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VALUE OF MHEALTH APPS FOR MATERNAL HEALTHCARE SERVICE DELIVERY

Research paper

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Abstract

The growing interest in using mHealth to increase access to maternal healthcare can be understood through the context of value co-creation. The value of mHealth apps is co-created with multiple actors, always including the beneficiary. Service dominant (S-D) logic conceptualizes value as value-in-context in which actors co-create and realize value differently in different channels and their experiences may shift over time. It is unclear of what value is co-created with the use of mHealth apps in maternal healthcare from an S-D perspective. In this paper, a case study approach is used to investigate use of two mHealth apps in Uganda. Interviews and focus group discussions were held with app users. Results were analyzed using S-D value co-creation model. Key findings show that mHealth has been used to co-create value beyond maternal healthcare to individuals. Value that is co-created includes adherence to antenatal care (ANC), skilled attendance at birth, improved resource planning and service delivery, prevention of complications, knowledge acquisition and sharing. Individual value includes improved productivity, knowledge, decision making and wellbeing. Further investigations on individuals' preferences of apps that trigger their active participation, value to family and friends and challenges faced when using mHealth apps to co-create value are suggested.

Keywords: Value, S-D logic, mHealth, maternal healthcare

1 Introduction

mHealth has received great interest as an innovative approach towards achieving the sustainable development goal 3.1 (SDG 3.1) (Sondaal *et al.*, 2016). mHealth is an approach in which practitioners, researchers, and beneficiaries use mobile devices for real-time monitoring of vital signs and direct provision of care (Braa and Sanner, 2011). mHealth can contribute to the creation of value if it is embedded in the entire care process to support new care models thereby shifting from inpatient to outpatient care (Nasi, Cucciniello and Guerrazzi, 2015). mHealth offers improved medical adherence, improved communication with providers, decrease in travel time, ability to receive expert advice, changes in clinical outcomes and new forms of cost-effective education (Hurt *et al.*, 2016). In low resource settings, most mHealth projects are small-scaled, donor funded with no evidence for their effectiveness in improving health outcomes (Lee *et al.*, 2016). Few studies evaluate the outcomes and effectiveness of mHealth interventions that would provide a basis for scaling and transferring research into practice (Agarwal *et al.*, 2015; Chib, Van Velthoven and Car, 2015; Lee *et al.*, 2016; Agnihotri *et al.*, 2018). In addition, few studies demonstrate the role of mHealth apps in maternal healthcare service utilization (Atnafu, Otto and Herbst, 2017). There is need to explore ways in which mHealth apps provide value to patients (Silva *et al.*, 2015) and how they impact on health outcomes (Agnihotri *et al.*, 2018). In addition, it is important to understand how value emerges through interaction and application of resources (including technology) within service systems (Vargo, Akaka and Vaughan, 2017) such as healthcare. Mainly because, value is 'a measure of a change in viability of a system' (Vargo and Lusch, 2017) and its creation influences the usability of a particular resource and its worthiness in exchange (Vargo, Akaka and Vaughan, 2017).

Research on mHealth has focused on organisational value obtained from using mHealth than understanding the individual's value creation potential through mHealth (Andersson and Rosenqvist, 2007). Value is co-created with multiple actors, always including the beneficiary, when resources such as

mHealth are used (Vargo and Lusch, 2004, 2016; Edvardsson, Tronvoll and Gruber, 2011). Value co-creation is defined as the processes or activities that underlie resource integration and incorporate different actor roles in the service ecosystem (Lusch and Nambisan, 2015). The value of a technology is co-created through institutional processes and the integration of a technology and other practices and resources (Wieland *et al.*, 2018). The perspective of extending value creation beyond an individual's actions or perceptions requires a systematic view of understanding value, as advocated for by service dominant (S-D) logic (Vargo, Akaka and Vaughan, 2017). S-D logic provides a theoretical lens to study value co-creation in service systems (Maglio and Spohrer, 2008; Vargo and Akaka, 2009) such as healthcare (McCull-Kennedy *et al.*, 2012, 2017). However, limited studies exist on the application of S-D in healthcare (Joiner and Lusch, 2016). In addition, previous studies on value co-creation in healthcare mainly focus on the provider's perspective to improve care service, safety and process efficiency (Sweeney, Danaher and McCull-Kennedy, 2015) but limited on the value co-creation from a patient's perspective (Lee, 2019). S-D logic can be used to study the value of mHealth apps from the individual perspective since mHealth permits actors to co-create value (Joiner and Lusch, 2016). However, little is known on what patients do to co-create value in healthcare (McCull-Kennedy *et al.*, 2012; Frow, McCull-Kennedy and Payne, 2016) and on the value co-created by individuals as a result of their interactions with mHealth services (Motamarri, 2017).

This paper aims at providing insights into value co-created by actors through the use of mHealth apps in maternal healthcare. We examine data from users of mHealth apps in Uganda to explore the research question "What value is co-created by the use of mHealth apps in maternal healthcare service delivery and how is it co-created?" This paper contributes to research on understanding the process of value co-creation in healthcare (Frow, McCull-Kennedy and Payne, 2016; McCull-Kennedy *et al.*, 2017), value co-created by individuals through the use of mHealth services (Motamarri, 2017) and the role of mHealth apps in maternal healthcare service utilization (Atnafu, Otto and Herbst, 2017). In addition, the paper reports unique empirical findings from a study on co-creation of value in maternal healthcare in rural Uganda.

In the following section, a review of literature on value co-creation in healthcare and value of mHealth apps is provided. This is followed by the data collection method and analysis used in the study. Next, findings of the study are presented and discussed. The paper concludes by identifying value co-created by using mHealth apps in maternal healthcare service delivery, value co-creation activities, enabling resources and directions for future research.

2 Literature Review

2.1 Value co-creation in healthcare

Vargo and Lusch (2016) articulate a narrative of S-D logic value co-creation that comprises of: institutions and institutional arrangements, service ecosystems, actors, resource integration and service exchange. Institutions are norms or practices that aid collaborations (Vargo and Lusch, 2016). Service ecosystem is defined as "relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange" (Vargo and Lusch, 2017). Actors are resource integrators within a network of other actors (Lusch and Nambisan 2015). Resource integration is a process of combining or bundling resources for usefulness of value and, service exchange is a process of coordinating, sequencing, integrating tasks and activities (Lusch and Nambisan 2015). This study adopts this narrative to understand the value co-created from using mHealth apps in maternal healthcare service delivery.

Value co-creation can be achieved at different levels of healthcare (Lee, 2019), thereby involving activities within and outside health facilities, and self-generated activities by patients (Sweeney, Danaher and McCull-Kennedy, 2015). Value co-creation practices in healthcare involves patients' interactions with healthcare providers or with friends and family or with other patients (McCull-Kennedy *et al.*, 2012). Such interactions lead to improved service outcomes that improve quality of life (*ibid*). Value co-creation in healthcare leads to reduced costs per patient, reduced operating costs, reduced length of

hospital stays, improved patient satisfaction and higher health staff retention and satisfaction (Frow, McColl-Kennedy and Payne, 2016). Research on how patients co-create value in healthcare is ongoing. Sweeney, Danaher and McColl-Kennedy (2015) identify a hierarchy of value co-creation activities with varying levels of difficulty for the customer (patient). Frow et al. (2016) suggest principles of adopting a more patient-centered approach to healthcare. Lee (2019) propose a co-creation process that enables patients and medical staff to exchange health-related information and treatment opinions through technologies.

Technology has supported value co-creation both as operant (triggering) and operand (enabling) resource (Lusch and Nambisan, 2015). Healthcare information technologies (HIT) and institutions support patients to actively participate in their own health treatment plans in order to improve the quality of life (McColl-Kennedy *et al.*, 2017). In maternal healthcare, HIT provides complete health information about pregnant women which, enables broader coverage of healthcare services (Nyende, 2018), saves time and costs and, leads to care continuity (Pinho *et al.*, 2014). In addition, HIT reduces cognitive distance among heterogenous actors by enabling them to collaborate and communicate value propositions as they serve pregnant women (Nyende, 2018). Value propositions are expectations of value-in-context, arise from the potential value inherent in actor's resources and shapes the nature of interactions (Frow *et al.*, 2014). It is important to understand the value propositions provided by mHealth apps in a specific social context for actors to co-create value. mHealth support value co-creation through providing access to information to pregnant women leading to co-learning and sharing of knowledge with their peers (Nyende, 2019). Inbuilt features in mHealth apps motivate actors to actively participate in value co-creation through rewards that are used to cover healthcare costs (*ibid*).

Limited research exists on the effects of value co-creation on well-being (McColl-Kennedy *et al.*, 2017) and on patient value co-creation through the use of medical devices or technologies (Lee, 2019).

2.2 Value of mHealth apps

The social context constitutes a system in which, service is exchanged for service and for how value is co-created (Edvardsson, Tronvoll and Gruber, 2011). This is because different actors may perceive the same service differently or same actor may perceive the service differently between occasions in a different social context (*ibid*). It is important to pay attention to the context in which mHealth interventions are being implemented (Opoku, Stephani and Quentin, 2017). Each actor brings unique quality to the context as they integrate and exchange resources with other actors (Chandler and Vargo, 2011). Value is realized when the beneficiary integrates resources from various sources including professionals in a given organization (*ibid*). Each individual actor depends on the operant and operand resources to enhance its own wellbeing through exchange (Vargo and Lusch, 2004). The emphasis on operant resource underscores the importance of interaction, knowledge and relationships of actors (Vargo, Akaka and Vaughan, 2017) who use mHealth apps in value co-creation.

In low-middle income countries, mHealth has been used by actors with different backgrounds, behaviors, skills and beliefs (Opoku, Stephani and Quentin, 2017). Value obtained from using mHealth apps include: increased number of antenatal care (ANC) visits (Feroz, Perveen and Aftab, 2017), deliveries attended by health workers (Lund *et al.*, 2012), use of contraceptives, improved work processes of health workers in rural settings and improved access to reproductive health services (Atnafu, Otto and Herbst, 2017). mHealth have enabled mid-level health workers to predict pregnancy risks (Payne *et al.*, 2014). In addition, mHealth improves knowledge of patients through promoting health education, personalized reminders, health status self-monitoring, counselling and client-to-client communication (Zhang *et al.*, 2018). mHealth enforces behavioral changes and improves communications (Labrique *et al.*, 2013). Full utilization of mHealth is constrained by technical issues and the need for both patients and providers to believe in its usefulness and ease of use (Opoku, Stephani and Quentin, 2017). A traditional view of healthcare that focuses on the role of the healthcare provider and with limited consideration to patients' involvement (Berry and Bendapudi, 2007) leads to designs of mHealth interventions with minimum input of users to be supported (Schnall *et al.*, 2016). Hence, failure to embed mHealth into broader health information systems (Nasi, Cucciniello and Guerrazzi, 2015). There is

need to adopt a systems level thinking to healthcare service system (Beirão, Patrício and Fisk, 2017) in which, mHealth apps support multiple actors at different levels to fully collaborate and interact to improve individual healthcare service (Akaka and Vargo, 2014; Frow, McColl-Kennedy and Payne, 2016). However, we lack studies on how mHealth apps provide value to patients and other individuals (Silva *et al.*, 2015; Motamarri, 2017) and how they impact on health outcomes (Agnihotri *et al.*, 2018).

3 Method

In this section, the method used to conduct the study including the research approach, study setting, selection of participants, data collection and analysis is described.

3.1 Research approach and study setting

This paper reports for a study based on a case study approach (Walsham, 1995) to investigate the value co-created by using two mHealth apps in maternal healthcare. Case study approach was used because it enables researchers to develop concepts, generate theory, draw specific implications and gain rich insights (ibid) on mHealth use in maternal healthcare. Uganda was selected because it has a high maternal mortality rate of 343 per 100,000 live births (WHO, 2015a) and has used mHealth apps to provide maternal healthcare services to pregnant women in hard to reach areas (Nyende, 2019).

The study addresses a call from an earlier study to investigate the use of mHealth apps for value co-creation in maternal healthcare (Nyende, 2019). Two apps in Uganda, referred to as app A and app B in this paper, were selected because both apps are used in districts with high rates of teenage pregnancies and with poor road infrastructure. Pregnant women have to walk long distances to health facilities for care. App A is used in two districts while app B is used in one district. Another reason for selection was because it was easy to get access to users of the apps. The Apps are developed by different organisations and their functions are presented in Table 2.

Uganda experiences a slow progress in reducing maternal mortality which stands at 2.8% decline annually, resulting from limited access to health care and the shortage of medically trained health professionals to deliver maternal healthcare services (Nabudere, Asiimwe and Mijumbi, 2011). The World Bank (2019) reports that births attended by skilled health providers in Uganda was at 74.2% in 2016 this means that about 25.8% of the pregnant women are still giving birth outside the health facilities. In addition, less than half of pregnant women receive the recommended antenatal care (ANC) visits (Benova *et al.*, 2018). Issues leading to low utilization of ANC and delivery care are mainly attributed to physical distance from services, low capacity of facilities, fear of mistreatment and neglect, lack of family support with care seeking and inadequacies in the referral system (Benova *et al.*, 2018). To address some of the issues, mHealth apps are used by midwives and village health teams (VHTs) to support pregnant women in the communities (Nyende, 2019).

3.2 Data collection and selection of participants

The data collection consisted of interviews with users of the mHealth apps. The interview participants were selected based on their roles and influence they have on using mHealth apps to provide healthcare services as shown in Table 1. The roles and influence were considered as a basis for selection because researchers needed to gain insights on how these roles are supported by mHealth apps. In addition, they needed to understand the participants' perceptions on the app use in terms of whether they are interested in using the apps to support their roles or not. This helped to provide insights on the value co-created by using apps in maternal healthcare service delivery.

The number of selected participants per location is shown in Table 2. Meetings were held with app developers who provided contacts and made appointments with administrators in districts in which, the apps are used. Permission to interview participants was gained from the district health officers (DHOs), who are in charge of all health facilities in their respective districts. The DHOs together with other administrators assisted with selecting and communicating to participants in each health facility.

Participants were provided with consent forms which they agreed to and signed before the interviews started. Participants' names were anonymized during analysis for ethical reasons.

Interview participants	Role in maternal healthcare
Midwives	Provide healthcare to pregnant women using mHealth apps and other technologies located at health facilities.
VHTs	Use mHealth apps and other resources to provide healthcare services to pregnant women in communities and report to midwives at health facilities. Thus, intermediaries between midwives and pregnant women
Administrators	Oversee the process of healthcare provision at health facilities and provide support in form of supervision and mentorship to midwives and VHTs.
Opinion leaders	Elderly women in communities that provide social support to pregnant women and raise community health awareness.
Decision makers	Elderly men in communities who are always consulted by others on issues of maternal healthcare.
Pregnant women	Interact with VHTs and midwives to obtain maternal healthcare services and are the target beneficiaries of mHealth apps.

Table 1. Interview participants and their roles in maternal healthcare

3.2.1 Data collection methods

Data was collected from selected mHealth app users from three districts in Uganda as shown in Table 2. Both interviews and focus group discussions were used in data collection. The interview guides were semi-structured in nature thereby enabling researchers to ask follow on questions and at the same time easily capture close-ended questions. Questions were focused on getting user perceptions of adoption, security and seeking of healthcare through the use of mHealth apps. This helped to understand app functions, practices and activities involved and how valuable they are to app users. Specifically, questions on how users perceived the satisfaction, usefulness, ease of use, trust, privacy, risks in using the app were asked. In addition, questions on convenience, communication, access to healthcare and information, benefits from using the app, resources used in seeking healthcare and other support provided from families and friends were asked.

Location	mHealth app and functions	Data Collection Method	Participant	No. of Participants
District 1 (27 participants)	App A functions: Assess pregnancy condition	Interviews	Midwives	2
			Pregnant Women	6
		FGD 1	VHTs	10
	Sense condition of the baby	FGD 2	Hospital In-charge	1
			Health Inspector	1
District 2 (30 participants)	Notify health workers about pregnancy condition	FGD 1	Pregnant Women	3
			Opinion Leaders	2
		FGD 2	Decision Makers	2
			Midwives	6
FGD 3	Pregnant Women	10		
	Health Inspector	1		
	VHTs	8		
Decision Makers	Opinion Leaders	2		
	Decision Makers	3		
	District 3	App B functions:	Interviews	Assistant District Health Of-

(22 participants)	Map and follow up pregnant women		ficer (ADHO)	
			District Population Officer (DPO)	1
	Refer pregnant women	FGD 1	Midwives	6
			VHTs	3
	Track missed appointments	FGD 2	Chief Administrative Officer (CAO)	1
			VHTs	10
Total				79

Table 2. Data collection method and study participants

3.3 Data analysis method

Qualitative data was analyzed using thematic analysis method and a step-by-step guide provided by Braun and Clarke (2006) was followed. Data analysis started by familiarizing with the data through transcription of the interviews and focus group discussions. Inductive codes were generated from the transcription and were grouped based on how they related to each other. Inductive codes were related together to form themes that were reviewed iteratively and refined. Final themes were mapped to the components of the S-D logic value co-creation narrative (Vargo and Lusch, 2016). Under institutions and institutional arrangements, the themes of practices in seeking maternal healthcare and skilled attendance at birth were placed. Under service ecosystem, the theme of supporting digital infrastructure was placed. Under actors, the theme of actor roles and how the roles are supported/triggered by apps was placed. Under resource integration, themes for enabling/triggering resources and, information and knowledge sharing were placed and, under service exchange, the theme of mechanisms for service exchange among actors was placed.

In addition, closed-ended questions from semi-structured interviews were analyzed using SPSS. This was done to identify the number of respondents who selected specific options in each of the questions. The results were used to complement and confirm the data collected from other interview questions.

4 Results

Results present insights on the reality of maternal healthcare in terms of how individuals use mHealth apps to co-create value for healthcare and for themselves during service delivery.

4.1 Institutions and institutional arrangements

4.1.1 Seeking maternal healthcare

The Ministry of Health requires that all pregnant women seek antenatal care (ANC) by visiting health facilities. Each pregnant woman must complete at least four ANC visits that are scheduled according to the stage of pregnancy. In districts with high teenage pregnancies, young girls fear to seek ANC because they are afraid of reactions from midwives. It is difficult for midwives to know the number of pregnant girls that need ANC which, makes it difficult for district administrators to plan for resources to run outreach programs. This leads to high deaths among teenage pregnant girls which could be reduced through encouraging them to visit health facilities. As quoted by the ADHO *“In Kanungu there are high rates of maternal and prenatal death. This year alone we have registered 6 deaths... we are badly off because over 60 children died during labor from August 2017 to May 2018.”*

App B has been used to improve healthcare-seeking behaviors by increasing adherence to ANC visits. To do this, project implementors of app B have identified and trained VHTs from communities. These VHTs identify pregnant girls below 25 years of age and use app B to map them to specific health facil-

ities in order to seek healthcare. The mapped girls who are due for ANC are followed up by VHTs and midwives. As quoted from the DPO *“786 women have been mapped in the district and Rutenga is the best sub-county so far since November 2017”*.

App B enables VHTs and midwives to easily track missed appointments which enables them to follow up pregnant women and greatly improves adherence to ANC visits. All the 6 midwives who use this app reported a great increase in the number of women seeking ANC. The app enables VHTs and midwives to obtain a list of women at least three days to the appointment dates. As quoted from the DPO *“We have a list of upcoming appointments where the midwife and the VHT can look through and know when this girl is coming so when she misses, the name will turn red.”*

During follow up visits, in case the VHT notices danger signs, he/she uses the app to check for a nearby hospital where the women can be referred to. The VHT notifies the women and gives them referral notes. The notes are used by midwives to provide services to the women. Follow up and referral activities led to improved communication between actors at different levels of maternal healthcare.

4.1.2 Skilled attendance at birth

A second practice is that pregnant women are required to give birth at health facilities. All the 13 VHTs reported that most women do not know their expected date of delivery (EDD) which, may lead to delivering at home instead of at a health facility. This may eventually lead to death especially in cases of complications. App B computes the EDD based on the date of the last menstrual cycle entered by the VHTs. This enables VHTs to keep following up women and ensure that they give birth at a health facility. All the VHTs who use app B reported that they use the app to capture teenage pregnancy in the district and, to encourage girls to go for ANC and deliver from health facilities by skilled midwives. 10 of the 13 VHTs reported that app B has enabled them to compute the date of delivery and inform the pregnant women to plan for delivery as quoted from one of the 10 VHTs *“I tell her that you expect to deliver on the date that is generated by the app and that they need to plan for basic needs such as gloves and transport.”*

The above excerpt indicates that App B aims at increasing skilled attendance at birth by computing the EDD to enable women prepare for delivery.

4.2 Service ecosystem

4.2.1 The supporting digital infrastructure

The digital infrastructure for maternal healthcare service delivery extends beyond the use of mHealth apps to include self-diagnostic devices and the district health information system (DHIS 2). The infrastructure holds together different actors and enables them to communicate and collaborate. Actors are supported by mHealth apps to make accurate diagnosis. All interviewed pregnant women reported that they are provided health education by both VHTs and midwives including ways to identify danger signs during pregnancy. They are also given books with illustrations on such signs. For signs that are not visual, it becomes difficult for pregnant women to assess the severity of the condition, which may lead to deaths. App A, is designed for use by pregnant women, VHTs and midwives and is aimed at diagnosing the pregnancy condition. The app is connected via Bluetooth to a hand-held self-diagnostic device attached to a sensor belt that enables actors to capture and record information about the pregnancy status. All the 8 midwives reported that the app helps to monitor pregnant women during ANC visits and in labor. 6 of the 8 midwives reported that the app enables early diagnosis making it possible to deliver safe babies. 2 of the 8 midwives reported that the app saves time because it monitors several parameters at once and provides quick results. All the 8 midwives reported that the information captured by the app includes the temperature, fetal heart rate and uterine contractions. Contraction trends during labor are displayed in form of graphs and are used by midwives to determine progress. Pregnant women and midwives can listen to the heart beat through head phones attached to the device. Temperature is shown in form of a reading displayed on the device or phone display. The device has

lights that are turned on depending on the status of the pregnancy as quoted by 1 of the 8 VHT using App A from district 2 and was agreed on by all the 8 VHTs *“If the condition is normal, the light signals green and when it is abnormal, it signals red”*.

Information captured by the app is stored on a memory card attached to the device. The app enables diagnostic information to be shared among actors including the pregnant women. Results from the app are also shared with the husbands of the pregnant women, which enables husbands to make quick decisions and encourage women to go to hospital for further checkups. As quoted from 1 of the 2 midwives from district 1 *“If you get information, the woman passes it quickly to the husband to see what to do”*.

Pregnant women did not report satisfaction because they had not used the app by themselves. Only 3 out of 19 pregnant women interviewed had mobile phones which they could use to access the app. Only 3 of the 8 midwives were very satisfied with using app A while the others were not sure. This is because they expected more features from the app. These included scanning babies, checking anemia of pregnant women and measuring fetal heart rate. Midwives also opted to use the device without the phone to avoid contamination.

Actors are also supported by mHealth apps to improve ANC seeking behaviors. App B is designed for VHTs and midwives to map and follow up pregnant women in rural communities to health facilities for ANC. All 13 VHTs from district 3 reported that they have been provided with smart phones, data subscriptions and airtime credit to enable them register pregnant women, monitor their health status and refer them to health facilities. The information collected by the app is stored on the smart phone device and a copy stored on the server. In cases of lack of internet connection, VHTs capture information and locally store it. When they reach an area with internet connection, they upload the information to the server. For App B, all actors have access to information through the app or a dashboard. The DPO uses a dashboard to check the number of women mapped on a daily basis, VHTs use it weekly to see which women are due for ANC and midwives use it daily to view the status of women.

App B provides several benefits to VHTs and midwives that include improved record keeping, data reporting by making it easy to view health summaries, secure data storage, improved interactions between midwives and VHTs, easy tracking of missed appointments. As quoted from 5 of the 6 midwives *“I am very satisfied because the app supports us in tracking missed appointments”*

As quoted from the DPO *“I am able to view a summary of all the pregnant girls mapped using the dashboard and then make informed decisions”*

Personal benefits to VHTs include technology skills development, recognition in the community, experience in healthcare, self-satisfaction and convenience in doing their work. As quoted from 3 of the 13 VHTs *“Women feel happy when you make a follow up”...“Am satisfied because I got a smart phone”... “I am satisfied because am among the few that was selected and I train many women”*

App B is also used as a basis for evaluating the performance of VHTs based on the number of pregnant women they have mapped to health facilities. A quoted from 1 of the 13 VHTs *“I have to keep checking to see if I have not lost the registered women”*

In addition to mHealth apps, DHIS is used at level-four health centers to capture data about the number of pregnancies and maternal deaths from all health facilities within a district. This greatly improves the reporting process of maternal deaths. It was also noted that the information captured by the mHealth apps is not linked to that in DHIS and vice versa.

4.3 Actors

4.3.1 How apps support/trigger of actor roles

Actors who use mHealth apps include VHTs, Pregnant women and midwives. App A is designed for use by pregnant women, VHTs and midwives whereas app B is designed for use by VHTs and midwives. Midwives provide services to pregnant women at health facilities and train VHTs on how to provide services to pregnant women including guidance and counselling and identifying danger signs.

They use app A to diagnose pregnant women and monitor them during labor. They also use App B to monitor ANC visits by tracking missed ANC appointments. As reported earlier, midwives use apps to better support their work hence suggest improvements in app designs. As quoted from each of the 3 out of the 6 midwives from district 2 who use app A *“We would like to see the baby moving, ...the heartbeat from conception to delivery ... how long it takes to connect and receive results from the device”*.

App B is used to share information between midwives and VHTs about pregnant women. As quoted from 1 of the 6 midwives from district 3 *“...based on the information in the app, I connect with VHTs to discuss about pregnant women”*.

VHTs use app B to map and collect data on pregnant women in rural communities, follow up on their status, make appointments and refer them to health facilities. VHTs are trained to keep secret the information they collect from pregnant women. They also provide activities such as counselling and identifying danger signs that are not supported by the app. As stated by 9 of the 13 VHTs from district 3 *“I am supposed to map girls that get pregnant when they are still young”*.

Pregnant women are the primary beneficiaries of maternal healthcare and interact with midwives and VHTs by providing them the information required and complying with their prescriptions. They do not use app A although it is designed for them due to lack of resources needed to use it.

4.4 Resource integration

4.4.1 Enabling/triggering resources

Enabling resources for mHealth app use include mobile phones, Internet connection, voucher system, family support. Mobile phones are key resources for mHealth apps and are used by VHTs in communities to map and follow up pregnant women. In cases where phones get technical problems or are stolen, VHTs use other resources such as books to record girls or they borrow phones from colleagues to map pregnant girls in their areas. Borrowing phones causes challenges with accountability because the mapped girls are shown on the VHT's account from whom the phone was borrowed. As quoted from 2 of the 13 VHTs *“I borrowed a phone and used my colleague's password, now my data is not showing” ... “I recorded in a book and I did not use the app to map because my phone got a problem.”*

Mobile phones require access to internet connection because the data captured from the pregnant women through the apps needs to be uploaded to the server. Internet connection is obtained through data subscriptions to telecommunication networks. Some areas have poor network making it difficult to exchange resources as reported by the ADHO *“There is a problem of network where people can receive and make a call ... some VHTs can't map women because of the network problem”*

VHTs and midwives are provided with airtime credit and data bandwidth subscriptions to use the apps however, it was noted that some of them use the credit and bandwidth for their personal benefits. As a solution to this, monthly meetings are organized in which, the credit and or bandwidth used by each VHT or midwife is compared to the number of girls mapped per month. This is done to reward VHTs with outstanding performance and to embarrass those using the resources availed by the project for personal gains. As quoted from the DPO *“We have a reward system and we are going to reward three best performing midwives and best VHTs”*

Other resources are used by actors to support the women mapped with the mHealth apps. These resources include the voucher system that provides transport to women to reach health facilities. As quoted from the ADHO *“Voucher system has helped women to deliver from some hospitals but it is not well distributed...some areas that are underserved and very far, lack the voucher system”*

Resources are also obtained from family and friends. Pregnant women communicate with their family and friends to obtain support including social support, financial support and psychological support. As quoted from 10 of the 19 pregnant women *“My husband helps me to fetch water and my relatives help me because I stay with them...”*

All the 19 pregnant women reported receiving financial support from their husbands in terms of paying for medical bills. However, all pregnant women reported that they are not escorted by their husbands for ANC. In addition, only 6 pregnant women report that they receive more support from relatives after delivery than during pregnancy.

Triggering resources include SMS reminders, signals about ANC missed appointments, pregnancy status notifications, knowledge on how to map using mHealth apps, knowledge on identifying danger signs. These resources trigger actions from different actors. For instance, SMS reminders from app B trigger women to go for ANC. App B signals about ANC missed appointments are shared with VHTs and midwives and triggers them to follow up pregnant women who missed ANC. Status light signals on App A trigger actions from midwives based on the condition of the pregnant women. Knowledge about the mapping activity trigger actions on the selection of the appropriate health facility to map pregnant women in case of complications based on location. Knowledge on identification of danger signs triggers actions from pregnant women to visit health facilities.

4.4.2 Information and knowledge sharing

Information from mHealth apps is shared among actors, creating awareness of the services need at the health facilities. Midwives and VHTs use apps to share information about pregnant women who are due or missed ANC appointments. mHealth app shows different colors as a signal for when appointments for pregnant women are due and when midwives are supposed to contact VHTs. As quoted from the ADHO *“On the next appointment, the name of the girl goes green and when it stays for 10 days, it turns to yellow and the midwife calls the VHT when it turns red, it is recorded in the app as missed”*

Midwives and pregnant women can share information by listening to the heartbeat of the fetus using the diagnostic device. App A provides an alert to show the condition of the baby. However, midwives wanted to use their own knowledge to identify complications in a pregnancy. As quoted from 1 of the 2 midwives in district 1 *“The app should just give us readings in figures and let us determine for ourselves if the situation is normal or abnormal”*

Training and refresher courses on how to use mHealth apps are organized for midwives, VHTs and pregnant women.

4.5 Service exchange

4.5.1 Service exchange mechanisms

Services are exchanged among actors as they use the apps to capture information from pregnant women. Results from app A are communicated directly by midwives to pregnant women or by VHTs to midwives. As quoted by 1 of the 2 midwives from district 1 *“We tell the woman that this is red and it means abnormal and write a report when they are seeing.”*

VHTs share records of mapped pregnant women by uploading them to the server. District officials and midwives can access records through a dashboard at health facilities. VHTs also share information about the status of pregnant women with midwives through direct talks or referral notes. In addition, SMS messages are sent to pregnant women based on the stage of pregnancy to remind them about their ANC appointments. Other health information in form of health tips and educative messages about immunization are shared through SMS with pregnant women.

5 Discussion

This study uses the S-D value co-creation narrative to identify value co-created by the use of mHealth apps for maternal healthcare. We identify collective value and for each collective value, we elaborate on how it is co-created, resources needed and the individual value to actors, as summarised in Table 3.

Value 1: Improved adherence to ANC visits

To improve healthcare seeking behaviors especially for pregnant teenage girls, mHealth apps are used by VHTs to map and follow up pregnant women and girls to specific health facilities in order to seek healthcare. VHTs are rewarded and recognised for mapping girls. App B triggers adherence to ANC visits through tracking missed appointments by notifying VHTs and midwives of women who missed appointments or women whose ANC appointments are due three days in advance. This makes it easy for VHTs and midwives to follow up such pregnant women, which greatly improves adherence to ANC visits. App B has enabled VHTs and midwives to map over 700 women for ANC, which has greatly increased the number of women seeking ANC. This finding is similar to Feroz, Perveen and Aftab (2017) who indicate that mHealth improves uptake of ANC services by triggering pregnant women to utilize preventive maternal healthcare services hence, reducing maternal mortality. This leads to improved wellbeing of pregnant women. In addition, the app provides a shared view of the status of the pregnant woman in the community among actors including the family members, VHTs and midwives. The shared view improves communication between actors at different levels of maternal healthcare. Thus, it enables midwives at the facilities to plan for resources when necessary, improves service provision and accountability. A shared worldview enables actors to interpret resource integration opportunities coherently and to quickly exchange services (Lusch and Nambisan, 2015).

Resources needed to increase adherence to ANC visits include mobile phones, access to the Internet, knowledge on how to use the apps to map and follow up pregnant women for ANC and SMS reminders to pregnant women to seek ANC. Pregnant women who receive SMS information about ANC are more likely to attend four or more ANC visits than those who don't receive SMS (Lee *et al.*, 2016). Access to mobile phones and a functional stable telecommuting network have been identified as key enablers for patients to use mHealth apps while power, functioning medical technologies, ambulance services, operational costs and telecom services are key enablers for first-contact providers (or VHTs) to use mHealth apps (Opoku, Stephani and Quentin, 2017).

Value 2: Increased skilled attendance at birth

Skilled birth attendance indicates that the health system has the ability to provide adequate care for pregnant women (World Bank, 2019) however, results show that most pregnant women do not know their EDD which may lead to home deliveries resulting into deaths in case of complications. App B is used by VHTs to compute the EDD and inform pregnant women and later follow them up to ensure that they give birth at health facilities. mHealth increases skilled delivery attendance through health education and appointment reminders, based on the gestational age (Lund *et al.*, 2012). Deliveries that occur at health facilities lead to better health outcomes and increased utilization of postnatal care services (Atnafu, Otto and Herbst, 2017). In addition, results show that knowing the EDD enables pregnant women to plan for delivery by ensuring that they save money to cover costs such as transport to health facilities and basic requirements such as gloves. Birth preparedness increase the use of skilled care at birth and timely use of facility care (WHO, 2015b), which enables midwives to plan for resources. Some women are linked to the voucher system by midwives at the health facilities. The voucher system is an enabling resource that covers transport and other associated medical costs for women to reach health facilities for delivery which, greatly improves skilled attendance at birth. Vouchers are used as incentives for clients to access subsidized health services and access resources for health (Labrique *et al.*, 2013). VHTs and midwives are provided resources such as phones, data subscriptions and credit to enable them register pregnant women, monitor their health status and refer them to health facilities. Mobile phone voucher system improves communication between pregnant women and health care providers, and facilitates referrals among health facilities (Lund *et al.*, 2012).

Value 3: Improved resource planning and service delivery

App B enables VHTs and midwives capture information about women who require healthcare services. Results show that capturing information about pregnant women enables VHTs to improve record keeping, data storage and reporting and interactions with other health providers. This finding is similar to Feroz, Perveen and Aftab (2017) who indicate that mHealth is utilised to increase quality of maternal healthcare and as a way of collecting pregnancy data to ensure data recording, completeness and reporting. Summary information captured by the app is viewed by the DPO and the ADHO using

dashboards located at the health facilities thus, improving the reporting process. This information enables healthcare providers to plan for resources required to serve the pregnant women and to plan for outreach programs within the district. Increased access and sharing of information enable shared decision making. Integrated health summaries improves productivity of health professionals by saving time needed to gather information about the status of pregnant women (Nyende, 2018), hence enabling pregnant women to receive better healthcare service. Results show the existence of DHIS that captures data on pregnancies and maternal deaths from health facilities within a district but, this information is not linked to that captured by app B. Integration of mHealth apps with the DHIS provides innovation opportunities to improve work practices and to scale up mHealth apps (Nyende, 2019).

Value 4: Prevention of complications due to early diagnosis

Prevention and treatment of pregnancy complications is achieved through early diagnosis of such complications using mHealth apps. Results show that VHTs and midwives use app A to identify pregnancy complications in time as they use a device connected to app A and sensor belts to assess the pregnancy status. mHealth enable VHTs to identify women at risk of hypersensitive disorders of pregnancy (Payne *et al.*, 2014). In addition, with limited training on identification of danger signs, pregnant women can self-diagnose themselves using the same app. However, most of the pregnant women cannot afford mobile phones and devices to use app A, which limits them to actively participate in co-creation of value through self-diagnosis. In addition, results show that using app A for early diagnosis provides value to midwives by improving their productivity through delivery of safe babies, saving time and cost, and improving information sharing with other midwives, pregnant women, family and friends. Family and friends are important sources of support and connecting with them provides a basis for value co-creation in healthcare (McCull-Kennedy *et al.*, 2012). Pregnant women share results from app A with their husband which, improves access to health information to guide decision making. Self-management of care and shared decision making between patients, families and healthcare team inspires doctors to seek opinions of patients and their families in designing supportive healthcare packages (Frow, McCull-Kennedy and Payne, 2016).

Value 5: Increased knowledge acquisition and information sharing

Results show that VHTs and midwives are trained to use mHealth apps as a tool to share and exchange knowledge about maternal healthcare, hence greatly reducing the cognitive distance between actors. Reducing cognitive distance facilitates development of a coherent view of the changes in the environment thereby enabling actors to obtain a common perspective of their environment (Lusch and Nambisan, 2015) and improves interactions among actors. In addition, results show that improved interactions among VHTs, midwives and pregnant women creates awareness of services needed hence leading to new knowledge acquisition, exchange and improved service quality. Actors share knowledge through interactions which, helps them to co-craft relevant offers and shape their expectations of their usage experiences. Results show that using mHealth apps provides personal benefits to VHTs that include technology skills development, recognition in the community, experience in healthcare, self-satisfaction through performance evaluation and convenience in doing their work.

Through app B, SMS is used to communicate and share information between healthcare providers and pregnant women. Results show that mHealth apps enable pregnant women to acquire knowledge through health tips and educative messages, and improve healthcare seeking behaviors through ANC appointment reminders, a similar finding that has been reported by Feroz, Perveen and Aftab (2017). Diagnostic information is also shared between midwives and pregnant women through listening and reading figures presented by app A. This information is further shared by pregnant women with their family and friends to obtain support. This implies that women are empowered with knowledge that enables them to participate freely in the co-creation activities. Timely health education and actionable health information delivered through SMS or videos that engage one or more actors influences health behaviors (Labrique *et al.*, 2013). App B enables VHTs to upload records of mapped pregnant women to the server and shared among healthcare professionals through a dashboard at the health facility. Improved access and sharing of information are value co-creation factors (Pinho *et al.*, 2014) and lead to improved healthcare seeking behaviors.

Collective Value	Value co-creation activities	Enabling Resources	Individual value to:		
			VHTs	Midwives	Pregnant women
Improved adherence to ANC visits	Mapping and following up women, tracking missed appointments	Mobile phones, Internet access, knowledge on using apps and SMS reminders	Rewards and recognition	Better communication, service provision and accountability	Improved wellbeing due to utilization of maternal healthcare services
Increased skilled attendance at birth	Following up and referring pregnant women, Computing the EDD	Voucher system EDD, Referral notes	Access to resources, improved communication with other actors	Access to resources, improved resource planning, communication and referrals	Improved birth preparedness, health education and communication, reduced medical and transport costs
Improved resource planning and service delivery	Reporting maternal deaths and analyzing information on dashboards	mHealth apps and DHIS, Integrated health summaries and reports	Improved record keeping, data storage and reporting	Improved productivity, reporting and shared decision making.	Improved wellbeing due to better healthcare service
Prevention of complications	Diagnosis of complications early enough	mHealth app, device connected to sensor belt and head phones	Easy identification of complications	Improved productivity and information sharing, time and cost saving	Informed decision making with family, delivery of safe babies
Increased knowledge acquisition and information sharing	Training, information and knowledge sharing and interactions	Training and information sharing sessions, and SMS reminders	Knowledge and experience, community recognition, self-satisfaction.	New knowledge acquisition and exchange, improved service quality	Knowledge acquisition and improved healthcare seeking behaviors, better healthcare

Table 3. Collective and individual value, value co-creation activities and enabling Resources

6 Conclusion

This study makes an important contribution to mHealth research, particularly on the role and value of mHealth apps to patients and other individuals, which is an under researched area (Silva *et al.*, 2015; Atnafu, Otto and Herbst, 2017; Motamarri, 2017). The study does this by identifying types of value co-created by actors both collectively (at the organisational level) and individually, as they use mHealth apps in maternal healthcare. We demonstrate that individuals use mHealth apps to co-create value beyond the maternal healthcare context to achieve individual value as shown in Table 3. Examples of individual value include acquisition of new knowledge, improved productivity, communication, wellbeing, decision making, rewards, costs and time saving. This study establishes a foundation upon which managerial implications can be suggested for planning and scaling up mHealth apps. Secondly, the study contributes to a scarcity of studies on the application of S-D logic in healthcare, specifically, understanding the process of value co-creation in healthcare (Frow, McColl-Kennedy and Payne, 2016; McColl-Kennedy *et al.*, 2017). We demonstrate the process of value co-creation through activities and resources integrated by actors while using mHealth apps for each collective value.

The study is limited by a small number of mHealth apps from one developing country whose views may vary from other app users. Secondly, the study did not investigate: 1.) personal preferences on mHealth apps that would trigger individuals to actively co-create value. 2.) value to family and friends and challenges faced when using mHealth apps to co-create value. Further investigations to address limitations are recommended.

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