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ICT FOR DEVELOPMENT IN RURAL INDIA: A LONGITUDINAL STUDY OF WOMEN'S HEALTH OUTCOMES[1]

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With a view toward improving the success of information and communication technology (ICT) initiatives in less developed countries in general and India in particular, this work seeks to uncover reasons for success and failure of ICT for development (ICT4D) initiatives. We drew on social networks theory in general and social contagion theory in particular, and examined the impact of advice network constructs on ICT kiosk use and the impact of ICT kiosk use on women's health outcomes (i.e., seeking modern medical care and maternal mortality). A two-level model (i.e., village and individual) was developed to understand how women in rural India were influenced by other women in their advice networks to use ICT kiosks, and the effects of ICT kiosk use on seeking modern medical care and maternal mortality. At the village level, we proposed lead user network effects. At the individual level, we proposed structural network effects of other women in a focal woman's network on individual outcomes of ICT kiosk use, seeking modern medical care, and maternal mortality. We focused on network position (i.e., centrality) and network tie strength (i.e., strong ties and weak ties) as explanatory variables. Specifically, we argued that strong tie centrality will have an adverse effect on ICT kiosk use, whereas weak tie centrality will have a favorable effect. We also argued ICT kiosk use will have a positive effect on seeking modern medical care and a negative effect on maternal mortality. Finally, we argued that seeking modern medical care will have a negative effect on maternal mortality. Our model was mostly supported in data collected about 6,710 women in 10 intervention group villages in rural India and 8,344 women in the control group villages over a period of approximately 7 years.

Keywords: Information and communication technology, ICT for development, women's health outcomes

Introduction

Due to the lack of access to accurate medical information and proper medical care, underprivileged groups in less developed countries (LDCs) have suffered from a high rate of mortality. For example, even as recently as 2015, with respect to maternal mortality, India was 10 times worse than the world's best countries (WHO 2015; UNICEF 2015).[2] To achieve the Millennium Development Goals (MDGs) of the United Nations (UN), which have been revised and formulated as the

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[2]At the time of the start of this study, about a decade back, these rates were significantly higher and hovering around 10% in rural India.

Sustainable Development Goals (SDGs), of reducing maternal, infant, and child mortality, ICT is often viewed as a critical tool (Andrade and Doolin 2016; UNDP 2004; Venkatesh, Rai, et al. 2016). For example, the government of India, NGOs, and private organizations have made significant investments in ICT for development (ICT4D) initiatives, such as the rural ICT kiosks (hereafter, a kiosk in this paper refers to an Internet-enabled ICT kiosk) that offer different information and services about on-going epidemics, preventive healthcare, and automation of health data (Jha 2003; Srivastava and Shainesh 2015; Venkatesh, Rai, et al. 2016), such as the Janmitra integrated platform that provided health, education, and government services through community information centers (Gorla 2009). ICT4D initiatives have greatly increased the opportunity for citizens living in rural India to access health information. However, studies indicate a low level of ICT use in rural Indian villages (e.g., Abraham 2013; Correa and Pavez 2016; Gollakota et al. 2012; Venkatesh, Rai, et al. 2016).

Various micro-level factors (e.g., lack of skills and time) or macro-level factors (e.g., lack of support from local government) may explain the low level of use. Research that can explain ICT use and its consequences is of substantial practical value to create a better and healthier life for women, infants, and children in rural India and their ongoing and future welfare, with lessons learned likely to be relevant to other LDCs. Although there is some evidence that the sociocultural environment in rural India prevents the use of modern medical care (e.g., Dutta and Das 2016; Patil et al. 2002; Ravi 2011), less is known about the success or failure of initiatives designed to offer education about and promotion of modern medical treatments or the factors contributing to the success or failure of such initiatives. The aim of this work is thus to understand what factors facilitate the use of ICTs and their downstream impacts, particularly related to women. We examine these issues in the context of Internet-enabled computers, termed *kiosks*, as an ICT intervention, implemented in rural India to facilitate the seeking of modern medical care by women.

As the role of ICT shifted from merely supporting businesses or organizations to occupying a major portion of people's daily lives, research started examining ways through which ICT can address societal challenges (e.g., employment, health, human migration) or lead to unintended or negative outcomes (Majchrzak et al. 2016). Further, the study of designing ICTs as change or persuasive agents (Oinas-Kukkonen and Chatterjee 2009) that can be used to alter people's attitudes or behavior has evolved to include a wider range of contextual factors. For instance, a recent special issue in *MIS Quarterly* on ICT4D focused on ICT use to achieve identity verification (McGrath 2016), alleviate poverty (Jha et al. 2016), address corruption (Srivastava et al. 2016), and combat infant mortality (Venkatesh, Brown, and Sullivan 2016). Specifically, recent ICT4D research reveals that providing end users with access to ICT is not sufficient to address a particular societal challenge, and shows that both ICT use and social networks in a particular context affect citizens' well-being (Hsieh, Rai, and Xu 2011; Venkatesh and Sykes 2013).

In an LDC context in particular, where literacy rates are low, there are relatively low levels of direct use of ICT, with most use being proxy use (see Parikh and Ghosh 2006; Venkatesh, Brown, and Sullivan 2016; Venkatesh et al. 2019; Venkatesh et al. 2017; Venkatesh and Sykes 2013).[3] Recent research of an ICT4D initiative in a village in India emphasized the role of information resources situated in the social networks of individuals in driving both direct and proxy ICT use and realizing benefits (Venkatesh, Brown, and Sullivan 2016; Venkatesh et al. 2019; Venkatesh et al. 2017; Venkatesh and Sykes 2013). Advice networks, which are key local resources for citizens to access information and knowledge,[4] play an important role in determining *use* of Internet information kiosks and in generating spillover benefits for citizens not using the kiosks (either directly or by proxy) through diffusion of information in the social system (Venkatesh and Sykes 2013). Specifically, advice networks of heads of households (i.e., the network of social relationships through which they seek advice) acted as vital informational resources that promoted economic outcomes (farmer income) by (1) fostering the direct/proxy use of ICT (*behavioral pathway*) and (2) providing the heads of household with access to superior information from the advice network resulting from ICT use by others in the advice network (*informational pathway*) (Venkatesh and Sykes 2013), with a follow-up on this work incorporating governance to study the impact on economic outcomes (Venkatesh et al. 2019).

Less is known about the dynamics of proxy use in the context of kiosks implemented in rural India to facilitate the seeking of modern medical care by women (see Venkatesh, Rai et al.

[3] Due to the low literacy in rural India, Parikh and Ghosh argued that technology use is often facilitated by someone, thus resulting in proxy use (see Venkatesh, Brown, and Sullivan 2016; Venkatesh et al. 2019; Venkatesh et al. 2017; Venkatesh and Sykes 2013). Indeed, in studies in villages in India, prior work found little direct use of the Internet kiosk, with much of the use being proxy use—so much so that, for example, Venkatesh and Sykes (2013) did not have enough of a sample to conduct a model test using direct use as a dependent variable. Based on this, when we refer to use, we mean either direct or proxy use and do not differentiate across the two—our expectation being that there will be little direct use in our context.

[4] The treatment of advice networks as resources is consistent with prior research on social networks in general (see Borgatti and Foster 2003) and IS research using social networks in particular (e.g., Sykes 2015; Sykes and Venkatesh 2017; Sykes et al. 2014; Venkatesh and Sykes 2013; Zhang and Venkatesh 2017).

2016). The importance of the noted study context stems from (1) the sociocultural set up of rural India, especially among women, (2) the traditional collectivist culture with a rich oral tradition for information and knowledge dissemination, and (3) low literacy, thus making social interactions, whether those related to lead users or other women, pivotal to their everyday lives and behaviors. In sum, the social networks in which women function represent crucial channels for support that remain understudied from the perspective of lead users and other women who are nonusers of the ICT intervention.

Against this backdrop, we draw on social contagion theory (we will elaborate on the reasons later) to argue that women in rural Indian villages are likely to seek advice from other women within their networks for decisions related to ICT use and health-related issues, thus driving the ultimate outcome of maternal mortality. In sum, our objectives are:

(1) *To develop a model to explain ICT use and its impacts on maternal mortality in rural Indian villages:* In the context of an ICT4D initiative,[5] we develop a multilevel model to understand one of the key drivers of ICT use (i.e., advice networks) and the consequences of ICT use (i.e., seeking modern medical care and maternal mortality).[6] Drawing on social contagion theory (Burt 1987; Friedkin 2011), we propose a two-level model; that is, at the village and individual levels.[7] At the village level, we propose lead user network effects. At the individual level, we propose structural network effects of other women in a focal woman's network on kiosk use, seeking modern medical care, and maternal mortality. Specifically, we theorize that strong ties can have negative effects on kiosk use due to sociocultural mores, whereas weak ties can have positive effects due to the potential for factual and diverse health information reaching women. In addition, we theorize the effects of kiosk use on seeking modern medical care and maternal mortality, and the effect of seeking modern medical care on maternal mortality.

(2) *To empirically validate the proposed model*: We test the proposed model in a study of approximately 7 years, with individual and network data gathered from and about women in 10 villages in India. We also gather archival data related to kiosk use, seeking modern medical care, and maternal mortality. Finally, in order to provide additional evidence of the impact of the ICT4D initiative, we compare the mortality rates in the villages that received the intervention with adjacent villages that did not.

This work is expected to make important theoretical and practical contributions. This work will further our knowledge regarding how to foster the success of ICT4D initiatives in LDCs, especially India, with a particular focus on women's health outcomes. In particular, these are important because they broaden the nature and scope of outcomes studied in IS research. Our fundamental idea in using a social networks lens to shed light on our understanding of ICT impacts can be applied to other domains that are important to advancing the human condition. In terms of practical contributions, understanding the drivers of the success of such ICT4D initiatives will foster lowering maternal mortality, which is a key MDG/SDG, in rural India.

Background

We review two research streams that inform our work—namely, ICT4D initiatives for development and social networks with a focus on social contagion theory. Additionally, given that we theorize about the changes in effects over time, we also discuss prior work related to theorizing about time.

ICT4D Initiatives: Overview and Gaps

Much prior research on the topic of ICT4D initiatives has taken a digital divide perspective. There are two types of digital divide, namely primary and secondary (Dewan and Riggins 2005; van Deursen and van Dijk 2014). The primary digital divide is related to ICT access, whereas the secondary digital divide is related to patterns of ICT use and the consequences thereof (Dewan and Riggins 2005; Venkatesh, Rai, et al. 2016). In the context of the digital divide, the existence of the privileged and the underprivileged is mainly due to their differences in income and education (Hsieh, Rai, and Keil 2008; Srivastava and Shainesh 2015). To reduce the gap between the privileged and the underprivileged, it is important to provide resources for the underprivileged to use ICTs (Kabbar and Crump 2006; Partridge 2007; Pick et al. 2014).

[5]Much like the literature on this topic, we use the terms *initiative* and *intervention* interchangeably in this paper. In order to facilitate readability and in keeping with the field quasi-experiment that we conducted, we frequently use the term intervention.

[6]We chose to focus on maternal mortality because the death of a mother will greatly endanger the life of her infant or child (Anderson et al. 2007). Another important reason for us to focus on maternal mortality is that of all the MDG goals, progress made to achieve this one has been patchy and results have been uneven (MDG Report 2010; Nanda et al. 2005).

[7]We note that because we have measures for each individual only at one point in time over the 7-year period (only the first full pregnancy during the study window is included), the individual level could be referred to as the individual at a particular time/year; however, because time/year here is only used to identify when during the 7-year study window a particular woman's data were collected, we refer to this as the individual level.

There have been calls for research on the secondary digital divide to understand predictors and consequences of use in LDCs (Dewan and Riggins 2005; Venkatesh, Rai, et al. 2016; Venkatesh and Sykes 2013). Against this backdrop, our work seeks to understand how ICT4D initiatives can improve the lives of the underprivileged in LDCs by addressing a few gaps in prior research.

First, much prior work on the digital divide has been conducted in developed countries that are starkly different from LDCs. The importance of taking into consideration contextual factors is underscored by views that context in general (Johns 2006) and the context of LDCs in particular (e.g., Silva and Hirschheim 2007; Venkatesh et al. 2010; Venkatesh, Rai, et al. 2016; Venkatesh and Sykes 2013) is vital to our understanding of phenomena. Often, ICT4D initiatives studied in developed countries deal with installing computers with Internet access in homes (e.g., Hsieh, Rai, and Keil 2008; Hsieh, Rai, and Xu 2011). In rural settings in LDCs, however, only a few shared kiosks are made available to serve entire villages (e.g., Venkatesh, Rai, et al. 2016; Venkatesh and Sykes 2013) that in turn create unique contextualized settings. To address this gap of how an ICT4D initiative works in such a setting, we will incorporate contextual information that highlights the social and cultural influences into our theory to gain a better understanding of the role of ICT in fostering positive consequences (i.e., related to the secondary digital divide) in rural India. Second, much prior work has been conducted over fairly short time frames. Our observation related to most IS research, including research on ICT4D, is that, perhaps for practical reasons, the durations of many studies were necessarily short—often a year or less (Agarwal et al. 2009; Hsieh, Rai, and Keil al. 2008; Hsieh, Rai, and Xu 2011; Venkatesh and Sykes 2013). Given that the impacts of ICT implementations may change over time or take years to materialize, studies with longer time frames are likely to help us gain a better understanding of impacts and thus the phenomenon. To address this gap, we conduct our study over 7 years. The longitudinal nature of our study allows us to develop a richer understanding of the role of ICT in fostering better outcomes related to women's health in LDCs, especially India. Finally, focal outcomes in these past works have predominantly been intention to use the ICT or actual use of the ICT (e.g., Hsieh, Rai, and Keil 2008; Hsieh, Rai, and Xu 2011) and income (e.g., Venkatesh et al. 2019; Venkatesh and Sykes 2013) including women's entrepreneurship and associated profit (Venkatesh et al. 2017), with little, if any, focus on health-related outcomes in general (see Venkatesh, Rai, et al. 2016) and maternal health in particular. To address this gap, we will focus on seeking modern medical care and maternal mortality. Taken together, addressing these key gaps will be of substantial scientific significance to the IS field in general and research on ICT4D in particular.

Social Networks

We use a social networks lens to understand the health impacts of an ICT4D initiative in rural India given that social networks are particularly vital to explaining information diffusion (Sarker, Ahuja et al. 2011; Sarker, Sarker et al. 2011), which we expect to be crucial to fostering favorable outcomes from ICT4D initiatives. The use of social networks is appropriate for three interrelated reasons. First, in rural India, the literacy rates, especially computer literacy (Parikh and Ghosh 2006), are very low, thus making social networks vital to information diffusion. Second, India is a collectivist society and this is even more pronounced in rural India (Venkatesh, Rai, et al. 2016; Venkatesh et al. 2019; Venkatesh et al. 2017; Venkatesh and Sykes 2013), particularly among women. Third, possibly due to the first two reasons, there is a strong oral tradition for information dissemination in India (Parikh and Ghosh 2006; Venkatesh, Rai, et al. 2016; Venkatesh et al. 2019; Venkatesh et al. 2017; Venkatesh and Sykes 2013).

Theories rooted in social networks explain individual behavior and performance beyond what can be explained by individual-level predictors, the link between social networks, behaviors, and behavioral/economic outcomes (e.g., Borgatti and Foster 2003; Lin 2001). Specifically, social networks can influence behaviors and behavioral or economic outcomes. Such effects have been demonstrated in different contexts, with better-connected individuals accruing performance benefits because these individuals can leverage useful information or knowledge acquired from their network connections to achieve desire outcomes (e.g., Sykes 2015; Sykes and Venkatesh 2017; Sykes et al. 2014; Zhang 2017; Zhang and Venkatesh 2013, 2017). Alternatively, better-connected individuals are likely to engage in certain behaviors, such as kiosk use, that could lead to desired outcomes, such as performance benefits (e.g., Sykes and Venkatesh 2017; Venkatesh et al. 2019; Venkatesh et al. 2017; Venkatesh and Sykes 2013). Thus, the impact of social networks on outcomes is both direct and partially mediated by behaviors.

In our context, social networks serve as channels through which information about the ICT4D initiative is exchanged, and thus shed light on how information received from others are interpreted, discussed, and used as a referent standard in making sense of the ICT4D initiative (see Ibarra and Andrews 1993; Roberson and Williamson 2012). Therefore, we chose to examine the advice network, defined as interpersonal ties that are concerned with the giving and getting of advice within a given contextual setup (Casciaro and Lobo 2008; Sparrowe et al. 2001; Yang and Tang 2003)—here, advice among women in rural Indian villages. In our context, infor-

mation regarding modern medical care usually originates from the kiosk (i.e., the ICT4D initiative) and from other women who have already sought modern medical care and/or have used the kiosk. We argue that the extent to which women will seek modern medical care is largely dependent on the advice they obtain from other women about the kiosk and modern medical care. The advice network thus matches our theoretical focus.

Social Contagion Theory

The social networks approach encompasses different theories. We specifically draw on social contagion theory (Burt 1987; Friedkin 2011) to explain the mechanisms underlying the behavioral changes resulting from an ICT4D initiative. Social contagion theory has its origin in explaining the network-driven social processes through which people manage the uncertainty of innovation (Burt 1987). Social contagion theory is relevant in examining social influence that explains how people's perceptions, attitudes, and behaviors are "modified primarily through interpersonal processes, and these processes occur largely in the boundaries of social networks" (Erickson 1988, p. 99). When making decisions in an ambiguous situation (e.g., implementation of kiosks), people tend to look for cues from others to assess the structure of the situation. Social contagion theory suggests that individuals' thoughts, emotions, and behaviors are affected by the displayed thoughts, emotions, and behaviors of other individuals in the network (Friedkin 2011; Galaskiewicz and Burt 1991). The main thrust of the theory is to understand the mechanisms whereby social influence transmitted via social networks in either the form of cognition/informational resources (e.g., advice, feedback), or the form of emotion/affective resources, such as trust and social support, affects adoption of ideas, innovations, and behaviors (Scherer and Cho 2003). Although social influence is the key component of social contagion theory, the theory does not require that there is intent to influence or even an awareness of influence; rather it requires only that interaction/communication take place.

According to social contagion theory, contact, communication and competition make an ego and an alter in a social network proximal, and such proximity causes contagion, resulting in attitude convergence among socially proximal pairs of individuals (Ho and Levesque 2005; Ibarra and Andrews 1993). For example, by witnessing an alter's adoption of an ICT4D initiative, an ego not only becomes aware of the initiative, but also develops a better understanding of the benefits and costs of the adoption. In explaining the social influence processes driven by proximity, social contagion theory focuses on two mechanisms—*social comparison* and *interaction/communication*—that transmits social influence (Burt 1987). Social comparison is triggered mainly by structural equivalence that indicates the extent to which two people have identical relations with all other individuals in the network. In our context, we argue that interaction/communication is more relevant and important than social comparison.[8]

To understand how interaction/communication transmits social influence, we examine *network centrality* that represents an individual's network position and describes the level of connectedness of an individual within a network (Borgatti 2005). We focus on centrality because of its relevance and importance in explaining social influence resulting from interaction and communication. Central individuals, in contrast to those in peripheral positions, have a larger number of contacts, thus gaining more opportunity or chance of interacting and communicating with others to transmit social influence (Borgatti 2005). In addition, central individuals are perceived to have more power and influence mainly because they have a large number of network contacts from whom they can obtain resources and to whom they can broadcast ideas and thoughts (e.g., Mehra et al. 2006; Sykes et al. 2014). In the context of women in rural India, availability of health-related information and social influences are likely to play important roles in affecting the likelihood that a woman will use a kiosk (Venkatesh, Rai, et al. 2016). Thus, based on the context, we reiterate that we examine centrality that captures the extent to which an individual is connected to well-connected others (Bonacich 2007). Such centrality represents the ability to access information and the potential for social influence, thus making it an appropriate construct to better understand social network effects on women seeking modern medical care.

In addition to the level of connectedness, the strength of connections is critical to understand the transmission of social influence (Burt 1987). We use frequency of interaction to

[8]Interaction/communication is more relevant and important than social comparison is for a few reasons. First, the collectivistic culture facilitates communication and interaction among women in rural Indian villages. Second, social comparison can be triggered even though two individuals who are structurally equivalent do not directly interact with each other (Burt 1987; Ho and Levesque 2005). It should, however, be noted that due to the collectivistic culture, women in rural Indian villages are more likely to interact directly. Third, according to social contagion theory, two individuals who are structurally equivalent are more substitutable for each other's role, such as job duties. To maintain their roles, they are likely to compete and compare with each other (Ho and Levesque 2005). However, in rural Indian villages, such competition and comparison are less likely to occur because the collectivistic culture emphasizes collaboration rather than competition.

refer to tie strength.[9] A *strong* tie indicates a high level of emotional closeness and reciprocity resulting from frequent interaction and close relationships (Isen et al. 1987; Madjar et al. 2002). A *weak tie* indicates infrequent interactions and distant relationships (Granovetter 1973; Hansen et al. 2005; Levin and Cross 2004). We distinguish between strong ties and weak ties to understand the transmission of social influence (Burt 1987; Roberson and Williamson 2012). First, strong ties indicate frequent interactions through which network members develop an accurate awareness and understanding of the established norms and culture, increasing network members' pressure to conform to established norms and enhancing the likelihood of establishing similar behavioral patterns among network members (Coleman 1990; Perry-Smith 2006). Given that most women in rural Indian villages live in poverty and have not learned about nor benefitted from modern medical care, they generally resort to traditional medical approaches that they believe to be the only solution to health problems they encounter (May et al. 2014). Such a strong belief is likely to prevent the acceptance of modern medical care or at least create barriers that slow down its acceptance. Strong ties are likely to reinforce the norms of using traditional medical approaches. In contrast, network members who are connected via weak ties are less subject to the pressure of the established norms and culture, and are less influenced by them. Women who are connected via weak ties interact infrequently, resulting in fewer opportunities to reinforce the acculturation toward traditional medicine. These central women will feel less obligated to reinforce the negative views toward modern medical care or advise other women to reject modern medical care. Second, strong ties are characterized by high intimacy and emotional intensity that channel the transmission of both cognitions and emotions (Balkundi and Harrison 2006), whereas weak ties are more likely to transmit cognitions than they are to transmit emotions given that people who are connected via weak ties will feel less comfortable in sharing strong emotional feelings (Levin and Cross 2004). Women connected via weak ties are acquaintances who may feel uncomfortable in expressing strong opinions or emotional feelings to one another (e.g., Perry-Smith 2006; Zhou et al. 2009). They are more likely to talk about factual information, such as the pros and cons of using traditional and modern approaches to medical care. Third, strong ties are likely to strengthen the capability to monitor network members, thus constraining individual actions and leading to greater consensus in members' perceptions, attitudes, and behaviors (Tortoriello and Krackhardt 2010; Zhang and Venkatesh 2013). Such a monitoring effect is attenuated when people are connected via weak ties and, consequently, they will feel more comfortable in proposing diverse or new ideas, such as sharing the positive experience of using kiosks (Perry-Smith 2014). In addition, weak ties are more likely to connect to different social circles that may have ideas and perspectives different from the acculturation against modern medical care (see Granovetter 1973). Finally, due to the frequency of interaction, social influence transmitted via strong ties is likely to be faster and stronger than the influence transmitted via weak ties (Hansen 1999; Levin and Cross 2004).

Role of Time

Although, in many cases, time is treated as a research design element to create separation between the measurement of the independent variables and dependent variables or for other methodological reasons, there has been a call in more recent years to give a role to time in theory development (Ancona, Goodman et al. 2001; Ancona, Okhuysen, and Perlow 2001) and explicitly model/measure it (Saunders and Kim 2007). Time can play a role in altering the nature of relationships and is a critical contextual variable (Johns 2006). Thus, following phenomena over time is critical to a richer understanding (e.g., Maruping et al. 2015; Venkatesh et al. 2006). When time is incorporated into an existing theory, it is likely to help uncover new explanations and understanding related to the theory. Given that some phenomena take time to evolve, it is important to capture at least the linear passage of time; for example, prior research has found that linear time played a key role in the unified theory of acceptance and use of technology (Venkatesh et al. 2003; Venkatesh et al. 2012). More recent works on ICT implementations (e.g., Morris and Venkatesh 2010; Sykes 2015), albeit in organizational settings, have more clearly delineated the validity interval in keeping with the existence interval of the phenomenon by focusing on the shakedown phase of the ICT implementation. Incorporating time such that the existence interval of the phenomenon is considered will in turn allow for the validity interval of the theory to be clearly delineated (see Zaheer et al. 1999). For instance, some studies of ICT implementations in organizational settings have clearly delineated the existence interval of the phenomenon to be the lifecycle of the implemented ICT while focusing, as noted above, on only a part of the lifecycle.

By incorporating time into our model, we theorize that adoption and impacts of an implemented ICT takes time as the citizens in the poorest regions of the world are likely to need time to understand the ICT, overcome their fear of the new ICT, learn to trust the ICT, and alter their ingrained behaviors,

[9]We use frequency of interaction to represent tie strength because people who interact more frequently are likely to be those who are emotionally close and who have a higher level of reciprocity. Prior research has shown that frequency of interaction can be used as a proxy for tie strength (Granovetter 1982; Krackhardt 1992): strong ties and weak ties.

which have been practiced for generations, and to which they have been tied for years and, likewise, abandoning traditional medical care in favor of more modern medical care will also take time. Thus, the existence interval of the phenomenon we are interested in studying is quite long and by conducting a longitudinal study (in our case, 7 years), we develop and test a theory with a longer validity interval and more in keeping with the phenomenon's existence interval. Overall, for a rich understanding of the phenomenon, passage of time is crucial.

Theory

We first present our construct definitions and then our hypotheses.

Construct Definitions

Lead users are those who use ICTs earlier in the diffusion cycle and more frequently than other users. The concept of a lead user is similar to that of a power user in that they both use the ICTs earlier in the adoption process. As a result of their earlier use, lead users, in contrast to later adopters, develop more experience with using a new ICT and also generally have a better understanding of the ICT. In our context, a lead user is a woman who uses the new kiosk implemented in the village early and most frequently. With the concept of a lead user, one village can potentially have several individuals who fit the description. However, in our context, we expect low levels of kiosk use (i.e., low base rate) (see Johns 2006). Taking such a contextual consideration into account is important from the perspective of theory development (Johns 2006). Consequently, we argue that the lead user is the one woman who begins using the kiosk the earliest and does so on a frequent basis. We expect such a woman will play an important role in disseminating information that she acquires from using the kiosk. The lead user is conceptualized at the village level because it is a key village property (i.e., the channel through which information about using a kiosk will be distributed among women in the village).[10]

We also consider a lead user's network position (i.e., centrality) and tie strength (i.e., strong tie and weak tie) to understand how it influences other women's kiosk use and seeking of modern medical care—specifically, *lead user strong tie centrality* and *lead user weak tie centrality* that differs in terms of channeling knowledge and information about using a kiosk. These centralities are global village properties that describe the village channel as a conduit for access to diverse and new information by identifying users at the village level who are lead users. *Lead user strong tie centrality* indicates the extent to which a lead user (woman) is widely connected via strong ties to other women who are also widely connected via strong ties. Strong ties are characterized by frequent interactions that create more opportunities for social influence (Granovetter 1973; Sosa 2010). Lead users are also regarded as powerful because they influence the attitude of others toward a new ICT (Burkhardt and Brass 1990). *Lead user strong tie centrality* is the extent of information flow among women as frequent interactions between the lead user and other women, and a strong influence of the lead user upon other women. *Lead user weak tie centrality* is the extent to which a lead user (woman) is widely connected via weak ties to other women who are also widely connected via weak ties. If a lead user's weak tie centrality is high, the lead user is likely to be able to access diverse and new information and have a lower level of conformity caused by social pressures (Perry-Smith 2006; Zhou et al. 2009). Such leaders can also be expected to diffuse information more widely.

Consistent with the definitions of lead user centralities, we define *a woman's strong tie centrality* as the extent to which a woman (who is not a lead user) is connected to other women who are widely connected via strong ties. Likewise, *a woman's weak tie centrality* is defined as the extent to which a woman (who is not a lead user) is connected to other women who are widely connected via weak ties.

Kiosk use is defined as the interactions a woman has with a kiosk for the purpose of obtaining information related to her health. In rural India, with the very low literacy rates, a woman will typically have another person, namely a proxy user, use the kiosk on her behalf (e.g., Parikh and Ghosh 2006; Venkatesh, Rai, et al. 2016; Venkatesh and Sykes 2013). Proxy use is pertinent in this context given that the majority of women in rural Indian villages do not know how to read or write or operate a computer. *Seeking modern medical care* is defined as the extent to which a woman seeks healthcare from modern medical professionals and/or institutions, such as clinics and hospitals. *Maternal mortality*, a key health-related outcome assessing quality of life in the context of the United Nation's MDGs/SDGs, is defined as the death of a woman when pregnant or within 42 days after child birth (WHO 2015).

Model Specification

Figure 1 shows our multilevel research model that links social networks (i.e., different centralities), behaviors (i.e., kiosk use

[10] It is also a global property given that it does not originate in or emerge from the characteristics of individual village members; in other words, the value of this village property is *not* determined by any aggregated statistics (e.g., sum of individual village members, indexes of variability among village members, the minimum or maximum value among a village's members; see Klein and Kozlowski 2000).

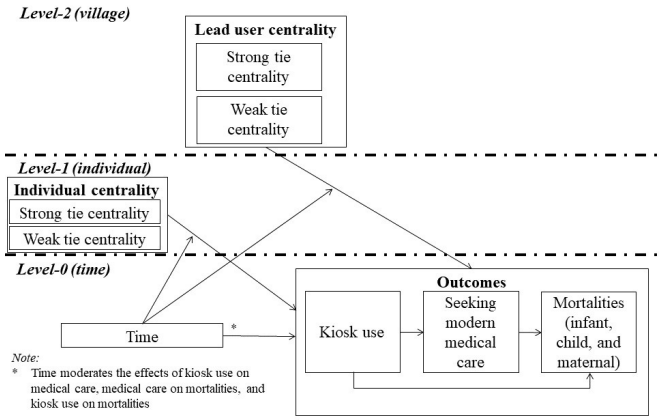

Figure 1. Research Model

and seeking modern medical care), and the key outcome (i.e., maternal mortality).

Hypotheses Development

Network Variables on Kiosk Use (Individual and Village Levels)

Individual Level (see footnote 6): Being widely connected to other women who are also central in their networks, women who have high strong tie centralities will be likely to have more opportunity to interact with other central women and learn about other central women's attitudes toward using the new kiosk. Influenced by other central women, they will be likely to develop a similar attitude toward the new kiosk as that of other central women (Borgatti 2005; Sykes et al. 2009; Sykes et al. 2014). Women in rural India in general have a negative view toward modern medical care and prefer traditional medical approaches (e.g., Patil et al. 2002; Ravi 2011). Consequently, using kiosks will likely be perceived as misconduct given that kiosks were implemented to distribute knowledge and information about modern medical care. Such beliefs and traditional practices of medical care will likely be the established social norms among women in rural India that will likely be reinforced by strong ties (see Hansen et al. 2005; West et al. 1999). Under such circumstances, we argue that women who have high strong tie centralities will be likely to develop a negative view toward kiosk use due to social influence from other central women. In addition, women who have strong ties will be more likely to be influenced by their connections due to frequent interactions and social pressure to conform (e.g., Granovetter 1973; Zhou et al. 2009). Perceptions that using kiosks constitute misconduct will likely be prevalent among women who are connected via strong ties because strong ties often relate to network closure that in turn prevents new or diverse perspectives that favor kiosk use and seeking modern medical care (e.g., Coleman 1990; Mizruchi et al. 2011). Therefore, women who have high strong tie centralities will be likely to accept the dominant negative view toward kiosk use, resulting in less kiosk use. Moreover, social contagion theory indicates that strong ties serve as a good conduit for the transmission of emotions, especially negative emotions (Barsade 2002). When a negative view toward kiosks is expressed, such a negative view will likely be transferred, acknowledged, and reinforced given that people tend to focus more on negative information (Barsade 2002). Moreover, strong ties will be likely to facilitate the transmission of emotions expressed with a high level of energy, resulting in stronger social influence because messages are communicated more clearly and accurately when emotions are expressed with a high level of energy than when they are expressed with a low level of energy (Barsade 2002). Thus, we hypothesize:

> *H1(a): A non-lead user woman's strong tie centrality will have a negative effect on her kiosk use.*

Social contagion theory also explains how women who have high weak tie centralities develop attitudes by processing information available to them through their social relationships (Burt 1987; Ibarra 1993). Women who have high weak tie centralities are those who are connected to other women via weak ties where these other women themselves have many weak ties to other women. Women who have high weak tie centralities will have more opportunities to interact with their weak ties from whom they will obtain opinions about the new kiosk. Influenced by their weak ties, women who have high weak tie centralities will be likely to develop a similar attitude toward kiosk use. With respect to tie strength, women who

are connected via weak ties interact less frequently and are less affected by the established norms against the kiosk that provides information related to modern medical care or the use of such a kiosk. They will have more opportunities to learn about diverse perspectives about kiosks, not simply the negative views. Their views, likely also influenced by some information obtained from kiosks, will focus on using the kiosk for maternal health issues. In addition, when women connected via weak ties distribute positive information about kiosk use in their networks, more women will use the kiosk. Moreover, women who are connected via weak ties will have less pressure to conform to the traditional negative view against the use of kiosks. They will be more likely to try out kiosks and learn about the various benefits of using kiosks. Thus, we hypothesize:

H1(b): A non-lead user woman's weak tie centrality will have a positive effect on her kiosk use.

Village Level: Lead User: According to social contagion theory, perceptions are more likely to be shaped by the opinions of salient or relevant others (Burt 1987; Rice 1993). In our context, lead users, given their experience in using kiosks that was rarely seen among women in rural India, will likely be the women whose opinions on how to use the kiosk, including to obtain modern medical care, will be salient and relevant to other women. Therefore, lead users will be more likely to influence other women.

Lead users who have high strong tie centralities will be likely to develop a negative attitude toward kiosk use given that they are influenced by other central women who will be likely to reinforce the established norms that essentially reject the kiosk and its role as a vehicle to facilitate seeking modern medical care. Although lead users may have favorable views toward kiosk use due to positive experiences from such use to obtain information about modern medical care, they may not feel comfortable in broadcasting the benefits to their strong ties because doing so is to challenge established norms and increase the likelihood of being disliked or even ostracized. Lead users who have more strong ties will be under greater social pressure to conform to traditional views of medical practice. They will have greater concern of being ostracized by other central women with whom they have strong ties (see Krackhardt 1992; Perry-Smith 2006; Thomas-Hunt et al. 2003; Zhou et al. 2009). To be consistent with traditional views as well as to protect themselves from being ostracized by other central women to whom they are tied, they will choose to talk more about the challenges of using kiosks and/or avoid mentioning the benefits of using kiosks. As a result, other women who approach lead users for advice will be less likely to learn the benefits of using kiosks, whereas their existing negative view toward the kiosk will likely be reinforced. Influenced by lead users, other women will be less likely to use kiosks. Thus, we hypothesize:

H2(a): Lead user strong tie centrality will have a negative effect on kiosk use by other women.

Lead users who have a large number of weak ties will be likely to have more sources for information about the kiosk. When seeking information from these sources (i.e., other women who also have a large number of weak ties), they will likely be influenced by the views of these sources. As noted earlier, women who are connected via weak ties will be less influenced by the established norms due to infrequent interactions and consequently, they will be more likely to support different views or perspectives, such as using kiosks to obtain modern medical care. When widely connected via weak ties, lead users will be subject to less social pressure to conform to traditional views of medical care and therefore will be more likely to broadcast the benefits of using kiosks. When approached by other women with questions about kiosks or modern medical care, such as how to use a kiosk to get health-related information, such lead users will be more likely to share factual information related to kiosk use and/or information related to modern medical care that they are likely to obtain from kiosk use. Once other women learn from lead users about the potential benefits of using kiosks, they will be likely to question their existing view that favors traditional medical care. Under such circumstances, women will develop a more favorable attitude toward kiosk use. Some of them might even want to learn more about a kiosk by trying it. Influenced by lead users, other women will be more likely to use kiosks. Thus, we hypothesize:

H2(b): Lead user weak tie centrality will have a positive effect on kiosk use by other women.

Effect of Kiosk Use on Seeking Modern Medical Care (Individual Level)

We argue that there will be a positive effect of kiosk use on seeking modern medical care for two reasons. First, the more women use kiosks, the more likely they will develop a positive view toward seeking modern medical care. By using kiosks, they learn about the effectiveness of modern medical care in helping pregnant women who have health problems (e.g., Brown and Lightfoot 2006; Marshall et al. 2005). In addition to questioning traditional medical practices in villages, especially when they recall their own or others' negative experiences related to receiving traditional medical care, they will start to trust modern medical care. As a result, they might want to try modern medical institutions, especially when they have some health problems that cannot be resolved using traditional medical approaches. Second, by using

kiosks, women learn about how to use modern medical institutions to obtain medical care. Even though some women might want to try modern medical care, they may not know the procedures for obtaining such services until they get the information by using kiosks. Thus, we hypothesize:

H3: A non-lead user woman's kiosk use will have a positive effect on her seeking modern medical care.

Effect of Kiosk Use on Maternal Mortality (Individual Level)

We argue that there will be negative effect of kiosk use on maternal mortality. Kiosks provide information (e.g., self-care guidance and videos) about how to administer self-help or home care in different situations (WHO 2016). If a woman or a care-giver follows the instructions and tips available from using a kiosk when a woman faces health problems during pregnancy, it may save her life. Kiosks also provide information about self-care, such as healthy diet during and after pregnancy. If a woman uses a kiosk frequently, she is likely to become familiar with various self-care practices and can then use them to improve her health or stay healthy, resulting in a decreased likelihood of death. Thus, we hypothesize:

H4: A non-lead user woman's kiosk use will have a negative effect on maternal mortality.

Effect of Seeking Modern Medical Care on Maternal Mortality (Individual Level)

We argue there will be a negative effect of seeking modern medical care on maternal mortality for two reasons. First, the more pregnant women seek modern medical care, the more likely they will receive timely and proper medical treatments. Routine check-ups for pregnant women are critical in identifying major risks for pregnant women, such as low fetal position or gestational diabetes. Hospitals or medical clinics have professional staff and the right equipment to provide timely and proper treatments for various diseases and conditions that pose a risk to the mother, thus in turn reducing maternal mortality. Second, the more women seek medical care in hospitals and medical clinics, the less they will seek medical care from traditional providers who typically lack adequate medical knowledge or professional medical training (e.g., folk practitioners base their actions on superstitions and do not make their decisions grounded in science or validated knowledge) (Patil et al. 2002). Thus, we hypothesize:

H5: Seeking modern medical care will have a negative effect on maternal mortality.

Moderation by Time

Interaction Effect of Network Variables and Time on Kiosk Use: Over time, women will feel more comfortable talking about benefits of using kiosks because their positive view toward kiosks will more likely be endorsed by other women when more and more women discover the benefits of using kiosks. Consequently, we expect that there will be an increase in the spread of positive information and a decrease in the spread of negative information about kiosk use among women who are connected via strong ties. When voices disconfirming the traditional views accumulate, the effects of strong tie centralities on kiosk use will likely be attenuated over time. In contrast, we argue that the effect of weak ties will strengthen over time. When more and more evidence confirming the benefits of using kiosks accumulate, women will have a higher level of trust in the channels (i.e., weak ties) that spread the information about the benefits of using kiosks. Due to an increased level of trust in weak ties, women will be more likely to follow the advice of their weak ties. Consequently, the effects of weak tie centralities on kiosk use will likely be stronger over time. Thus, we hypothesize:

H6(a): The effect of a non-lead user woman's strong tie centrality on her kiosk use will become weaker over time.

H6(b): The effect of a non-lead user woman's weak tie centrality on her kiosk use will become stronger over time.

H6(c): The effect of a lead user woman's strong tie centrality on kiosk use by other women will become weaker over time.

H6(d): The effect of a lead user woman's weak tie centrality on kiosk use by other women will become stronger over time.

Interaction Effect of Kiosk Use and Time on Seeking Modern Medical Care: We argue that the effect of kiosk use on seeking modern medical care will be stronger over time for two reasons. First, women will be likely to have more trust in kiosks as there will be significant evidence confirming the benefits of using kiosks. When they trust the information acquired from kiosks, they will be more likely to seek modern medical care for various health problems during and after pregnancy because the information from kiosks will be likely to suggest that they do so. Second, women will be likely to have a better understanding of the information from kiosks over time, such as knowledge about certain ailments, successful treatment of the ailments and that modern medical care is able to effectively cure the ailments. As positive results of

seeking modern medical care accumulate among women, kiosk use will translate more into seeking modern medical care over time. Thus, we hypothesize:

H7: The effect of kiosk use on seeking modern medical care will become stronger over time.

Interaction Effect of Kiosk Use and Time on Maternal Mortality: With time, women will become more familiar with kiosks and what they can obtain from it, such as types of information, level of detail of the information and usefulness or reliability of the information. Over time, they will develop better capability to utilize the information to improve their health. For example, they will be likely to have a better idea of how to select the best approaches to deal with certain ailments after trying out different approaches, resulting in an improvement of their health. They will also gain more knowledge in self-care techniques, such as eating small and frequent meals throughout pregnancy, doing exercise, monitoring weight increase especially for those who are obese, drinking a lot of water, and obtaining nutrients that build stamina. The passage of time will strengthen the benefits from kiosk use to reduce maternal mortality. Thus, we hypothesize:

H8: The effect of kiosk use on maternal mortality will become stronger over time.

Interaction Effect of Seeking Modern Medical Care and Time on Maternal Mortality: Over time, with more positive information available, the follow-up behaviors, such as taking medicines and routine checkups, will likely be greater. Such follow-up behaviors are crucial for the effectiveness of the modern medical care received. For instance, a routine checkup may help discover a severe disease, requiring immediate treatment without which the lives of mother and baby could be endangered. Further, with time, women will likely trust modern medical practitioners more and will be more likely to truthfully share information regarding symptoms, thus creating opportunities for practitioners to provide better medical care. Thus, we hypothesize:

H9: The effect of seeking modern medical care on maternal mortality will become stronger over time.

Method

In this section, we describe the ICT4D setting and initiative, participants, data collection procedure, and measurement. This study is part of a large-scale project among families in villages in rural India, with other published/accepted papers focusing on short-term (one year) farmer income (Venkatesh and Sykes 2013), long-term (7 years) farmer income (Venkatesh et al. 2019), infant mortality (Venkatesh, Rai, et al. 2016), and women's entrepreneurship (Venkatesh et al. 2017).

Setting and Participants

Our study was conducted in 10 villages in rural India that were chosen for an ICT4D initiative aimed toward providing villagers, especially women, with health-related information. The specific initiative involved providing Internet-enabled information kiosks (one for every 100 families in each village), training to use the kiosks, and the provision of staff members to aid villagers in using the kiosks. Another group of 10 villages, each geographically proximal to one of the 10 villages where the intervention was being deployed, that were not implementing the kiosks were used as a "control group." Data were collected from and about women in the villages over a period of approximately 7 years. Given the low literacy rates, the focus of the training was about the type of information that could be obtained from the kiosks, with only a little information about how to use a browser or health portals. Subsequently, the kiosks were staffed by individuals, at least one of whom was a woman, who were to serve as proxy users (see Parikh and Ghosh 2006; Venkatesh, Rai, et al. 2016; Venkatesh et al. 2019; Venkatesh et al. 2017; Venkatesh and Sykes 2013). The kiosks were available 7 days a week for 16 hours a day.

Participants were adult women in the 10 villages. The sampling frame had 8,330 adult women in the 10 villages; of these, 8,107 women were eligible to be included in the final sample (the measurement section discusses criteria for exclusion). Our sample included 6,710 women for a response rate greater than 80% overall; also, the response rate in each village was greater than 80%, which is important for social network studies. Data were gathered from and about these women in the 10 villages. The average age of the participants was approximately 37 years and most of them (83%) were married. The control group village participants (women) did not statistically significantly differ in terms of demographic profile. The control group villages consisted of 8,344 women (out of 9,220 women) about and from whom we sought to collect similar data, except for kiosk use.

Procedure

The data were collected over approximately 7 years. Prior to the kiosks being installed, a survey via personal interview by a trained professional was administered to all adult women in each village to obtain baseline information regarding their social networks and various control variables. After the initial

data collection, the same training session was provided every day for a month, with the training session lasting about two hours every night. These sessions, conducted by the same two women in each village, were used to highlight the benefits of using the kiosks, the procedures that should be followed to use the kiosks, and a detailed explanation of exactly the types of information the kiosks could provide. Women could attend as many or as few of the training sessions as they wished. As with the initial survey, given the low literacy rates, survey data were collected from each woman via a personal interview in the local language by a trained professional.[11] In follow-up surveys each year, networks, kiosk use, seeking modern medical care, and mortality data were collected. Each interview (survey) took approximately 3 to 4 hours to complete, which was expected given that this was an ego network study. An incentive was offered to each participant at each point of data collection in the study. The amount of the incentive was approximately 500 Indian Rupees, which was a substantial amount given that the annual household income in the villages we studied was approximately 20,000 Indian Rupees at the start of our study.

Our focal study window was approximately one year for each woman, with the period of pregnancy and 6 weeks following child birth. This period is considered to be the period during which a mother's death is counted as maternal mortality (WHO 2015). We included any woman only once in the sample as it related to the first pregnancy in the study window.[12] Figure 2 shows our data collection timeline.

Measurement

Given that the effects of women's network centralities on kiosk use, the effects of kiosk use on seeking modern medical care and maternal mortality, and the effect of seeking modern medical care on maternal mortality were likely to change over time, we treated social network variables, kiosk use, and seeking modern medical care as time variant. All other variables, including the control variables (e.g., education), given that they could change annually, were also treated as time variant.

Social Network Constructs

Social network data were collected in each village using rosters that listed each adult woman in the village. Each village roster was created using the information available from local government offices. Each woman was asked to identify other women from whom she sought advice on a 5-point scale (1–less than once a month, 2–once a month, 3–once a week, 4–once a day, 5–many times a day). Participants were asked to skip those women they did not know or with whom they did not interact. We distinguished strong ties and weak ties based on frequency of interaction such that a strong tie was identified between two people if they interacted at least once a week (tie strengths of 3, 4, and 5) and a weak tie (tie strengths of 1 and 2) was identified between two people if they interacted less than once a week. Eigenvector centrality was used to create a measure for strong tie and weak tie centralities to examine how influential or powerful a woman is within her advice network. The formula for eigenvector centrality is more formally represented as $\lambda v = Av$.[13] UCINET identifies factors of the distances among actors and eigenvector centrality is determined by the eigenvalues derived from the location of each actor on each dimension (Bonacich 1972; Borgatti et al. 2002; for an application, see Mehra et al. 2006).

Lead User Centrality (village level). To identify the lead user for each village, we identified women who engaged both in early and frequent use. Given the constraints of the context (i.e., limited use), we identified the women who used the kiosk both at least once within the first three months *and* at least six times in the first year. Among these women, we then chose the one woman who used the kiosk most frequently as the lead user for each village. We calculated the strong tie centrality of the lead user for each village using eigenvector centrality. For the same women, we calculated lead user weak tie centrality similarly—the key difference was that in

[11]Following best practices for translating survey instruments (Brislin et al. 1973), the original survey instrument, written in English, was given to a local language speaker, who was also fluent in English, to translate from English into the local language. This local language version of the survey was then translated back to English by a second local language speaker who was fluent in English. The translators discussed any discrepancies and resolved them.

[12]Three additional questions regarding the inclusion of women in the sample are relevant. First is the issue of women who were already pregnant at the start of the study: because they were not going to be able to fully leverage the kiosk and consequently influenced to seek modern medical care during the pregnancy term, they were excluded. Second is the issue of women who gave birth after our study was concluded: they were also excluded. These two issues imply that there are some base rate issues in the first and last years of our study. Third is the issue of women who did not become pregnant or who were unable to become pregnant (e.g., women past menopause): these women were retained in the sample but their need for modern medical care as it related to pregnancy (control variable) was set to 0.

[13]*Eigenvector centrality* (Bonacich 1972) is defined as the principal eigenvector of the adjacency matrix defining the give-advice network. The defining equation of an eigenvector is $\mathbf{\lambda v = Av}$, where $\mathbf{A}$ is the adjacency matrix of the graph, $\mathbf{\lambda}$ is a constant (the eigenvalue), and $\mathbf{v}$ is the eigenvector. The equation lends itself to the interpretation that a node that has a high eigenvector score is one that is adjacent to nodes that are themselves high scorers. UCINET calculates eigenvector centralities in a range of zero to one. We multiply this score by 100 to get a range from 0 to 100.

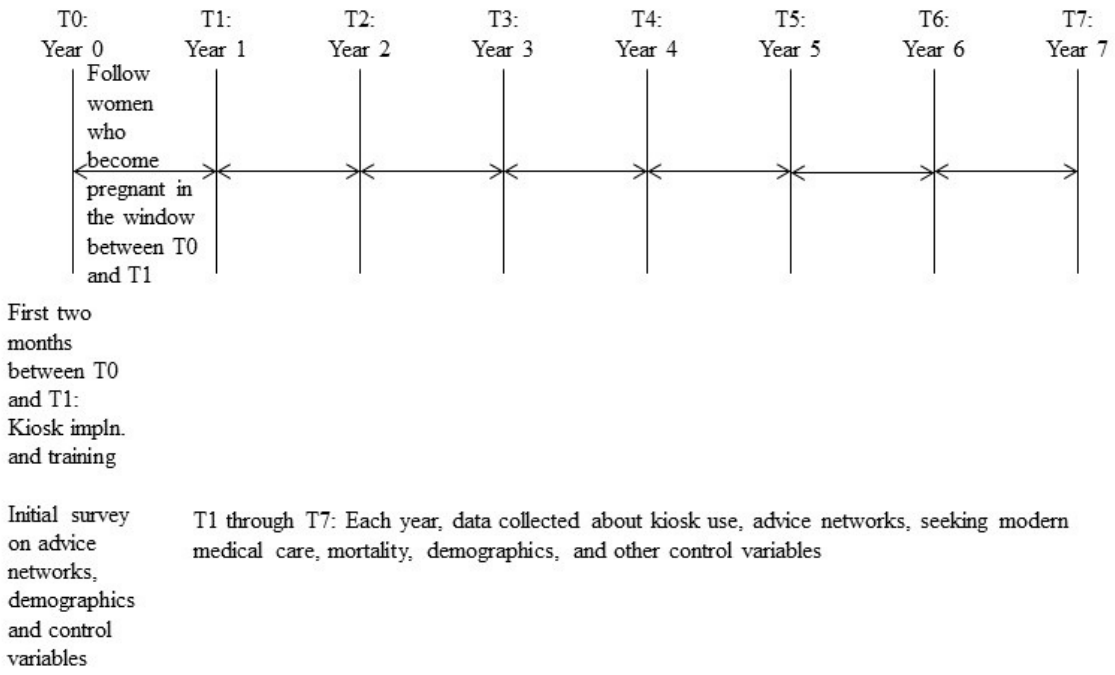

Figure 2. Data Collection Time Line

this case, ties with tie strengths 1 or 2 (i.e., less than once a month) were treated as the presence of a tie and strong ties were excluded.

Centrality (individual level). This construct was operationalized similar to the village-level construct. The key difference was that this was at the individual level and thus calculated for all other women (except lead user) in the network using eigenvector centrality based on their strong ties (tie strengths of 3, 4, and 5) and weak ties (ties strengths of 1 and 2) to yield strong tie centrality and weak tie centrality, respectively.

Time

Time was operationalized to reflect each year of our data collection and is consistent with a conceptualization of time that treats it as linear (see Ancona, Okhuysen, and Perlow 2001; Venkatesh et al. 2006). For example, we collected the data about kiosk use and seeking modern medical care over the period of seven years but include only the data corresponding to the timeframe for when a woman was pregnant and 42 days after child birth. In light of this, we created a variable called Year (1 to 7) that denotes the year that a woman becomes pregnant for the first time within the study window, such that the entire year for which we follow her is completed within our data collection.

Kiosk Use

Kiosk use was measured as duration (see Venkatesh et al. 2003; Venkatesh et al. 2008). The use data were obtained from the paper-based usage log books pertaining to the year in which a woman was pregnant and for the 42 days after child birth. The usage logs were further used to validate the data such that only use relevant to our context was included.[14]

[14]If a woman used a kiosk, her name, date of birth, and time of usage were noted in the usage log book. When a woman came to use a kiosk, she first checked in and began use the start time was noted. After she finished using the kiosk and departed, the end time was noted. Specifically, as noted earlier, given the literacy rate, much of the kiosk use was proxy use mediated by the kiosk attendant (see also Venkatesh, Rai, et al. 2016; Venkatesh et al. 2019; Venkatesh et al. 2017; Venkatesh and Sykes 2013). Total time of use was calculated as the duration between the start time and the end time. Based on usage logs, the time of use was adjusted to reflect only the time spent on health-related information retrieval.

Seeking Modern Medical Care

Seeking modern medical care was measured based on actual visits by women to the mobile clinic that visited each village as well as visits to in-town hospitals. The data were gathered from the archives of the mobile clinic that visited the village and the in-town hospital, both of which were required to keep track of patients. Specifically, modern medical care is recorded separately at the individual level, with a visit date to track visits.[15]

Maternal Mortality

Mortality was coded as a 1 if the mother died during the pregnancy or within 42 days after child birth, which is consistent with accepted conventions for the measurement of maternal mortality (WHO 2015). If women who were not mothers died due to natural causes or other ailments during the study window, they were not recorded as mortalities for the primary analysis. This was done in order to not contaminate the primary dependent variable. As in the case of seeking modern medical care, mortality, should it occur, was recorded in the time window in which it happened.[16]

Control Variables

At the village level, we controlled for village population as network effects can often be influenced by the size of the network (e.g., Fleming et al. 2007; Rodan and Galunic 2004). This also serves as a broad brush control for other potential sources of information and influences in the network. At the individual level, we controlled for four demographic variables and three contextual variables. The four demographic variables were age, marital status (set to 1 if married at the start of pregnancy), number of children at the start of pregnancy, and education level (we code this as no school, primary school attended, primary school completed, middle school attended, middle school completed, high school attended, high school completed; we found that formal education was absent among all women in our focal villages, so we collected the additional data of informal education and used it to code this variable). The three contextual variables were number of maternal, infant, and child mortalities in the participant's family (we restricted this to maternal, infant, or child mortalities at the time of pregnancy), knowledge (tested via a 10-question quiz about maternal, infant, and child health), and need for medical care (coded as a 1 if the participant became pregnant). We also controlled for prior experience with modern medical care (yes or no) because women who have used modern medical care could be expected to use it again compared to those who have not used it.

Given that kiosk use and seeking modern medical care are skewed, we performed data transformations on these two variables. Of the three commonly used transformation methods (i.e., square root, log, and inverse), we used log transformation because this method is suitable when there are extreme values (Osborne 2002). In addition, square root transformation is not suitable for continuous variables, with values ranging between 0 and 1 and inverse transformation has the effect of reversing the order of scores (Osborne 2002).

Results

We used UCINET 6.29 (Borgatti et al. 2002) to calculate the various network centralities. Given that variables were measured at different levels (i.e., advice network centralities), time (i.e., year), kiosk use, seeking modern medical care, and maternal mortality at the individual level; and lead user centralities at the village level, hierarchical linear modeling (HLM) was used to test our model because it takes into account the nonindependence of observations and adjusts the degrees of freedom to account for relationships of individuals nested within villages (see Bryk and Raudenbush 1992; Singer and Willett 2003). Specifically, we used HLM 6.29 (Bryk and Raudenbush 1992) to test the model. A prerequisite for running HLM models is a significantly higher level of unit variance in the outcome measure (Hofmann 1997; Hofmann et al. 2000), which was found to be true. The NULL two-level model with no predictors showed that significant variance was explained between villages. The statistics (i.e., r_{wg}), ICC(1) and ICC(2), that assess agreement among individuals at a lower level are not necessary in this context because lead user centralities are conceptualized as a global property at the village level (Klein and Kozlowski 2000).

[15] Understandably, this measure has the potential to be biased because when a woman faces ailments, the need for medical care increases—rather than only preventive care visits. After carefully studying the archival data about medical care sought, we found that when a mother went to see a modern medical practitioner, the newborn's or another infant's or another child's health was often discussed. Likewise, often when a woman went to see a modern medical practitioner for an infant's or a child's health, she often discussed her own health. Given that the potential noise in the seeking medical care is only relevant in the 42 days after child birth (the window when maternal mortality measurement ends), for the sake of analytical simplicity, we counted all of a woman's visits as seeking modern medical care for her health.

[16] Our primary analysis examined maternal mortality during the 7-year period of our study. We exclude pregnancies that started before or concluded after our study window—the rationale, as noted earlier, is that we could not gather complete data about such women.

Table 1 shows the descriptive statistics and correlations. The pattern of correlations between the different centralities and seeking modern medical care and maternal mortality was in the expected direction, thus lending preliminary support to our hypotheses. Several of the control variables were also correlated with the dependent variables. As shown in Table 2, maternal mortality rates in the intervention group were lower than those in the control group after the kiosks were implemented and used for some time, indicating the effectiveness of the kiosks in assisting women seeking medical care. It should be noted that these are overall statistics for the villages we studied and are not necessarily restricted only to those women who we followed during the study.

Our data indicated that less than 20 women in each village used a kiosk, especially in the first year, thus lending face validity to a focus on one lead user. The results of the primary model testing are shown in Table 3. The main effects model that included strong tie and weak tie centralities at both the individual and village levels explained 31% of the variance in kiosk use (model 2), an increase of 12% of the variance compared to the model with control variables only (model 1). We found that strong tie centralities at both levels had negative effects on kiosk use, whereas weak tie centralities had positive effects on kiosk use. Thus, H1a, H1b, H2a, and H2b were supported. The main effects model that included kiosk use explained 38% of the variance in seeking modern medical care (model 2), an increase of 10% of the variance compared to the model with control variables only (model 1). We found that kiosk use had a positive effect on seeking modern medical care. Therefore, H3 was supported. In predicting maternal mortality, the main effects model that included kiosk use and seeking modern medical care explained 37% of the variance in maternal mortality (model 2), an increase of 11% of the variance compared to the model with control variables only (model 1). We found that kiosk use and seeking modern medical care had negative effects on maternal mortality, thus supporting H4 and H5. The addition of kiosk use and seeking modern medical care to the control variables only model resulted in a significant increase in the variance explained in maternal mortality.

The model with the interaction effects of network variables and time on kiosk use explained 43% of the variance in kiosk use (model 3), an increase of 12% of the variance compared to the model with main effects only (model 2). We examined the results with increasing time (i.e., year). We found that the effects of strong and weak tie centralities on kiosk use varied across time in that the effects of weak tie centralities became stronger over time, whereas the effects of strong tie centralities became weaker over time. Thus, H6a, H6b, and H6d were supported. Given that the moderating effect was not significant for strong tie centrality at the village level, H6c was not supported. The model with the interaction effect of kiosk use and time on seeking modern medical care explained 46% of the variance in seeking modern medical care (model 3), an increase of 8% of the variance compared to the model with main effects only (model 2). We found the positive effect of kiosk use on seeking modern medical care became stronger over time, thus supporting H7. The model with the interaction effects of kiosk use and time on maternal mortality and seeking modern medical care and time on maternal mortality explained 48% of the variance in maternal mortality (model 3), an increase of 11% of the variance compared to the model with main effects only (model 2). We found the negative effect of kiosk use on maternal mortality became stronger over time, thus supporting H8. We also found the negative effect of seeking modern medical care on maternal mortality became stronger over time, thus supporting H9. As a robustness check, we conducted additional analyses to fortify the pattern of findings.[17] Although not directly related to the hypotheses, we examined whether the effects of social network ties on seeking modern medical care and maternal mortality were mediated by kiosk use (detailed results not reported here); interestingly, we found that kiosk use partially mediated the effects of strong tie and weak tie centralities on seeking modern medical care and maternal mortality.

[17]One of the challenges with data such as ours is the low base rate of pregnancies, kiosk use, seeking modern medical care, and mortalities that results in a skewed distribution. Although we can seek analytical remedies (i.e., data transformation—here, log transformation) to address skewed or non-normal data (Fujioka and Maesono 2000; Osborne 2002), to address this issue, we conducted additional analysis with other data that would help fortify the pattern of findings. To this end, we examined women seeking modern medical care in general, regardless of pregnancy. Such an examination provided insights into whether or not modern medical care could lead to positive impact. Such an analysis still had noise as the need for medical care is often tied to age and overall health, and for the latter, we had no way to measure or control. We see this analysis as one that can be viewed in conjunction with our other analyses to provide evidence of robustness. The results of these additional analyses (not reported in detail here) were similar to those reported in Table 3. Specifically, we observed negative effects of strong tie centralities on kiosk use and seeking modern medical care and the weakening of these effects over time. Likewise, we observed positive effects of weak tie centralities on kiosk use and seeking modern medical care and the strengthening of these effects over time. We also observed negative effects of kiosk use and seeking modern medical care on mortalities and the strengthening of these effects over time.

Table 1. Descriptive Statistics and Correlations

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Village population	1,540.22	78.51																
2. Lead user strong tie centrality	42.28	7.73	.13*															
3. Lead user weak tie centrality	31.80	6.90	.14**	-.21***														
4. Time (year)	NA	NA	.16**	.14*	.16**													
5. Age	27.12	13.21	.07	.15**	.17**	.16**												
6. Marital status (1– married)	NA	NA	.05	.13*	.14*	.09	.05											
7. Number of children	3.81	1.01	.19***	.19**	-.08	.19**	.23***	.22***										
8. Education	NA	NA	.03	-.12*	.15**	.05	-.10*	-.12*	-.19***									
9. Mortalities in family	1.07	0.44	.15**	.20***	-.21***	.11*	.14**	.08	-.15**	-.21***								
10. Knowledge (10-point scale)	4.20	2.89	.03	-.13*	.15**	.17**	-.17**	-.13*	-.20***	.28***	.13*							
11. Need (pregnancy)	0.20	0.11	.15**	.07	.10*	.17**	.13*	.35***	.20***	-.15**	.16**	-.20***						
12. Exp with modern medical care	0.13	0.10	.17**	-.23***	.25***	.10*	-.20***	-.17**	.03	.31***	-.23***	.38***	-.14*					
13. Strong tie centrality	35.59	10.25	.20***	.09	.07	.10*	.24***	.13*	.19***	-.21***	.23***	-.21***	.20***	-.20***				
14. Weak tie centrality	29.16	11.20	.23***	.13**	.14**	.08	-.19***	-.14**	-.24***	-.28***	-.25***	.24***	-.13*	.24***	-.20***			
15. Kiosk use	1.16	5.36	.14*	-.28***	.31***	.29***	-.15**	-.17**	.13*	.15**	.28***	.16**	.19**	.29***	-.39***	.38***		
16. Seeking modern medical care	1.06	0.55	.19**	-.30***	.34***	.28***	.28***	.07	.24***	.24***	.16**	.34***	.29***	.38***	-.44***	.44***	.28***	
17. Maternal mortality	0.10	0.04	.12*	.28***	-.31***	-.17**	-.10*	.12*	.12*	-.15**	.14**	-.26***	.23***	-.33***	-.34***	.37***	-.24***	-.28***

*p < .05; **p < .01; ***p < .001.

Table 2. Mortality Rates

	Maternal Mortality	
Year	**Control Group**	**Intervention Group**
2002	73.1	73.5
2003	70.3	70.8
2004 (intervention)	68.4	68.5
2005	66.2	65.1
2006	64.1	61.8
2007	61.8	56.4
2008	59.4	52.2
2009	57.3	49.1
2010	55.2	47.4
2011	52.8	46.1

*Coded as the number per 1,000 live births (still-born data accuracy was low, thus excluded).

Table 3. Results of Model Testing

	Kiosk Use						Seeking Modern Medical Care						Maternal Mortality					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.	Est.	S.E.
R^2	.19		.31		.43		.28		.38		.46		.26		.37		.48	
ΔR^2			.12***		.12***				.10***		.08**				.11***		.11***	
Level 2																		
Control variable:																		
Village population	.11*	.06	.05	.09	.03	.13	-.14*	.04	-.12**	.08	-.05	.17	.24***	.06	.20***	.04	.14*	.05
Predictors:																		
Lead user strong tie centrality (LUSTC)			-.19**	.04	-.13*	.05												
Lead user weak tie centrality (LUWTC)			.16**	.05	.12*	.06												
Cross-level interactions:																		
LUSTC X Time					.04	.15												
LUWTC X Time					.26***	.04												
Level 1																		
Control variables:																		
Age	-.12*	.05	.11*	.04	.06	.16	.19***	.04	.17**	.06	.11*	.05	.15**	.06	.13*	.05	.11*	.04
Marital status	-.13*	.05	.05	.19	.03	.20	-.11*	.05	-.10*	.17	.06	.14	-.12*	.07	-.12*	.07	.10*	.10
# of children	.12*	.03	.06	.18	.04	.21	.05	.16	.05	.15	.02	.14	.04	.15	.04	.14	.02	.13
Education	.05	.14	.03	.17	.02	.16	.06	.19	.06	.13	.02	.11	-.07	.13	.04	.14	.02	.12
Mortalities in family	.19**	.04	.15**	.04	.11*	.04	.17**	.04	.16**	.06	.10*	.07	.13*	.04	.13*	.03	.12*	.05
Knowledge	.08	.10	.05	.18	.03	.17	.22***	.04	.19***	.05	.13*	.06	-.17**	.04	-.14**	.05	-.14*	.04
Need (pregnancy)	.07	.12	.04	.22	.03	.19	.30***	.05	.24***	.04	.16**	.04	.28***	.05	.25***	.03	.21***	.03
Exp with modern medical care	.24***	.06	.18**	.06	.14**	.03	.19***	.04	.16**	.05	.09	.08	-.19***	.04	-.17**	.04	.15**	.02
Predictors:																		
Strong tie centrality (STC)			-.24***	.04	-.17**	.04												
Weak tie centrality (WTC)			.19**	.05	.16**	.04												
Time (year)					.15**	.04					.18**	.04					-.13*	.02
STC X Time					-.13*	.05												
WTC X Time					.30***	.04												
ICT kiosk use (KU)									.38***	.04	.25***	.04			-.24***	.03	-.16**	.03
Seeking modern medical care (SMMC)															-.42***	.04	-.29***	.05
Interactions:																		
KU X Time											.28***	.05					-.17**	.05
SMMC X Time																	-.30***	.04

*p < .05; **p < .01; ***p < .001.

Discussion

We developed a two-level model to understand the role of social ties of women in rural India in influencing their use of a new kiosk, the effects of kiosk use on seeking modern medical care and maternal mortality, and seeking modern medical care on maternal mortality. Our model was largely supported and the network variables at different levels played an important role in explaining kiosk use (i.e., our model explained 31% of the variance in kiosk use, 38% in seeking modern medical care, and 37% in maternal mortality). As predicted, weak tie centralities had positive effects on kiosk use, whereas strong tie centralities had negative effects on kiosk use. In addition, as predicted, kiosk use had a positive effect on seeking modern medical care and a negative effect on maternal mortality, and seeking modern medical care had a negative effect on maternal mortality. Finally, we found that the effects of various predictors changed over time. By incorporating time, our model explained 43% of the variance in kiosk use, 46% in seeking modern medical care, and 48% in maternal mortality.

Theoretical Contributions and Implications

We make important contributions to research on ICT implementations, ICT4D initiatives, and e-government. Our work goes beyond prior IS research that focuses on techno-centric outcomes, especially technology use, by examining the consequences of an IS implementation (see Venkatesh, Thong, and Xu 2016). Two important outcomes (i.e., seeking modern medical care and maternal mortality) were examined in the relatively understudied context of an ICT4D initiative in a rural area of an LDC. By examining consequences of such an ICT4D initiative, we develop a more holistic understanding of the nomological network around technology use, thus extending the theory bases used to understand technology adoption, use, and success (e.g., Chatterjee et al. 2009; Sarker et al. 2010; Venkatesh et al. 2003; Venkatesh, Thong, and Xu 2016). In addition, our work leverages social networks research, particularly social contagion theory, to better understand ICT implementation outcomes. We thus gain a better understanding of the role of social influence in affecting ICT diffusion (e.g., Sarker, Ahuja et al. 2011; Sarker, Sarker et al. 2011) by overcoming the limitations of focusing only on technology factors. Specifically, the fact that network effects can cut both ways—positively and negatively—is potentially worrisome and its presence in other contexts, including organizational settings, should be investigated (see Sykes and Venkatesh 2017; Venkatesh et al. 2017).

Our model can be adapted to other domains that are important to advancing the human condition. Whereas this paper seeks to address the problem of information asymmetry in medical care for women in LDCs, our model sheds light on how to resolve information asymmetry in other domains. For example, it will be interesting to examine the roles of ICT and social networks in transmitting social influence and disseminating the best practices in agriculture, fishing, and environmental protection. In addition to addressing the problem of information asymmetry, social networks and ICT are expected to advance the human condition in other domains, such as improving quality of education by enabling speedy access to diverse knowledge or strengthening social bonding by extending offline communication to online media (see also Zhang and Venkatesh 2013).

Our work contributes to research on ICT4D. Whereas most prior research examines the ICT4D initiatives in developed countries (e.g., Agarwal et al. 2009; Hsieh, Rai, and Keil 2008), there has been a call for research on ICT4D in LDCs given that the most severe forms of the digital divide exist in LDCs (UNDP 2004). By developing and testing a model of women's health outcomes of an ICT4D initiative in rural India, our work makes a contribution to this literature base. Research that seeks to understand the drivers of the success of such initiatives is limited. By conducting a longitudinal study examining the impacts of an ICT4D initiative, our work complements prior research on this topic (e.g., Keniston and Kumar 2004). Also, prior research has mainly focused on understanding the digital divide at either a micro- or macro-level and this work extends prior research by developing a multilevel model that incorporates cross-level network effects to gain a better understanding of healthcare outcomes. Further, as we articulated at the outset, it is important to understand how ICTs can impact key outcomes. The type of outcomes and the impacts studied in this work place ICT in a key role in helping to save lives.

This work contributes to the literature on strategic uses of ICTs that underscores the key role of "champions"—managers who actively promote their personal vision for using ICTs and overcoming hurdles to successful implementations of ICTs (e.g., Beath 1991; Liang et al. 2007). Although lead users defined in this work are not the same as champions noted in prior literature, they are similar in that both emphasize the use of personal characteristics (e.g., charisma, inspiration, and stimulation) to influence the success of ICT implementations. However, we suggest that it is not sufficient to only examine personal characteristics to understand the role of lead users in influencing implementations of ICTs. The broader social context (e.g., advice networks) and the underlying mechanisms of social contagion theory that explain opinions of salient or relevant others need to be incorporated to understand the influence of lead users. We found that lead users who have high strong tie centrality

are likely to work against the ICT4D initiative. This suggests that we should also examine the role of champions in other contexts to gain a better understanding of their influence on ICT implementations.

Our results underscore the importance of incorporating time in theory development (see Venkatesh et al. 2006; Venkatesh et al. 2008). This work helps us to develop a better understanding of the effects of networks on kiosk use, the effect of kiosk use on seeking modern medical care, and the effect of seeking modern medical care on maternal mortality. Specifically, we found that it takes time for the positive effects to build up (i.e., the effects of weak tie centralities on kiosk use, the effect of kiosk use on seeking modern medical care, and the effect of seeking modern medical care on maternal mortality became stronger over time). This work indicates the theoretical formulation and methodological approaches will be different when time is considered. Specifically, theorizing about and empirically examining time enriched our understanding of the phenomenon. Future research should also translate time into specific temporal concepts, such as timing and sequencing, to more richly treat and validate the effects of time in the context of ICT implementations, such as this one and even organizational implementations (see Venkatesh et al. 2006; Venkatesh et al. 2008).

Our findings also have implications for social networks research. Whereas prior social networks research has discussed the general implications of strong ties—for example, trust and reciprocity (Granovetter 1973; Krackhardt 1992) and transfer of complex knowledge (Reagans and McEvily 2003)—and weak ties—for example, access to diverse and novel information (Baer 2010; Perry-Smith 2006; Zhou et al. 2009)—there is still an inadequate understanding of when strong ties or weak ties will have positive effects on outcomes of interest. For example, the question of whether strong ties or weak ties contribute to innovation has not been adequately understood. Prior research indicates that the incorporation of contextual factors will shed light on our understanding of phenomena in general (e.g., Johns 2006; Zhou et al. 2009). In this vein, this work extends prior research by incorporating important contextual mechanisms and arguments to better understand the effects of strong ties and weak ties on women's behaviors and outcomes in rural India. In addition, the incorporation of social contagion theory sheds light on our understanding of the differences between strong ties and weak ties in transmitting social influence that is critical for the success of ICT4D initiatives. Moreover, the cross-level theorizing of network factors helps us develop a more holistic understanding of the phenomenon. The conceptualization of the lead user at the village level helps us gain a better understanding of how networks affect lower-level outcomes. Our work thus indicates the importance of conceptualizing key roles, such as lead user, as a higher-level network construct, in understanding outcomes of interest. Such effects could also be examined in other research using social networks.

Limitations and Future Research

First, whereas we conducted a longitudinal study (about 7 years) to enhance the robustness of our results, we did not study network change. Both lead user's and women's networks could change over time. We thus suggest examining network change and its impacts on change in kiosk use in future research using approaches, such as latent growth modeling (see Bala and Venkatesh 2013). Second, we argue that acculturation and prevalent social cultural norms play an important role in affecting women's attitudes toward using technologies to obtain information about seeking modern medical care, but we have not actually measured these mechanisms. Future research can empirically validate the impacts of these two mechanisms. Third, our work indicates the critical role of a lead user in affecting women's views toward using the kiosk and the information they provide about medical care. Future research should account for differences across lead users (e.g., personality, espoused culture) to rule out alternative explanations based on individual differences. In addition, given that our study identified only one woman as a lead user for each village, the results could be biased if the lead user cannot represent the influence on the majority (i.e., women who used the kiosks on a frequent basis in a village). This concern is likely to be trivial in our study due to the low base rate of kiosk use in the villages. However, future research could include more lead users to enrich our understanding of their role in this context. In addition, future research could include men in the network, and investigate their influence both as lead users and in cross-gender communication. Fourth, some of our measures have limitations. We defined a lead user as the one woman who began using the ICT the earliest and did so on a frequent basis. Such a definition may be problematic when the following scenarios occur: (1) if one woman used the kiosk earlier than another woman but the latter used the kiosk more frequently; and (2) if the lead user also has the largest number of strong ties, the largest number of weak ties, or the least of either category. With respect to the measure of maternal mortality, we have not distinguished among different causes of death. Some women might die during or immediately after pregnancy due to reasons unrelated to being unwilling to seek modern medical care, such as natural catastrophe, health issues in tropical countries (e.g., snake bite), car accidents, or suicide. We found the number of mothers who died because of these other reasons to be small. However, future research could classify mortality in a more nuanced fashion. Fifth, as the technology introduced was quite novel given the context, it is possible

that an expectation confirmation perspective considering both expectations and experiences may yield useful insights (Brown et al. 2012, 2014; Venkatesh and Goyal 2010). Finally, our work, although extensive, was a quantitative study that has known limitations (see Venkatesh et al. 2013; Venkatesh, Brown, and Sullivan 2016). Conducting a qualitative study through a combination of unstructured interviews and observations and/or using a mixed methods approach may afford us a more complete understanding of the phenomenon (see Bernardi 2017; Holeman and Barrett 2017; Kelly and Noonan 2017; Venkatesh, Brown, and Sullivan 2016), especially as we transition to understanding specific services using mobile devices (Thong et al. 2011) and in different cultural/country contexts outside India (Hoehle et al. 2015).

Practical Implications

Successful deployments of ICT4D initiatives in LDCs are rare. In rural India, there are significant obstacles to using ICTs to promote modern medical care for women. We found evidence that using ICTs to obtain information about modern medical care is more likely to be reinforced via strong ties. Therefore, it is crucial to develop ways to overcome the negative effects of strong ties. One possible approach to help reduce negative acculturation is to create opportunities for women in villages to use the kiosks to obtain information about modern medical care that are positive experiences. When women experience the benefits of using ICTs to obtain information about modern medical care, they are more likely to challenge traditional medical practices. The more women use ICTs, the more likely they will experience the benefits of using ICTs to obtain information about medical care. Such positive experiences are likely to be transmitted via the network to accelerate the diffusion of ICTs. In order to facilitate use of ICTs, governments can allocate more resources to help women to learn and use ICTs—but, in the case of remote Indian villages, this starts with basic literacy and ICTs could be used to achieve this purpose as well. Governments can also promote the benefits of using ICTs, such as asking women who have benefited from using ICTs to obtain information about modern medical care and using modern medical care, to share their experience and stories in meetings in the villages in which they live and also in neighboring villages. The local village government (i.e., *Panchayat*) meetings in villages in India provide an excellent setting for such information sharing as such meetings tend to be more sociopolitical rather than being purely political.

Our work found that the effects of acculturation are likely to diminish and women to feel less social pressure to conform when they were connected via weak ties, especially over time. Weak ties were more likely to disseminate factual information about how ICTs can be leveraged to obtain information about modern medical care and about modern medical care itself. Thus, it will be useful to foster more weak ties. One approach to create more weak ties is to hold social events among villagers, many of whom may not know each other, especially as the villages targeted with such initiatives become larger. People are likely to talk to others during such events and they may start contacting each other after the events occasionally, thus forming weak ties. Using these weak ties, the lead users can share information about modern medical care with other women. Gradually, the negative views that prevail about the new kiosk and modern medical care will then attenuate. A further step could be to carefully identify a woman with high weak tie centrality and recruit her to be the lead user. Thus, weak ties may be employed as a solution to the problems caused by strong ties.

Conclusions

This work drew on social networks theory in general and social contagion theory in particular to develop a multilevel model to predict kiosk use, seeking modern medical care, and maternal mortality. In the context of an ICT4D initiative designed to assist women in rural India to obtain maternal health care, our work found that an advice network played a dual role in affecting the objectives of the ICT4D initiative. The duality of the network effects, such that both positive and negative effects occur, is at the heart of our understanding of the phenomenon. Our work not only provides an important explanation for why some ICT4D initiatives in rural parts of LDCs fail, but also identifies potential solutions to address the problem. Finally, given that our work was conducted in rural India, the implications for deploying such initiatives to foster better health outcomes among women are substantial.

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