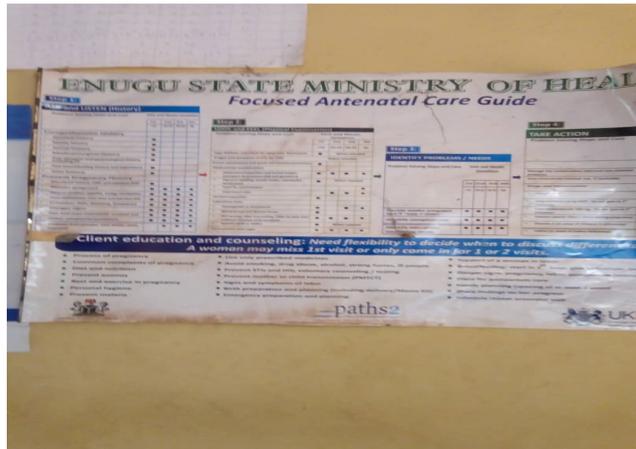


Plate 5.
Wall-mounted
healthcare-
related chart

Additional data were also captured by taking photographs of different facilities, paper-based SOPs used by RHCWs, paper-based facility registers, paper-based summary forms (Plate 4) and wall-mounted photographs of healthcare-related charts (e.g. Plate 5). These documents were reviewed to elicit background information about Enugu State's existing rural healthcare system and to corroborate data from interviews and observations.

Data analysis

Data analysis focusses on interview transcripts, documents/records, observations (Obs.) and field notes (Notes) and photographs (Photos) that identify situations/events in which socio-materiality was seen to be significant in healthcare practice. Our analysis focusses on identifying key types of *social* and *material agencies, practices* and signs of *imbrication* that have the potential to influence the widespread adoption and assimilation of mHealth in this context. Data analysis was performed using the thematic analysis method proposed by Braun and Clarke (2006). Thematic analysis is a flexible approach to theorising, used by many IS scholars to make sense of complex systems (Newman *et al.*, 2016; Aronson, 1995). Thematic analysis concentrates on the identification of recurring patterns and narratives. These recurring patterns and narratives do not always maintain the clear discriminatory boundaries of construct-based variance or process theorising, though they do provide a rich foundation for subsequent studies with those goals (Vaismoradi *et al.*, 2013).

Braun and Clarke (2006) identify six phases for thematic analysis. The first phase demands the researchers familiarise themselves with the data. We did this by repeatedly revisiting interview transcripts, photographs and field notes during the study. The second phase involves generating initial codes. This involved listing patterns of experiences and observations in relation to the already classified categories, that is, *social agencies; material agencies; practices and imbrications*. Examples included “materialities for transport” and “practices of traditional healing”. The third phase involves searching for themes. These themes represent the meanings attributed by the researchers to specific quotes or other pieces of data (Taylor and Bogdan, 1984). For this study, this meant relating different *material* and *social agencies* to particular *practices* and *imbrications*. For example, a key theme in *social agency* was the “perceived divide between urban and rural healthcare systems”, and it became evident early on that this had a clear link with the *imbrication* theme of “accumulated breakdowns in payment practices”. The fourth phase reviewed these themes. This involved

testing the ability of data to support specific themes or their underlying explanations. This resulted in some themes being abandoned and others being refined. An example of this was the separation of the *material agency* theme of “limited material-resources in rural healthcare centres” into two separate themes, that is, “inextensible practical utilities in rural healthcare centres” and “limited material-security apparatus at rural healthcare centres”. This was done to reflect the differences in impact these two limitations had on observed *practices*, such as the “reliance on centrally regulated diagnosis and treatment practices” (for which limited utilities were more meaningful but limited security). The fifth phase requires that themes be given names. This demanded we connect all the themes that emerged from the data to provide a wide-ranging picture of the experience of the stakeholders following the works of Aronson (1995). It also required that we commit to the “essence” of what each theme was about and thus provided a “feedback point” between the authors and the stakeholders in this analysis. An example of this was the reframing of *practices* in terms of “reliance”, as the accounts of common practices focussed on the absence of alternatives, rather than a strong confidence in the *practices* themselves. Hence “practices of traditional healing” became “reliance on informal traditional healer-driven diagnosis and treatment practices”. A similar change occurred for *material agency*, where the overarching trend “limitations” was revealed. Phase 6 required for the research to be compiled into a report. This took the form of a descriptive “theme statement” (Aronson, 1995), which is presented in the research findings in this paper.

Key quality markers were identified prior to data collection. The first, “*reflexivity*” (Creswell, 2002; Koch and Harrington, 1998), describes the importance of attending to researcher bias (Cohen and Crabtree, 2008). The researchers made effort to reflect on bias wherever possible, both in the data itself and in our interpretation. The second, “*ontological authenticity*” (Manning, 1997; Schwandt *et al.*, 2007; Amin *et al.*, 2020), describes the extent to which shared knowledge and social action between the participants and researcher are fair and balanced. This was managed through multiple visits to Enugu to share findings with participants as part of “venting” or “member-checking” exercise, used to attest to the “*truthfulness*” and “*trustworthiness*” of the findings (Manning, 1997; Northcote, 2012). The third, “*internal validity*” (Yin, 2013), describes the degree to which the emerging themes are logically consistent with one another (Street and Ward, 2012; Gwet, 2014). This was managed by relating themes within and across high-level categories to ensure observed *material* and *social agencies*, *practices* and *imbrications* were clearly linked. The fourth, the “*interpretive validity threat*” (Maxwell, 2012), occurs when alternative explanations, interpretations or hypotheses are not given sufficient opportunity (Huck and Sandler, 1979). This was managed by maintaining an “audit trail” (Creswell and Miller, 2000; Rodgers and Cowles, 1993) that included “thick, rich description” (Creswell and Miller, 2000) and illustrative quotes. Finally, the fifth issue “*generalisability*” (Lee and Baskerville, 2003) or “*external validity*” (Yin, 2013) describes the extent to which findings from this study are generalisable beyond this context. This was managed by linking findings with recurring socio-material categories, so creating natural parallels with socio-material studies in other contexts.

Analysis

The following sections present and discuss emerging themes for *social agency* (Table 1), *material agency* (Table 2), *health-related practices* (Table 3) and *imbrication* (Table 4). Individual themes under each heading are accompanied by in-depth descriptions and illustrative extracts of data.

Themes for social agency

The first theme for *social agency* describes the *perceived threat to existing roles and individual autonomy*. This took two main forms. One threat was that the new system could diminish the

Theme	Description	Illustrative data extracts
Perceived threat to existing roles and individual autonomy	Social actors believe that initiatives like the mHealth app might lead to a devaluing of roles and individuals	“... this thing coming in is going to take away his job, he may not come out openly to say I do not accept it but you can be sure that deep down in him he will do all he can to frustrate it Ok” (Developer 6) “... using this phone we do not need to consult any doctor in as much as it has been programmed for us to use it for treatment in the rural areas” (RHCW3)
Perceived limitations in skilled personnel in rural areas	Social actors (PGs, RHCWs, facilitators, and developers) feel that there is lack of necessary human resources in rural health centres	“I want a place I can go and see a doctor as there are no doctors at this centre” (PG2) “We lack health workers in the rural health centres” (RHCW3) “Observed that there were no medical doctors in rural clinics during the research period” (Notes/Obs.)
Perceived apathy by urban institutions towards rural healthcare systems	Social actors (RHCWs, developers, and facilitators) believe rural healthcare needs are secondary to those administering urban health systems	“... we share a feeling of being left out by the system” (RHCW4) “The aberration in healthcare distribution and healthcare provision is hurting the primary healthcare system in Enugu State” (Facilitator 2) “Observed participants prefer treatment in urban than rural centres due to perceived better treatment measures” (Notes/Obs.)
Perceived collegiality among stakeholders in rural community	Social actors (PGs and RHCWs) share a sense of common identity in addressing challenges and difficulties confronting them	“I approach my friends or neighbours who may know what is happening to my child and they offer some suggestions on how to go about it in the immediate” (PG3) “We interact with the villagers that come here as patients, like children with various illness, sharing in their feelings especially as most are poor and find it difficult to go for medical treatment in the urban area” (RHCW5)

Table 1.
Social agency themes,
descriptions and
illustrative quotes

respect towards specific individuals. Facilitator 1 explained, “the doctors and to some extent the nurses will not be happy in that they will feel that some parts of their jobs are being taken away from them when such a tool is introduced in the healthcare system”. The perceived threat of angering individual doctors, rather than nurses, seemed counterintuitive at first, given it was the general RHCWs who would require new skills and whose tasks were becoming regimented. Yet, the expansion of general RHCWs into diagnosis arguably broadened their role in a way that blurred the distinction from doctors. RHCW3 acknowledged the tension this created, lamenting “I know some doctors may be feeling we are trying to take part of their job. But I do not think the doctors should feel we are trying to take their job since it is in the interest of the poor rural communities”. Another threat came from the perceived oversight from urban institutions. Developers and Facilitators viewed this

as a positive, describing the benefits of monitoring and continuous interaction and oversight. However, this monitoring was viewed with scepticism in remote areas, as it would mean individuals would have to continuously answer to central institutions, explain their behaviours and possibly accept more micromanagement.

The second theme for *social agency* concerns the constitution of social actors in rural healthcare settings, specifically the *perceived limitations of skilled personnel in the rural health centres*. PGs and RHCWs complain about a lack of nurses and doctors in rural health centres, which they interpret as a reduced capacity for sophisticated healthcare delivery. This is a challenging problem to address, as noted by Facilitator 6, who explained that “most well-trained personnel do not like to work in rural areas”. Developer 6 agreed with this assessment, remarking that “the properly trained nurses are not available at all because every nurse that is properly trained will want to stay in the town . . . doctors, they are not also not there, even the ones that are in the rural communities are involved in their own private practice, they are not involved in the healthcare system in the State, . . . and of course . . . the consultants who should be taking decisions are not available in all the rural communities in Enugu State”. This appears to result from the minimal incentives for qualified health professionals to work and live in the rural areas. Qualified healthcare workers migrate to urban areas where they can earn better wages and have their children attend better schools. Thus, the *social agencies* of rural health centres are discouraging skilled social healthcare professionals and therefore sophisticated healthcare delivery, through the lack of complementary skilled teachers and wealthy healthcare consumers. This creates a natural “chicken and egg” scenario, where those complementary individuals are also likely discouraged by the lack of quality healthcare.

The third theme for *social agency* describes a *perceived apathy by urban institutions towards rural healthcare systems*. RHCWs and PGs feel rural healthcare systems are isolated from urban health systems and of low priority to urban actors. Developer 6 reflected “at the beginning, the rural healthcare system has no institutional base, as they were not accorded any status on which to operate in relation to the . . . healthcare delivery centres in the rest of the State”. Thus, the *social agency* tends to produce power imbalances between the urban and rural areas. Developer 6 further explained “to compound issues, the . . . healthcare centres that would have helped support/nurture the rural/primary healthcare apparatus have broken down leaving only the tertiary institutions as the sole functional healthcare delivery structures”. Thus, the prevailing *social agencies* of urban and rural social systems have no obvious connective institutional structures or systematic relationships to unite them in healthcare delivery. Instead, each appears to be operating within relatively distinct social configurations that present little opportunity for convergence.

The fourth theme for *social agency* describes a perceived collegiality among actors in the rural community. This collegiality contrasts with the perceived disconnect between these actors and those in urban areas. Data suggest strong *social agencies* for relationship building and collaboration between (and among) PGs and RHCWs. PGs can typically reach RHCWs outside their working hours with health-related queries, suggesting the agencies of that role go beyond professional contexts. PGs also help each other to find solutions to health problems. PG2 summarised this by saying “I approach my friends or neighbours who may know what is happening to my child and they offer some suggestions on how to go about it in the immediate”. This means PGs and RHCWs rely on *social agencies* for word of mouth and informal learning when dealing with healthcare challenges. RHCWs also noted a sense of personal responsibility for protecting PGs from third parties who may exploit their desperation or lack of understanding, for example, pharmacies selling illegitimate or overpriced drugs. RHCW2 explained “if you leave them to buy for themselves, they may buy fake drugs which is being sold out there”.

Themes for material agency

The first theme for *material agency* describes the *mobility of mHealth-enabled smartphones*. The introduction of the mHealth app meant the introduction of sufficiently sophisticated smartphones, and these smartphones provided a broad range of new material agencies. While the focus of the development was the app, establishing a digital connection between remote areas and urban centres created new capabilities that provoked a social reaction from either side of this historic divide. Several Facilitators saw the app as a tracer bullet for subsequent innovation, for example, Facilitator 3 noted it was not the idea of the app that was novel, the project was “. . . novel in the sense that it will be quite helpful in reaching those people in the villages and also making healthcare services available to them . . .” This reflected a common assumption that this type of approach was the only feasible way to establish connectivity and begin the larger task of bringing these remote areas back into the mainstream health system. This was mirrored by RHCWs, who described the connectivity-related material agency of the smartphones as an empowering force that would take on a momentum of its own, for example, “. . . it will help those people that are living there since it will bring healthcare to the grassroots” (RHCW1) and “it is really for humanity that such way of services should be extended to the rural poor communities” (RHCW3). The app embraced this form of *material agency* by guiding RHCWs to collate data in summary forms and transfer these records to local government headquarters. These data are subsequently transferred to the federal health office via Enugu State’s Ministry of Health. New mobile apps were being introduced to collect and transfer data at the time of writing. These apps help workers at rural health centres to collate health data more efficiently and forward this data electronically to state and federal bodies.

The second theme for *material agency* is once again centred upon the device rather than the app, this time describing the *Web connectivity of mHealth-enabled smartphones*. The previous theme described how adding sophisticated smartphones added a new force that pulled remote areas into the digital sphere of urban areas. Equally importantly, these smartphones added a material agency that pulled these remote areas into the larger digital sphere of the Web. This second dimension of material agency provoked individuals to begin thinking about other, potentially unregulated health-related content on the Web. Facilitators were keenly aware of this possibility. Facilitator 1 noted how the inadequacies of the formal health system could make these capabilities more prevalent, noting “since this [android features] gives them access to Internet . . . [and] especially with the shortage of Doctors in the rural areas, they can now start looking for remedies to sickness via the Internet”. Others further noted that even if they could meet remote healthcare needs, the material agency of the smartphones naturally lends individuals to searching the Web as a habit.

The third theme for *material agency* describes the *rigid existing paper-based diagnostic guidelines that are integrated into the mHealth app*. The Ministry of Health introduced a set of guidelines called the standing operation procedure (SOP) for use by RHCWs throughout Nigeria. Developer 5 described this as “a step by step, blow-by-blow method whereby a well-trained health officer can act in the absence of a doctor or when a doctor cannot be physically present”. However, RHCWs had concerns about the rigid rules associated with the SOP and long processes involved, which often added unwelcome delays and complexity to interactions. RHCW6 commented “before they used to treat them under one page but now, they have split it into different pages, which makes it very difficult and stressful for us somehow”. Some of these issues would be attenuated by the mHealth app, for example, the delays associated with finding records. Others would persist. For example, several RHCWs noted that the *material agencies* of these SOPs typically lead to PGs being referred for further diagnosis and treatment in urban health centres. These agencies jar with the emotional attachment many RHCWs feel towards PGs. Further, frequent referrals undermine RHCWs’ clinical expertise and PGs’ perceptions of the quality of treatment delivered at rural health

Theme	Description	Illustrative data extracts
Mobility of mHealth-enabled smartphones	The wireless nature of smartphones means they can extend digital systems into remote areas with minimal digital infrastructure	“You find out that many areas in the rural communities are not covered and can only be covered by this type of mobile technology” (Facilitator 4) “... with this app any person even the village volunteer health workers in the village, the patent medicine vendors, they can use it to save lives.” (RHCW3) “... since this gives them access to the Internet, they can equally use that to look for diagnosis or treatment being offered through the net... especially with the shortage of doctors in the rural areas” (Facilitator 1) “Apart from the app itself they can use the phone to browse for things that will help them do their work” (Facilitator 2)
Web connectivity of mHealth-enabled smartphones	The ability to connect to the Internet creates access to a range of health-related and unrelated online content	“we need something that will help us in treating our patients instead of the many referrals that are recommended in the present SOP” (RHCW4) “most of the steps in SOP is always refer, refer, even simple things we can treat they direct us to refer” (RHCW7) “Observed 1) there were limited copies of SOP booklets available, causing frustration among workers and 2) Booklets are large, fairly heavy and maybe not ideal in terms of carry around” (Notes/Obs.) “Facilities in the villages are poor” (Developer 5); “we do not have the required drugs for treatment here” (RHCW1) “Ill equipped facilities” (Notes/Photo) “Observed ill-equipped facilities, including little or no regular clean water (most health facilities rely heavily on rain water collected in tanks (Plate 7))” (Notes/Obs) “There are many things we do not have... we do not have security in our place of work” (RHCW5) “The major thing is security, no security in the villages. No security in any of the health centres, even on the road to move around especially in the night when you can have emergencies” (Facilitator 6) “Roads are filled with gullies in the rural communities.” (RHCW3) “... most roads are inaccessible” (Developer 5) “motorcycles (Okada) or Tricycles (Keke) are being used in the rural areas, with the exception of private individuals with their personal cars” (PG5) Observed 1) Roads not surfaced and poorly maintained (Plate 9) and 2) Can damage vehicles” (Notes/Obs.)
Rigid existing paper-based diagnostic guidelines that are integrated into the mHealth app	The treatment steps of health guidelines built into the app are considered cumbersome. Strict adherence is required, often resulting in a referral	
Insufficient practical utilities in rural healthcare centres in which the mHealth app is used	The supply of drugs and utilities, such as water and electricity limit healthcare workers to basic interactions with patients	
Insufficient security apparatus at rural healthcare centres in which the mHealth app is used	The rural healthcare centres do not have physical security personnel to protect RHCWs from threat (e.g. night marauders and detractors)	
Insufficient roads for transportation to and from rural healthcare centres in which the mHealth app is used	The roads used by PGs and RHCWs to access health centres are often too poor to travel	

Table 2. Material agency themes, descriptions and illustrative data extracts

centres. RCHWs would like to offer immediate accessible solutions where possible. As a result, the SOPs embodied in the app are often treated as an inconvenience by PGs and RHCWs. Developer 6 remarked “my experience is that the [RHCWs] do not actually use this SOP as it should because . . . it is a very cumbersome thing”. This was obviously a concern for the proposed mHealth app, in which the implementation of the guidelines would be hardcoded into the process.

The fourth theme for *material agency* describes the *insufficient practical utilities in rural health centres in which the mHealth app is used*. Health centres in rural villages are not equipped to anything like the standard of urban health centres (Plate 6). Developer 6 noted the limited *material agencies* further exacerbated staffing problems, remarking “no properly trained nurse would like to work in such an environment”. Facilitator 6 acknowledged “there is lack of infrastructure and very few health centres are worth to be called places where any sick person can even go into”. Facilitator 3 suggested this was not solely limited to rural areas, “Even in urban centres where we refer as having adequate facilities, it is not so in many cases. Doctors and nurses work with old equipment and this brings a lot of stress to them. They have protested about this, but it all came to nothing.” *Material agencies* for water supply are a major cause for concern for the RHCWs in the communities, as there is no steady supply of clean water. This means RHCWs often rely on private supplies of water or resort to harvesting rainfall water in tanks (Plate 7). Another *material agency* from these limited utilities concerns the irregular availability of drugs at rural health centres. RHCW2 remarked “the availability of the drugs we use is also a challenge, if drugs are supplied to us in large quantity it will be a good thing, instead of having to stay and wait for the request to come through”. Even where equipment, water and appropriate drugs are present, *material agencies* may be limited by the poor or non-existent access to electricity in health centres. RHCW2 pointed out, “In the Nigeria of today, the irregular supply of power is considered as a normal way of life. The small generators used by individuals comes as a saviour in charging of phones, those centres in the urban areas have electricity generators in their various offices while there is none at the rural health centres”. As a result, RHCWs rely on oil-based lanterns (Plate 8) in the evening at health centres and personal charging facilities to maintain the batteries of mobile devices. This raises concerns about maintaining charge in the smartphones for the proposed mHealth app. Once RHCWs become reliant on this app, a lack of charge could stop care delivery for PGs and children who have undertaken the long journey to the centre.



Plate 6.
The inside of the rural
health centre at Edem-
Ani Community

The fifth theme for *material agency* describes *insufficient security apparatus at the rural healthcare centres in which the mHealth app is used*. Most of these centres are not wall-fenced, nor are there obvious security measures to prevent unwanted intruders. The lack of *material agencies* for physical security at rural health centres is a serious concern for RHCWs and PGs due to the perceived ongoing threat of attack from night marauders. This threat is further compounded by the fact that many RHCWs work in the centres during the night. RHCW4 said “When somebody knocks at the door at night you will be afraid to open because you do not know whether the person knocking is a patient or those that are coming to rob or harm you”. When asked about the security issue at rural healthcare centres, Facilitator 2 explained “the resources of the state are limited and government . . . provides infrastructure as much as it can”. In the absence of government-provided security resources, the *material agencies* of rural centres give way to community-based agencies, notably the weapons and vehicles of volunteers from local villages. These volunteers, usually groups of youths, form neighbourhood watches to guard centres and surrounding areas, so helping to prevent attacks from night marauders.

The sixth theme for *material agency* describes the *insufficient roads for transportation and from rural healthcare centres in which the mHealth app is used*. First-hand observations and feedback from interviewees suggested that roads in urban areas are better than roads in



Plate 7.
The entrance to the health centre, showing the strategy adopted to collect water into a tank and one of the modes of transportation (motorcycles – known locally as “Okada”)



Plate 8.
Oil-based lanterns used for lighting health centre due to the absence of electricity

the areas (Plate 9). PG1 remarked “there are gullies and ditches on these roads and here you see, no public motor transport driver wants to work on the rural roads because of this”. This lack of *material agencies* to enable public road transportation means rural inhabitants are forced to pay for rides on motorcycles known as “*okada*” (Plate 7) or tricycles known as “*keke*” to travel anything other than short distances. Yet this presents new problems, as many rural inhabitants cannot pay the required fees and must instead walk to centres. Facilitator 6 summarised the limited transport-related *material agencies* of the area, explaining “a good number of communities are completely inaccessible, inaccessible by road, which is the major means of transportation in this part of the world, and the fact that you cannot access those places no matter how you want to look at it is disheartening”. Photographs captured some of these insufficiencies in detail (e.g. Plate 9). This is especially problematic during the rainy season, at which time most of these villages are almost entirely cut off from other parts of Enugu State. This compounds the earlier theme concerning the rigidity of existing guidelines, as referrals to urban centres to use the mHealth app become even more frustrating when transport resources are lacking.

Themes for practices

The first *practice-related* theme describes the *reliance on centrally regulated diagnosis and treatment practices, like those in the mHealth app*. These practices are designed to advance best practice in rural areas and compensate for some of the social and material limitations. Hence, RHCWs have already been trained to use material SOPs for the assessment, classification and treatment of patients. Also, confidence has built up in rural areas around these guidelines, which are seen as an accurate representation of best practice in urban centres. One RHCW predicted, “People will be rushing to be treated with this modern technology . . . to assess and treat. Because after seeing what we are using for treatment they will tell others who will rush to be treated with an accurate instrument unlike the human assessment” (RHCW1). Parents echoed this excitement, as well as the positive sentiment towards technology-based assessment. However, while RHCWs, Developers and Facilitators may wish to use these SOPs as broadly as possible, this relies on PGs making their way to the health centres. This is not a reliable assumption, as earlier limitations of *material* and *social agencies* mean many PGs do not have access to the transportation resources required for such



Plate 9.
A typical rural road

Table 3. Health-related practice themes, descriptions and illustrative data extracts

Theme	Description	Illustrative data extracts
Reliance on centrally regulated diagnosis and treatment practices, like those in the mHealth app	RHCWs already rely on SOPs similar to those in the proposed mHealth app for diagnosis and treatment of patients in rural health centres	“The SOP is used to diagnose illnesses, treat or refer the patient to a doctor” (Developer 3) “we were using the paper-format before they brought an app for sending to State and federal directly” (RHCW4)
Reliance on informal PG-driven diagnosis and treatment practices, which are not represented in the mHealth app	PGs circumvent RHCWs and SOPs like those in the mHealth app to buy medicine directly from pharmacists	“I visit the pharmacy to get some medications I use at home before I take the person to the clinics” (PG3) “If my child is sick I buy drugs that I feel is going to cure my child” (PG6) “Observed (1) Parents contact peers for treatment advice, (2) Parents often times buy drugs/ medicine from pharmacies without prescription” (Note/Obs.)
Reliance on informal traditional healer-driven diagnosis and treatment practices, which are not represented in the mHealth app	PGs use traditional healing practices to treat sicknesses, e.g. drinking liquid from boiled mango leafs to treat various stomach ailments	“Sometimes when we have no money we make use of herbal methods of treatment within our village” (PG7) “Parents do make use of traditional healing methods for treatment” (RHCW7)
Reliance on informal and clustered communication practices, which are not represented in the mHealth app	PGs and RHCWs rely on informal communication channels between these groups, rather than communication with urban centres	“[RHCWs] do not refer to us and we do not write back to them even if their referrals will come in a secret way” (Developer 5) “We are not even in talking terms with [RHCWs]” (Developer 6)

travel. This means these *practices* make up only one aspect of the *socio-material* system for healthcare in these areas.

The second *practice-related* theme describes a *reliance on informal PG-driven diagnosis and treatment practices which are not represented in the mHealth app*, whereby parents bypass doctors and go straight to pharmacists for medicines. These diagnosis and treatment practices are typical in Nsukka. PG7 described “Once I notice that my child is not feeling well, I make use of some medication I have at home first before going anywhere”. PG3 commented similarly “I only take my child to a health centre when I notice that the medication I have administered to my child at home is not working”. This is possible because PGs often have drugs stocked at home, drugs bought from pharmacy attendants without formal prescription from a healthcare professional. These *practices* do not require the same level of travel and expertise as the formal SOP-driven practices at rural health centres, therefore PGs find it easier and more satisfying to enact these informal diagnosis and treatment practices instead. Many pharmacist attendants have embraced the opportunities presented by this new practice, due in part to their own limited *material* and *social agencies* for wealth and expertise. Thus, these *practices* effectively circumvent limitations in the *material agencies* of rural centres for rapid, dynamic and physically accessible diagnosis and treatment, albeit at the expense of accuracy, reliability and long-term health outcomes.

The third *practice-related* theme describes a *reliance on informal traditional healer-driven diagnosis and treatment practices, which are not represented in the mHealth app*. This was seen as the next-best alternative when PGs could not secure suitable drugs from pharmacy assistants for their children. Many individuals continued to avoid rural centres due to *material agencies* prohibiting long journeys and community-based *social agencies* that value tradition and respect for one's elders. Instead, these individuals turned to local traditional African healers. PG7 explained "traditional healing remedies were handed down by our forefathers to us and it worked for them before the advent modern drugs, so, I still use traditional remedies for certain sicknesses, such as malaria, etc." These treatments were also typically cheaper than formal *practices* at rural centres or buying drugs from pharmacy assistants. PG3 lamented "I go to African traditional herbal homes to treat sickness with herbal remedies especially when the prescribed drugs at the health centre are too expensive for me to bear". The RHCWs found this frustrating, noting the futility of trying to convince people of little means to opt for the more expensive options. RHCW7 further linked this to limited *social agencies* for skilled personnel in rural areas, remarking "For those of us who work in the village, the most people we work with do not have good knowledge of healthcare systems. So, we need to boost health education for rural people".

The fourth *practice-related* theme describes a *reliance on informal and clustered communication practices in Enugu State, which are not represented in the mHealth app*. A lack of formal communication *practices* was observed between rural health systems and urban health systems. Where cases become serious, PGs often find their way independently to urban teaching hospitals without referrals or any accompanying records. Developer 6 noted "how many references have I gotten from [rural health centres]? None, I mean zero, at best, those centres are just glorified maternity centres". The researchers witnessed this first-hand when one rural woman with an advanced illness was brought to a consulting physician by her brother without any accompanying documentation. Developer 6, the consulting physician, explained "it is very strange that I had to attend to this woman without any previous records on what my juniors in the ladder have done, what 'things' am I going to consider? How do I start?" Developer 6 further elaborated "that kind of woman cannot see a specialist like me without formal referral from where she was first treated, where a record has been established stating the history of her sickness and records of the treatments administered on her before now". These *practices* once again enact *material agencies* for limited transport, as this is part of the reason that historical paper-based records are not transported correctly. However, they also enact *social agencies* for the perceived divide between urban and rural healthcare systems and entangle with other informal *practices* that avoid those rural centres in favour of buying drugs or traditional remedies directly.

Themes for imbrication

The first *imbrication-related* theme describes *accumulated breakdowns in payment practices*. RHCWs complained that local governments routinely missed salary payments, arguing it had negatively affected their motivation to work. RHCW5 remarked "payments of our salaries is a problem, when you are not paid promptly the satisfaction and the zeal to do the job will not be there". MOH argue this has nothing to do with them, as in Nigeria, each state is responsible for providing the regulation and technical support to rural healthcare services but the local government level is responsible for rural healthcare. Those local government bodies suggest they are not given the funds to follow through on these payments, creating a circle of blame with no obvious sign of ending. Developer 5 suggested the only way to resolve this was to consolidate the payment in one place, arguing "It is just not right to leave the funding of primary healthcare systems in the hands of the local governments, it should be the primary responsibility of the Federal Government". In any case, this accumulation of missed payments has been a significant contributor for *social agencies* that undermine the

Theme	Description	Illustrative data extracts
Accumulated breakdowns in payment practices	The payment of RHCWs' salaries has repeatedly broken down, leading to frustration and a lack of trust	"... our salaries are not being paid to us" (RHCW1) "... we are expected to report to work without any incentives" (RHCW6) "Local governments in Enugu State are autonomous, so, it is their responsibility to pay the salaries of the RHCWs" (Facilitator 2)
Accumulated personal and professional phone-related practices	RHCWs and PGS have become accustomed to carrying phones for unrelated personal and social practices	"my friend called me to ask which hospital I took my child to when she was having cough" (PG5) "... phones enable communication channel between us and our patients anywhere" (RHCW2) "Observed (1) People carry phones around for text and voice messages, and (2) video calls and conferences" (Notes/Obs.)

Table 4. Health-related imbrication themes, descriptions and illustrative data extracts

widespread adoption and assimilation of mHealth tools. The resentment has increased the perceived divide between urban and rural healthcare systems and further discouraged skilled workers from remaining in rural areas, so contributing to perceived limitations in skilled healthcare personnel in rural areas. Those that stay must often make personal sacrifices to compensate, so deepening the perceived collegiality among RHCWs and PGs in rural communities.

The second *imbrication-related* theme describes *accumulated personal and professional phone-related practices*. Many RHCWs and PGs are in the habit of carrying their personal phones. This has not been a straightforward transition, as phones are in danger of loss, theft or damage. RHCW1 explained, "I now have to carry this particular phone with me in conjunction with my personal phone, protecting them both is a challenge to me". Facilitator 1 echoed this concern, noting "we had to introduce an MOU [Memorandum of Understanding], which is once you lose your phone you have to replace it". This threat is sufficient that some RHCWs do not want to take the responsibility of carrying these additional professional phones for fear of having to replace them. For those that carry professional phones, or use personal ones instead, the benefits have been accumulating over time. PGs may also use their phones to make personal calls to RHCWs or contact friends to ask questions. PG6 remarked "I can reach my friend with my mobile phone to ask of what to do about a particular sickness I feel my child is experiencing". The accumulation of personal phones also means PGs have independent access to third-party health information, provided they have the literacy to browse the Web. Like the aforementioned accumulation of missed salary payments, this accumulation of personal and professional phone-related *practices* has been a significant contributor for the informal *practices* that undermine the widespread adoption and assimilation of mHealth tools. The ease with which rural inhabitants can access one another and spread knowledge through word of mouth fuels increasing reliance on informal and clustered communication practices. This encourages individuals to copy the informal PG-driven diagnosis and treatment practices and traditional healer-driven diagnosis and treatment practices adopted by their peers. It also creates multiple information channels that dilute the information being passed on by RHCWs and urban medical professionals.

Discussion

This paper explores the contextual factors that may influence the assimilation of mHealth technologies and retention in rural areas of developing countries. This research identifies several new issues for IS research. Table 5 summarised these issues, which we now discuss in more detail.

At the level of *social agency*, it is clear that the urban and rural healthcare environments represent separate social worlds. The lack of highly trained workers is recognised as a significant challenge to healthcare in rural communities of developing countries (Naicker *et al.*, 2009). In Africa, there are 2.3 healthcare workers per 1,000 population, compared with developed countries such as the USA, which have 24.8 healthcare workers per 1,000 population (Naicker *et al.*, 2009). Most well-trained healthcare workers prefer migrating abroad where they have better remunerations (Scheffler *et al.*, 2009; Naicker *et al.*, 2009; Stilwell *et al.*, 2004), while others often prefer to work in urban centres that are better connected and better resourced. In Enugu State, this has created a sense of isolation and neglect that binds PGs and RHCWs into systems of making do. These systems build on *material* and *social agencies* to enact new *practices* that bypass short-term limitations at the expense of longer-term outcomes. This tendency of rural communities in developing countries to find creative healthcare workarounds has been documented in existing literature (e.g. Bergström, 2005; Werner, 1987). It has also fostered an increasing emotional attachment (Pignot, 2016) between RHCWs and PGs that has helped to support a group that are otherwise neglected (Wilson *et al.*, 2009; Katz *et al.*, 2011). Thus, a sub-optimal but stable equilibrium has formed that creates challenges for mHealth initiatives in these communities.

At the level of *material agency*, it seems that rural health centres lack the breadth and depth of appropriate complementary materiality for mHealth to be meaningfully enacted in healthcare delivery. Most RHCWs do not enjoy working in the rural health centres due to the lack of basic material utilities, transportation and security. Adequate medicines and electricity are often unavailable. Similarly, most roads in rural areas are unpaved and in disrepair, so restricting public transportation in favour of alternative modes that lend themselves to shorter journeys. The threat of intruders means RHCWs are continuously watching for signs of danger and thus leave them feeling unsafe in their workplaces. These observations of infrastructural deficiencies in rural health centres are consistent with findings from existing research in a range of developing contexts (e.g. Sanner *et al.*, 2014; Manda and Herstad, 2015). Taken together, these limitations discourage RHCWs and PGs from using rural health centres extensively or even spending prolonged periods there, both of which are necessary for those centres to become properly entangled into the rural healthcare system. Holeman and Barrett (2017) highlight how technologies imbricate with a range of existing local materials; thus, the successful enactment of mHealth technologies is likely to require greater development of ancillary material resources, for example, medicines, infrastructure, technologies, guidelines.

At the level of *practice*, rural healthcare systems are dominated by informal practices that bypass dedicated local centres. The structured and referral-heavy step-by-step approach in

Table 5.
Challenges that inhibit
mHealth (ICT4D)
implementation

Rural areas	Existing socio-material differences "World Apart"	Urban areas
<i>Distributed</i>	Social	<i>Hierarchical</i>
<i>Insufficient</i>	Material	<i>Adequate</i>
<i>Medically and peer-driven</i>	Practice	<i>Medically driven</i>
<i>Emergent</i>	Imbrication	<i>Structured</i>

the SOPs provides limited immediate satisfaction for PGs. Instead, those PGs gravitate towards informal diagnosis and treatment practices that can be performed more cheaply and with less delay, such as buying medicine directly from pharmacies without prescription or alternative treatments from traditional healers. These findings are also consistent with existing literature (e.g. Ruebush *et al.*, 1995; McCombie, 2002; Deressa *et al.*, 2003). It further appears there is little direct communication between rural and urban health centres. Instead, we noted clustered communication practices among rural stakeholders. This creates a lack of information about rural individuals in urban centres, which becomes particularly problematic given those rural dwellers may have to travel great distances to attend those centres (e.g. Larson and Fleishman, 2003; Mars, 2013). This breakdown in communication is not only delaying the spread of new *practices* and information from rural healthcare centres (Asuzu, 2004), it is also creating a growing threat of misinformation and malpractice within rural communities.

At the level of *imbrication*, the lack of social and material entanglement between urban and rural systems can be attributed to historic breakdowns in practices that could otherwise have acted to strengthen these connections. This is consistent with basic assumptions of socio-materiality, which assumes that social and material elements are mutually generative (Leonardi, 2012). Breakdowns in payment practices have caused RHCWs to rely on other ways to earn an income in their community. This has eroded the authority of urban actors, particularly where tensions may be perceived between urban and rural interests. Indeed, before mobile technologies were made available to RHCWs for healthcare-specific reasons, many RHCWs and other rural dwellers had taken it upon themselves to acquire personal smartphones. Thus, there is no clear indication that urban actors have the authority to tell rural actors how they should use those devices. Modern mobile phones clearly have *material agencies* which can be enacted into centrally prescribed medical practices. For example, they can be leveraged to support on-the-spot diagnosis and treatments from a specialist somewhere outside a rural context or to facilitate referrals practices (Noordam *et al.*, 2011). However, they also have *material agencies* that lend to greater informal communication and third-party information access. This is significant for future mHealth initiatives, as the sourcing of information from this unregulated space may hamper structured healthcare delivery processes in rural areas (Murray *et al.*, 2003; Moreland *et al.*, 2016). The isolation of rural *social agencies*, the limited *material agencies* of rural health centres and the dominance of informal *practices* have contributed to deepening and potential harmful local equilibria. Ignoring these equilibria by focussing on pilot studies and controlled population samples may only leave these areas further behind.

Finally, we contribute to socio-materiality by providing another model or exemplar study where that perspective adds tangible value for a complex design context. This has been a concern for socio-materiality since its introduction to IS research, as the practical impact of studies is not always as obvious as other forms of mid-range theorising (Mutch, 2013). One obvious source of value for the critical realist school of socio-materiality is the ability to step back and view socio-material phenomena that are missed by theories/approaches which hone in on pre-defined variance or process relationships (Wagner *et al.*, 2010; Cecez-Kecmanovic *et al.*, 2014; Gleasure *et al.*, 2017). This study provides another example, such as in Jones (2014) and Oberländer *et al.* (2018) of this value by stepping back from application-level theorisation, such as interface design or data processing, and individual-level theorisation, such as perceptions and intentions. Instead, building on the recommendations of Cecez-Kecmanovic *et al.* (2014), we pay significant attention to the *material agency* of the system under study, while also showing how these entangle with *social agencies* to form specific *practices*. This demonstrates how a socio-material approach can provide theoretical and empirical triangulation that lends itself to more robust and diligent future theorising (Mingers, 2004).

This study further contributes to differentiating the value of socio-materiality from the preceding theories, such as actor network theory (Latour, 1999) or practice theory (Nicolini, 2009). Although those theories are also useful for extending theorising beyond the reach of variance or process theories, yet they put less emphasis on delineating and distinguishing social and material influences (Cecez-Kecmanovic *et al.*, 2014). This distinction was vital in this study, as a key advantage of mHealth interventions is the ability to make small material changes that still produce significant socio-technical changes (Aryee, 2014; Chetley *et al.*, 2006; Kahn *et al.*, 2010). Socio-materiality further enabled the study of not just “what is” but also “what could be”. Notably, the concept of *material agency* illuminates the potential uses of mobile phones in the future, based on the embedded structures in that technology. Examining actor-network structures and/or practices in isolation would likely miss these insights, as they turn attention to existing patterns and tensions, rather than latent material potential. Yet, it is this analysis of future potential that makes findings actionable and allows challenges to be pre-empted.

Summary and conclusions

This study presents a detailed thematic overview of the existing socio-material structures properties, health-related practices and imbrications of rural healthcare systems that may impact the widespread adoption and assimilation of new mHealth technologies. The emerging themes combine to tell a story of a structured but minimal professional healthcare delivery system, with decentralised and peer-based *practices* increasingly filling in the gaps. They tell a story of isolated rural *social agencies* that limit the authority and value of centralised initiatives and *material agencies* that are not aligned for the desired enactment of mHealth tools like the one proposed. Historic *imbrications* mean trained healthcare professionals are rare, communities of practice are distributed and informal, and mobile phones are treated as tools to support communication among peers.

Building on these, we propose four key questions to be addressed in future research targeting mHealth in rural areas of developing countries:

- (1) How do we design mHealth solutions that complement the existing materiality of rural areas, for example, by minimising the need for travel where transport options are limited? This likely requires more engaged research (Van de Ven, 2007) on the deployment of mHealth tools. This study highlights how practical issues such as electricity, security and road quality can prevent the spread of systems. More engaged designers who understand these issues better may be able to create more robust designs.
- (2) How do we design mHealth solutions that reinforce the connection to urban centres while still allowing rural healthcare workers the autonomy to offer immediate solutions? Our findings showed that cultural differences across rural and urban areas are inhibiting participants’ interest in mHealth projects. One way to approach this question is to consider the types of “design ethnography” advocated by (Baskerville and Myers, 2015). This would bring social and cultural practices and values to the forefront of the design.
- (3) How do we change embedded practices, particularly those that have cultural origins that go against contemporary health treatment methods? Change management is notoriously difficult, it is particularly challenging within healthcare. For this reason, Markus (2004) argued that organisations may need to align technology projects with deep structural change. The same appears true of mHealth, where the enactment of specific tools is tied to the acceptance of medical best practice. Education is therefore both a requirement for the deployment of these tools and an outcome. We therefore

suggest that the design of mHealth tools should also consider more pedagogical theory.

- (4) How do we avoid interference or destructive competition from unregulated information or health-related applications available from peers or on the Web? The addition of IT is not always a social good, and many of the contemporary issues with pseudoscience and “post truth” are linked with social media and Web access (Gewin, 2017). This is a global issue, with many poorer countries and/or countries with low trust in their governments suffering disproportionately (Jamison *et al.*, 2019). Building on the previous questions, this suggests mHealth will be at the forefront of these challenges in the coming years. We call for more studies of information sharing and perceived credibility in mHealth contexts to help understand their relationship in the future.

Limitations

We acknowledge two important limitations of this study. First, our research focussed on a region in which technology-enabled guideline-driven treatment remains the priority mHealth concern. However, several other forms of mHealth initiatives exist, for example, those focussed on data gathering (Chang *et al.*, 2011; Medhanyie *et al.*, 2015) or those focussed on remote diagnosis and treatment (Hufnagel, 2012; Knoble and Bhusal, 2015). We call for similar research on those alternative topics to compare results. Second, consistent with the exploratory nature of our study, the qualitative methodology and the single-case design, we make no claims of statistical generalisability (Yin, 2013). Rather, the intention was to draw attention to important existing socio-material considerations that will add to understanding in this space (Patton, 1990; Maxwell, 1992). This understanding, as well as being of value in itself, can be used to underpin other forms of increasingly structured theorising (Weick, 1995; Mutch, 2013). Thus, we believe the themes identified (Table 5) should be used to inform future theorising in the ICT4D domain that seeks to create more tightly bounded and predictive frameworks or models (Holeman and Barrett, 2017; Oberländer *et al.*, 2018; Vassilakopoulou *et al.*, 2018).

Note

1. Note that socio-materiality is a contested space, with two diverging schools of philosophical grounding (substantialist/critical realist vs agential realism). This study adopts the substantialist/critical realist “socio-materiality” proposed by Leonardi (2013). Appendix 1 explains this distinction in more detail.

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Appendix 1

Philosophical differences in socio-material theorising

The ontological and epistemological foundations for a socio-material analysis may vary (Kautz and Jensen, 2013). One position builds on the work of Barad (2003, 2007) and Latour (1992, 2005) to argue that social and material are inseparably related (Orlikowski, 2007, 2010; Feldman and Orlikowski, 2011). This argument is hinged on the idea of *agential realism* developed by Barad, who argues “phenomena do not merely mark the epistemological inseparability of ‘observer’ and ‘observed’; rather, phenomena are the ontological inseparability of intra-acting ‘agencies’” (Barad, 2003, p. 815). This was summarised by Orlikowski (2007, p. 1437) as “there is no social that is not also material, and that there is no material that is not also social”. Diaz and Urquhart, 2010, p. 353) explain “we live in a world made of both social and technical artefacts; we cannot detach society from technology – neither can we isolate technology in the abstract”. This view is also closely related to Latour’s work on actor-network theory (Cecez-Kecmanovic *et al.*, 2014), who proposed the term “actors” to avoid differentiating human and nonhuman influencers (Latour, 2005), though socio-materiality often prefers “entities” or “agents” (Orlikowski and Scott, 2008; Leonardi, 2013). Collectively, this view of sociotechnical systems “makes a distinctive move away from seeing actors and objects as primary self-contained entities that influence each other . . . either through impacts . . . or interactions . . . away from discrete entities of people and technology . . . to composite and shifting assemblages” (Orlikowski and Scott, 2008, p. 455). In effect, humans or technology (entities) has no intrinsic properties, but obtains form, characteristics and abilities through constitutive entanglement (Orlikowski and Scott, 2008). Further, this view suggests that entities, people and technology have no intrinsic boundaries but are relationally manifested in practice (Cecez-Kecmanovic *et al.*, 2014).

An alternative view of socio-materiality is adopted in this study, namely the view proposed by Leonardi (2012, 2013). This view is grounded on a critical realist ontology that is substantialist (non-relational) in nature (Mutch, 2013). The substantialist ontology “takes as its point of departure in the notion that it is *substances* of various kinds . . . that constitute the fundamental units . . . self-subsistent entities, which come ‘preformed,’ and only then to consider the dynamic flows in which they subsequently involve themselves” (Emirbayer, 1997, pp. 282–283). That is, entities, be it humans (social) or things (material) exist as separate and self-contained entities that interrelate and affect each other in practice (Cecez-Kecmanovic *et al.*, 2014). Building on the works of Mutch (2002, 2010, 2013) and Faulkner and Runde (2012, 2013), it is difficult to operationalise the empirical constructs in an agential realist approach due to the interlocking of the social and material (Leonardi, 2011, 2012). Instead, the substantialist approach assumes an inherent distinction between *material* and *social agencies*, though at the same time recognises that practices and outcomes are dependent on how they are entwined in some context (Leonardi, 2011). Applied to a mHealth context, this means the introduction of a mHealth tool to a developing country should be treated as a change in that system’s *material agency*. During this process of change, the essential building blocks of the mHealth tool are *imbricated* to fit with the goals, needs and expectations of *social* actors, which react to form new *practices*. The degree of this *imbrication* depends on the extent to which *social* actors enact the new *material agencies* introduced, that is, “ultimately, people decide how they will respond to a technology” (Leonardi, 2011). Thus, *social agency* determines which features are enacted and how, while the *material agencies* enable and constrain the possibilities.

Appendix 2

Discussion of Nsukka Local Government Area, Enugu State, Nigeria

Nigeria is an African country on the Gulf of Guinea located in Sub-Saharan Africa. Nigeria is bordered on the west by Benin Republic, on the east by Chad and Cameroon, on the north by Niger Republic and on the south by the Atlantic Ocean. Nigeria is a developing country with an estimated population of more than 198m (NPopC, 2017), divided across 36 states and the Federal Capital Territory, Abuja. It is estimated that 120m Nigerians still live below or around the poverty line (House-of-Commons, 2016).

The under-fives mortality rate in Nigeria is the eighth highest in the world (Adewemimo *et al.*, 2017), with over 100 mortalities per 1,000 births (UN, 2018). Malaria (20%) is the leading causes of death in Nigeria (Liu *et al.*, 2015), closely followed by respiratory infections (19%) (CDC, 2013). In other to address this situation, clinical guidelines for rural healthcare workers (community healthcare workers) were developed by WHO and UNICEF to deliver healthcare services to children under the age of 5 in remote, hard-to-reach rural areas of developing countries (UNICEF-WHO, 2015). These guidelines are known as

integrated Community Case Management (iCCM), which are to be adopted by individual countries basis based on their respective National Child Health Index. iCCM presents a set of meticulous and systematic guideline which enables healthcare workers to assess, classify and treat seriously ill children in rural areas (UNICEF-WHO, 2012, 2015). Rural healthcare workers capture socio-demographic characteristics and clinical information regarding diseases, illness and recommend treatments, especially in malaria prevalent countries in Africa (UNICEF-WHO, 2015).

The Nigerian healthcare system is structured as a three-tier structure comprised of federal, state and local government levels (Okojie, 2009; Oluwatolania and Philip, 2010). The 36 state governments and the 774 local government areas within the states combine to assume responsibility for the provision of basic public services for Nigerians (House-of-Commons, 2016). At the federal level, the government must enact policies and provide resources. At the state level, the ministries of health must provide regulation and technical support. At the local level, local governments must deliver individual healthcare services. The distribution of resources to primary healthcare is a continuous source of tension, as “the spending priorities of states often fail to sufficiently focus on basic services” (House-of-Commons, 2016, p. 34). This means rural communities are often underserved when compared with urban counterparts (e.g. Efe, 2013; Ameh *et al.*, 2016; Alao, 2013; Ademiluyi and Aluko-Arowolo, 2009). A referral system is intended to extend access to urban centres for those living in rural areas; however, this system does not function effectively (Abdulraheem *et al.*, 2012; Onah *et al.*, 2006; Welcome, 2011; Erim *et al.*, 2012).

Enugu state is one of the 36 states in Nigeria and located at the south-eastern part of the country (Igwe *et al.*, 2010; Ezech and Ugwu, 2010). The state is positioned between latitude 50 56N–706’N and longitude 6,053E and 7,055E (Agwu *et al.*, 2008; Ozor and Cynthia, 2011). Enugu is bounded to the North by the states of Kogi and Benue, to the east by the Ebonyi, to the south by Abia and to the west by Anambra states (Agwu *et al.*, 2008; Uzochukwu *et al.*, 2011). Its capital is Enugu, and the name of the State is derived from its capital city, Enugu, means the top of the hill. Enugu state’s area includes most of the Udi-Nsukka Plateau, which rises to more than 300 m (Encyclopædia, 2018b) and partly lies within the tropical rain forest belt to the south (Uzochukwu *et al.*, 2011; Ozor and Cynthia, 2011). Enugu state is covered by open grassland, with occasional woodlands and clusters of oil palm trees. The State was created out of the then Anambra state in the year 1991 during the Military regime of General Badamusi Babangida (Uzochukwu *et al.*, 2011). The State is divided into 17 local government areas (Onah *et al.*, 2005; Nzeadibe and Ajaero, 2010) and three senatorial zones, namely Enugu East, Enugu North and Enugu West senatorial districts (Onah *et al.*, 2005). The population of the state is approximately 3.3m with a land area of about 7,618 sq. km (NPoC, 2018; Onwujekwe *et al.*, 2013; Ani *et al.*, 2014).

In Enugu State, the rate of under-fives deaths (131) (Adewemimo *et al.*, 2017) is notably higher than the national average. The causes of these deaths include: (1) for neonatal it was attributed to sepsis, birth/asphyxia and neonatal pneumonia; (2) for 1–59-month mortality it was attribute to malaria, diarrhoea and pneumonia (Adewemimo *et al.*, 2017). The Igbo (Ibo) ethnic group constitutes the majority of Enugu state’s population (Uzochukwu *et al.*, 2011; Encyclopædia, 2018a; Ani *et al.*, 2014), most of which live in the rural areas (Chukwuma, 2017). Farming plays an important role in the state’s economy; yams, oil palm products, taro, corn (maize), rice and cassava (manioc) are the main crops (Ozor and Cynthia, 2011). Enugu, the state capital, is a major centre for coal mining – hence, it is referred to as “Coal City”. Besides coal, iron ore also is mined, and deposits of limestone, fine clay, marble and silica sand (Encyclopædia, 2018a). Industries include textile manufacturing, food processing, lumbering, soft drink bottling, brewing and furniture manufacturing. A network of roads connects Enugu town with Awgu, Ezzamgbo and Nsukka. Economically, Nsukka local government people are typically farmers (Obidike, 2011; Ozor *et al.*, 2015). Trading occurs but mainly on agricultural products (Ozor *et al.*, 2015). Weaving is a traditional local craft, and coal deposits have been discovered in Obollo area east of Nsukka located on the main Onitsha and Makurdi road (Encyclopædia, 2018b).

Nsukka Local Government Area is one of the 17 local governments in Enugu State. The headquarters is located at the hilly sites of Nsukka town. Nsukka town lies between the geographical coordinates of latitudes 6°45’N and 7°00’N, and longitude 7°15’E and 7°30’E of the Greenwich meridian (Ozor *et al.*, 2015; Felix *et al.*, 2017; Chukwuma, 2017). Nsukka local government shares common border with Igbo-Etiti L.G.A on the South, Uzo-Uwani L.G.A on the West, Udenu L.G.A on the East and Igboeze-North L.G.A on the North (Ozor *et al.*, 2015; Chukwuma, 2017). The local government has an area of 1,810 km² and a population of 309,633 (NPoC, 2018; Ozor *et al.*, 2015).

The Nsukka local government area, located within Enugu state, is subject to especially high rates of abject poverty (Ataguba *et al.*, 2011). For example, in early year 2000, the maternal mortality rate was estimated to be more than three deaths per 100 live births in the Nsukka senatorial zone of the Enugu state (Okeibunor *et al.*, 2010).

Currently, integrated community case management (iCCM) is being piloted in two states in Nigeria, namely Niger and Abia, with future scale-up planned in an effort to cover the basic health needs of over 300,000 children (Malaria-Consortium, 2013; Ozor, 2013). Meanwhile, research findings in other countries have shown defects emanating from the paper-based iCCM method with documentations of poor adherence of rural healthcare workers to the guidelines, leading to poor-quality diagnosis and treatment measures (e.g. Guenther *et al.*, 2014; Amouzou *et al.*, 2014; Miller *et al.*, 2014; Chandani *et al.*, 2017). Recent research findings show that these defects or inadequacies could be remedied with the introduction of information communication technology (e.g. Tumusiime *et al.*, 2014; HealthEnabled, 2016; Oliphant *et al.*, 2017). The current project takes place as one possible mHealth solution, developed and tested in Malawi, is being discussed and demonstrated with urban and rural actors in Nsukka. This provides a unique opportunity to explore possible influences in the earliest stages of a possible transition.

Appendix 3

Detailed information on the app

The app was proposed in early 2016 as part of the Irish Research Council competitive funded IMPACT project. As part of a patient assessment, the app users (i.e. Rural Healthcare Workers) are required to complete several validated fields including the personal information of the patient (e.g. family name, name date of birth, etc.), patient vital sign data, for example, respiratory rate, weight and data about the child's presenting symptoms, for example, cough, fever, diarrhoea and other symptoms. Based on these inputs, the app presents a recommended diagnosis and treatment supporting rural healthcare workers in their clinical decision-making. Depending on the data entered, treatment alternatives may include food and fluids, pain relief and/or broad-spectrum antibiotics. If the presenting child is very unwell, the clinical algorithm recommends that the child is referred to higher-level medical centre or hospital for further treatment.

During the 15-month funded project, approximately 170 stakeholders were exposed to our app. These included RHCWs and other healthcare professionals (e.g. trainee nurses and doctors), parents/guardians of children, developers and facilitators. It was introduced to support RHCWs in their work in assessing young children in the rural community with particular focus on improving adherence to the existing clinical guidelines (Fox *et al.*, 2020). Enforced form validation features means that RHCWs must complete the required form fields (by answering specific questions as per the WHO/UNICEF guidelines) before they are permitted to move to the next assessment question, thus overcoming issues arising from existing paper-based data collection methods and poor data quality at the level of the state (Fox *et al.*, 2020). Following patient assessment, RHCWs are provided with diagnosis and treatment recommendations, compliance with care suggestions is beyond the boundary of the app.

International healthcare guidelines are updated regularly, the fixed nature of the embedded clinical algorithm means that significant additional rework is required to incorporate the latest clinical guidelines in the app. Further, our app was designed with the specific aim of assessing young children, this may be deemed a limitation in terms of supporting broader patient healthcare assessment needs including expectant mothers, other communicable diseases (e.g. HIV), escalating instances of non-communicable diseases (e.g. diabetes type 2) and general adult healthcare.

Appendix 4

Structured interview guide

Research questions for rural healthcare workers (RHCWs)

How do you feel about this new mHealth app?

To what extent do you think that this new app would have a positive impact on your work practices?

To what extent do you think that this new app would have a positive impact on co-workers' work practices?

To what extent do you think that this new app would have a negative impact on your work practices?

To what extent do you think that this new app would have a negative impact on co-workers' work practices?

To what extent do you believe this new app would be part of a broader positive/negative trend in healthcare delivery in Enugu State?

To what extent do you intend to explore different features on this new app?

What, if any, other things do you think this new app could do for you?

What, if any, challenges did you face connecting to the Internet?

To what extent do you see this new app changing the way you perform your duties?

To what extent do you think you can perform your duties using this new app without outside help?

What, if any, challenges did you face when trying to get familiar using this new app?

Is there any reason why you would avoid using this new app in the future?

How do you feel after using this new mHealth app?

After using this new app, to what extent do you think that it would have a positive impact on your work practices?

After using this new app, to what extent do you think that it would have a positive impact on co-workers' work practices?

After using this new app, to what extent do you think that it would have a negative impact on your work practices?

After using this new app, to what extent do you think that this new app would have a negative impact on co-workers' work practice?

After using this new app, to what extent do you believe it would be part of a broader positive/negative trend in healthcare delivery in Enugu State?

Research questions for parents/guardians (PGs)

How do you feel about this new mHealth app?

To what extent do you think that this new app would have a positive impact on the way your child would be assessed at the health centre?

To what extent do you think that this new app would have a positive impact on fellow parents in your community?

To what extent do you think that this new app would have a negative impact on fellow parents in your community?

To what extent do you believe this new app would be part of a broader positive/negative trend in healthcare delivery in Enugu State?

To what extent do you think that healthcare workers would like to explore the different features on this new app?

What, if any, other things do you think this new app could do for rural healthcare workers?

What, if any, challenges do you think that rural healthcare workers would face connecting to the Internet?

To what extent do you see this new app changing the way rural healthcare workers perform their duties?

To what extent do you think that healthcare workers can perform their duties using this new app without outside help?

What, if any, challenges do you think that rural healthcare workers would face when trying to get familiar with using this new app?

Is there any reason why you think that rural healthcare workers would avoid using this new app in the future?

How do you feel after using this new mHealth app?

After using this new app, to what extent do you think that it would have a positive impact on healthcare practices in Enugu State?

After using this new app, to what extent do you think that it would have a positive impact on rural healthcare workers' practices?

After using this new app, to what extent do you think that it would have a negative impact on health practices in Enugu State?

After using this new app, to what extent do you think that this new app would have a negative impact on rural healthcare workers' practices?

After using this new app on your child/children, to what extent do you believe it would be part of a broader positive/negative trend in healthcare delivery in Enugu State?

Research questions for facilitators

How do you feel about this new mHealth app?

To what extent do you think that this new app would have a positive impact on the way you want children to be assessed in Enugu State?

To what extent do you think that this new app would have a positive impact on fellow facilitators in Enugu healthcare system?

To what extent do you think that this new app would have a negative impact on fellow facilitators in Enugu healthcare system?

To what extent do you believe this new app would be part of a broader positive/negative trend in healthcare delivery in Enugu State?

To what extent do you think that rural healthcare workers would like to explore the different features on this new app?

What, if any, other things do you think this new app could do for rural healthcare workers?

What, if any, challenges do you think that rural healthcare workers would face connecting to the Internet?

To what extent do you see this new app changing the way rural healthcare workers perform their duties?

To what extent do you think that rural healthcare workers can perform their duties using this new app without outside help?

What, if any, challenges do you think that rural healthcare workers would face when trying to get familiar with using this new app?

Is there any reason why you think that rural healthcare workers would avoid using this new app in the future?

How do you feel after using this new mHealth app?

After using this new app, to what extent do you think that it would have a positive impact on healthcare practices in Enugu State?

After using this new app, to what extent do you think that it would have a positive impact on healthcare workers' practices?

After using this new app, to what extent do you think that it would have a negative impact on health practices in Enugu State?

After using this new app, to what extent do you think that this new app would have a negative impact on healthcare workers' practices?

After using this new app, to what extent do you believe it would be part of a broader positive/negative trend in healthcare delivery in Enugu State?

Research questions for developers

How do you feel about this new mHealth app?

To what extent do you think that this new app would have a positive impact on the way you want children to be assessed in Enugu State?

To what extent do you think that this new app would have a positive impact on fellow developers in Enugu healthcare system?

To what extent do you think that this new app would have a negative impact on fellow developers in Enugu healthcare system?

To what extent do you believe this new app would be part of a broader positive/negative trend in healthcare delivery in Enugu State?

To what extent do you think that rural healthcare workers would like to explore the different features on this new app?

What, if any, other things do you think this new app could do for rural healthcare workers in Enugu State?

What, if any, challenges do you think that rural healthcare workers would face connecting to the Internet?

To what extent do you see this new app changing the way healthcare workers perform their duties?

To what extent do you think that rural healthcare workers can perform their duties using this new app without outside help?

What, if any, challenges do you think that rural healthcare workers would face when trying to get familiar with using this new app?

Is there any reason why you think that rural healthcare workers would avoid using this new app in the future?

How do you feel after using this new mHealth app?

After using this new app, to what extent do you think that it would have a positive impact on healthcare practices in Enugu State?

After using this new app, to what extent do you think that it would have a positive impact on rural healthcare workers' practices?

After using this new app, to what extent do you think that it would have a negative impact on health practices in Enugu State?

After using this new app, to what extent do you think that this new app would have a negative impact rural healthcare workers' practices?

After using this new app, to what extent do you believe it would be part of a broader positive/negative trend in healthcare delivery in Enugu State?

A socio-
material
exploration of
mHealth

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