

# Performance factors of mobile rich media job aids for community health workers

Jose F Florez-Arango,<sup>1</sup> M Sriram Iyengar,<sup>2</sup> Kim Dunn,<sup>2</sup> Jiajie Zhang<sup>2</sup>

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<sup>1</sup>Faculty of Medicine, University of Antioquia, Medellin, Colombia  
<sup>2</sup>School of Health Information Sciences, The University of Texas Health Science Center at Houston, Houston, Texas, USA

## Correspondence to

Dr M Sriram Iyengar, University of Texas, Houston, 7000 Fannin ST Suite 600, Houston, TX 77030, USA;  
[m.sriram.iyengar@uth.tmc.edu](mailto:m.sriram.iyengar@uth.tmc.edu)

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## ABSTRACT

**Objective** To study and analyze the possible benefits on performance of community health workers using point-of-care clinical guidelines implemented as interactive rich media job aids on small-format mobile platforms.

**Design** A crossover study with one intervention (rich media job aids) and one control (traditional job aids), two periods, with 50 community health workers, each subject solving a total 15 standardized cases per period per period (30 cases in total per subject).

**Measurements** Error rate per case and task, protocol compliance.

**Results** A total of 1394 cases were evaluated. Intervention reduces errors by an average of 33.15% ( $p=0.001$ ) and increases protocol compliance 30.18% ( $p<0.001$ ).

**Limitations** Medical cases were presented on human patient simulators in a laboratory setting, not on real patients.

**Conclusion** These results indicate encouraging prospects for mHealth technologies in general, and the use of rich media clinical guidelines on cell phones in particular, for the improvement of community health worker performance in developing countries.

## INTRODUCTION AND BACKGROUND

In developing countries, where the density of trained physicians and nurses is low, community health workers (CHWs) are typically the primary and sometimes sole providers of healthcare to millions.<sup>1–2</sup> Their educational qualifications vary, and their clinical training tends to be basic. For example, the average CHW's reading level in Kenya is equivalent to seventh grade.<sup>3</sup>

While CHWs perform a vital function, studies have shown that their performance is often suboptimal,<sup>3–6</sup> potentially leading to high levels of morbidity and mortality.<sup>5</sup> One strategy to improve their performance is the use of job aids.<sup>7–8</sup> Formally, job aids are defined as an external device or cognitive artifact that provides just-in-time knowledge and information to help individuals with tasks by directing, guiding, and enhancing performance.<sup>7–9</sup> However, studies have shown that even well-motivated CHWs using paper-based job aids demonstrate less-than-desirable rates of treatment and diagnosis errors, and low protocol compliance.<sup>3</sup> Explanations include poor design, incomplete explanations presented at reading/comprehension levels beyond the user's capabilities, lack of explicit workflow, and, possibly as a consequence, increase in the user's workload.<sup>3, 7, 10–12</sup>

Cognitive science and learning theory provide evidence that presenting information with rich media including text, audio, and visual aids such as

images, video or animations, in the context of learning can enhance understanding, decrease complexity, and reduce cognitive load.<sup>13–17</sup> However, the benefits of rich media in the context of improving health worker performance have received inadequate formal investigation.<sup>8, 14</sup>

Currently, a natural choice for a computing device for presentation of rich media guidelines is the cell phone. The use of cell phones worldwide, including 'smart phones,' is exploding, even in developing countries, and there is a growing interest in 'mhealth' technologies.<sup>14, 18–21</sup> Due to decreasing costs, rich-media capabilities, high portability, and local data storage, smart phones can potentially prove extremely useful in assisting CHWs by providing point-of-care clinical information and decision support. Also, since CHWs often need to travel to care locations, portability of cell phones is a great benefit.

In this paper, we describe a prospective, randomized controlled study among CHWs in Colombia where clinical guidelines were presented on cell phones in a structured interactive workflow using rich media (text, audio/voice, images/video). This intervention was compared to traditional paper-based job aids using several metrics including error rates, measures of guideline compliance, case completion time, usability measures, and six dimensions of workload. Due to space limitations, only the first three will be presented here.

## Training of community health workers

Education and training of CHWs is expensive, especially after accounting for the social cost of removing the only source of healthcare for a community. Alternatives such as online education have been tested but are not entirely satisfactory, due to lack of computers or connectivity.<sup>3, 22</sup> Job aids have been proposed to complement training and coaching.<sup>8</sup> The importance of asynchronous job aids has been presented in Austin *et al.*<sup>23</sup>

## Community health workers and job aids

Controlled studies regarding job aids and health workers performance are few. Many such studies focus on manual job aids and do not provide task-based analyses.<sup>8</sup> Most job aids currently in use by community health workers are static and paper-based, offer passive support for decision-making, and have limited interactivity.<sup>13</sup> Other studies have small sample sizes or are focused on user acceptability.<sup>19, 20, 24</sup>

## Problem statement/research question

The research objective here is to investigate and analyze the possible benefits on performance of

CHWs of point-of-care clinical guidelines implemented as interactive rich media job aids on small-format mobile platforms.

**METHODS**

**Summary of study design and data collection**

A randomized prospective crossover study with one control and one intervention was conducted at the Simulation Lab, University of Antioquia, Medellin, Colombia, from December 2008 to April 2009. The intervention comprised clinical guidelines presented with interactive rich-media on cell phones, and the control comprised existing practices, that is, the same guidelines presented on paper. Study subjects were local CHWs. To adjust for learning effects, the subjects were divided into two groups. Group A first received the intervention and then the control, while Group B first received the control and then the intervention. Each subject diagnosed and treated 30 clinical cases: 10 pediatric, 10 adult trauma, and 10 adult medical. In each category, each subject analyzed five cases using the intervention and five matched ones using the control presented in a randomized order. Clinical cases were presented on human patient simulators, rather than actual patients, to ensure case consistency across subjects. Also, ethically, it was felt that new technologies for providing clinical advice should be applied to human patients only after study on simulators.

All subjects were observed by at least one physician during the experiment and videotaped with prior consent. Performance of the subjects with respect to errors and protocol compliance was scored by the observing physicians. Consistency and reliability were supported by means of checklists for scoring and identification of errors. Errors were identified by reference to the checklist. In over 80% of cases, subjects were evaluated by at least two physicians. Also, if at least one observing physician detected an error, an error was recorded. Due to the small number of physician reviewers, statistical reliability measures could not be used. Table 1 summarizes the subject demographics.

**Clinical guidelines**

**Guideline selection**

Three evidence-based, peer-reviewed, published guidelines, common in Colombia, were selected:

1. Atención Integrada para las Enfermedades Prevalentes de la Infancia (AIEPI), the Spanish version of Integral Management of Childhood Illnesses (IMCI), authored by WHO. There are two AIEPIs, one for neonates 1 week to 2 months, and another for children 2 months to 5 years old.
2. Trauma guidelines including initial assessment, management of thorax wounds, general management, burn management, and immobilization guidelines.
3. Non-trauma guidelines including stroke and myocardial infarction. The last two are approved by the Colombian Association of Pre-hospital Care, published by the Ministry of Social Protection.

**Control: guidelines on paper**

The control consisted of paper-based versions of these guidelines grouped by guideline type. Subjects received a briefing about the location and use of each guideline.

**Intervention: an interactive, structured, rich-media mobile job aid**

The experimental intervention in this study consisted of the same guidelines presented on HTC Tilt cell phones running Windows Mobile 6.1 using a system called GuideView that presents the guidelines interactively, step by step. The instructions of each step are presented simultaneously with voice/audio, text, images/video. If the step is an instruction for performing some task, video is presented. Otherwise, a static image of the relevant medication, supply item, or other object is presented. At each step, the user is presented with up to five choices for the next step. To enable their use when connectivity is poor, the rich-media guideline is loaded into cell-phone memory or micro-SD cards. Each executed step is saved into a time-stamped history log in the phone for later analysis. Further details of the system can be found in the literature.<sup>25-27</sup> The interactive rich-media guideline is created using an authoring program that enables development of guidelines in a directed graph, and embedding of rich media content in each step.

Three rich-media guidelines were developed using a Delphi method with at least three Colombian clinicians. These consisted of AIEPI 1 week to 2 months, AIEPI 2 months to 5 years, and adult assessment (trauma and non-trauma).

**Table 1** Subject demographics

Variable	Values	N	Percentage (of 50)
Gender	Male	29	58
	Female	21	42
Educational level	High school	22	44
	Certified technician	13	26
	Undergraduate	8	16
	Other	7	14
Prior Training	Prehospital technician	19	38
	Nursing assistant	12	24
	Public health assistant	10	20
	Other	4	8
	Unknown	5	10
Service Area	Urban	17	34
	Rural	12	24
	Both urban and rural	3	6
	Unknown	18	36
Employed	Yes	20	40
	No	24	48
	Unknown	6	12
Age (years)	Mean=26.8, SD=8.68	50	
Years of experience	Mean=3.24, SD=5.48	50	

**Study subjects**

The study location was the Simulation laboratory of the Faculty of Medicine, University of Antioquia, Medellin, Colombia. Subjects were selected from persons attending the SENA (Colombian National Service for Learning) for certification or recertification as public health assistants, nursing assistants or prehospital care technicians.<sup>28</sup> Table 1 (appendix 1, supplementary material at [www.jamia.org](http://www.jamia.org)) presents details of study subjects.

**Clinical tasks**

Clinical tasks (referred to as tasks) are atomic units in the subject evaluation. A task is an activity that needs to be performed by the subject. There are three types of tasks: actions, decisions and plans. An action is a single unambiguous task such as ‘Measure rectal temperature.’ A decision is a task involving selecting a choice from given options such as ‘Is the patient responsive? Yes or no.’ Plans refer to a task that can contain a named collection of tasks, without specifying the members of the collection. An example of a plan can be ‘Evaluate nutritional status.’ This plan can be performed by performed by obtaining age, measuring weight and height, and then comparing data

with standardized curves. Tasks were embedded within clinical cases.

**Cases**

A case is a standardized clinical scenario. Cases were presented to subjects on human patient simulators (Laerdal Medical, SimMan, and SimBaby). Each case has a predefined clinical condition and context, which is expected to be identified by subjects. It is expected that subjects provide care according to predefined protocols or guidelines. Since the study required repeated measurements, a set of 30 cases was adapted from an existing case bank at the study location.

Cases were matched across intervention/control and time periods by type of case (pediatrics, trauma, no trauma), number of tasks involved, time constraints, expected cognitive load, physical demand, and priority. These matching criteria (see table 2) were assigned by Colombian physicians using task analysis based on an ontology of clinical tasks developed by the authors.<sup>29</sup> Matching criteria resulted in pairs of matched cases shown in table 3.

For example, according to the classification of table 2, mastoiditis matches severe malnutrition, since both are pediatric cases, they are both high priority, and they have equivalent types and numbers of tasks, comparable time pressure, cognitive load, and physical demand.

**Sample size determination**

**Number of subjects**

One parameter of interest is the difference in means between metrics relating to the difference between Groups A and B (see above). To detect a significant difference with a two-tailed  $\alpha=0.05$  and power of 0.9, Schoenfeld's method<sup>30</sup> required 22 subjects in each group, resulting in a total of 44 subjects. In the study, 25 subjects were enrolled in each group.

**Number of cases**

In addition, to establish differences in performance comparing intervention and control, sample size was calculated using proportion of errors differences. For a significance level of 95% ( $\alpha=0.05$ ), a  $\beta$  error of 0.8, with a minimum 5% of expected proportion differences, and equal sample sizes for both groups, the experiment required at least 725 observations per group,<sup>31</sup> requiring 14.5 comparisons of cases per subject between intervention and control. Rounding up to 15 cases per group, each subject was expected to solve 30 cases.

**Table 2** Case-matching criteria

Variable	Explanation	Values
Priority	Need for an expert	3=high 2=medium 1=low
Time pressure	Level of urgency of the clinical case	1=non-urgent (patient can wait) 2=urgent (patient is at risk of death or disability) 3=emergency (patient is at risk of death within minutes)
Cognitive load		3=cases that require learning development and long-term memory 2=cases where calculation is important and working memory needed to classify 1=others
Physical demand	Amount and intensity of physical strength needed	3=case needs muscular strength, the whole body, or need to constantly switch positions 2=both hands for patient manipulation 1=fine manual skills/single hand manipulation 0=others

**Table 3** Cases matched according to criteria in table 2

Mastoiditis	Severe disease+malnutrition
Malaria	Suppurated pharyngomigdalitis
Pneumonia	Severe pneumonia
Diarrhea, no dehydration	Diarrhea with some dehydration
Common cold	Healthy
Femur fracture	Poly-trauma
Burning	Distal leg amputation
Brain injury+open fx+closed fx	Hand amputation
Dirty wound	Ligament elongation grade II
Closed fracture forearm	Superficial wound
Airway obstruction	Heart arrest
Stroke	Atrial fibrillation
Myocardial infarction	Brain transitory ischemia
Hypertension	Cephalea
Food poisoning	Osteochondritis

**Study metrics**

The metrics described in this paper include mean error rate, protocol compliance, and case duration time. Case duration time, measured in minutes, starts from the moment when a case on a 'patient' was presented to a subject until the time that an outcome decision was made. The other two are defined below.

**Errors**

Errors were defined as any intervention or omission which a subject performed on a simulated patient, which, in the context of the protocol to be followed given the case, could potentially harm a real patient. The error classification provided in Rowe *et al*<sup>3</sup> was used.

This classification includes:

No error: complete absence of error during the intervention;  
 Minor error: an intervention or an omission that does not risk the life of patient—for example, taking the temperature with the hand when a thermometer is available or offering more liquids than necessary by mouth, to a child with moderate dehydration;

Major error: an intervention or omission that risks the life of the patient—for example, misclassification of a severely ill patient requiring immediate attention, or physician referral.

This error classification takes into account a spectrum of medical diagnostic and treatment tasks of varying criticality affecting patient health. A taxonomy for patient safety developed by Makeham *et al*<sup>32</sup> was integrated with the Ontology of Clinical Tasks<sup>29</sup> to enable automatic computation of type of error related with tasks.

**Mean error rate**

A task error was defined as occurring when at least one observer reported an error in performing a task. To account for the types of tasks in a case and the number of times these tasks are performed in that case, we define a normalized error rate as follows. Suppose that a particular case includes N tasks, denoted as Task<sub>i</sub>, where i=1, 2, ..., N. Then:

$$\text{Error rate}_i = \frac{\text{Number of errors in Task}_i \text{ of case}}{\text{Number of times Task}_i \text{ is performed in case}}$$

The Mean Error Rate for the CHW treating the case is defined as

$$\text{Mean error rate} = \frac{\sum_{i=1}^N \text{error rate}_i}{N}$$

Each CHW generates one mean error rate value for every case handled.

**Protocol compliance**

Protocol compliance refers to the agreement of an individual executing a protocol with the expected path determined by experts. We quantify this notion as follows:

$$PC = \frac{\text{tasks}_{\text{performed}} \epsilon_{\text{path}}}{\text{tasks}_{\text{path}}}$$

**Data analysis**

Table 4 (appendix 1, supplementary material at [www.jamia.org](http://www.jamia.org)) lists all the variables measured in the study.

A mixed linear model<sup>33</sup> of the basic form shown below was used to compare intervention versus control adjusting for concomitant variables such as type of training, and educational background. Mixed linear models can analyze crossover designs and unbalanced data.

$$X_{i,j} = (1 - \delta)\mu_0 + \delta\mu_1 + (1 - \delta)\beta_{0,j} + \delta\beta_{1,j} + \epsilon_{i,j}$$

Here,  $\delta=0$  for intervention and 1 for control;  $i=1$  to number of cases;  $\mu_0$  and  $\mu_1$  are the intercept terms of the dependent variable for control and intervention respectively;  $j=1$  to number of independent variables;  $\beta_{0,j}$ ,  $\beta_{1,j}$ , are effect estimates for the  $j$ th independent variable in control and intervention respectively; and finally the epsilons represent normally distributed error terms with zero means.

**RESULTS**

**Subjects**

Among 50 subjects, 44 completed all 30 cases, and six completed a smaller number. Data errors occurred in the recording of several other cases, resulting in 1394 (98.8% of 1500) analysis cases. Table 5 (appendix 1, supplementary material at [www.jamia.org](http://www.jamia.org)) presents the distribution of subjects across cases and groups showing that there was no statistical difference across Group A and Group B for variables of interest.

Figures 1 and 2 display the error rate and protocol compliance, plotted against the order in which subjects performed cases. Each figure consists of two plots, corresponding to data for intervention or control. The lines represent the mean across all subjects that solved the case in that sequence order for intervention and control respectively.

**Mean error rate**

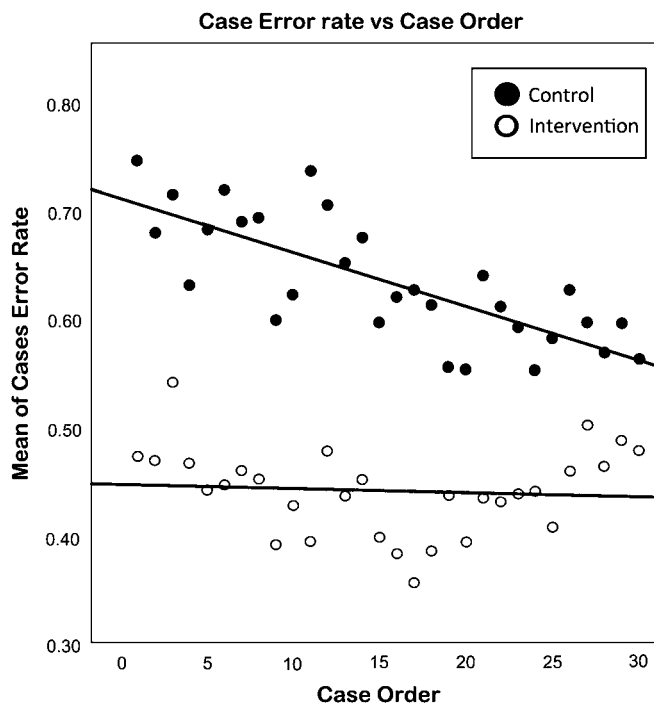
The mixed linear model included the mean error rate, defined in III.G.2 as the dependent variable. Fixed effects included intervention (vs control), group, type of prior experience, years of experience and interaction effects between group and case order, type of training and intervention, years of training and intervention, intervention, and case order. Case order was included as a random effect, and measurements were repeated across subjects.

The size of the intervention effect is 33.15% ( $p=0.001$ ), that is, use of intervention reduce errors by a mean of 33.15%. Other significant effects included the type of training ( $p=0.004$ ) and case order ( $p=0.020$ ). Significant interaction effects included intervention and case order ( $p=0.037$ ), type of training and intervention ( $p=0.001$ ), and type of training and experience ( $p<0.001$ ).

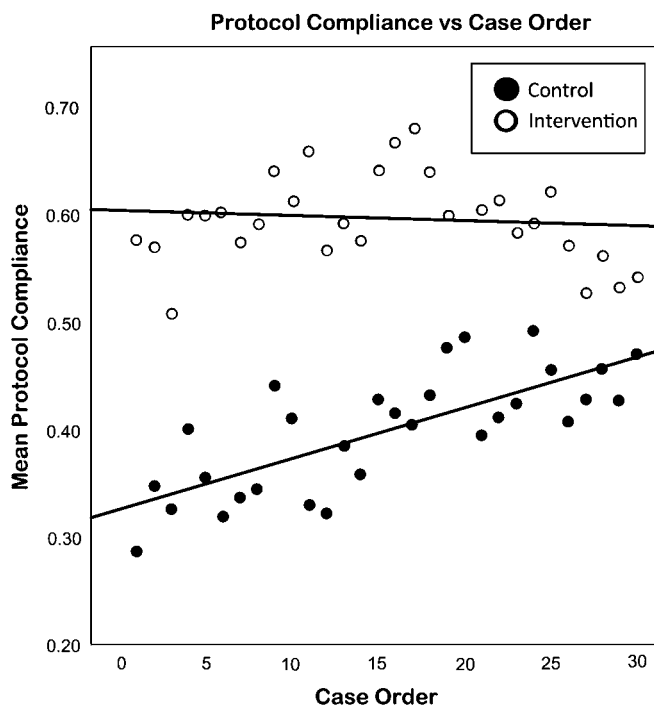
Figure 1 plots error rate versus case order (time sequence of cases performed).

**Protocol compliance**

The MLM model for protocol compliance included the PC metric defined above as the dependent variable. Independent variables were identical to that for case error. Figure 2 displays



**Figure 1** Error rate. The lower line corresponds to intervention (ie, use of rich media system on cell phone), while the upper corresponds to control. Case orders 1 to 15 of the lower line represent subjects from Group A, while the upper line represents Group B subjects. Case orders 16 to 30 in the lower line correspond to Group B subjects and those in the upper line are Group A subjects.



**Figure 2** Protocol compliance. The upper line corresponds to intervention (ie, use of interactive rich media structured protocols on cell phones), while the lower line corresponds to control. Case orders 1 to 15 of the upper line represent subjects from Group A, while the lower line represents Group B subjects. Case orders 16 to 30 in the upper line correspond to Group B subjects, and those in the lower line are Group A subjects.

the variation of protocol compliance over case order (time sequence of cases performed). The average intervention effect was 30.18% ( $p < 0.001$ ), that is, on average the intervention increased compliance by 30.18%.

Figure 2 plots the measure of protocol compliance versus case order (time sequence of cases performed).

### Case duration time

With case duration time as the dependent variable, the MLM analysis included the same effects as the error and protocol compliance models. Figure 3 plots case duration time versus case order. Subjects spend on average 6.28 min (377.24 s) more per case using the intervention. This difference was found to be statistically different ( $p < 0.001$ ). In addition, the case order and interaction effect of intervention with case order were also significant.

Figure 3 shows additionally a cyclic peak every five cases. These peaks appear to reflect the change in the type of case that the subject is solving; the first case of each set requires slightly more time than the remaining four. It is interesting that the peaks appear to be of greater amplitude in the intervention rather than the control.

## DISCUSSION

The results above indicate that presenting clinical guidelines in an interactive rich media structured format on small phones can decrease error rates and enhance protocol compliance, indicating significant potential benefits for health outcomes and standardization of care.

### Protocol compliance

There are several reasons why the intervention enhanced protocol compliance. The rich media guidelines presented detailed instructions in a highly structured manner. For example,

the encoded AIEPI guideline has 220 steps presented in the compact and highly portable cell phone, rather than in volumes of paper. This fine level of granularity enabled complex medical advice to be broken down into small steps, thereby reducing cognitive overload. The need to recall complicated guidelines or procedural information was eliminated, thus decreasing the chances of forgetting portions of the protocol. Finally, the technology implements user-interface design principles of proximity and compatibility that are difficult, if not impossible, to do in a non-electronic medium.

### Error rates

Increased protocol compliance contributes to decreased error rates but does not account for it entirely. A subject could follow all steps in a guideline but incorrectly perform several of them. Therefore, the decrease in error rates can be attributed in addition to other features of the intervention, principally the use of rich media, that is, images, videos, and audio. The system provided videos whenever the particular step in the protocol called for performing a procedural task that involved observation and movement, such as performing a pinch test. Video durations did not exceed 18 s; complex procedures were divided into multiple steps. Still images assisted recall/recognition of static entities including skin rashes. Clearly, images and videos can be more effective, can reduce ambiguity, and can be faster at conveying these kinds of information than text. Audio, mainly in the form of voiced instructions, enhanced other modes and was seen as particularly useful whenever subjects had to use both hands to perform the task. In such cases they needed to look at the simulated patient rather than at the phone.

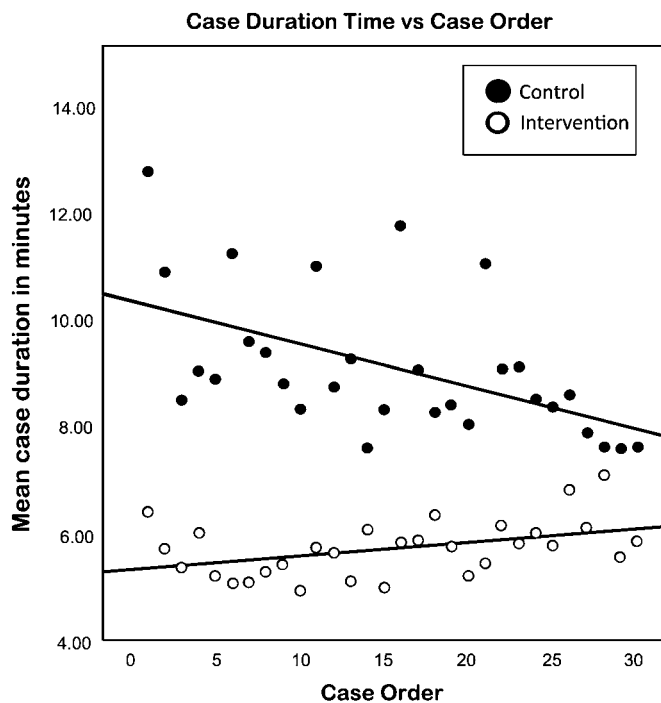
The error rate in the control group is comparable to that reported in the literature.<sup>3</sup> Despite significant decreases in errors due to intervention, there is still some distance to go in reaching optimality. This may be achievable by increasing task granularity and by providing better-quality rich media.

### Case duration time

The time to complete a case was greater using intervention than when using paper-based guidelines. This is because the CHW was more compliant with the guideline, since the system explicitly instructed them to perform each step and did not skip necessary steps. Figure 3 shows that even though the use of intervention causes an increase in time per case, the case duration time has a decreasing trend with case order, while these times are either flat or slightly increasing using the control. The former indicates that subjects are learning to use the system and that the time taken for a case decreases as the CHW gains experience with the tool. At the same time, figures 1, 2 show that the CHWs display an increasing trend in protocol compliance, and decreasing trend in error rates with case order when using the system. Combined, these results indicate that while the use of the rich-media cell phone system causes a slight increase in case duration time, these times decrease with practice while accompanied by enhanced protocol compliance and decreased errors.

### Workload and usability evaluation

Adoption of any technology is predicated on its usability and acceptability by the intended users. In this study, we performed detailed usability and workload studies. Usability was measured using a standardized questionnaire developed originally by IBM.<sup>34</sup> In addition, after completing each case, each subject completed the NASA Task Load Index<sup>35</sup> that measures workload in six dimensions and also the overall workload. Due to space



**Figure 3** Case duration time. Case orders 1 to 15 in the upper line represent data from Group A, while the lower line represents Group B subjects. Case orders 16 to 30 in the upper line correspond to Group B subjects, and those in the lower line are Group A subjects.

limitations, we will report these results in a separate article. However, we can report here that the intervention resulted in statistically significant decreases in mental workload, frustration, and overall workload as compared to the control. The other four measures of workload were not significantly different for intervention versus control. Ninety per cent of subjects rated both usability and their level of interest in adopting the system for daily use as 'high.'

### Limitations

While the study explored in detail several aspects of the use of rich media systems to improve performance of CHWs, several limitations should be noted. The CHWs applied the three sets of guidelines not on real patients but on human patient simulators. The benefits of this approach were elimination of case variability, ensuring that all study subjects saw identical cases, and keeping study sample sizes at a feasible number. While the simulators provided very realistic depictions of clinical cases, real patients exhibiting the same medical conditions will necessarily vary in presentation and severity. These factors must be considered when extrapolating our results to real-world contexts. The encouraging results found with simulators provide motivation to extend the study to real patients.

Learning effects on protocol compliance and error rate were not explored, in particular whether there were any differences over time in retained knowledge between the use of the intervention and control.

### CONCLUSIONS

Community health workers constitute the backbone of health-care in developing countries, yet they often have poor training and low education levels. Studies have shown that their performance is often less than optimal, characterized by high error rates and low protocol compliance, even when equipped with paper-based clinical guidelines.

In this paper, we have described a randomized prospective controlled study on the performance of community health workers in Colombia, when using interactive structured rich media (text, audio, images/video) clinical guidelines on cell phones to diagnose and treat pediatric and adult medical conditions in a simulated setting. Principal results include statistically significant decrease in error rates (33.15%) and increase in protocol compliance (30.18%) of the intervention versus control. Study subjects had completed high school. In some countries, CHWs have lower educational levels and serve populations that have very poor literacy, especially among women. Even in such countries, cell phones have achieved widespread acceptability.<sup>36</sup> Since the system described here provides information and guidance using audio, images, and video, we conjecture that the study results would persist. However, further research with CHWs and patients across a spectrum of educational levels is needed.

These results indicate encouraging prospects for mHealth technologies in general and the use of rich media clinical guidelines on mobile phones in particular, to support global health. Potentially, the long-term result from using such systems could be improvements in patient health outcomes. Future work could include enhancing the user interface, adding features such as GPS location, and repeating the study with human patients in Colombia and elsewhere.

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**Competing interests** JFF-A and MSI are part owners of a portfolio company of the University of Texas whose product is based on the intervention described in this paper.

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