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Dear Audience,

It is with great pleasure that the editorial board presents in the third issue of the Journal for this year a glimpse of the potential for virtual reality (VR) environments in patient care. In the current issue, Lehman and colleagues discuss the current capabilities and limitations of virtual reality environments in assessing the safety of patients in a spectrum of "real-world" settings. The authors highlight poignant examples of VR in simulating complex tasks of personal and social activities of daily living such as shopping, behavior control, memory and attention. Whilst these examples give a glimpse of the current capacity of VR, there remain questions regarding the validity and sensitivity of methods to test these applications. As discussed by the authors, the major foreseeable challenge is the ability of VR devices to remain sensitive to the tasks performed, whilst having the external validity to test the device against a broad range of contexts and situations.

As healthcare, moves towards a community based approach for many problems, VR environments offer a variety of potential in certain specialties such as rehabilitation medicine. By recreating certain environments and situations, patients are able to carry out abstract exercises which would otherwise be difficult to learn and perform.

Another example of VR is its potential for use as a diagnostic tool. Medical imaging modalities capture 3D structures, and project them onto 2D viewing surfaces such as computer screens. However through the utilization of appropriate VR technology, it is possible to view these 3D structures keeping their original three dimensionality. An example of this is provided by Yu et al who have adapted a commercial VR device to view wide field ophthalmic retinal photographs, which is a novel way to view such images.

VR has an immense potential in medical applications. As with all new technological modalities however, there needs to be a compelling evidence base to use these technologies, together with demonstration of potential economic benefits.

References
MOBILE PHONE USE AND PERSPECTIVES ON TAILORED TEXTING IN ADULTS WITH DIABETES

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Background: Mobile phone text messaging has become increasingly popular and text-based systems for patients with chronic diseases like diabetes are being rapidly developed. A paucity of information exists about preferences for and acceptance of health-related text messages by patients for self-management support.

Aims: To evaluate the use of mobile phones, acceptance of text messaging, and perspectives on receiving tailored text messages in adults with diabetes.

Methods: A total of 48 subjects were recruited into a randomized controlled study to improve medication adherence; 21 individuals provided responses on technology acceptance and 12 semi-structured telephone interviews were conducted at follow-up. After 90 days of tailored text messages, intervention arm subjects provided feedback on acceptance of the technology, personal perspectives on the receipt of tailored materials, and preferences for mobile phone use as part of their diabetes self-management.

Results: On average, participants exchanged less than 10 messages per day and those texting more frequently tended to be younger and owned smartphones. Participants’ perception of the utility and ease of use of text messaging was positive, both of which were more positive among participants with greater perceived competence for managing their diabetes and lower perceived barriers to treatment. Subjects felt that receiving one message per day was appropriate and they benefitted from the content. In general, subjects indicated the messages were primarily useful as reminders rather than a source of new information.

Conclusions: Acceptance of tailored text messages was high in adults with diabetes and subjects felt they could benefit from receiving similar messages in the future.
Introduction

Mobile phones are now commonplace, and reflect the overall growth in wireless phone subscriptions from just over 11 million in 1992 to over 326 million in 2012. Currently, an estimated 91% of American adults own a mobile phone, a 78% increase from five years ago. Currently, most mobile devices owned by American adults are smartphones (56%), the ownership of which has increased over 20% in the past two years and penetrating all socio-economic levels. A higher percentage of American adults now own mobile phones than report using the Internet. Moreover, while minutes of talk time have remained relatively stable, the estimated number of text messages exchanged between devices has more than doubled since 2008 to over two trillion messages in 2013.

Capitalizing on connectivity, the healthcare community has begun leveraging mobile phones in the care process. As of 2012, nearly one-third of cell phone owners reported using their phone to search for health information, nearly double the number from two years before. Nearly one in five adults now own applications on their phone to assist in the tracking or management of health conditions.

Considering the penetration of mobile applications and operability in the healthcare market, researchers and program developers have employed mobile technology to facilitate behavioral interventions for chronic illness self-management support. To date, text messaging has been the most popular for promoting healthy lifestyles and effective chronic disease self-care. Targets of these conditions have included behaviors such as smoking, appointment keeping, medication adherence, and physical activity among people with chronic diseases including diabetes, hypertension, and asthma. Medication taking has also been addressed, primarily using reminder messages to encourage medication adherence, mostly in chronic conditions.

Despite these advances in mobile health service development, less than 10% of American adults receive support for disease management via text message; and less than 20% of mobile Internet usage is among adults ages 50+, i.e., those most likely to be living with chronic disease. However, when chronically-ill patients’ acceptance of such interventions has been evaluated, most studies have shown high levels of receptivity and satisfaction. In particular, satisfaction with receiving text messages focused on medication adherence is generally high across studies evaluating interventions with a range of messaging frequencies. However, if mobile health interventions are to be more widely adopted, further research is needed into the use of cell phones, and their capabilities, as well as the needs and preferences in prevalent, high-risk patient populations.

Theory regarding adoption of technologies suggests that perceived ease of use and perceived usefulness (Figure 1) are both independent determinants, and both concepts are likely to play a major role in influencing chronically-ill patients’ intention to use mobile text messaging. While several investigations have considered the influence of external variables on perceived ease of use and usefulness, our understanding of how chronically-ill patients perceive and accept mobile messaging, in the context of healthcare delivery, is limited. In particular, factors such as patients’ age, socioeconomic class, or the complexity of their regimen may make these users’ experience different than those of healthy adults or people. Thus, a better understanding of potential factors influencing patients’ adoption and satisfaction of mobile health messages would aide practitioners and developers in improving the exchange of information with patients.

As part of an intervention focused on improving medication adherence in adults with diabetes, the current study sought to better understand how

![Figure 1: The Technology Acceptance Model (Adapted from Davis (1989))](image-url)
patients use their mobile phone and in what ways they would be willing to use their phone as part of their self-management support. Here, we describe use of text messaging among adults with diabetes using anti-hyperglycemic medication. We also describe users’ responses related to the receipt of tailored text messages, and evaluate their mobile phone acceptance.

Methods

Design

Mobile phone use and acceptance in adults with diabetes was evaluated as part of a randomized, controlled intervention using tailored text messages to address antidiabetic medication nonadherence. The intervention employed theory-based, individualized text messages focused on condition and treatment-related beliefs as well as medication-specific information about efficacy, side effects, and mechanism of action over a period of 90 days with the primary intent of improving diabetes medication adherence. The message development and delivery process is described elsewhere.21 Participants in the active arm received a daily text message timed to coincide with their first medication dose; control arm subjects received a monthly “thank you” message throughout their 90-day period in addition to their standard care. Institutional Review Board approval was received from both the University of Michigan and Mercy Health Partners (Muskegon, MI) for all study components. A total of 168 theory-driven messages and 128 medication-specific messages were developed for the study. Subjects in the intervention arm were sent a total of 2,230 messages and 94.3% were properly delivered as scheduled according to the system. Of the theory-based messages delivered, 41.4% were designed to provide encouragement (rather than reinforcement) to improve subjects’ baseline health beliefs and attitudes. Only three out of the 168 theory-based messages were not used at least once; however, more than half (55.5%) of all medication messages in the library were never used as several classes of medications were not represented.

Subjects

Participants were recruited from a community-based primary care network in western Michigan. To be eligible, participants had to be at least 21 years of age, diagnosed with diabetes, taking at least one antidiabetic medication, and have a hemoglobin A1c measured in the prior three months of at least 8.0%. Individuals were excluded if they: had experienced a stroke or heart attack, had been diagnosed with congestive heart failure, or did not own a mobile phone. Following screening and informed consent, eligible individuals were randomized to the intervention arm, in which they received one tailored text message per day for 90 days, or to standard care. All participants were mailed a baseline survey after randomization and were considered enrolled once the survey was returned. A similar survey was mailed immediately after the intervention. All participants were compensated $50 for their participation to cover the costs of receiving text messages during the study.

Subjects in the tailored text messaging arm were asked to participate in a brief phone interview (10–15 minutes) at the end of the study to capture their perspectives on the receipt of the messages. Subjects were randomly selected from the intervention cohort until half of the cohort had participated, and oral consent to participate was obtained from each interviewee prior to participating. All subjects were compensated $10 to offset the time required to be interviewed.

Data Collection

Participants’ baseline surveys included questions about their general mobile phone use and ownership (Appendix A). Among subjects in the intervention arm, technology acceptance was evaluated at follow-up (Appendix B). Four items guided by the Technology Acceptance Model were included in the endpoint survey and adapted for patients with diabetes from an instrument used to investigate SMS (text) messaging employed previously by Kim and colleagues.18,20 The included items surveyed subjects on perceived usefulness and perceived ease of use (two items for each concept), the degree of which, according to the model, influences the user’s attitude toward texting, as part of their self-care support, and their particular technology and, ultimately, their intention to use similar technology.18 Each of these items used a seven-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree). Scale reliability for perceived usefulness and perceived ease of use were 0.77 and 0.91, respectively.20 Additionally, subjects were asked about their health beliefs and level of self-determination (according to concepts related to the Health Belief Model and Self-Determination Theory) using previously validated items.21 Perceived benefit, severity,
susceptibility, and barriers as well as external regulation, autonomous motivation, and perceived competence were measured using five-point and seven-point Likert scales, respectively.22–24

Questions in the telephone semi-structured interviews of intervention-group subjects focused on participants’ opinions of the text messages in terms of the messages’ content, their role in supporting self-management, whether the frequency was appropriate, and the user’s anticipated acceptance of mobile phones for diabetes management in the future (Appendix C). Interview notes were recorded on a standardized form for each response item. Electronic data were either saved on a password-protected computer or stored in a locked office within the University of Michigan College of Pharmacy.

Data Analysis

Responses to baseline survey items were combined with demographic characteristics reported by each subject and descriptively reported using t-tests or Fisher’s exact tests for continuous and categorical variables, respectively. To summarize responses for Technology Acceptance Model concepts, mean values were determined using scores from items within each concept; descriptive statistics and comparisons across demographic groups were made using Mann-Whitney tests.25 To determine whether differences in acceptance varied according to subjects’ demographic characteristics or perceptions of their diabetes self-efficacy and barriers mean values for both Technology Acceptance Model measures were compared between categorical variables by Mann-Whitney tests and among continuous variables by Spearman rank correlation.26 A key predictor of interest was users’ frequency of texting at baseline, as a measure of their acceptance of mobile technology. For analyses presented here, two groups of texters were defined, i.e., those sending or receiving no more than 10 texts per day and those who sent or received on average 11 or more per day. Annual household income was dichotomized as less than or equal to $50,000 versus higher; race was defined as White versus other race/ethnicity. Among participants from the intervention arm who participated in the endpoint interviews, responses to Technology Acceptance Model items were examined separately according to groups defined by frequency of texting and diabetes self-care self-efficacy. STATA 11.0 (College Station, TX) was used for all analyses.

Results

Subject and Mobile Phone Characteristics

A total of 400 patients were initially identified. Of those, 75 were screened for eligibility by telephone and 48 were randomized; 44 randomized patients provided outcome data at 90 days and were included in the analyses presented here. At baseline, the average age was 47 years, with half of the subjects aged 50 years and older. Nearly all subjects were Caucasian or African American, and just over half were married. Incomes tended to be higher among older participants, although there were no significant differences in income between races or genders. On average, participants reported taking two diabetes medications each day with an average of four doses per day. At endpoint, the number of medications remained unchanged but the average daily dose was slightly less (mean = 3.9, SD: 1.56). Participants in the two arms had comparable characteristics at baseline (all p > 0.05). Characteristics of the intervention arm subjects are detailed in Table 1.

Overall, two-thirds of participants reported texting 10 times or fewer per day. Among participants who texted more than 10 times per day, a significant majority (p < 0.01) were 49 years of age and younger- nearly all were 39 years or younger. More frequent texting was observed in women than men (p < 0.05), and texting was more frequent among smartphone users than users of basic cell phones (p < 0.05). No differences in the frequency of text messaging were observed across income categories, races, or between service providers. Spending on service was no different between low and high texting subjects. At baseline, no difference in texting frequency was observed between study arms (p = 0.682) and all other mobile phone characteristics were similar across arms.

Smartphones were the dominant phone type, and a majority was owned by subjects 49 years of age and younger (72%). Also, a larger share of subjects who reported annual household incomes of $50,000 or less (62%) owned smartphones. Differences in ownership of the two types of phones were not observed by race or gender.

Technology Acceptance

By and large, acceptance was high in this population. Specifically, the mean perceived ease of use was 6.33 (SD: 0.885) and the mean for usefulness was 5.67 (SD: 1.38). Only two subjects indicated
some level of disagreement to the usefulness items, and only one subject did so for the items measuring ease of use. All three of these subjects reported low daily texting, were contracted with major carriers, were male, were over the age of 50, and took their diabetes medications at least six times per day.

Among all subjects, 76% moderately or strongly agreed to both ease of use items; just over half (52%) had this level of agreement for both perceived usefulness questions. Those subjects reporting such high acceptance to all four items (42%) were similar to the characteristics of other respondents, except that they tended to be slightly older than average. No significant differences in either acceptance concepts were identified across groups defined by subjects’ demographic characteristics or types of medication regimen (oral medication alone versus insulin use). Similarly, mean values for usefulness and ease of use were comparable for subjects regardless of texting frequency and whether the participant used a smartphone (Table 2). Measures of ease of use and utility trended toward a significant relationship but did not reach statistical significance ($r = 0.39$, $p = 0.07$). There was a trend toward significant correlation between perceived usefulness and daily doses of diabetes medications, suggesting that patients with more intensive regimens had a more positive reaction to the intervention ($r = -0.385$, $p = 0.08$).

Responses for usefulness and ease of use were also compared to patients’ responses to items measuring each of the seven health belief and self-determination concepts. Correlation analysis indicated that only ease of use was observed to have a significant relationship with other theory-driven concepts, demonstrating strong, positive association with perceived competence ($r = 0.6$, $p < 0.01$) and perceived barriers ($r = 0.43$, $p = 0.05$) to managing their diabetes self-care.

### Perspectives on Treatment and Condition-Tailored Messages

Characteristics of the 12 subjects completing qualitative interviews of follow-up were generally similar to those who were not interviewed. However, interviewees were more likely to be Caucasian than non-interviewed subjects and more likely to be male ($N = 8$). Similar to the overall sample, two-thirds reported texting 10 times or fewer per day, slightly more than half owned a smartphone, and all income categories were represented.

All but one of the subjects interviewed indicated enjoying a daily tailored text message. That remaining individual indicated that the messages were ‘‘not worth the [additional] cost’’. Subjects commonly suggested that they enjoyed the messages because they served as reminders, provided encouragement, or gave helpful tips and information. Most (9/12) reported that they found the information in the

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**Table 1**: Tailored Messaging Cohort Demographics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active Group</strong></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>24</td>
</tr>
<tr>
<td>Age*</td>
<td>46.4 (11.57)</td>
</tr>
<tr>
<td>Age Group</td>
<td></td>
</tr>
<tr>
<td>21–29</td>
<td>3 (12.5)</td>
</tr>
<tr>
<td>30–39</td>
<td>3 (12.5)</td>
</tr>
<tr>
<td>40–49</td>
<td>6 (25.0)</td>
</tr>
<tr>
<td>50–59</td>
<td>9 (37.5)</td>
</tr>
<tr>
<td>60–64</td>
<td>3 (12.5)</td>
</tr>
<tr>
<td>Female</td>
<td>12 (50.0)</td>
</tr>
<tr>
<td>Marital Status</td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>3 (12.5)</td>
</tr>
<tr>
<td>Living Together</td>
<td>3 (12.5)</td>
</tr>
<tr>
<td>Married</td>
<td>12 (50.0)</td>
</tr>
<tr>
<td>Separated/Divorced</td>
<td>6 (25.0)</td>
</tr>
<tr>
<td>Race</td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>14 (58.3)</td>
</tr>
<tr>
<td>African American</td>
<td>8 (33.3)</td>
</tr>
<tr>
<td>Native American</td>
<td>1 (4.2)</td>
</tr>
<tr>
<td>Latino</td>
<td>1 (4.2)</td>
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<tr>
<td>Household Income</td>
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<td>$0–25,000</td>
<td>7 (29.2)</td>
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<tr>
<td>$25,001–50,000</td>
<td>7 (29.2)</td>
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<tr>
<td>$50,001–75,000</td>
<td>8 (33.3)</td>
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<tr>
<td>$75,001–100,000</td>
<td>1 (4.2)</td>
</tr>
<tr>
<td>&gt;$100,000</td>
<td>1 (4.2)</td>
</tr>
<tr>
<td>Daily Diabetes Medications*</td>
<td>2 (0.85)</td>
</tr>
<tr>
<td>Daily Doses*</td>
<td>4.5 (1.64)</td>
</tr>
<tr>
<td>Daily Texting</td>
<td></td>
</tr>
<tr>
<td>0–10</td>
<td>16 (66.7)</td>
</tr>
<tr>
<td>11–20</td>
<td>5 (20.8)</td>
</tr>
<tr>
<td>21–30</td>
<td>2 (8.3)</td>
</tr>
<tr>
<td>&gt;31</td>
<td>1 (4.2)</td>
</tr>
<tr>
<td>Phone Type</td>
<td></td>
</tr>
<tr>
<td>Basic</td>
<td>10 (41.7)</td>
</tr>
<tr>
<td>Smart</td>
<td>14 (58.3)</td>
</tr>
<tr>
<td>Average Monthly Bill ($)*</td>
<td>98.27 (70.36)</td>
</tr>
</tbody>
</table>

*Presented as mean (± SD)
messages helpful; specific comments indicated that the information was “educational,” “encouraging,” and a “little bit of a confidence booster” or a “pep talk”. The remaining three subjects felt that the messages could have been better tailored to their specific needs or that the information provided was not relevant to their current point in treatment. One subject suggested that “[the messages] would have been more handy if [they were] based on checking sugars. I struggle with that every day. So, a reminder about sugars would have been helpful.” However, all but one person indicated that the tailoring was appropriate and that the individualization made them more likely to read and consider each message since they, “liked knowing [the message] was for me, not just generic.” Another subject noted, “I could tell they were tailored for me because they mentioned the medications I am on. Made me more likely to take them.”

In terms of the impact of the messages, a majority of interviewees (8/12) indicated that the messages made them more confident about managing their diabetes and more likely to take their medication each day (8/12). However, the most commonly mentioned motivation for taking each dose was that the timing of the message served as a reminder.

Those interviewed most commonly indicated that the messages where most helpful when the content focused on motivation, but a comparable number found medication information useful. One subject commented, “The type that gave encouragement, those ones [were the most helpful]. By remembering to take my meds like I am supposed to, I can live a longer life. Gave me encouragement to take my meds.” The messages focused on medication education were also well-received; comments included, “[I] liked the information about what your medications do, how they react, and why I should take them” and “[I] learned more about my Levemir; how it works throughout the day.” No types of messages were specifically identified as bothersome or unhelpful. All subjects indicated that it was convenient for them to receive messages by mobile phone and that receiving one message per day was sufficient. Some respondents felt the messaging dose could be individualized (e.g. additional messages to

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Table 2: Technology Acceptance by Category

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Ease of Use mean (SD)</th>
<th>p-value</th>
<th>Usefulness mean (SD)</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Age Group</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21–49</td>
<td>6.7 (0.67)</td>
<td>0.109</td>
<td>5.9 (0.77)</td>
<td>0.886</td>
</tr>
<tr>
<td>50–64</td>
<td>6.0 (0.99)</td>
<td></td>
<td>5.5 (1.78)</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>6.5 (0.71)</td>
<td>0.590</td>
<td>5.7 (0.67)</td>
<td>0.427</td>
</tr>
<tr>
<td>Male</td>
<td>6.2 (1.01)</td>
<td></td>
<td>5.6 (1.77)</td>
<td></td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>6.5 (0.92)</td>
<td>0.326</td>
<td>6.0 (0.97)</td>
<td>0.186</td>
</tr>
<tr>
<td>Minority</td>
<td>6.2 (0.84)</td>
<td></td>
<td>5.5 (0.50)</td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; $50,000</td>
<td>6.2 (0.93)</td>
<td>0.313</td>
<td>5.5 (1.57)</td>
<td>0.762</td>
</tr>
<tr>
<td>≥ $50,001</td>
<td>6.6 (0.79)</td>
<td></td>
<td>5.9 (0.93)</td>
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</tr>
<tr>
<td>Texting Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>≤ 10 per day</td>
<td>6.2 (0.93)</td>
<td>0.226</td>
<td>5.6 (1.60)</td>
<td>0.850</td>
</tr>
<tr>
<td>≥ 11 per day</td>
<td>6.6 (0.75)</td>
<td></td>
<td>5.8 (0.91)</td>
<td></td>
</tr>
<tr>
<td>Phone Type</td>
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<tr>
<td>Basic</td>
<td>6.2 (0.75)</td>
<td>0.218</td>
<td>5.4 (1.93)</td>
<td>0.914</td>
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<tr>
<td>Smart</td>
<td>6.5 (0.99)</td>
<td></td>
<td>5.8 (0.83)</td>
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<tr>
<td>Treatment Regimen</td>
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<tr>
<td>Oral alone</td>
<td>6.4 (0.75)</td>
<td>0.961</td>
<td>6.4 (0.95)</td>
<td>0.145</td>
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<tr>
<td>Combination therapy</td>
<td>6.3 (0.93)</td>
<td></td>
<td>5.5 (1.44)</td>
<td></td>
</tr>
</tbody>
</table>

Possible scores ranged from 1–7
match dosing schedules) based on demand without being bothersome.

Suggestions for similar, future texting interventions varied but were generally suggestive of either increased specificity and/or the inclusion of feedback mechanisms. Participants felt that they would benefit from messages that focused on other ways to control their diabetes (e.g. diet, exercise), individualization around self-identified areas of difficulty (e.g. checking sugars), and more technical medication information. For example, one subject who was taking both short- and long-acting insulin mentioned, “I don’t know if the benefits or synergies [between the two insulin types] were discussed. A lot of programs lack giving an understanding of what the short- and long-term insulins are doing together. [I] need more messages about understanding how the medications are working together- don’t think that gets addressed.” The ability to relay information back to a provider was commonly suggested to “keep in touch with the doctor” or even find a way to receive “feedback on sugars: these were my sugars, these were my activities, my insulin doses, and recommendations on what I could do.” All but one subject indicated they would want to participate in a similar tailored messaging program if it were available in the future.

In addition to simple messaging, other functions of mobile phones that could be used for health-related purposes were mentioned; the most frequently mentioned functions were the ability to track disease progression, specifically the recording of tests and the scheduling of reminders. If subjects mentioned they would like to interact with a provider (n = 8) they tended to specify this would be with their physician; however, the desire to interact with a pharmacist was indicated, “because of insurance status, especially about cost.”

Discussion
As part of a randomized controlled trial, this investigation sought to better understand the extent to which adults with diabetes use and accept mobile phone text messaging during their ongoing disease management. We found that in this population text messaging was relatively limited and younger subjects texted more frequently. Importantly, acceptance of using texting as a tool in their diabetes self-management support was high, even among older participants and those with less frequent texting. Specifically, users found the text messages user-friendly and helpful. Theoretical models about technology adoption and sustained engagement suggest that these high acceptance ratings indicate that participants would be likely to use this type of intervention in the future. To our knowledge, no similar diabetes texting system is currently in use as part of standard care, but these findings are encouraging in that they suggest that a similar tailored messaging system aimed at improving treatment adherence would be accepted and used.

That finding is consistent with evidence from prior studies. However, as suggested in some participants’ interviews, a texting support system might be even more useful if messages were more deeply tailored to their specific treatment needs (e.g. checking sugars, lifestyle management) and the stage of therapy.

A key issue across studies of text messaging interventions focused on medication adherence has been the determination of an appropriate frequency of messaging. To date, investigations have employed a variety of such “dosing” strategies, ranging from sending messages weekly to sending messages up to 12 times per day. Approaches also have included varying the number of messages sent based on the subject’s specific medication dosing pattern or by stepping down the number of messages from twice daily to approximately one every other day. However, the most popular frequency used in text-based adherence studies has been sending one message per day. Our study found that a daily message was an appropriate level for our subjects, corroborating those earlier findings, however we also found that users would be open to variable levels of messaging as at least one other study had determined.

Several types of messages were applied in this study, adding to our understanding of the most appropriate content for patients with diabetes. In our population, respondents’ reactions to the message content were roughly equally split between users who felt that the medication education messages were most helpful and others who found the motivational messages most useful. Respondents who preferred medication-specific messages tended to be younger and were taking more diabetes medications, and more often. Overall, this suggests that tailoring could be improved by focusing messaging on either of these two message types according to the patient’s preferences. Such an approach may then be more likely to result in positive behavior change and serve as more of a tool for motivating changes in health beliefs that drive
adherence, rather than serving only as a reminder for patients who are already motivated. Interestingly, we found that participants’ perception regarding the messages’ ease of use were positively correlated with theory-driven concepts of perceived competence for diabetes self-management as well as with participants’ perceptions of the barriers to diabetes self-care. In other words, those finding text messaging relatively simple to use are also likely to be those who perceive themselves as able to successfully meet the challenge of controlling their condition and those who feel that relatively few barriers exist to effectively manage their diabetes. Future research should investigate how best to leverage mobile tools, such as text messaging, for those with a higher level of competence and with few perceived barriers to reinforce behaviors and further improve the odds of positive health outcomes. Moreover, methods should consider the impact that advanced devices (smartphones) may have on health-related behaviors and investigate the mechanisms by which text messaging and other functions built into these technologies may be leveraged to improve medication adherence and other self-management strategies.

This study was limited in several ways. The sample size for this investigation was relatively small and only some of those who participated were surveyed on technology acceptance and interviewed to obtain their personal perspectives about the intervention. While the responses provide guidance on how adults with diabetes use their mobile phones and how text messaging studies may be structured, the views reported may not be representative of the general population of adults with diabetes. Additionally, only a limited set of messages was sent to the subjects throughout the study; the mix of messages may have influenced the usefulness of the messaging program. Furthermore, the subjects recruited could also have had either type 1 or type 2 diabetes and may have had their condition for any number of years; however, the messages were not drafted with either type of diabetes or stage of treatment in mind. The intervention also assumed that individual medication regimens were the same throughout the three months of the study. While only three subjects within the intervention arm reported a change in medications over the 90-day period, the inability to alter medication messages after baseline limited the extent to which these messages could have been tailored, resulting in some inappropriate messaging for those placed on a new medication. Finally, while the system used to deliver the messages was able to confirm that the messages reached participants’ phones, we could not confirm that each message was read.

Conclusions
This study found that adults with diabetes are accepting of text messaging as a tool for assisting them with self-management. Daily messages focused on behavioral motivations, health beliefs, or medication education were generally viewed as appropriate. The use of a similar intervention may benefit adults with diabetes or other chronic conditions, and future investigations should evaluate how best to leverage tailored material delivered by mobile phones. Next generation interventions should consider individual patient preferences in terms of messaging content and dose, the relaying of feedback, and direct communication between patients and providers in order to improve patient engagement and the impact of these services on health outcomes.

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The study authors wish to thank Jason Barnum, PharmD (Mercy Health Partners) for his assistance with identifying potentially eligible subjects and Katie S. Kaminski, PharmD (University of North Carolina Hospitals) for her assistance with recruiting subjects for the intervention. We are also grateful for the financial assistance provided by the University of Michigan Rackham Graduate School and the supporting funding from the Agency for Healthcare Research and Quality through grant number HS021976 (R36). John Piette is a VA Senior Research Career Scientist. Additional financial support came from grant number P30DK092926 from the National Institute of Diabetes and Digestive and Kidney Diseases.

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Disclosure
All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: support from the Agency for Healthcare Research and Quality and the University of Michigan for the submitted work; no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities...
that could appear to have influenced the submitted work.

REFERENCES
Appendix A: Mobile Phone Use Survey
The following 4 questions relate to your use of mobile phone text messaging. If you own and operate more than one mobile phone, please answer them based on your primary phone only. If you do not know exact numbers, please estimate as best as possible. Place your answer in the space provided.

1. In a typical day, how many text messages do you send and receive?
   ___1–10
   ___11–20
   ___21–30
   ___31 or more

2. What best describes the type of phone you own?
   ___Smartphone
   ___Basic phone

3. To which of the following service providers do you subscribe?
   ___Verizon
   ___AT&T
   ___Sprint
   ___T Mobile
   ___Cricket
   ___MetroPCS
   ___Other

Appendix B: Technology Acceptance Survey Items
1. Using text messaging as part of my diabetes treatment increases my chances of achieving things that are important to me.

2. Using text messaging as part of my diabetes treatment helps me accomplish things more quickly.

3. I think learning how to use text messaging as part of my diabetes treatment is easy for me.

4. I find text messaging as part of my diabetes treatment easy to use.

Appendix C: Intervention Exit Interview Items
1. Did you enjoy receiving messages on your phone specific to your condition and treatment?
   a. Yes: What specifically did you enjoy?
   b. No: Why were these messages not enjoyable to receive?
      i. Potential follow-up: Was this due to the content of the message?
      ii. Potential follow-up: Was this because it was received on your phone?

2. Did you find the information in these messages helpful in your ongoing treatment?
   a. Yes: What did you find most helpful?
   b. No: Why do you feel these messages were not helpful?

3. You received several types of messages over the course of these 3 months. Could you describe the ones that you found to be the most helpful, interesting, or educational?

4. Similarly, could you also describe the types of messages you found to be the most distracting, unhelpful, or bothersome?

5. If you were to continue to receive messages on your phone about your treatment and/or condition, what topics or material should these messages focus on?

6. You received one message each day for 90 days. Was this too much, too little, or about right?
   a. Potential follow-up: How often and how many messages would you prefer to receive?

7. Was it convenient for you to receive these messages on your phone?
   a. Yes: Is this your preferred method of receiving health-related information?
   b. No: How else would you prefer to receive health-related information? (Suggested sources: online, e-mail, mail.)
8. The messages you received were created specifically for you, meaning they were tailored to your treatment and current condition. Did this make you more or less likely to read, consider, and act on each message?

9. After receiving these messages for 90 days, do you feel more confident about managing your diabetes than you did before the study began?

10. When you received these messages did it make you more or less likely to take your prescribed medication for the day?
   a. Yes: What made you more likely to do so?
   b. No: What aspect of the messages made you less likely to do so?

11. In the future, how could we make a message-based system, similar to this one, more effective in terms of providing individual information and support? (Suggested topics: types of messages, interaction, timing.)

12. In the future, would you consider receiving tailored messages on your phone throughout the course of your treatment, similar to what you have for the past 3 months?

13. After receiving health-related information on your phone for 90 days, how likely are you to use your mobile phone for other health-related activities, such as tracking your condition, interacting with a healthcare provider, or looking up information?
Background: Persons who inject drugs (PWID) are at high risk for hepatitis C virus (HCV) and human immunodeficiency virus (HIV) infection. In a 2008 cross-sectional study of 1056 PWID in Tijuana, Baja California, Mexico, 59% of participants reported lifetime receptive needle sharing. Similarly, a 2010 cross-sectional study of 510 PWID in San Diego, CA, found that 49% of participants receptively shared needles and 68% shared injection paraphernalia. In addition to

Methods: We aimed to determine the prevalence and correlates of cell phone access among PWID enrolled in the ‘El Cuete’ cohort study in Tijuana. Participants were asked for detailed contact information at baseline—including a cell phone number if available—to facilitate retention. Interviews obtained socio-demographic data, health information, and lifetime/recent drug and sexual risk behaviors. Logistic regression was used to assess factors independently associated with providing a cell phone number.

Results: Of 735 participants enrolled, 16% of participants had access to a cell phone at baseline. Mean age was 37 years old, ranging from 18–63. Sixty two percent of participants were male, 96% were Hispanic, and 27% reported recent homelessness. Higher education and a monthly income ≥2500 pesos were associated with higher odds of cell phone access. Inversely, homelessness, daily injection drug use, and older age were associated with lower odds of cell phone access.

Conclusions: Cell phone access among PWID in Tijuana is low and should be considered in the design of mHealth interventions targeting this population.
engaging in risky behaviors, PWID are at high risk for loss-to-follow-up for treatment adherence and demonstrate low access to and use of health care services.

Tijuana is thought to have approximately 10,000 injection drug users, with a high prevalence of heavy drug use in the Zona Norte colonia, or neighborhood, close to the U.S.—Mexico Border. The Zona Norte is home to the largest red-light district (e.g., zona roja) in North America, known for its brothels, street prostitution, and illicit drug sales. In addition, HIV and HCV rates among PWID living in Tijuana are approximately 4% and 95% respectively. Successful treatment and prevention approaches for HIV and HCV require strict adherence to medication regimens and continuity in care, as well as significant reductions in risk behaviors to prevent the spread of infection to others.

mHealth—the use of mobile and wireless devices to improve health outcomes, health care services, and health research—may offer some promise for reducing risk and increasing engagement in health care for PWID. mHealth intervention strategies have proved effective in non-substance using populations to improve self-management of diabetes, increase physical activity, improve medication adherence, and decrease smoking. These strategies have also been used successfully in research among vulnerable populations, including providing support for those participating in addictions treatment, reducing sexually transmitted infection (STI) among female sex workers, and improving HIV anti-retroviral therapy (ART) adherence among non-injection substance users.

To assess technology access and use among high-risk individuals, one study of substance users enrolled in drug treatment in Baltimore reported that 91% of participants had access to a cell phone and 79% to text messaging. Another study among homeless youth in Los Angeles, of which 55% used a substance in the past 30 days, reported 62% of respondents owning a cell phone. However, less is known about mHealth strategies to improve health outcomes among PWID specifically. One small study assessing ART adherence among HIV-positive PWID in China suggests that although participants found mHealth tools acceptable, privacy and confidentiality were of the utmost concern. Another study among PWID in Sweden, found that mobile phones were a successful tool for communication and prospective follow-up among PWID who owned a mobile device.

To successfully implement mHealth interventions among PWID, it is first necessary to know what proportion are already using cell phones in this population. Thus, we assessed the prevalence and correlates of cell phone access among PWID enrolled in a longitudinal cohort study of HIV risk behaviors in Tijuana. The results of this analysis will be valuable for informing the development and implementation of mHealth interventions among PWID.

Methods

Study Population and Eligibility

“Proyecto El Cuete IV” is a prospective longitudinal cohort study of 735 PWID in Tijuana; detailed study methods are described elsewhere. At baseline, participants completed a behavioral risk assessment interview and serologic testing for HIV. Baseline enrollment was completed from 2011 to 2012; semi-annual follow-up visits are ongoing. Baseline quantitative study instruments assessed lifetime and recent drug use and risk behaviors. Eligibility criteria included the following: 1) being at least 18 years of age, 2) having evidence of injecting illicit drugs within the past month confirmed by observation of track marks or other physical evidence of injecting, 3) being able to converse in English or Spanish, 4) currently residing in Tijuana with no plans to move away within 24 months from enrollment date, and 5) not currently participating in any intervention studies. Individuals with severe cognitive deficiencies who were unable, or those who were unwilling to provide informed consent were excluded. Individuals who were too intoxicated or sleepy to provide consent and complete the study procedures were asked to return at a later date. The Human Research Protections Program of the University of California San Diego and the Institutional Review Board at the Colegio de la Frontera Norte (COLEF) approved all study procedures.

Recruitment

Recruitment involved targeted street-based outreach. Outreach teams established temporary mobile recruitment sites (such as vans and tents) in ten different colonias around Tijuana. Recruitment was also conducted out of the El Cuete field office located in the Zona Norte.
Data Collection
After participants were screened for eligibility and provided informed consent, trained bilingual research assistants conducted behavioral risk assessment interviews in English or Spanish in a confidential setting. Interviews were administered using computer-assisted personal interviewing (CAPI) technology, which has been used previously for studies in Mexico and the United States. Instruments at baseline assessed lifetime and recent experiences and behaviors. To facilitate study retention, detailed locator information, including cell phone number if available, was collected at baseline and updated at subsequent visits. Since the validity of findings from this longitudinal study depended on achieving high retention rates, interviewers made every effort to obtain all possible forms of contact, including cell phone numbers.

Measures
Socio-demographic measures included race/ethnicity, place of birth, education, language proficiency, citizenship and immigration status, marital status, living situation, incarceration, and reporting a landline phone number when asked for contact information. Drug use behaviors included lifetime and recent use of specific drugs, including drug of choice and frequency of injection, and sharing of syringes and/or other drug-related paraphernalia. Drug treatment and harm reduction measures included lifetime and recent experiences with voluntary and court-mandated drug treatment (e.g., methadone, outpatient vs. residential drug treatment, self-help groups), syringe exchange program (SEP) use, and obtaining syringes from a pharmacy or another safe source. Sexual risk behaviors included exchanging sex for money or other material goods. Other measures included history of prior HIV diagnosis and study retention at six months.

Data Analysis
The outcome measure for this analysis was whether or not the participant had access to a cell phone, which was assessed by whether or not s/he provided a cell phone number at baseline (yes/no). Descriptive statistics of the socio-demographic and risk behavior variables were calculated for each of the two cell phone groups. Frequencies were calculated for the binary variables, whereas means and standard deviations were calculated for continuous variables. A bivariate analysis was conducted to assess unadjusted associations with our outcome. Variables with a \( p \leq 0.10 \) in bivariate analysis were considered for inclusion multivariable models. Manual stepwise logistic regression was used to build these models, and variables with \( p \leq 0.05 \) were retained in the final model to determine odds ratios and 95% confidence limits for correlates of cell phone access. Confounding was assessed by determining significant changes (>10%) in crude associations, and maintaining confounding variables in the final model. Multi-collinearity was assessed using variance inflation factors (VIF), and models were compared using likelihood ratio tests. All analyses were performed with SAS version 9.3 (SAS, Cary, NC).

Results
Sample Characteristics
All participants who were enrolled in El Cuete IV (\( n = 735 \)) were included in this analysis. One hundred and seventeen participants (16%) had access to a cell phone at baseline (Table 1). Overall, the mean age was 37 years old, ranging from 18–63. Sixty two percent of participants were male and 96% were Hispanic. Twenty-seven percent reported being mostly homeless in the past six months; 59% reported ever having lived in the United States, 49% had an average monthly income above 2500 Pesos (~$200 USD), and participants reported a mean of eight years of education. Twenty-six participants (3.5%) tested HIV-positive at baseline.

Prevalence and Correlates of Cell Phone Access
In bivariate analysis (Table 1) cell phone access was positively associated with more years of education, having an average monthly income \( \geq 2500 \) Pesos, and reporting a landline phone number. Self-reported homelessness in the past 6 months, lifetime incarceration, HIV seropositivity, daily heroin injection, daily injection of any hard drug, and injecting more than once per day with any hard drug were inversely associated with cell phone access. Lastly, for every ten-year increase in age there was a 40% decrease in the likelihood of cell phone access (i.e., 4% per year). All \( p \)-values for significant differences were less than 0.05.

While self reported homelessness and reporting a landline phone number were both significant in bivariate analyses, these variables were highly collinear and could not be retained in the same multivariable model. Thus, the authors elected to...
retain homelessness in this analysis due to its importance as a risk factor among PWID. In the final multivariable model (Table 2), homelessness (Adjusted Odds Ratio [AOR] = 0.44, 95% Confidence Interval [CI] = 0.25, 0.77), daily injection drug use (AOR = 0.34, 95% CI = 0.16, 0.71) and age (AOR = 0.96 per year, 95% CI = 0.93, 0.98) were independently associated with lower odds of cell

Table 1: Bivariate analysis of socio-demographic characteristics, health outcomes and substance risk and harm reduction behaviors by cell phone access among people who inject drugs, Tijuana, BC, Mexico, 2011–2012.
phone access; whereas years of education (AOR = 1.11 per year, 95% CI = 1.02, 1.18), and having average monthly income ≥2500 pesos (AOR = 1.51, 95% CI = 0.99, 2.31) were associated with higher odds of cell phone access.

### Discussion

Overall, a low percentage (16%) of this cohort of PWID living in Tijuana had access to a cell phone. In comparison, the Mexican National Census estimated that two-thirds (67%) of Mexicans owned a cell phone in 2010.22 Cell phone use throughout Mexico has since risen, with 87% of Mexicans estimated to have access to a cell phone in 2013.23 However, Tijuana is thought to have a higher percentage of PWID than any Mexican state—PWID in Tijuana are generally lower SES and more likely to be socially marginalized individuals.2 This could partially account for the low cell phone coverage among the El Cuete study population.

Younger age was associated with cell phone access in this study, which is consistent with trends in the general Mexican population.24,25 Additionally, participants with higher SES (e.g., more education and higher monthly income) were more likely to have access to a cell phone, consistent with international polling about the growing use of technology in global emerging economies including Mexico.24,25 Marginalized participants, including individuals who were poorer, homeless, and those engaging in daily injection practices, were significantly less likely to have access to a cell phone. Given their marginalized status, these participants may also have less access to the resources required for owning and maintaining a cell phone, and thus less likely to report cell phone access to study staff. Researchers will need to consider cell phone coverage when developing mHealth intervention studies among PWID in Tijuana, because a high percentage of this population will be similarly resource-deprived.2

It was notable that none of the HIV seropositive participants reported a cell phone number to study staff. However, the low HIV prevalence in the study population may have precluded a significant finding for this variable in the final model. Landline use in Mexico has fallen below 50% in recent years22 and access to a phone, whether it’s a landline or a cell phone, is important for a population such as this to stay in contact with health care providers. These individuals may have elected not to share this type of contact information due to stigmatization or privacy concerns related to cell phone use and/or their HIV status. More research is needed to understand how HIV-positive PWID in Tijuana access appointments, communicate with their provider, and manage HIV treatment.

Some limitations should be considered when interpreting these findings. This study did not specifically ask participants if they owned or had access to a cell phone in the risk assessment interview. Instead, participants were asked to provide a cell phone number, if they had one, when providing locator information at the baseline and subsequent study visits. Participants may have owned or had access to a communal cell phone, but elected not to provide the number to study staff due to privacy concerns. This could potentially underestimate the proportion of participants who had access to a cell phone. Nonetheless, from the perspective of conducting research, willingness to provide a cell phone number to study staff is critical to implementing mHealth interventions. In addition, the baseline cross-sectional data used in this analysis do not permit temporal correlations between reporting a cell phone number and the other study variables. All risk behaviors were self-reported, which is subject to problems with recall. However, since the cell phone access variable was obtained from the participant contact form and was unrelated to the original study objectives, any problems with recall would be

### Table 2: Multivariable logistic regression analysis of factors associated with cell phone access among people who inject drugs, Tijuana, BC, Mexico, 2011–2012.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted Odds Ratio (95%CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.96(0.94, 0.98)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Years of Education</td>
<td>1.11(1.02, 1.18)</td>
<td>0.001</td>
</tr>
<tr>
<td>Average Monthly Income ≥2500 Pesos</td>
<td>1.51(0.99, 2.31)</td>
<td>0.054</td>
</tr>
<tr>
<td>Mostly homeless past 6 months</td>
<td>0.44(0.25, 0.77)</td>
<td>0.004</td>
</tr>
<tr>
<td>Daily injection of any hard drug</td>
<td>0.34(0.16, 0.71)</td>
<td>0.004</td>
</tr>
</tbody>
</table>

1 Variables adjusted for all other variables in the model
non-differential with regards to cell phone access and would tend to bias the results toward null findings.

Recall and social desirability bias may have resulted in an under-reporting of risk behaviors, and thus biased the associations between cell phone number reporting and correlates towards the null. However, a short recall period (six months for substance abuse and injection behavior questions) was used here to minimize bias. To minimize socially desirable responses, interviews were conducted in private settings with trained interviewers. Due to the convenience sampling used to recruit study participants for El Cuete Phase IV, these data might not be generalizable across all PWID in Tijuana. However, sampling and recruitment were designed to reach a variety of PWID across varying backgrounds and socioeconomic status. Despite these limitations, this research yields novel information regarding cell phone access among PWID, and identifies potential barriers to implementing mHealth research and interventions among PWID in the future.

Conclusions
mHealth interventions designed for PWID will need to consider levels of cell phone coverage for this low income, marginalized population. Only a small percentage of PWID in Tijuana provided a cell phone number when asked—the majority of participants either did not have access to a phone or were unwilling to share this information with El Cuete study staff. However, due to rapidly changing economic and societal norms, access to mobile technology is becoming ubiquitous across all levels of socioeconomic status, even in resource poor areas like Tijuana. More research may be needed among HIV-positive PWID to understand cell phone coverage among this population and determine how these individuals stay connected with care and any intervention research project staff. Future research should also assess smartphone ownership and/or mobile technology use in this population to better understand how mHealth tools may be utilized to implement interventions among PWID.

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References


REST – AN INNOVATIVE RAPID EYE SCREENING TEST

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Objectives: To determine the agreement and correlation of visual acuity between Rapid Eye Screening Test (REST) app and Early Treatment Diabetic Retinopathy Study (ETDRS) tumbling ‘E’ chart.

Methods: A visual acuity tool was designed for Android and iOS users based on ETDRS. A pilot study was conducted involving 101 subjects. Visual acuity of each subject was tested using ETDRS chart and crossover to REST at 3 meters or vice versa.

Results: Mean visual acuity using ETDRS was 0.086 ± 0.194 for right eye (RE) and 0.085 ± 0.196 for left eye (LE) while REST measurement was 0.091 ± 0.182 for RE and 0.098 ± 0.203 for LE. There was significant and strong direct correlation between visual acuity using ETDRS and REST in both eyes (RE: r = 0.829; p < 0.001, LE: r = 0.871; p < 0.001). The 95% limits of agreement between the two charts was ±0.11 LogMAR for right eye and ±0.10 LogMAR for left eye. Time taken for REST was significantly shorter than ETDRS (p < 0.001).

Conclusion: REST is accurate and time-saving, thus potentially ideal for mass screening in remote area.

Introduction
Community vision screening plays an important role in the detection of eye diseases, with the hope of early detection and prevention of potentially reversible causes of blindness. Approximately 285 million people have visual impairment worldwide, according to World Health Organization (WHO) estimates. Out of this, 90% of the visually impaired live in low-income settings1. In the community setting, healthcare workers usually perform visual acuity testing with a variety of tools such as Snellen chart2 and Early Treatment Diabetic Retinopathy Study (ETDRS) tumbling ‘E’ chart3, which have been validated4,5.

A wide range of products and greater affordability of digital devices such as smartphones and tablet computers have made these devices ubiquitous. Various innovations have been created to take advantage of these devices for the screening of eye diseases6, capturing of high-quality images of the eye7, or as an indispensable tool in patient education. Applications (or apps in short) created for these devices are convenient to use and can be easily
downloaded. We are introducing an app called Rapid Eye Screening Test (REST) that is easily downloadable, and simple to use.

The purpose of this study was to determine the agreement and correlation of our REST app in comparison with the standard ETDRS tumbling ‘E’ chart.

**Methods**

**Development of REST**

The REST app (Fig. 1) was written using HTML5 coding and is available for free on both Android and iOS operating system (OS) platforms for both smartphones and Ipads/Android tablets as well (downloadable from Google Play and App Store respectively) (Fig. 2). The tumbling E chart is recreated in the app and the optotype size is calibrated according to the testing distance of either 1 metre or 3 metres. The touchscreen function in these devices plus the addition of sound cues in the app allow for the tester to perform testing without having to look at the screen.

**Calibration of the REST app**

An initial calibration of the REST app needs to be done prior to initial use. On the main screen, user needs to click on the “Settings” tab. An option of 3 meters and 1 meter will be displayed and both need to be set. With the help of a ruler, the letter E displayed on the phone screen needs to be measured to 43 mm for 3 meters and 14 mm for 1 meter by sliding the toggle just below the E (Figure 3). Once the setting is done, user needs to click on save and the memory of the optosizing will be saved.

**Instructions on how to use the REST app**

The tester holds the smartphone or tablet at the preferred testing distance (either 1 or 3 meters) from the subject. Testing is done under normal lighting conditions and the device brightness is set to its highest setting. The subject is instructed to point with fingers to indicate the direction of the tumbling ‘E’ shown on the device. The tester then swipes accordingly. If the correct answer is given, a positive sound is played and the test proceeds to a smaller ‘E’. The test continues to reach a vision of 6/6 and a different positive sound will be played indicating end of testing. If the subject indicates a wrong direction anytime during the test i.e. the tester swipes to the wrong direction on the touchscreen, a negative sound will be played and the final vision will be displayed.

**REST as Screening Tool**

The video links to example of how REST is used as a screening tool.

Link: [https://youtu.be/oWOP4wbB_J0](https://youtu.be/oWOP4wbB_J0)

**Pilot Study: Comparison between REST and ETDRS tumbling ‘E’ chart**

This was a cross-sectional study employing universal sampling conducted in Universiti Sains Malaysia Hospital, a tertiary eye referral centre in the east coast of Malaysia. The study was...
conducted throughout the month of November 2014.

Study subjects comprised patients who attended the eye clinic and staff in the eye clinic at Hospital Universiti Sains Malaysia. Subjects with visual acuity of worse than 6/60 were excluded from the study. Visual acuity screening was performed sequentially in both eyes using the ETDRS tumbling ‘E’ chart at 3 meters, followed by the REST app at the same distance. The time taken for both tests to be completed and the final visual acuity were recorded. Demographics data of age, sex, race, highest education level, and nature of occupation were obtained from the subjects.

Visual acuity was then converted to logMAR (Minimal Angle of Resolution) for data analysis. Data analysis was done using SPSS software version 22.0. The intra-class correlation coefficient (ICC) was used to assess the test-retest reliability of the REST app and ETDRS tumbling ‘E’ chart. The Bland-Altman comparison method was used to assess agreement between the two methods. Pearson Correlation was used to determine the correlation while paired t-test was used to compare the time taken. A p value <0.05 was deemed statistically significant.

Results
A total of 101 subjects were recruited in this study. Mean age was 37.0 ± 15.9 years (range: 5.0 – 75.0 years). There were slightly more females (55.4%) compared to males. Majority of our subjects (62.4%) were Malays, followed by Chinese (31.7%) and Indians (5.9%), generally reflecting the racial distribution of the Malaysian population.

Figure 2: REST app across platforms (From Right: iPhone 5s, Xiaomi Redmi Note, iPad Mini 2, iPhone 6 Plus)
50.5% of the subjects were working professionals (doctors, nurses, optometrists), while 28.7% were non-professionals. The remaining 20.8% of subjects were unemployed.

In the standard ETDRS tumbling ‘E’ chart, the mean logMAR visual acuity was $0.086 \pm 0.194$ for the right eye and $0.085 \pm 0.196$ for the left eye. Meanwhile, the mean logMAR visual acuity for REST was $0.091 \pm 0.182$ for the right eye and $0.098 \pm 0.203$ for the left eye.

The ICC was found to be $0.905$ (95% CI from 0.859 to 0.936, $p < 0.001$) for right eye and $0.931$ (95% CI from 0.898 to 0.954, $p < 0.001$) for left eye. The extent of agreement between REST app and ETDRS tumbling ‘E’ chart is illustrated on Figure 4A and 4B. The 95% limits of agreement between the two charts were between $+0.10$ and $-0.15$ for right eye and $+0.10$ and $-0.30$ for left eye. There was strong direct correlation between visual acuity using ETDRS tumbling ‘E’ chart and REST in both eyes (right eye: $r = 0.829$; $p < 0.001$, left eye: $r = 0.871$; $p < 0.001$) (Figure 5 and Figure 6). The time taken to perform ETDRS tumbling ‘E’ chart and REST visual acuity examination is shown in Table 1. The results showed that the time taken for REST was $2.8 \pm 2.8$ seconds shorter than ETDRS tumbling ‘E’ chart in the right eye and $3.0 \pm 2.7$ seconds shorter in the left eye. Both were statistically significant with $p < 0.001$. 

Figure 3: Initial setting of REST app

Figure 4: Bland-Altman plot for difference in LogMAR visual acuity of right eye (A) and left eye (B) between REST app and ETDRS tumbling ‘E’ chart. In each instance, the mean difference and upper and lower 95% limits of each agreement are plotted.
Discussion

Visual acuity testing is an important first step in detecting reversible causes of visual impairment such as cataract and refractive errors. In screening of large general population, a screening tool should be affordable to acquire, highly portable, and easy to use.

There is a variety of visual acuity screening tools in the market currently, including digital versions available as apps. However, one major shortcoming is the lack of ability to standardise or adjust the size of the optotype according to different testing distances. To our knowledge, at the time of writing, there is no paper published that studied the agreement and correlation between these visual acuity testing apps and the standard charts already available in the market.

In our study, we found that there was a strong direct correlation between REST and ETDRS tumbling ‘E’ chart as a visual acuity screening tool. The time taken to perform the test was significantly shorter compared to ETDRS tumbling ‘E’ chart.

There are, however, limitations to our app. The screen contrast and brightness of the various touchscreen devices cannot be standardised due to the different builds and models. In addition, for our app to display properly, a minimum screen size of 3.5 inches (e.g. the screen size of an iPhone 4) is required. This is required due to the size of the optotype.

As our REST app is run on digital devices, it is highly reliant on the battery lifespan of each individual device. Nevertheless, this can be overcome by plugging the device into a power source.

<table>
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<tr>
<th>Laterality</th>
<th>Time Taken Mean Time ± SD (seconds)</th>
<th>Mean difference (LCI, UCI)</th>
<th>t-statistic</th>
<th>p-value</th>
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<tr>
<td></td>
<td>ETDRS tumbling ‘E’</td>
<td>REST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>15.9 ± 3.9</td>
<td>13.2 ± 2.8</td>
<td>2.8 (2.2, 3.3)</td>
<td>9.818</td>
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<tr>
<td>Left</td>
<td>15.9 ± 3.9</td>
<td>12.8 ± 3.3</td>
<td>3.0 (2.5, 3.5)</td>
<td>11.267</td>
</tr>
</tbody>
</table>

Paired t-test, p-value < 0.05 significant

Abbreviations: ETDRS, Early Treatment Diabetic Retinopathy Study; REST, Rapid Eye Screening Test; SD, Standard Deviation; LCI, Lower Confidence Interval; UCI, Upper Confidence Interval.

Table 1: Comparison of time taken between ETDRS tumbling ‘E’ chart and REST
Conclusions
The REST app is a potentially ideal app for visual acuity assessment in the general population, especially in remote areas where access to healthcare facilities may prove difficult. Its compact portability, ease of use and intuitive testing method offer users a rapid yet accurate means of testing visual acuity.

References


Appendix
Link to App:


iOS: https://itunes.apple.com/app/id964867413
The Potential Value of Virtual Environments (VEs) in Rehabilitation

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Virtual Environments (VEs) are computer-generated immersive, interactive simulations. These controlled settings can be designed to enable assessment and training of a wide variety of daily tasks, including those that are difficult to practice in the real-world for practical and safety reasons. The use of VEs has attracted increased interest as shown by increasing publications in the realm of rehabilitation. VEs are especially promising in the area of rehabilitation of instrumental activities of daily living (IADLs). Despite this recent growth in research, the use of these technologies lacks the validation necessary to establish them as standard practices in rehabilitation. Given the growing use and potential of VEs in rehabilitation, there is a need for specific guidelines to be established for the validity testing of these constructs.

Advantages of VEs

Rehabilitation necessitates extensive practice, feedback, detailed instruction, and strategy implementation, typically requiring multiple visits to a clinician. The patient must not only invest the time of treatment session but also the time and expense of traveling to and from the therapist’s office. The logistics of travel may be particularly troublesome for those with involved disabilities. Often, the recommended course of face to face therapy is prohibitively impractical, and the limited therapy provided is not effective. Virtual Environments may be designed to be engaged in at home via an individual’s personal computer, providing a mechanism for many more opportunities for practice and strategy formation while eliminating the barrier of travel.

Three Existing Virtual Environments (VEs) Showing Potential for Use in Rehabilitation

VMall
Among the virtual shopping malls that have been developed, one of the most thoroughly described and tested is one developed by Rand and colleagues. This mall is called the VMall and is described in detail by Rand and colleagues in their 2007 article. It has been tested for use in rehabilitation. One especially unique and innovative feature of the mall is that the individual participating in the shopping experience actually appears in the mall, which consists of nine aisles.

In a critical study, Rand and colleagues tested the ecological and construct validity of tasks on the Virtual Multiple Errands Test (VMET) when performed in the VMall. To help establish ecological validity, participants’ VMET scores (obtained in the virtual store) were compared to their scores on the Multiple Errands Test-Hospital Version (MET-HV) (scores obtained in the real hospital store). To study evidence of construct validity, scores on the VMET were also compared to scores on two established tests, the Zoo Map subtest of the Behavioral Assessment of Dysexecutive Syndrome (BADS) and an Instrumental Activities of Daily Living (IADL) questionnaire. Correlations between VMET and MET-HV scores were high for total number of mistakes, partial mistakes, and non-efficiency mistakes. Strong relationships were also found between the scores of the VMET and MET-HV and Zoo Map and IADL measures.

V-STORE
A second virtual store, the V-STORE was developed by Lo Priore and colleagues in 2002. Its
features were designed to assess similar constructs as established tests such as the Tower of London Test and the Wisconsin Card Sorting Test (WCST). In the V-STORE the patient’s challenge is to solve a sequence of tasks, ordered in six levels of increasing complexity. Tasks are designed to require problem solving, behavioral control, memory and attention. Uniquely, a series of distracting elements have been added to the tasks.\(^6\)

One pilot study\(^6\) compared feelings of engagement experienced by twelve normal subjects to versions of the V-STORE that were designed to be more immersive (three dimensional with head mounted display and tracking device) or less immersive (flat screen). Three different measures were obtained: psychophysiological responses (GSR, skin conductance), a test of incidental recall memory related to auditory information coming from the outside environment, and a self-report questionnaire relating to feelings during and after the experience in the store.\(^6\) For GSR, subjects of both groups showed an increase in GSR response while completing the tasks, however, the increase was significantly higher for the head-mounted display group. The number of questions answered correctly about events in the outside environment was less for the HMD group. This was thought to represent a deeper involvement in the virtual environment. There were no differences between the groups on the self-report questionnaire.

**The Virtual Supermarket**

Lee and colleagues developed a virtual supermarket environment in 2003\(^{10}\) for assessing and training activities of daily living. Unique features of this environment include four display stands and refrigerators that open both from the top and the front. Participants pick up objects by moving the cursor over the object, which will then change color, and pressing the joystick button. The joystick utilized by participants is a Joystick (Airstik 2000) (See Figure 1). To open the refrigerators, the participant must in a similar manner move to in front of the door using the joystick and press the joystick button. After opening a refrigerator door, objects may be selected from the refrigerator. Tasks in the virtual supermarket include navigating and exploring the supermarket, picking up goods at the supermarket and placing them in the cart, and exiting the supermarket.\(^{10}\)

In a study of the virtual supermarket conducted by Lee and colleagues,\(^{10}\) five participants who were receiving rehabilitation treatment participated. Time elapsed, distance moved, and numbers of collisions with walls were recorded. In addition the number of goods selected, number of doors open, number of joystick button presses, and error rate were obtained for each participant. Next, participants completed the Immersive Tendencies Questionnaire (ITQ), the Simulator Sickness Questionnaire (SSQ), the Presence Questionnaire (PQ), and the Virtual Reality Questionnaire (VRQ). Participants returned for four additional sessions in the virtual supermarket. The time, distance, and number of collisions with walls tended to decrease with the number of sessions. The number of goods selected and number of joystick button presses tended to increase with time. Participants reported on the questionnaires that they could not control the joystick well during the experience and had difficulty navigating in the store.

**Future of Virtual Environments (VEs) in Rehabilitation**

What is the future for Virtual Environments (VEs) in rehabilitation? There is great potential for using VEs in assessment and treatment. First, we have only begun to test the use of Virtual Environments (VEs) with a few populations with impairments, mainly stroke and traumatic brain injury. There are
many diagnoses, including multiple sclerosis, for whom VEs might be especially effective in treatment.\textsuperscript{11} To best facilitate rehabilitation development of different environments is needed. For example, practicing strategies that might be performed in the home in a VE might be useful to assess suitability to live independently and also help train habits most likely to ensure home safety. Also, busy stores, the dentist, the doctor’s office, or the department of motor vehicles might be most suitable for some individuals to practice in virtually. Furthermore, the development of diverse challenges within each environment is needed. Some tasks might require navigation of novel routes, others might require planning a daily schedule, or performing a sequence of steps. The end goal would be to build a corpus of tasks in multiple challenging environments that would be appropriately tailored for each individual.

Once virtual environments are created their use might be extended to build mobile applications which can be deployed on mobile phones and tablets. Once successful and safe performance is obtained in the virtual environment (presented on screen in the home or clinic location), use of the mobile extension app might allow the individual/client to go into the actual environment while still receiving support and cues from a remote clinician or assistant. This way grading the experience until the ultimate goal is obtained. See Figure 2. While there are deficiencies in current available software, rapid advances in the field of technology related to rehabilitation are making these goals more and more achievable.

Strategies for Validity Testing of Virtual Environments (VEs)

A protocol is needed for testing the validity of tasks performed in VEs. First, face validity, the degree to which an assessment appears to be evaluating what it intends to measure,\textsuperscript{4,12–15} would need to be

![Figure 2: Potential Areas of Expansion of the Use of Virtual Environments in Rehabilitation.](image-url)
established. This is typically done through the use of focus groups initially with clinicians/experts and then with affected individuals.\textsuperscript{16-18} With VEs, this would entail clinicians/experts going through the tasks in the environment themselves and evaluating, perhaps in the form of a survey or a group/individual meeting, the appropriateness of the difficulty and content of the tasks. Following this, the same type of assessment of the tasks in the environment would be completed by the end user (i.e. the patient).

Next, external validity, also referred to as generalizability, would need to be assessed. This type of validity implies the ability to generalize to other situations, contexts, or people.\textsuperscript{12} It is essential to

**Figure 3:** Suggested Approach for Testing the Validity of Tasks Performed in Virtual Environments.
verify that results produced in simulated environments are similar to those in the real world.\textsuperscript{2,19} Assessing external validity would involve having affected individuals complete tasks both in the virtual and real environments and comparing performance in both settings. Similar performance would indicate that the virtual world was an accurate depiction of the actual one.

Finally, concurrent and discriminant validity should be ascertained. Concurrent validity determines if the results correlate well with measures of similar constructs. Discriminate validity addresses the extent to which performance on tasks is not correlated with dissimilar measures, those intended to measure something different than the assessment of interest.\textsuperscript{12,20–22} This would involve identifying tests measuring constructs intended to be measured by tasks for concurrent validity testing and tests measuring constructs that are not intended to be measured by the tasks for discriminate validity testing. Patients would complete both established tests and the tasks in the virtual environment and results would determine the correlation between assessments of similar and dissimilar constructs. Finally, further analyses involving detailed item/task analysis (i.e., factor analysis, differential item functioning) should be completed. See Figure 3.

References


Within Health Delivery Organizations (HDOs), leaders, information technologists and privacy officers have been focused on the acquisition, implementation, and security of enterprise Electronic Medical Record (EMR) systems. Unfortunately the investment of money, human resources and time is at the expense of addressing daily physician workflow complexities. To optimize patient centered care, we must unshackled the physician from the EMR desktop and move them closer to the patient. For this reason, physicians should engage with key stakeholders to identify the financial, legal, administrative and human resource challenges of delivering efficient workflow solutions alongside the deployment of enterprise EMRs.

**Resetting the Investment Tipping Point**

In 2011, the Canadian Medical Association (CMA) presented a 5-year strategy for Health Information Technologies (HIT) investments in Canada.1 They proposed a framework to: a) support significant adoption of EMRs, b) increase the effective use of EMRs and HIT solutions, and, c) accelerate the exchange of health information. Recognizing the difficult financial climate, they recommended a “bottom-up” grassroots approach to deliver tangible short-term benefits to the front lines. Yet 80% of the proposed $923 million dollar investment was directed towards the adoption of EMRs;1 an allocation that not only included initial EMR investments, but also costly post installation customizations and data migration.

Incentivizing rapid EMR adoption over workflow analysis and patient engagement solutions has not met physician needs. Accordingly, physicians have developed their own creative manual and electronic processes to capture and share information. Despite their ingenuity, they have often employed their own devices (i.e. smart phones, tablet computers) and have not gone through proper regulatory channels,2 thus exposing themselves to a milieu of potential medico-legal risks.

Presented with this reality, investments should “tip” where physicians have already pointed: integrating mobile HIT solutions into clinical processes to share data at a local or regional level. Canadian Health Infoway stated that mobile health is “more than an emerging set of technologies” and “should be regarded as a priority component of the health enterprise’s IT strategy and supported as platform”.3 Their findings suggest that mobile health offers many benefits to maximize efficiency, including viewing clinical documentation, and being able to access EMRs. In agreement, a recent mobile health review commented on its key role for healthcare solutions, and outlined an expanded vision of addressing the emerging problems of health services: access to care, cost, and patient empowerment.4

**Untangling the Web of Policy and Legislation**

Beyond financial priorities and constraints, a significant obstacle in addressing physician requirements is the patchwork of privacy legislation and policies that exist concerning personal health information (PHI). In Canada, the Canadian Medical Protection Association (CMPA) actively engages stakeholders to advance these issues and their interim recommendation is for physicians to be aware of the provisions that apply in their jurisdiction.5 Using the province of Manitoba as an example, the major levels include provincial legislation with the Personal Health Information Act,6 the regional health authority,7 and the College of Physician and Surgeons of Manitoba,8 and the national CMA.9 In total, they represent
over 20 multi-jurisdictional policy statements that physicians are held accountable to.

Ultimately, these policies are enacted to address the administrative, physical and technical safeguards that must be in place to safeguard PHI as required by law. For mobile solutions, administrative safeguards may include signed pledges of confidentiality or record keeping of user activity for manual and electronic systems that do not have this capability built into the software. Physical safeguards would ensure that tablets, printers and fax machines are located in restricted access areas with secure disposal of confidential information. Finally, technical safeguards would address the security of electronic devices and protect PHI in transit across HDO networks and the Internet, or on portable storage devices like USB keys.

While enterprise EMRs vendors have the resources to untangle the web, simplifying the coordination, adoption and deployment of HIT solutions is needed. Developing multi-jurisdictional policy matrices and appropriate safeguards—where possible—would greatly simplify inter-physician and data sharing agreements, and promote grassroots solutions.

Building a Championship Team to Deliver Patient Centered Care

Although the physician must have skin in the game, a complete team is critical. The CMA should continue to advocate for HIT investments that support front line points of care, report on HIT spending and efforts to date, and host Centres of Excellence to showcase successes and lessons learned. The CMPA has an instrumental role in educating physicians about their responsibilities and medico-legal risks under PHI legislation. If appropriate, they can also develop safe harbor provisions to simplify the creation of inter-physician and data sharing agreements, thereby accelerating the deployment of HIT solutions within HDOs.

The role of Chief Medical Information Officer can bring the voice of physicians to the management table and executively sponsor initiatives. Health Records Management Officers may assist physicians in identifying and classifying PHI in the context of its use. This includes guidance regarding data input, collection, copying or sharing, and that the “medical record” should only exist for as long as needed to meet legislative or policy requirements.\(^ {10,11}\)

In the context of HIT investments and solutions, HDO Privacy Officers and Information Technologists can educate physicians on PHI safeguards, and provide information and advice on commercial off the shelf and open source solutions. These alternatives are low risk and cost effective, and address the interoperability and mobility requirements of physicians. Privacy Officers certify HIT solutions for use within the HDO by conducting privacy impact assessments as required by provincial legislation. Lastly, the Information Manager can assist in translating and documenting workflow requirements, resulting in business cases to take forward to the Chief Medical Information Officer for consideration.

Confirmed by the Ottawa Hospital

After Telus Health declined to develop a custom tablet version of their EMR (for the Apple iPad), the Ottawa Hospital developed an in-house solution.\(^ {12}\) Their considerable enterprise enabled 70 internal and contract employees to develop what their Chief Medical Information Officer described as part of a larger “back to the bedside” strategy.\(^ {13}\) He observed that “over the past 10 years or more . . . clinical teams have become computer-centric as opposed to being patient-centric” and that clinicians were “always gravitating back to nursing stations where the computers are to get information”.\(^ {13}\) These barriers of patient centred care are not novel, and have been well documented in primary care encounters with observations of lessened dialogue, protracted screen attentiveness that disrupted emotional disclosure, and non-receptive body positioning.\(^ {14–16}\)

By introducing iPads and other mobile devices, their goal was “to free up . . . clinicians’ time so they spend more time with the patient”.\(^ {13}\) While exemplifying Canada Health Infoway’s recommendations for a mobile strategy as a platform,\(^ {3}\) the focus of moving away from the screen and back to the patient’s bedside demonstrated the role HIT and mobile health can have on delivering patient centered care.

Conclusion

Although enterprise EMR adoption continues to be the focus of HDOs, they have missed the mark for mobility and optimization for patient engagement. Physicians who have limited access to funds are searching for their own solutions, but find themselves stuck in a legislative web of complexity, and are searching for guidance from a strong team.
While the Ottawa Hospital example shows what is possible with executive support, this represents the exception in the current fiscal climate. However, opportunities do exist to address this problem through the use of commercial off the shelf, open source and mobile solutions. If physicians are a critical component to patient centered care, then we need to ensure that they are not left chained to the EMR desktop without resources or support.

Research scholarship
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References


Mobile Virtual Reality for Ophthalmic Image Display and Diagnosis

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We here present the use of mobile technology (Samsung Gear VR) in the field of ophthalmology for the display of retinal imaging and demonstrate its use in diagnosis of ocular pathology. In this study a trained retina specialist used the Samsung Gear VR device to view ten wide field photos of retinal pathology, generating a diagnosis for each photograph. Another ophthalmologist then reviewed the ten photos in the traditional manner on a computer. Their diagnoses were compared to the known diagnoses. There was 100% concordance between the device and the traditional method as well as the known diagnosis. The increased display size and realistic presentation of the virtual reality display have the potential to improve diagnosis of ocular disease.


Supplemental Video 1: Video capture of virtual display showing rhegmatogenous retinal detachment. The clinician feels that he or she is within the eye.

Case details
Virtual reality (VR) has been an emerging technology in the past years. In particular Oculus, a company acquired by Facebook (Menlo Park, CA), has been producing development kits but has not yet released a consumer version. A recent study demonstrated the use of an Oculus Rift device in adjunctive pain control.1 In partnership Oculus and Samsung (Seoul, South Korea) recently released the Gear VR headset to consumers. This device consists of an Oculus-powered head mount into which a Samsung Galaxy Note 4 smartphone is inserted. [Figure 1] The phone provides the computing power and display (2560 x 1440 resolution, 515 pixels per inch), while the head mount incorporates precise accelerometers to track head movements to update the display. The head mount also includes a touchpad on the right side to allow for user interface. The device can be used to display 3D video and audio in an immersive 360-degree manner without any attachments to a computer.

Due to the clarity of the visual axis photographs are very often used clinically in ophthalmology.2 They allow for disease documentation, education, and can aid in making diagnoses, especially of retinal conditions such as macular degeneration and diabetic retinopathy. In particular, the Optomap (Marlborough, MA) system captures ultra wide field (270 degrees) images of the retina.3 These images are currently viewed on a computer monitor or printed out and are distorted in order to display a three dimensional object, the human retina, on a flat surface. (Figure 2)
To study the use of virtual reality for display of retinal imaging, we collected ten publically available de-identified wide field photographs of common retinal pathologies with a known diagnosis. [Table 1] We then uploaded them into the 360-degree photograph mode of the Gear VR. We found that a 40”x20” photograph size incorporating a 8” black border on each horizontal side accounted for the areas of the eye not included in the wide-field photograph and makes for minimal distortion. (Figure 2) Once the ophthalmologist (LH) put the device on, she could turn her head left, right, up or down to examine closely the photograph of the eye. (Supplemental video 1, Figure 3) She was asked to make a primary diagnosis of each retinal pathology pictured. Another ophthalmologist (CQY) then examined the photographs in a traditional manner on a computer monitor and made a primary diagnosis. These were then both compared to the known diagnosis. (Table 1)

The ophthalmologist was able to view all the photographs successfully using the native device interface. There was no significant learning curve and she was able to navigate through the photographs using the touchpad after a few minutes of instruction. The device was comfortable to wear and could be easily adjusted to fit properly. The battery life was more than adequate for extended periods of use. The images were displayed in native resolution without noticeable compression and without blur or color distortion. There was minimal screen door

Figure 1: The Gear VR device, showing attached smart phone (A) and oculars (B).

Figure 2: Wide field retinal photograph. The pathology here depicted is a rhegmatogenous retinal detachment. A 40” x 20” photograph size incorporating a 8” black border on each horizontal side allowed display of the image with minimal distortion within the device.

<table>
<thead>
<tr>
<th>Deixted Pathology</th>
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<tbody>
<tr>
<td>1. Central retinal vein occlusion</td>
</tr>
<tr>
<td>2. Rhegmatogenous retinal detachment</td>
</tr>
<tr>
<td>3. Horseshoe retinal tear</td>
</tr>
<tr>
<td>4. Central retinal artery occlusion</td>
</tr>
<tr>
<td>5. Retinitis pigmentosa</td>
</tr>
<tr>
<td>6. Proliferative diabetic retinopathy</td>
</tr>
<tr>
<td>7. Choroidal melanoma</td>
</tr>
<tr>
<td>8. Nonexudative age related macular degeneration</td>
</tr>
<tr>
<td>9. Exudative age related macular degeneration</td>
</tr>
<tr>
<td>10. Normal retina</td>
</tr>
</tbody>
</table>

Table 1: Depicted Pathology
effect (visible pixel borders), which did not hinder use of the device. She did not experience nausea or motion sickness or eye strain.

She was able to see pathology including exudate, drusen, hemorrhage, neovascularization, retinal pigmented epithelium atrophy, retinal tear, retinal detachment, pigmented lesion, and bone spicules. She was able to identify the correct diagnosis in all ten VR displayed photographs as detailed in Table 1. Therefore, there was 100% concordance between the diagnosis made by the virtual reality display with the traditional method of computer monitor display and the known diagnoses.

Discussion
Our study demonstrates the proof of concept that VR display technology can allow retina photographs to be examined in a more three dimensional manner than with a computer monitor display. There is reduced distortion since the image of the concave retina does not need to be flattened for display. Also the image on the virtual display is an order of magnitude larger, surrounding the viewer’s entire field of view in multiple directions instead of restricted within a monitor. With this technology the ophthalmologist is able to, for the first time, virtually go “inside the eye.”

The virtual display was not in this study superior in diagnostic ability to the traditional method, but this was not unexpected given the clear primary diagnosis demonstrated in each retinal photograph. However we speculate that in cases of subtle findings and multiple diagnoses, the enlarged and more natural viewing provided by a VR display may prove superior. This will need to be confirmed with additional study. In this study the photographs were two-dimensional images converted back to a 360-degree configuration. A more ideal method

![Figure 3: (A) and (B) traditional method of viewing retinal images on the computer. (B) and (C) using the virtual display greatly magnifies the image and reduces distortion.](image-url)
would be a camera designed specifically to take stereoscopic wide field photos of the eye. This would take full advantage of the Oculus display technology and provide an unprecedented level of fidelity and detail.

A few small barriers remain to widespread adoption of VR technology in the field of retina image display. The device takes time to put on and take off – though in a manner similar to the indirect ophthalmoscope that is commonly used. It is not integrated with the image acquisition systems and therefore is not currently convenient to use in every day clinical practice. Lastly the clinician must also be careful to turn his or her head in order to examine all areas of the photograph so as not to miss pathology that is not apparent in one field of view.

There is no way currently to easily manipulate the image or zoom in on a particular area, which is important for examination of subtle details. We hope there will be development of virtual reality input devices such as gloves or controllers that will allow for improved manipulation and magnification of displayed data. This could allow the device to not only display spherical images but also volumetric data such as optical coherence tomography or computed tomography scans.

New retinal imaging technologies are generating ever higher resolution images of the human eye. Adaptive optics now allows for visualization of the retina on the cellular level, providing images too large to be practically displayed using a computer monitor. This enhanced visualization at a cellular level may also accelerate nanotechnology applications, which act on the molecular level of single cellular structures. We feel the use of virtual displays for such applications has great potential for use in research and in the clinic. The future of virtual reality technology in medicine in general is very bright. It is clear to the authors that VR technology is coming to fruition and will find numerous uses. Among many possible uses, it could make telemedicine more personal and practical, could restore quality of life and perhaps virtual mobility to the disabled, and will certainly have uses in the training of physicians especially in surgery.

**Conclusion**

This use of a virtual display for ophthalmic photographs is the first demonstration of mobile VR technology in the field of eye care. We show that VR technology can already be a useful tool in the eye clinic. With further improvement and development VR technology has the potential to revolutionize many different aspects of medicine.

**Disclosures**

All authors have completed the Unified Competing Interest form at [www.icmje.org/coi_disclosure.pdf](http://www.icmje.org/coi_disclosure.pdf) (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous 3 years; no other relationships or activities that could appear to have influenced the submitted work.

**Acknowledgements**

None

**References**


Introduction

Video recording and still photography is an essential component of documenting surgical and clinical details. Additionally, videos have an important role in skill transfer, demonstration of new procedures, and as material of clinical evidence. We here describe the use of an Android smartphone, (HTC Incredible S) for capturing High Definition (HD) video of ocular surgery through the assistant observer scope of an operating microscope.

We have described the arrangement used to mount the smartphone to microscope and discussed the advantages and limitations of this arrangement when compared to a conventional capturing and recording system used with the operating microscope.


Video recording and still photography is an essential component for documenting surgical and clinical details. Additionally, videos have an important role in skill transfer, demonstration of new procedures, and as material of clinical evidence. Conventionally, the video and still imaging of surgical videos has been done using CCD (Charged Couple Device) camera attached to a beam splitter and C-mount. These cameras produce analog signal which is then transferred to a recording device (VCR, DVD recorder, Hard Disk Recorder, Commuter video Capture Card etc.). Later on this is edited using computer to produce a video of desired quality, with narration and captions.

Recently the availability of smartphones with processing capabilities comparable to computers and plethora of sensors has made their application in medical science increasingly popular.4 The camera interface of these smartphones has rich features and has numerous advantages over the conventional imaging system used in ophthalmology, both for stills and videos. Further, we will be discussing only the smartphones with Android operating system and camera supporting at least 8 megapixel camera and full HD (1280*720 pixels) video recording at 30 frames per second.

We here describe the use of one such smartphone, (HTC Incredible S) for acquiring High Definition video of ocular surgery through standard operating microscope with assistant observer scope.

This kind of arrangement can be cost effective and capture high quality images and videos with added advantages of easy sharing and transfer to other devices.
Subjects and Methods

An operating microscope (Model YZ20T, from 66 Vision-Tech Co., Ltd, China), with binocular assistant observation tube was used in conjunction with an android Smartphone (HTC Incredible S). The phone has Android operating system 4.1 version with 8 megapixel camera with autofocus and full HD (High Definition 1280*720) video capturing capability. An adaptor was developed to hold the phone securely in place aligned to the optics of the assistant viewing scope with help of supporting engineering staff (L & M Automatics, H-3 Panki Industrial area, Site-1, Kanpur, U.P., India. landmautomatics@gmail.com). The phone was cradled in a hard phone case compatible for the phone model. In turn this phone case was mounted to an adaptor which was secured and optically aligned to one of the oculus of the assistant observation scope. The components and the assembled arrangement are shown in the photographs.

Once assembled, the camera software on the phone was turned on and the microscope was focussed and centred on the operating field. The phone screen showed the view congruent to the surgeon’s view and the independent focus and magnification control of the observer tube was used to obtain focus and desired level of field/zoom in the phone screen. Fine focus was done using touch to focus feature of the camera software of the phone. This also helped in a hard phone case compatible for the phone model. In turn this phone case was mounted to an adaptor which was secured and optically aligned to one of the oculus of the assistant observation scope. The components and the assembled arrangement are shown in the photographs.

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in the attaining proper white balance and exposure control of the area of interest in the phone’s camera viewfinder.

This arrangement allowed full HD video capturing and 8 Megapixel (3264*2448 pixels) still photos. The arrangement allows simple and intuitive touch based control of still image capturing, video recording start and stop process, and touch to focus the area of interest on the viewfinder screen. The video and stills are saved on the device removable 16 Gigabyte memory card which can be easily accessed using USB (Universal serial Bus) cable attached to computer.

**Results**
The captured videos had to be rotated 90 degree to obtain surgeon’s perspective view which is used as conventional viewing angle for surgical videos.

The captured videos and still show excellent clarity and being full HD can be viewed in original resolution without any pixilation when viewed on computer, TV or projected through a projected. These videos were better than the standard definition videos captured using the pre-existing CCD camera with DVD recording system.

The still images captured also needed to be rotated but apart from that they were excellent in sharpness, resolution and colour saturation.

**Discussion**
In the present era of evidence based medicine videos and photographs make an essential component of documenting the surgical events and cases. The video presentations also aid in skill transfer which otherwise is not possible using still photographs and text. Importance of a good video in scientific presentations to draw the attention of the audience and make them understand the steps of the procedure cannot be overemphasised.

Present era arrangement of video capturing and recording consists of beam splitter, C mount, a CCD camera (Standard definition or High Definition), a display system (TV or computer screen), a recording system (DVD recorder, Hard disk based recorder or computer attached video capture cards) and significant lengths of electric and video cables. This arrangement cause’s loss of quality of video signal and due to its nature is prone to frequent breakdown.

The smart phone based solution is single component system incorporating capturing, recording and viewing system attached to the microscope. The video quality can be easily controlled using the phone software which includes the focus, exposure control, colour hue, coloursaturation and the resolution of the video.

The arrangement is especially useful for capturing posterior segment video and images which suffer from overexposure due to very bright operating field surrounded by the unlit dark area. This arrangement with a touch screen allows touch to focus/exposure setting to easily focus and adjust the exposure according to the illumination of the area of interest.

The additional software on the smartphone allows for immediate review of the recorded video on the device screen. Limited editing of the still images and video is also possible on the device itself.

The recorded video does not capture any other detail apart from the view obtained through the operating microscope view hence unless the patient’s identity is manually added to the file details the patients’ privacy is not compromised.

Additionally sharing the video online is possible by attaching a video out cable from the phone to any television with HDMI input. Offlinesharing is possible through Wi-Fi, Bluetooth or USB connectivity, out of which USB may be the preferable as the video files are large in size and thus its high transfer speed will be faster. There is no need of burning DVDs or CDs as may be the case with Computer or DVD recorder based recording.

The arrangement of using smartphone camera for capturing, recording video and still images is a single device solution which is inherently simple cost effective, easily available, robust system which is less likely to fail. The videos and images are in full high definition resolution which can show the minute details of surgical procedures. Additionally image quality adjustments and easy transfer of the video are features which are not possible with conventional recording system.

This arrangement occupies one of the oculus of the assistant scope and hence the assistant cannot get the same conventional stereoscopic view needed for ideal assistance. Though this limitation can be
overcome by mounting the phone through an appropriate beam splitter.

The recording time will be limited by the memory space of the micro SD card used. Presently these memory cards are available in sizes from 8 Gigabyte to 128 Gigabyte allowing recording duration of 1 hour to 16 hours of HD video. This limits the amount of video which can be stored in the device and will need frequent transfer to a device with higher storage capacity. This issue can be solved with the new generation of phones having capability to support external storage device using OTG (On The Go) cable attached to the micro USB port of the device. Thus not only this will increase the storage space available for recording but also make the transfer of the recorded video fast and easy. Further this arrangement presently does not allow capture of 3D images or videos.

In conclusion this arrangement of using Android smartphone to capture images and high definition video through the assistant scope of the operating microscope is compact, robust with easy storage, preview, sharing arrangements. The ease with which the exposure and focus control can be adjusted for optimum image and video is additional feature not possible with conventional CCD camera arrangement presently used.

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None

**References**


