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MOBILE & WIRELESS HEALTH

Promoting Relational Agent for Health Behavior Change in Low and Middle - Income Countries (LMICs): Issues and Approaches

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Abstract

The use of contemporary technologies in healthcare systems to improve quality of care and to promote behavioral healthcare outcomes are prevalent in high-income countries. However, low and middle-income countries (LMICs) are not receiving the same advantages of technology, which may be due to inadequate technological infrastructure and financial resources, lack of interest among policy makers and healthcare service providers, lack of skills and capacity among healthcare professionals in using technology based interventions, and resistance of the public to the use of technologies for healthcare or health promotion activities. Technology-based interventions offer considerable promise to develop entirely new models of healthcare both within and outside of formal systems of care and offer the opportunity to have a large public health impact. Such technology-based interventions could be used to address targeted global health problems in LMICs, including the chronic non-communicable diseases (NCDs) - a growing health system burden in LMICs. Major preventable behavioral risk factors of chronic NCDs are increasing in LMICs, and innovative interventions are essential to address these risk factors. Computer-based or mobile-based virtual coaches or Relational Agents (RAs) are increasingly being explored for counseling patients to change their health behavior in high-income countries; however, the use of RAs in LMICs has not been studied. In this paper, we summarize the growing application of RA technology in behavior change interventions in high-income countries and describe the potential of its use in LMICs. Finally, we review the potential barriers and challenges in promoting RAs in LMICs.

Keywords Relational agent · Mobile health (mHealth) · Low and middle-income countries (LMICs) · Information and communication technology (ICT)

Abbreviations

LMICs	Low and middle-income countries
RAs	Relational Agents (RAs)
ICT	Information and Communication Technology
WHO	World Health Organization
mHealth	Mobile health
ECA	Embodied conversational agents
PDA	Personal digital assistants
IMF	International Monetary Fund

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Background

The advancement of mobile technology has introduced new potentials in the field of medical informatics. Combining technological advances with medical expertise has led to the use of mobile phones in health promotion intervention in high-income, and low and middle-income countries (LMICs). High-income countries are in the leading position of developing the latest mobile technologies used in healthcare [1]. According to a World Health Organization (WHO) report, high-income countries reported a growing range of mHealth initiatives compared to lower-income countries [2]. As of

2015, 64% of American adults and 82% of those aged 18–49 years owned an app-enabled mobile phone [3]; 15% of consumers reported using mobile-phone connected wearable devices such as smartwatches and fitness bands in their daily lives [4]. Mobile health (mHealth) can deliver a subset of healthcare services anytime and anywhere overcoming geographical, temporal, and even organizational barriers with low and affordable costs [5]. Several research topics related to healthcare have gathered significant findings and contributions from mHealth, such as cardiology [6–9], diabetes [10–12], obesity [13–15], smoking cessation [16, 17], elder care, and management of other chronic conditions [18, 19]. Mobile health technology is frequently used for the detection of diseases, and risky behavior, monitoring of diseases progress and/or adherence to medication intake, as well as disease prevention programs. The use of mHealth are also becoming popular in LMICs [20, 21]. However, LMICs have major restrictions on its healthcare systems and healthcare delivery due to a lack of infrastructure, insufficient human and financial resources, as well as the burden of poverty and disease management [22]. Mobile applications for healthcare systems are rapidly growing and evolving [5]. As of 2013, there were over 40,000 healthcare apps available only in the U.S. Apple iTunes store [3, 23]. In LMICs, mHealth in healthcare service delivery systems are also becoming popular [24]. However, the translation of mHealth projects from pilot projects to effective large-scale nationwide implementation was scarce [2].

Recent advancements in mobile device technology and the development boom of mobile device apps (mobile applications) have opened windows of opportunities to promote technology-driven healthcare programs. There is an enormous number of health-related apps available, covering a wide range of common topic areas such as anxiety, depression, smoking, alcohol use, diet, exercise, weight loss, nutrition, and relaxation [25]. Smartphone apps provide useful functions in health promotion intervention [25]. However, these require careful review for compliance with evidence-based guidelines and reference to current health strategies [1]. Also, despite the promising findings demonstrated by some mHealth interventions, a systematic review [26] has concluded that the current evidence base is insufficient to guide decisions on policy and practice. A recent survey [27] concluded that, among a large number of fitness and workout apps, very few are of sufficient quality to provide evidence-based exercise prescription, especially for beginners. Also, most apps, for example, did not offer an evidence-based training plan [27]. The general public may be unable to identify apps that are appropriate to their needs.

One of the fundamental characteristics and methodological challenges in the evaluation of eHealth applications is that participants stop using the applications and/or are lost to follow-up. Researchers call it the law of attrition [28], and they argue to develop models for discontinuation of eHealth applications. For health-related apps, this is also true. For example, chronic diseases (i.e. asthma, diabetes) require long-term self-management [29]; however, researchers have observed limited engagement among long-term app users [30]. One possible way to improve long-term commitment to engage with apps use, which has been successfully applied to physical activity, are interactions with virtual coaches [31]. Thus, developers of future apps addressing chronic diseases might consider the implementation of virtual coaches to enhance long-term engagement.

A "virtual coach" is a computer artifact designed to reproduce some aspects of human-delivered health coaching. The interpersonal relationship between human coach and client is typically treated as a crucial part of a successful (human-delivered) health coaching interventions [32]. A relational agent (RA) is a computer artifact designed to reproduce some aspects of human-human interpersonal relationships with its users [33]. Motivated by this, RAs are increasingly being explored for patient education, counseling, health behavior training and coaching, and other mHealth applications [6, 34–38]. Virtual coaches or RAs can potentially be adapted to a range of health behavior training and coaching – both the cessation of unhealthy behavior such as smoking, unhealthy diet, substance abuse and the acquisition of healthy behavior like exercise or a disease specific-diet (e.g., for hypertension or diabetes). The promise of these mHealth technologies are that RAs may deliver customized interventions with substantially greater reach compared to human-delivered coaching, while, due to their ability to build (some aspects of) interpersonal relationships, retaining much of the efficacy, and help larger populations of patients to establish long-lasting regiments and behavioral changes [39,40].

In this paper, we summarize the growing application of RA in behavior change interventions in high-income countries and describe the potential of its use in LMICs, as many LMICs are moving towards using information and communication technology (ICT) for healthcare delivery. We also summarize the potential barriers and challenges in promoting RAs in LMICs.

Describing relational agents (RAs)

Human-Computer Interaction (HCI) research has a long history of examining social interaction between computer artifacts and users, beginning with the work by Reeves and Nass on the "media equation [41]." In this and subsequent research, they identified numerous examples in which social cues in a computer interface – that is, cues similar to those present in human-human social interaction – elicited social responses from users [42].

Subsequent work has sought to apply these insights by designing computer artifacts to reproduce aspects of human

social behavior in application domains – such as health coaching – where social behavior may be a key determinant of outcomes. A variety of terminology (i.e., social agents, RAs) appears in the literature, reflecting different and overlapping approaches to producing social behavior. The term social agent is used to describe computer artifacts that use human relationship-building techniques to build a socio-emotional relationship with a user [33]. RAs are social agents that are designed to develop and maintain long-term social-emotional relationships with people [36], via processes which are believed to serve this function in human relationship-building, including empathy, shared self-disclosure, emotional feedback, phatic interaction (e.g. "small talk"), humor, and reference to shared history and background.

While implementation approaches to RAs have varied, most have been designed as embodied conversational agents (ECA), with an anthropomorphic representation who attempt to interact via face-to-face conversations with users [43]. These ECA facilitate face-to-face conversations using numerous verbal and nonverbal (e.g., hand gestures, facial expressions) relational cues [44]. The reproduction of these cues has been demonstrated to build user-reported rapport and therapeutic alliance over time [45].

The embodiment of ECA-RAs varies, including animated characters on client PCs, large special screens, internet sites, mobile computer screens and personal digital assistants (PDA's) [6, 37, 38], as well as robots with a humanized interface [46]. Implementations have also explored a variety of computational models of dialogue to produce realistic and effective verbal and nonverbal behavior, ranging from stage models [47] to modeling the relationship-relevant beliefs and intentions of users [48].

Use of RAs to promote health in the United States and other high-income countries

Over the last decade, several RAs have been developed to deliver healthcare interventions. The first RA implemented was part of the MIT FitTrack system "Laura," a computer-generated exercise advisor to whom users reported the extent of their exercise behavior [6, 36–38, 49, 50]. Laura's purpose was to encourage long-term adherence to daily exercise through relational strategies such as interacting with users daily, remembering previous interactions, participating in small talk and responding with apparent empathy to user activity. Since its first application, RAs have been used in various healthcare interventions (Table 1).

Evidence for the effectiveness and cost-effectiveness of these RAs to promote healthcare interventions have also been reported [51–60]. Besides, the expansion of RAs uses in diverse healthcare settings and programs, as well as in the healthcare settings of LMICs has also been discussed [61–67].

Potential to use RAs in LMICs

Although RAs have been gaining popularity for promoting healthcare interventions in high-income countries, little or no attention has been given to their use in LMICs. The lack of trained healthcare professionals in LMICs and the scarcity of resources available to counsel patients underscore the need to promote RAs and other health information technology in LMICs. For instance, there are an estimated 3.89 physicians per 10,000 populations in Bangladesh-a low-income country, whereas, in the United States – a high-income country, the corresponding number is 24.92 physicians per 10,000 people [68]. For nurses and midwives, the corresponding numbers are 2.1, and 98.38 per 10,000 populations respectively for Bangladesh and the United States. Such high gaps in provider-patient ratios do not allow physicians or nurses to provide adequate counseling or health promotion advice to their patients in Bangladesh, a pattern typical in many LMICs. RAs, along with brief engagement from trained healthcare providers, could help motivate patients to change risky behaviors or support adherence to care plans. Like in many high-income countries, RAs can be used in LMICs for multiple sectors of population health to address a lack of trained human resources and/or geographical barriers. Below we describe a few significant areas in which RAs can be used in LMICs.

Addressing chronic non-communicable diseases (NCDs) risk factors

Major risk factors for chronic NCDs, including cigarette smoking, alcohol abuse, physical inactivity, and unhealthy diet, are common in LMICs [69] and a growing health systems burden. Policymakers in many LMICs are taking measures to address these risk factors and associated NCDs; however, lack of resources and sub-standard health systems is a challenge in making progress [69, 70]. RAs has excellent potential to address multiple risk factors at reduced resource usage by developing, testing and implementing a culturally appropriate agent to deliver health promotion intervention [71]. Here we illustrate two examples of obesity and tobacco use to emphasize the use of RAs for risk factor reduction.

Obesity in children and adolescents is emerging as a public health crisis in LMICs, associated with socioeconomic development and related changes in a lifestyle characterized by physical inactivity and an unhealthy diet. Lower self-esteem, social isolation, poor academic achievements and stigmatization from peers are the most apparent immediate consequences in obese children [61]. Using current best practices, well designed and culturally appropriate RAs have the potential to promote physical activity and healthy diets among these vulnerable groups.

Table 1 Examples of relational agents with their purpose(s) in health-related area

Agent	Target user (s)	Purpose(s)
Comforting agent [51]	Patients experiencing stress	To provide emotional and social support and to develop personal relationships
		To ease users anxieties in stressful situations
Health literacy [52]	Patients with low health literacy	To effectively explain health document to individuals with low health literacy
Palliative Care Agent [53]	Older adults; patients with serious illnesses	To counsel patients in order to alleviate their suffering and improve their quality of life
Pre-surgery Counseling [54]	Pre-surgery patients	To counsel patients on their options for anesthesia, including the risks and benefits of each, what to expect before, during, and after surgery, and how to prepare before coming to the hospital
Eldercare Agent [55]	Socially isolated older adults	To provide social, instrumental, and social network support to older adults living alone
Weight loss [56]	Overweight adults	To provide daily physical activity counseling for overweight adults
Education and Counseling [57, 58]	Hospital patients with inadequate health literacy	To educate and counsel hospital patients with inadequate health literacy in their hospital beds at the time of discharge
Preconception care [59, 60]	New mothers; women	To boost motivation and provide basic information about breastfeeding
		To support women as they improve their personal preconception risks to improve their preconception health status and improve their chances of having a healthy pregnancy and baby

Tobacco smoking, a prevalent preventable risk factor for NCDs, is common in LMICs and tobacco-related deaths are increasing in LMICs [62]. Most smokers are in the pre-contemplation stage, and measures are needed to move smokers from pre-contemplation to the contemplation and the action stage. Evidence-based interventions to help smokers in their quitting process are available [72–74]; however, there use in LMICs are scarce. Similar to the use of RAs for smoking cessation in high income countries [75], RAs designed to address contextual, cultural and linguistic barriers could play a vital role to promote smoking cessation in LMICs by counseling the smokers and/or linking them with appropriate healthcare services [71].

Similarly, RAs could also be used for other chronic health conditions, such as diabetes management [76], suicide prevention [77], and other health behavior change programs (i.e., alcohol use, medication adherence) [16–19] in LMICs.

Supporting wellbeing of elderly

Older people are vulnerable because they need companionship and physical care and assistance. The extent of the vulnerability of older people varies considerably from one population group to another [78]. They are also at high risk of loneliness and social isolation. They may experience a loss of social interactions through the death of a friend or loved one. There is a relationship between health risks, and social isolation and loneliness [79]. Social isolation may trigger various health conditions, including depression, increased systolic blood pressure, infection, and impaired cognitive function [79]. To improve this situation in the elderly population, RAs could build emotional relationships with these vulnerable patients and encourage them to maintain healthy lifestyles [80].

Improving health literacy

In general, people with low health literacy make more medication or treatment errors, are less able to comply with treatments, lack the skills needed to negotiate with the healthcare system successfully, and are at higher risk for hospitalization than people with adequate literacy skills [63–65]. While significant progress was made to use RAs to improve health literacy in high-income countries [58], no such initiative is yet available in LMICs. RAs could be deployed, as an additional support tool, to educate patients, to improve their health knowledge and provide educational counseling in LMICs.

Preconception care

In the LMICs, doctors, especially female doctors are scarce [81]. Usually, in LMICs, women feel confident and comfortable to discuss their health and/or childcare related problems with their female doctors rather than a male doctor [82]. In many cases, women even don't visit male doctors due to family, social, and cultural obligations [82, 83]. RA could be useful to overcome some of these barriers. For example, necessary information about breastfeeding and preconception issues could be provided to women through a RA. In the United States, RAs was acceptable as an agent to promote preconception care in the healthcare setting for low-income women [60].

Mental health or disability

Mental health has become a significant public health problem worldwide. About 40% of people suffering from mental disorders such as schizophrenia, depression, intellectual disability, alcohol use disorders, epilepsy, and those committing suicide are living in LMICs [66]. At the same time, between 76% and 85% of people with severe mental disorders receive no treatment for their mental health conditions in LMICs [66]. Also, in some LMIC settings patients with mental disorders do not have access to basic primary healthcare services, such as general health check-ups or dental care [67]. This is related to the inadequate mental healthcare services and lack of resources in LMICs. Stigmatization associated with mental health problems may also play a role [66, 84], which discourages people with mental disorder to seek medical care. Maladaptive coping responses, such as avoiding social interaction, are also common [85]. To address these mental health related social barriers, RAs can play useful role to provide mental health support in LMICs.

Issues to consider in promoting relational agents in LMICs

Although there are opportunities for the use of RAs in the delivery of healthcare interventions in LMICs, there are also several issues that both providers and consumers of healthcare should be aware of.

Usability and acceptance issues

Although studies in high-income countries have shown greater acceptance of RAs use in different health promotion and health services delivery programs [60, 86], there are possibilities that people in LMICs, especially those with low health literacy might not accept RAs. They might not be interested in building a relationship with RAs as it's new to them and they are not used to technology-based services or educational program. Besides, the behavior of RAs is not real and not human-like, which might lead to poor interpersonal relationships. Also, healthcare organizations or hospitals may not be interested in deploying RAs for the initial investments or costs due to the lack of local feasibility and effectiveness data. Promoting the benefits of RA, based on the evidence-based interventions of using RAs in the high-income countries, may encourage policymakers and health administrators in LMICs to consider using RA. Before designing and implementing RAs, it is essential to consider usability and acceptance by the end users [25]. Review of published findings from usability and feasibility testing can be useful to identify an appropriate RA, which could then be assessed for local use in the LMICs.

Cultural context

Cultural context play an important role in the delivery of evidence based healthcare interventions [87, 88]. Programs those are culturally specific and competent, and are based on values and norms of a specific culture, are more likely to be acceptable to individuals [89–91]. In earlier studies of RA [92, 93], people favored a virtual agent resembling an in-group member of their own culture. Therefore, adaptations of RAs in the LMIC settings should consider the socio-cultural context in the implementation process. To address the local cultural context, the visual appearance or choice of male or female voice narration of RA may need to be adjusted [25].

Infrastructure of healthcare systems

Health worker shortages and weak health information systems have led to a lack of preventive and curative healthcare services in LMICs [94, 95]. The health systems in LMICs also suffer from insufficient financial resources, limited institutional capacity and infrastructure, embedded inequity and discrimination in the availability of services, absence of community participation, and lack of transparency and accountability [94–97]. All these issues were identified as barriers for LMICs to achieve the Millennium Development Goals [98]. While RAs can facilitate convenient dissemination of health information or health promotion interventions, the availability of appropriate infrastructure to deliver RA based programs is crucial. Therefore, before deploying RA and other information communication technology (ICT)-enabled services in LMICs, it is suggested to conduct formative research to assess the existing situation and to ensure there is no inconsistency with the existing infrastructure of health and public health system, as well as to ensure that the program will reach the target population efficiently [39, 40].

Capacity building of healthcare professionals in LMICs

Capacity building can play an essential role in addressing the major health challenges and improving the quality of health care [99, 100]. Healthcare professionals have to possess the required knowledge and skills to perform numerous medical tasks, including an understanding of the changing disease epidemiology and exposure to globally relevant diseases [101]. They are required to exercise their professional expertise sensibly. In case of technology-assisted care provision, in addition to the standard medical or healthcare related qualifications, they are expected to possess a certain degree of extra technical knowledge and skills that will enable them to use technology safely and effectively [102]. However, setting standards for ICT-knowledgeable healthcare professionals remain a challenge. There is a need for all healthcare workers to be trained with the underlying cutting-edge technology that are relevant to their practice and healthcare management. Such training efforts will improve health workforce capacity, confidence, and motivation in using technologies (i.e. RAs) for healthcare delivery [103]. Whenever healthcare professionals make a clinical judgment utilizing available technological support systems, they must be ensured that they have sufficient and updated evidence-based information available to form such opinion and that the information itself is of appropriate quality and reliability [104, 105].

Willingness of healthcare administrators and service providers to utilize ICT

Deploying new technology for healthcare intervention remain a challenge in LMICs. Usually, service providers are not interested in investing in new technology, as they do not see immediate benefits of their investments [106, 107]. Besides, healthcare administrators need to provide training to the existing healthcare workforce or hire staff with new technical skills demanding additional resources and costs [108–110], which discourages them for investing on new technologies. At the same time, the acceptability and affordability of technology based healthcare interventions among the public also play a role in the healthcare delivery process [111, 112]. It is suggested to promote the benefits of RA among policy makers and healthcare administrators, based on the cost-effectiveness studies that are available in high-income countries where RAs have been deployed, to encourage policy makers and service providers in supporting the use of RAs for healthcare delivery in LMICs. Once programs are developed and implemented, conducting cost-effectiveness studies of RAs in the local setting would be important to document local evidence and encourage service providers and policy-makers in adopting and/or supporting the use of RAs.

Quality standards and safety

Quality control of any technology-based healthcare interventions, including the use of RAs, is a significant concern in LMICs. Some observers warranted to follow strict quality control measures while using technology based interventions [113]. It is possible that the information delivered through the technology based programs are not accurate, which may cause negative consequences [26, 114]. Therefore, it is crucial for those planning the use of health-related RAs to consult evidence-based information for their use [115]. Patient safety should also be considered when using RAs or other technology in healthcare interventions [116]. Technological problems could occur, like undesirable behavior of the RA, due to the malfunction of the device, and appropriate monitoring and problem-solving mechanism should be in place to avoid any unwanted consequences.

Data security and privacy

Data security and patient privacy must be carefully considered when adapting RAs in healthcare interventions. Some of the most common threats to data security and patient privacy come from unauthorized access or physical loss of the device [117, 118]. Some RA devices receive users' sensitive information including username and password, age, gender, location, and contact information. This could be a significant risk to users' confidentiality if the information is released or leaked to third parties without the user's consent [117–119]. To reduce risk to patient privacy, clinicians and service providers in healthcare settings should be aware of what information RAs gather, how this information is used once obtained, and how the data is stored and protected. It is suggested that, in the absence of any data safety policy, the concerned organizations develop data security and privacy policies following international guidelines [120, 121].

Additional ethical and policy related issues

There are also a number of ethical and policy related issues that are common to the use of any technology in the delivery of healthcare interventions which should also be considered. If the accuracy of the information delivered through the RA or other technology then there are risks for ethical implications. The ethics of persuading users to change their behavior, even when it is for their

health benefits, seems even more critical when it is an automated system doing the persuading [98]. Also, interaction with the agents involves several other ethical issues. For instance, it might be possible that users are building trusting relationships with agents and would release some sensitive information that they would not release to a human counselor. It may also increase concerns about promoting social isolation if users become too dependent upon their artificial relationships with the RA. The ethical principles of psychologists and Code of Conduct [122] provide general guidance regarding these types of issues that should be considered when RA communicates with its user. It should also be acknowledged that the RAs do not alleviate, but a supplement, the need for providers or policymakers to follow existing policy and local jurisdictional requirements while promoting public health.

Conclusion

RAs have great potential for addressing the shortages of human resources for health in LMICs and facilitate the delivery of healthcare services in a convenient and timely manner. RAs are not replacements for physicians or nurse practitioners or other healthcare delivery personnel but can provide additional support to the services provided by these healthcare workers and facilities. While it's not possible to replicate the knowledge, expertise of such highly trained professionals in the foreseeable future, supplementing their expert recommendations with RAs to improve health outcomes has public health benefits. Technology based interventions if coupled with target counselling and education by healthcare professionals may increase health literacy, empower patients to take a more active and informed role in the management of their own health, and bestow on patients more testimonial credibility [123]. Overall, along with qualified and trained healthcare personnel RAs can play significant roles in the delivery of healthcare interventions in LMICs. To do so, more research needs to be conducted to validate the feasibility and efficacy of RAs in LMIC settings. Policymakers should be informed that ICT-enabled technologies, such as mHealth or eHealth, can improve population health by supporting the existing healthcare delivery programs and participating in the delivery of health promotion interventions to address geographical as well as human resources barriers, thus ensuring health equity. International bodies such as the World Health Organization (WHO), the World Bank, the International Monetary Fund (IMF), and other organizations should support pilot projects to promote RAs or other ICT-enable technology in LMICs to address major global health issues to optimize the reach, impact, and cost-effectiveness of healthcare. Rigorous evaluation of these pilot programs will guide the further development and promotion of RA-based interventions in LMICs. Lessons learned from the experiences of high-income countries should also be consulted in designing and evaluating RAs for LMICs.

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Authors' contributions ASA planned the study and oversee the overall review process. FK led the review, identified relevant articles and summarized the findings. FK drafted the first draft of the manuscript and distributed to co-authors for comments. DS and ASA critically reviewed the draft manuscript and commented on the final draft. All authors approved the final draft of the paper.

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Compliance with Ethical Standards

Ethics Approval and Consent to Participate This is a review article and no ethical approval was required.

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Competing Interests The authors declare that they have no competing interests.

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