Out-of-the-Box Deployment to Support Research on In-Home Care of Alzheimer's Patients

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COVID-19 has caused many disruptions in conducting smart health research. Both in-lab sessions and in-home deployments had to be delayed or canceled because in-person meetings were no longer allowed. Our research project on "in-home monitoring with personalized recommendations to reduce the stress of caregivers of Alzheimer's patients" was affected. To enable continued research without any person-to-person contact, we created an out-of-the-box deployment solution. The solution is multifaceted and deals with everything from technical adjustments, deployment documentation, EMA additions, additional monitoring software, use of videos, Zoom and TeamViewer, budget changes, new logistics, and changes to IRBs. This article briefly describes the purpose and design of the original system and then articulates the necessitated changes. We also provide lessons learned and an initial evaluation of the effectiveness of the solutions after the changes. The evaluation surveys the opinions of seven people that assembled, initialized, and deployed our system in home environments. We believe that the various solutions we developed can be applied to other similar projects, and will be helpful to new projects even when personal contact returns.

Research work in many fields were affected significantly due to the COVID-19 pandemic,[1] especially the research tasks needed to be deployed in households, such as the three works.[2–4] Equipment deployments are usually performed by research teams and the participants do not have to set up or fix equipment problems themselves. However, COVID-19 curtailed new deployments and ongoing deployments with in-person contacts. A major challenge is how can such in-home studies continue without in-person contact.

To date, approaches adopted by researchers to overcome the challenge that no contact is allowed during traditionally contact-permitted activities, includes, but not limited to teaching in classrooms and collecting data. Martin *et al.*[5] described the challenges faced by dermatology students participating in a class along with possible remedies such as using

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online tools. However, conventional online solutions like video conferencing cannot replace some practical aspects of education such as laboratory experiments. To mitigate this shortcoming, smartphones and augmented reality techniques have been suggested to monitor student's virtual experiments. An additional advantage of the suggested virtual laboratory can collect physiological data for educational purposes.[6] Data collection for experimental purposes has to change due to the pandemic. Hensen *et al.* suggested using mobile phones and online platforms to collect data instead of using traditional in-person methods during the pandemic.[7]

To overcome the challenge on continuing in-home studies without in-person contact, we developed a collection of techniques for out-of-the-box deployments usable by the general public. In this article, we examine the feasibility and practicality of developing out-of-the-box deployments as applied to a study of Alzheimer's patient–caregiver relationships in home settings. We describe the obstacles that we solved and the lessons learned from the effort. We believe that our out-of-the-box deployment solution will also help other research studies that require in-person contact.

In more detail, the overall challenges that we have encountered are:

- COVID-19 permits no contact. The research team is no longer able to physically meet the participants. Also, face-to-face meetings among the entire research team are also limited, because it is not advisable for research team members to meet (frequently) either, which potentially slows down the research study. The quarantine demands that participant training must be virtual and online.
- Participants are not knowledgeable in technology of the deployed system. Our participants are dyads of persons with dementia and their informal, family caregivers. Dementia mostly affects older adults and 30% of caregivers are also over the age of 65, hence study participants may have limited familiarity with technology.[8]
- The system is complex and setting it up requires training. Participants must complete the system set up, including the installation of a laptop, smartphone, microphone, and router, all without in-person contact. Participants must also provide voice samples so we can perform speaker identification. Additionally, study procedures include use of mindfulness-based stress management techniques, and participants must be trained in these techniques prior to initiation of study procedures.
- Logistics and Budget. New EMA surveys and updates to IRBs, documentation, budgets, and logistics are required.

The main contributions of this article are as follows:

- We provide a set of solutions for successful no-contact out-of-the-box deployments as a useful experience to other research teams facing similar challenges.
- Our evaluation demonstrates that our out-of-the-box solutions are effective in enabling research study in-home deployments without any in-person contact. In other words, our techniques can allow ongoing studies even when no contact is permitted.
- We present key lessons learned from our experiences: First, the deployment techniques provide an added degree of robustness, which improves the initial deployment process of a complicated in-home system (the participants were successful and less frustrated with setting up the system). Second, the Zoom and TeamViewer combination is able to overcome the more technical and difficult aspects of having dyads deploy a system by themselves.

Our evaluation consists of seven out-of-the-box deployments performed in three stages. There were two participants from Stage 1, two participants from Stage 2, and three participants from Stage 3. The number of participants was limited by the COVID-19 pandemic as recruiting was difficult. In stage 1, the first two deployments were performed by skilled technical people as a first trial to identify needed improvements. Based on their feedback, we made changes to the out-of-the-box deployment solution. Stage 2 had three deployments with nontechnical individuals, one elderly and one middle aged. We made changes based on the feedback from stage 2. Finally, stage 3 had three elderly people perform the deployment.

THE PATIENT-CAREGIVER RECOMMENDATION SYSTEM (PCR)

In this section, we briefly describe the PCR System in order to provide the context for the updates we made for an out of the box deployment. We stress that the goal of this study is to assess the out-of-the-box deployment protocol, not the PCR system itself. This

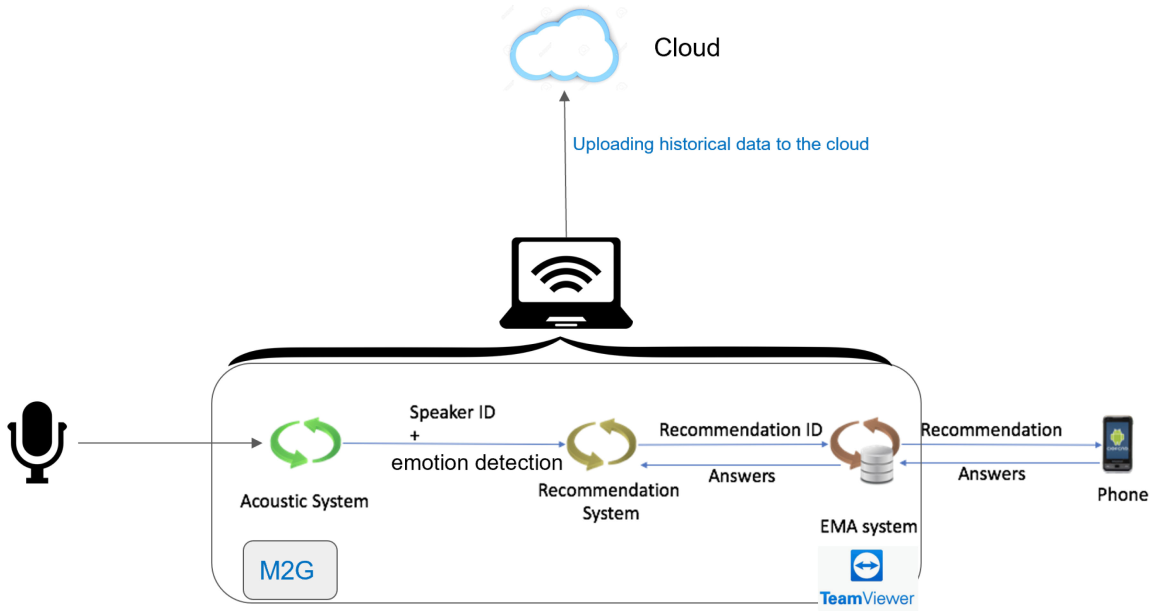


FIGURE 1. The Overview of the PCR system with its four major components: the Acoustic Pipeline, the Recommendation System, and EMA system, and M2G.

section explains the major components (the acoustic pipeline, the recommendation system, the EMA, and M2G) so that the deployment approach can be understood in context. The details of the out-of-the-box solution are in the following section.

Overview

The PCR system is deployed in homes with a family caregiver and an Alzheimer's patient. The hardware consists of a laptop, an external microphone, a router, and a smartphone. Using a microphone, the system detects affective states of the caregiver and reduces their stress by presenting learned, personalized stress reduction recommendations. To serve as the backdrop to the changes needed to handle COVID-19 restrictions, we briefly describe the system. The PCR system consists of the four major components, as shown in Figure 1. In addition to the major components, we also upload real-time data and logs to the cloud.

Acoustic Pipeline

The acoustic pipeline monitors the vocal interaction between caregiver and patient, and recognizes the caregiver's mood. When our system is on during awake hours, the microphone constantly listens to the ambient environment. The incoming data stream is sliced into nonoverlapping five-second audio windows. For each window, we drop the segment if it is silence. If there is a sound, we apply a robust voice activity detection (VAD) module to determine if there exist discernible segments of speech. After the VAD module classifies that an audio window contains speech, the audio window is passed to the speaker identification (SID) model to identify if the speech is from the caregiver, the patient, or another speaker (including speakers on TV). The SID model is pretrained using the voice of the caregiver and patient. If the SID model decides that a particular audio window contains speech by the caregiver or the patient, this audio window is sent to a CNN-based emotion detection model. The model has five output classes: happiness, anger, neutrality, sadness, and fear/disgust. If the model classifies a sample as angry speech, it notifies the recommendation system.

Recommendation System and EMA

The goal of our recommendation system is to increase the mindfulness skills of caregivers. Randomized control trials indicate that brief psychoeducation on mindfulness and self-guided practice using online exercises significantly reduce depression and anxiety, and a brief intervention involves training in mindfulness and ecological momentary assessment strategies. The PCR system crafts four stress management techniques: 1) emotion regulation and 2) time-out techniques, as well as 3) brief mindfulness training, and 4) environment modification techniques to increase emotional acceptance, as our recommendation candidates. PCR learns to adapt recommendations based on the monitored acoustic events and caregiver's feedback on previous recommendations via federated learning based on a contextual bandit algorithm. We consider time of the day, category of the recommendations, and detected acoustic events as context for recommendation generation. To deliver recommendations to the caregiver, we utilize an Ecological Momentary Assessment (EMA) system (the software of EMA is Nubis developed by USC[9]). The EMA is installed on a workstation deployed in the dyads' homes, which connects the acoustic monitoring system, the recommendation system, and an EMA app on a smartphone to send recommendation messages to caregivers. This feedback is used to update the estimation of recommendation effectiveness for future improvement. To ensure the execution of these stress management techniques by the caregivers, we provide them with an instructional handout and brief training before the deployment of the system.

The recommendation system is backed by a contextual bandit algorithm, which is designed to handle cold start in recommendations. Specifically, the algorithm adapts its recommendation policy based on users' feedback over time: from nearly random recommendations (i.e., exploration) to precisely calculated ones (i.e., exploitation). The algorithm is able to quickly find the most effective recommendation under each given context (e.g., detected emotional state).

Our EMA has two periods: the baseline period and the recommendation period. The baseline period lasts for three weeks, while the recommendation period lasts until the end of the deployment (3–4 months). During the baseline period, the EMA is triggered by acoustic events, such as angry voices from the participants, and asks the participants to confirm if they are angry. This is to provide ground truth for us to evaluate the emotion detection model. In the baseline period, we also randomly recommend recommendations, such as mindfulness techniques to the participants and later ask for the effectiveness of the techniques at the calming effect. The participants' response to such questions help us estimate recommendation effectiveness, so that in the recommendation period, we recommend items that are most effective at helping the participants calm down. The detailed technique backing up our recommendation module is an upper confidence bound based contextual bandit algorithm. As the purpose of this article is not to explain this specific module, and due to space limit, we decided to withhold the technical details. Also, due to the purpose of the article being evaluating the deployment protocol instead of the PCR system, we do not provide how the participants reacted to the randomized recommendations during the baseline period. The participants are aware that the EMA has two periods (the cold-start, baseline period in which the contextual bandit algorithm learns and the recommendation period).

Monitoring Support

M2G[10] is a real time and automated system for operation monitoring and system ground truth validation of research-oriented residential applications. PCR installs M2G to monitor the operation of devices and subsystems, including the processes, files, device battery levels, disk memory, connectivity of the microphone and smartphone, and the cloud server. It sends notifications to remote administrators and other personnel to report any dysfunction or inaccuracy of the system in real time.

Other Components

The system also includes deployment time support software that tests the operation of each of the system components to ensure initial correct operation of the system. This testing would be controlled by technical members of our team when, prior to COVID-19, we were allowed to go into people's homes. The TeamViewer software[11] is also installed on the laptop and smartphone to allow remote monitoring and updates or corrections as needed.

OUT-OF-THE-BOX DEPLOYMENT SOLUTIONS

Deployment Preparation

To create a user-friendly out-of-the-box deployment experience, the study team premarked study equipment at all connection points (for example, the charging port of the phone and the wire used to charge the phone were put on with tags of the same color). To minimize setup requirements at time of out-of-the-box deployment, the team preconnected portions of the system that would not create equipment destruction during shipment to participants' homes. For example, the ethernet cable and router power cord were preconnected to the study router prior to shipment. The system included connection points for power supply to the laptop, router, and smartphone. Additional connection points included, "microphone to USB cable to study laptop" and "study router to ethernet cable to participant home router." The study team also marked power buttons on the study laptop and smartphone to increase ease of use. Each connection point was given a label (microphone, power port, etc.) and designated with a different color. The labels and color scheme were incorporated into the step-by-step out-of-the-box deployment instructions given to the participants.

Deployment Instructions

Prior to the pandemic, research team members on the system development side created deployment instructions to be used internally by team members on the patient-caregiver relation side during system deployment in participant homes. To facilitate out-of-the-box deployment by study participants, the team revised deployment instructions to target older adult audiences. More technical descriptions were rewritten using layman's terms, pictures of study equipment were added, and, as already mentioned, a color scheme was incorporated. Figure 2 shows three examples of the major changes.

At Deployment Time Itself

The new contactless deployment includes two distinct processes, the out-of-the-box participant deployment, and Zoom-assisted research team deployment. During telephone screening and consenting, participants provide their home address for shipment delivery and are instructed to contact the study team upon receipt. Upon receipt of study equipment via UPS delivery, the team instruct the participants to complete initial deployment using the out-of-the-box deployment instructions. Instructions provided to participants offer step-by-step instructions up to initiation of a video call between the research team and participants. The last step of the study instructions directs participants to await initiation of this call by the study team. Once study equipment is "online," the research team proceeds with the Zoom-assisted portion of deployment, wherein team members use TeamViewer[11] to access the study laptop, launch the Zoom application, and complete the remaining deployment via video call with participants. During Zoom-assisted deployment, the research team launches the appropriate computer programs to initiate audio monitoring and the recommendation system, completes speaker identification training by recording participants' uninterrupted speech for five minutes, connects the study smartphone to the server, tests all study equipment and programs to verify successful deployment, orients participants to study smartphone and EMA messaging application functionality, and provides instructions for completing study activities.

EMA

Prior to COVID-19, we designed the EMA questions to focus on the caregiver's mood, anger, stress, and conflict, and the effectiveness of the recommendations. We also had morning and evening messages with encouragements. With the extra delay in preparing the out-of-the-box deployments, we received more time to rethink the EMA questions. We made the following changes.

We added additional messages that inquire about the mental and physical health of the caregiver. These messages ask the users about their physical health, emotional health, stress level, loneliness, and unpleasant interactions.

We added a recommendation request button. As quarantine has increased tensions inside homes, we decided to give caregivers the ability to request recommendations at any time during the day to help relieve stress. With the added stress of COVID-19, we expect more missed EMA messages by the caregiver. Consequently, we added the functionality of giving caregivers a "second chance" to answer questions in case they are occupied by other responsibilities. We also decided to keep messages on the screen (available to be answered) for longer periods of time to give caregivers a greater degree of flexibility. We also tried to become more accommodating with our recommendations by providing in-app meditation sessions for the caregiver. We have included an example of an in-app meditation and the survey questions associated with it in Figure 3.

Logistics

Contactless delivery procedures were added to the study IRB application and protocol in addition to previously planned in-person procedures. Procedures for in-person deployment were purposefully retained in the event that in-person research activities are deemed necessary or reinstituted. Additionally, changes to the study budget were requested from the grant-holding institution. Previously, budgeted mileage for travel to and from participant homes was replaced with anticipated shipping costs. Logistically, shipping and receiving coordination occurred with front office staff at the recruiting institution. Graduate research associates performed equipment processing prior to and between deployments. Processing included disinfecting all equipment, performing previously described deployment preparation, and repackaging equipment with new study documents (the

Staged Changes of Written Instructions			
Equipment Type	Stage 1	Stage 2	Stage 3
Ports	No description provided	*What is a port?* *You will use three different types of "ports" to complete the set-up process.* Provided descriptions and images of USB, laptop power, router power, and ethernet ports	*What is a port?* *A port is an opening where you can connect and plug in electrical wires.* *You will use three different types of "ports" to complete the set-up process. The ports on our study equipment and the corresponding wires will be color-coded.*
Laptop	*Turn on the laptop and plug the power cord into the wall and logon.*	*2) Turn on the laptop we provided.* *3) Connect the power cord to the laptop and plug the other end in to an outlet or power source in your home.* *4) Press the power button to turn on the laptop.*	*1) Connect the power cord to the laptop (YELLOW Port) and plug the other end in to an outlet or power source in your home.* *2) Turn on the laptop we provided by pressing the button on the left side of the computer. It is a small button marked with ORANGE tape.*
Router	*Connect the router to the modem or router using an Ethernet cable.* *a. If connecting to user's modem, make sure connecting the Ethernet port of the modem and the Ethernet port of our router (blue one).* *b. If connecting to user's router, connect one port from their router to our Ethernet port (blue one).*	*5) Connect the Ethernet port on the router we provided (blue port) to the Ethernet port on your home modem or router using the Ethernet cable we provided.* *6) Plug the router we provided into an outlet or power source in your home and press the power button on the router we provided.*	*1) If it is not already connected, connect the BLUE ethernet cable we provided to the Internet port on the router we provided (it will be a different color than all the other ports).* *2) Next connect the other end of the BLUE ethernet cable to the Ethernet port on your home modem or router.* *3) Plug the router we provided into an outlet or power source in your home.* *4) If green lights do not appear on the router, press the power button on the back of the router we provided*
Note: Italicized font represents text as it appears in the participant-facing written instructions			

FIGURE 2. Examples of the changes that we made in our three main stages/phases of developing the out-of-the-box solution.

deployment instructions, training manual, consent document).

EVALUATION

Our evaluation consists of seven out-of-the-box deployments performed in three stages. There were two participants from Stage 1, two participants from Stage 2, and three participants from Stage 3. The number of participants was limited by the COVID-19 Pandemic as recruiting was difficult. In stage 1, the first two deployments were performed by skilled technical people as a first trial to identify needed improvements. Based on their feedback, we made changes to the out-

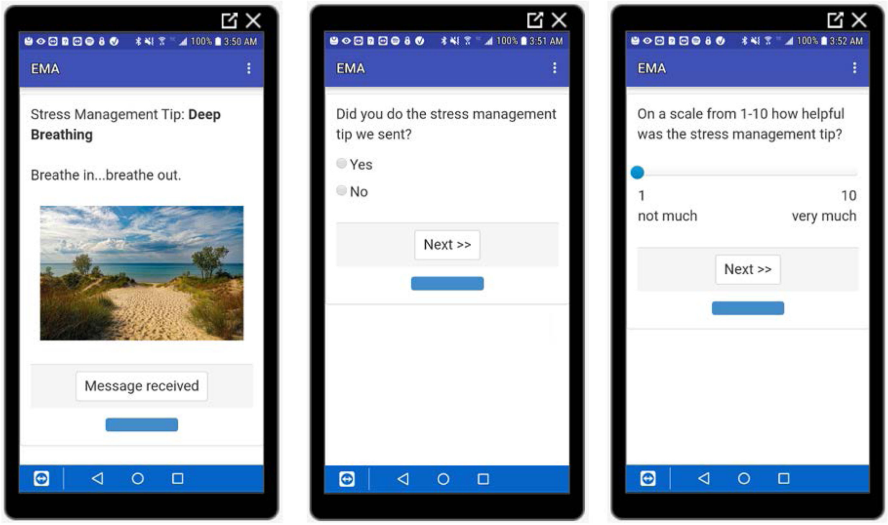


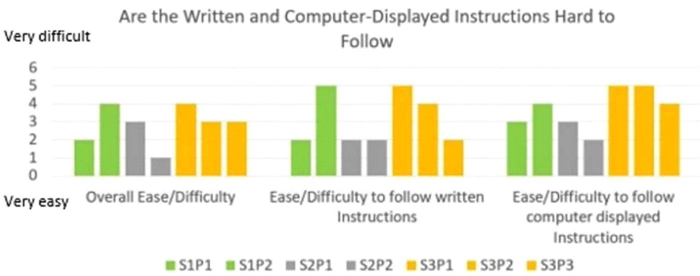
FIGURE 3. An example on how the EMA is conducted: In-app meditation and the survey questions associated with it are pushed to the participant's phone. The first image is the in-app meditation. After a preset time of recommending this meditation, we ask the participants if they did follow through the meditation (middle image) and how effective the meditation was (last image) if they did follow through. The responses to the two survey questions help us figure out what mindfulness techniques work better for the particular participants and recommend those effective ones more often to those participants.

of-the-box deployment solution. Stage 2 had three deployments with nontechnical individuals, one elderly and one middle aged. We made changes based on the feedback from stage 2. Finally, stage 3 had three elderly people perform the deployment. Below is a list of the main changes made between stages. The instructions remained the same except for what we describe below on the in-stage changes. During the first 24–48 hours, no critical failure of any of the participants' systems was seen and all processes of all systems were functioning as expected until the deployments were manually terminated.

We would like to emphasize that the purpose of the article is to evaluate the out-of-the-box deployment protocol, not the components of the PCR system. Therefore, the evaluation is not about the performance measurements such as accuracy of the acoustic system or how well the participants' responded to the recommendations.

During the three stages of the experiments, all participants, including the experts from the first stage and the nonexperts from the other stages, used the same manual.

- Major Changes from Stage 1 → Stage 2:
  1) Technical terms in the written instructions were replaced with names that a layperson understands.
  2) A progress bar was added to the interface of Speaker ID training software to inform the participants when the model training is expected to finish.
  3) We assigned members from the research team to use Zoom as a video-call to the participants to walk them through the set-up process.
- Major Changes from Stage 2 → Stage 3:
  1) Text size was increased on the smartphone.
  2) Other visible apps on the smartphone were removed except the EMA app.
  3) The lock screen on the smartphone was turned OFF.
  4) Keypad and button sensitivity levels were adjusted.
  5) Name stickers were tagged near the ports on the equipment.
- Major Changes made after feedback from stage 3:
  1) Page numbers to written instructions were added.
  2) Participants were instructed to read port descriptions prior to initiating the setup.
  3) Participants were familiarized with color-coded scheme in the beginning of written instructions.



(a)

	Stage 1	Stage 2	Stage 3
No significant trouble	0	0	1
Smartphone hard to navigate	0	0	0
Equipment hard to assemble	0	1	1
Confusing technical terms	1	2	1
Connect laptop to Wi-Fi	0	1	1
Unclear Computer-displayed instructions	0	0	0
Unclear Written instructions	1	1	1

(b)

	Stage 1	Stage 2	Stage 3
Enlarged font size	1	1	2
Image display in addition to text	1	1	2
Labels and color-coding scheme	0	1	3

(c)

FIGURE 4. Participants' responses to Questions 1-3, from which we evaluate the clarity of the written and computer-displayed instructions. For all questions in the three subplots, we asked the participants to answer them after they finished up following the manual to deploy the system out-of-the-box.

4) Pictures of completed system setup were added.
5) Tightness of binding around system wires was adjusted.
6) Equipment was labeled with number corresponding to the specific instruction step.

After each of the seven out-of-the-box deployments, we collected data on their deployment experience using a survey questionnaire. Appropriate questions below used a Likert scale from 1 to 5 where 1 was very difficult and 5 was very easy. We have listed the questions that we asked:

› Overall, how easy was the system setup process?
› Overall, how easy were the written instructions to follow?
› How easy were the computer display and instructions to follow?
› Were you eventually successful in setting up the system?
› How long did it take to get the system setup?
› If you had trouble in the setup process, which part(s) of the setup process confused you?
› Which principle(s) that we adopted do you find helpful during the setup process?
› How comfortable/familiar are you with computers and smartphones?

Figure 4's three subplots show the participants' responses to our survey questions. The two participants from stage 1 are denoted in green. The two participants from stage 2 are denoted in gray. The three participants from stage 3 are denoted in yellow. To interpret the legends of the first subplot: Each of the 7 participants are denoted by the stage that they are in and the number used to represent them in that stage. For example, S1P1 means the first participant from the first stage, and S3P1 means the first participant from the third stage. We made changes to stage 2 based on the responses of participants of stage 1, and to stage 3 based on the responses of participants of stage 2.

From Figure 4, we observe that the two participants from stage 1 experienced less difficulties than the participants in stage 2, as the first stage participants rated that the average difficulty being 3, the difficulty of following written instructions being 3.5, and the difficulty of following computer-displayed instructions being 3.5. Meanwhile, the averages of the scores that the participants of stage 2 gave are 2, 2, 2.5. The difference between the scores given by the two stages is expected, as the stage 1 participants were skilled technical people while the stage 2 participants had no technical background.

After making the improvement based on the responses from stage 2, we see a significant increase of ratings. The three participants of stage 3 rated a difficulty score of 3.33 on average on the overall easiness/difficulty to follow the instructions, and an average of 3.66 and an average of 4.66 on written and computer-displayed instructions, respectively. Comparing the ratings obtained from stage 1 and stage 3, our improvements enable the third stage elderly participants to follow the instructions as easily as the technically skilled people from stage 1. We conclude that our improvements made on the written and computer displayed instructions are effective.

In Figure 4(b), we identify what caused confusion to the participants. The technical terms in our instructions were the leading cause of confusion. This is to be expected, as the general population are not familiar with terms that skilled technical people are.

Figure 4(c) describes the assessment result of the effectiveness of the principles that we adopted to help the participants set up the process. Each of our three principles received four votes; all three participants of stage 3 reported that our labeling and color-coding scheme were helpful.

Five out of our seven participants finished the setup process within an hour, and the other two of them spent between 1 to 2 hours. Also, all participants of stage 3 were able to successfully set up the deployment within an hour, suggesting that the improvements we made between stages 2 and 3 were effective. The average time to complete the deployment for all our participants was 1.28 hours with a standard deviation of 0.49 hour.

LESSONS LEARNED AND GENERALIZATION

In the previous sections we have described the out-of-the-box techniques we developed, provided observations about those techniques, and described an initial evaluation. In this section, we summarize the lessons learned and discuss generalization of these techniques to other deployments.

One main result was that there were few technical changes required to the core system. Rather, most changes were to auxiliary aspects of the deployed system.

Many changes were required to the documentation for the caregiver who now has to set up the system. We made heavy use of pictures, videos, and large lettering labels on equipment, even for ON–OFF buttons. We found that budget flexibility was needed (e.g., transferring money from travel to mailing costs). Significant IRB changes were also required.

Changes made to study procedures increased the geographic reach of recruitment from clinic patients living in surrounding counties to out-of-state patients receiving services from the recruiting clinic. This can be considered a positive outcome for contactless deployments. Additionally, strategies employed for contactless deployment may also augment future in-person deployments.

While the techniques we described in this article were developed for a single research deployment, most of the techniques are general and can be applied to many home deployments. For example, Zoom, M2G, and TeamViewer are basic products that can be used by any deployment. The documentation we created can be used as a template for what is required for users, suitably changed based on the hardware used for a given deployment. More specifically, the essential takeaways are as follows:

- The deployment adjustments provide an added degree of robustness, which improves the initial deployment process of a complicated in-home systems(the participants are successful and less frustrated with setting up the system).
- The Zoom and Teamviewer combination is able to overcome the more technical and difficult aspects of having dyads deploy a system by themselves.

Our takeaways have the following implications to our discipline:

- Our techniques can allow nondisruption of studies even when no contact is permitted. This prevents the advancement of our discipline from being slowed down by the no contact mandate.
- Even when contact is allowed, the techniques make it easier for project members such as

behavioral scientist graduate students to deploy the system even though they are often not as aware of the technology as the computer scientists. This opens the door for more potential interdisciplinary collaboration between the computer science department and other departments, such as the behavioral science department.

- In-home deployments require the core system being developed and significant additional software and tools. The techniques, software, and tools such as M2G, Zoom, Teamviewer, etc., presented are suggested as key and enabling technical researchers to focus on the core.
- Our techniques allows for the increased geographical reach when researchers recruit participants, which allows for more data to be produced for the research projects. The additional data can yield more evaluation results for the studies.

CONCLUSION

Deploying technology in homes to study and improve healthcare can be a complex endeavor even for technically savvy people. COVID-19 delayed or stopped many studies. This article describes a set of solutions and lessons learned that support participants in setting up the system by themselves without any personal contact. An evaluation demonstrates its effectiveness in an Alzheimer's study. It is hypothesized that the techniques and lessons are also useful to be applied to deployments even after personal contact returns.

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