

RESEARCH ARTICLE

Effectiveness of tablet computers in spatial data collection and surveys in rural Tanzania

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Abstract

Worldwide, there is increasing application of tablet computers and other portable electronic devices in research. Effectiveness of these devices as data collection tools is widely appreciated, but several challenges exist when used in remote/rural settings. A household survey and spatial data collection were undertaken using tablet computers in rural Tanzania. Over 5 days in the study village of Naitolia, 12 enumerators visited 170 households completing 154 household surveys and 156 women's surveys while simultaneously collecting spatial data on wet/dry season water sources for 92 households using the tablets. Power supply, internet connectivity, and app faults were among the primary challenges that require attention to facilitate efficient use of tablets to collect data in remote areas. Lessons learnt include the importance of alternative energy (eg, solar energy) for charging, carrying hard copies of survey instruments as a backup, and ensuring that newly developed apps have been thoroughly field tested.

KEYWORDS

computer-aided personal interviewing, GPS, mobile devices, spatial, survey

1 | BACKGROUND

Rapid growth of mobile electronic devices (eg, personal digital assistant [PDA], tablet computers, and mobile phones) in societies around the world has created opportunities for wider applications in research. This trend is supported by advancements in the fields of distributed computer networking and mobile computing (Satyanarayanan, 2001) that have led to the development of computer-aided survey techniques such as computer-assisted personal interviewing (CAPI) (Heerden, Van, Norris, & Richter, 2014) and in decreased prices for various tablet devices. In many areas, even remote ones, there have been attempts to use these portable electronic devices to help in data collection. PDAs, tablets, and mobile phones have been used to collect large-scale surveys like census information, demographic and health surveys, and consumer interviews (Paudel, Ahmed, Pradhan, & Dangol, 2013). The use of tablets, mobile phones, and PDAs in surveys is growing very fast and may, in the near future, be the preferred alternative to traditional paper-based surveys (Leisher, 2014) or stand-alone GPS receivers.

Several studies suggest that mobile electronic devices are cheaper and faster way of data collection (Leisher, 2014; Paudel et al., 2013; Rajput et al., 2012). Additionally, these devices are thought to decrease error related to both hand-to-paper and paper-to-computer data entries (Leisher, 2014). Such devices also increase the ease of transferring information from one device to the next and in sharing information instantly (Heerden et al., 2014; Vidas, Zhang, & Christin, 2011). Data can typically be collected without internet access and then uploaded to a server via the internet at the end of the data collection period.

Successful use of tablets depends on, among other things, the availability of reliable high-speed internet connectivity for data management and security and electricity for charging the devices (Adenuga, Ojehomon, Diagne, Omotesho, & Ayinde, 2016). This can be a challenge in many low- and middle-income countries where many research settings, particularly in the rural areas, lack internet connectivity and reliable electricity

(Newell, Henrietta, Yi, John, & James, 2015). Other challenges associated with tablet use in underdeveloped areas are data security, virus infection from the internet or devices that are used for off-loading the data, data loss that may result from technical faults, and the loss or theft of tablets.

In this research, we report the effectiveness (both challenges and benefits) of using tablets computers as a primary data collection tool in a rural village in Monduli District, Tanzania. The purpose of using the tablets was to conduct two separate surveys (a household and women's survey) and to collect spatial data on water sources used by households in the wet/dry seasons. Furthermore, we tested the ease with which we could share this data among Tanzania Partnership Program (TPP) partners in Tanzania and Michigan State University. We noted the difficulties experienced in using this technology in this rural setting.

2 | METHODS

2.1 | Ethical approval

Participation of the MSU TPP team was approved by Michigan State University (IRB# x15-423e) and the Tanzanian COSTECH (#2015-207-NA-2015-149).

2.2 | The study area

The study took place in Naitolia village in Monduli District (Figure 1); the village was selected as it is the location where TPP has been involved in developing longitudinal surveys and development activities since 2009. Naitolia is located 5 km from the Arusha-Ngorongoro road at an altitude of approximately 1100 to 1200 m. Naitolia is an agro-pastoralist village with a population of approximately 1800 people (United Republic of Tanzania [URT], 2012). The large part of the community engages in cattle rearing, farming largely constrained by weather, and small-scale business. The semiarid conditions pose a significant challenge to the community to access water. There is no central living area; instead *bomas* (circular compounds of homes) are spread out throughout the village over 10 km along the main road and down the east side of the hill to the plains below.



FIGURE 1 Naitolia village study area

2.3 | Household sampling procedure

Households were randomly selected using a spatial data frame, as outlined in detail elsewhere (Pearson, Rzotkiewicz, & Zwickle, 2015). Out of a total of 307 households (either stand-alone or *bomas*) identified, 200 were randomly selected to be included in the sample.

2.4 | Materials and prefield development

Twelve Asus Nexus 7 tablet computers were used for data collection purposes. The tablets had screen size of 7 in., 1280 × 800 HD display (216 ppi), 1.2-MP front-facing camera, and a total size of 198.5 × 120 × 10.45 mm and weight of 340 g. The tablets had a Wi-Fi 802.11 b/g/n, Bluetooth NFC android beam, and 16-GB internal storage, battery for 4325 mAh (up to 8-h operating time), and built-in global positioning system (GPS). The tablets had several means of data sharing, including Bluetooth, wireless, and a USB cable. The device was selected because of its battery capacity, reasonable price, user friendliness, and large storage capacity.

Two software programs were added for data collection. Qualtrics was installed for survey data collection (an additional Research Suite license was required to collect data offline), and Collector for ArcGIS was installed for spatial data collection. Prior to field data collection, spatial data features and attributes of those features to be collected were added to ArcMap and then shared as a service to ArcGIS online. The Collector application then consumed the service, which included all features and possible attributes. Whenever possible, dropdown menus were used to reduce data entry errors and enumerator time. The tablets were preloaded with aerial imagery of the study area and the locations of the randomly selected homes. The MSU and TPP teams tested the units and the procedures handbook on campus in two sessions prior to entering the field.

In addition, two survey instruments were downloaded to tablets via the Qualtrics server and field tested by two Tanzanian researchers from Dar es Salaam University College of Education (DUCE). This field testing revealed some errors in question format and the overall flow of the survey instrument. It was discovered that some survey features are not compatible for use when collecting data offline. These were remotely fixed by the MSU team in the United States, and the updated instruments were redownloaded to the tablets prior to entering the field.

2.5 | Selection of enumerators and training

Twelve enumerators were recruited from DUCE and trained twice, first for spatial data collection and then for survey data collection. During the spatial data collection training, the enumerators had the opportunity to use the tablets and had hands-on activities to build and test their skills in spatial data collection. This training involved actual spatial feature creation and attribute collection using a base map of the DUCE campus. The training took place over one 8-hour day.

During the second survey training, the enumerators had opportunity to go through the two surveys and make some necessary adjustments to the structure and flow of the survey. The enumerators were then organized to work in pairs, with male enumerators conducting household surveys (typically with a male head of household) and females conducting the women's surveys. The tablets were labeled with user numbers (1-12), and data collection zones within the study area were assigned to each pair of enumerators.

3 | DATA COLLECTION

Enumerators visited the locations of randomly selected households that were assigned to the pair, by walking from house to house. Enumerators were to create spatial features (with attributes) for water sources used in the wet/dry season for each household, along with housing materials of the home they visited (eg, roof type, walls, and floor). The water source features were created, with attributes noted including seasonality of source, type of source, and primary use of water collected from the source. Enumerators then conducted both surveys in tandem when possible, by dividing the pair of enumerators. Surveys and spatial data collection were conducted at the homes of the respondents to ease participation (see Figure 2). Survey and spatial data collected were entered in real time into the touch screen tablets.

At the end of each day of data collection, the team returned to base facilities in Twiga camp, Mto wa Mbu town, where the internet connection was considered fairly reliable. Each evening, the team leader attempted to upload both spatial and survey data to the Qualtrics server, to be reviewed by the TPP team at MSU, to assist in error detection or other issues that might need attention. The entire team sat together and reviewed the progress, difficulties, and benefits that they faced before uploading the data collected.

4 | RESULTS OF DATA COLLECTION AND UPLOAD

Over the 4.5 days, a total of 170 households were visited, with 154 household surveys, 156 women's surveys, and spatial data on wet/dry season water sources collected for 92 households using the tablets. On the first day, only 25 surveys were completed, and no spatial data were



FIGURE 2 Survey data collection

collected due to a late start (2:30 PM) as a result of logistics and supplementary training to the 12 village members who joined the enumerators team. At the end of the day, completed surveys were easily and quickly uploaded to the Qualtrics survey. However, the spatial data were unable to be synced to the Collector for ArcGIS server, despite repeated attempts.

On the second day, surveys were conducted, and spatial data on water sources were collected for 30 households. At the end of the day, completed surveys were similarly easily and quickly uploaded to the Qualtrics server, and the spatial data were unable to be synced to the Collector server, despite repeated attempts again. From the third day, enumerators had mastered the use of tablets and got used to the survey; thus, data collection speed increased. At the beginning, some enumerators spent up to an hour conducting a survey due to lack of experience in using the tablets also interviewing. As time went on, surveys could be conducted within 15 minutes.

The team at MSU was able to monitor progress of the field work and was able to discuss the challenges researchers faced in the field while also having opportunity to view the data and make possible suggestions on how to proceed. For example, it was discovered that some of the randomly selected households were actually located out of the village boundary. The MSU team therefore refined the base maps and uploaded 15 new random households for those outside the bounds before the next day of data collection. In the field, the Tanzania and MSU teams communicated via email and messaging on personal hotspots on mobile phones.

5 | CHALLENGES AND FUTURE RECOMMENDATIONS

A number of challenges were encountered, which are outlined below and summarized in Table 1. A set of recommendations based on the field experience here is outlined for each.

TABLE 1 Challenges and future recommendations

Challenge Area	Description	Future Recommendation
GPS training	Difficulty in locating and navigating to selected households	More than 1 day of training with the GPS locator
Study site	Poor satellite connectivity	Allow more days for data collection or plan to days with poor connectivity from clouds, etc
Study site	Unreliable electricity	Designate one team member to be responsible for charging devices; bring solar or car charging alternatives
App bugs	Inability to sync data to the server using the Collector app	Feedback has been provided to the manufacturer, with possible improvements with newer versions; backup data sharing options such as Dropbox
Study site	Poor internet connectivity	Alternatives to Wi-Fi at facilities, such as mobile phone hotspots or hard-wired internet
App bugs	Preview function in Qualtrics did not work	Contact manufacturer; conduct duplicate data entry using pairs to test for errors; examine completed surveys from within the cloud, rather than on devices

5.1 | Locating selected households using base maps on tablets

Locating selected households was very challenging for the enumerators since most of them were using the GPS function for the second time after the training. Because households were located far apart, it took a long time to locate and navigate to them. The designation of zones for the pairs of enumerators reduced the travel time overall, and the speed of locating households improved over the collection period. At times, the GPS locator did not function properly, due to poor satellite connectivity (on very cloudy days) and few satellites resulting in poor signals.

5.2 | Power supply for device recharge

Since the study village had no electrical power supply, the team stayed in a nearby town with access to power (or a generator) each evening. On the first day, charging the tablets and power banks was unsuccessful because the power shut off just after the evening field briefing meeting from 10 PM to 4 AM. When it returned, it was discovered that some outlets were nonfunctioning and thus, devices were not charged even when electricity returned. As a result, the next day, some tablets lost power in the middle of the day during data collection. After that, it was decided that the charging exercise be monitored by a single person for smooth running of this process each evening. Each tablet required 2.5 hours and power banks up to 3 hours for a full charge. The power banks took long to charge, but their lifetime was far much less as compared with the tablet devices capacity to store and use energy. When using the power banks, they caught heat fast; they became very hot; probably, the hot weather also accelerated the heat. When required for use, the enumerators were forced to pose in shed and recharge the devices before they continued using them. That costed them more time contrary to prior expectation of charging their devices while proceeding with data collection.

5.3 | Data sync and the reliance on internet connectivity

In order to upload the spatial data, data sync in Collector was to be used. However, for most of the tablets, the sync function did not work. For the tablets that this function worked, the data took over 1 hour to sync (point data only with limited attributes). Poor internet connectivity was in part to blame, despite the availability of Wi-Fi service at the base facilities. However, the manufacturers of Collector were notified and were troubleshooting with the MSU team in real time. As a last resort, the team used a Dropbox to upload spatial data and abandoned the use of the sync in Collector, to be viewed by the MSU team. Enumerators also stopped using the Wi-Fi services at the base facility and instead used their mobile phone hotspots, which was found to be far more reliable. Note that if transporting tablets and using airplane, base maps need to be reloaded in Collector (which is time intensive and requires a reliable and fast internet connection) when at final destination and airplane mode should not be used again until after data collection concludes.

5.4 | Preview function stopped working

Except for two tablets, for unknown reasons, the preview function in Qualtrics did not work. As a result, it was not possible for the team to see what they had collected (either actual responses or the number of surveys). In the beginning, this caused great concern for the enumerators, as they were unable to perform quality control on the data they had collected. In the absence of this function, the team agreed that each enumerator should work extremely carefully in entering the data to minimize any errors in entry.

6 | BENEFITS

Despite the noted challenges, a number of benefits of using this methodology were identified, which are outlined in Table 2 and described in detail below.

6.1 | Time reduction in data collection and entry

Compared with the previous paper version of the TPP survey that was conducted 5 years ago in Naitolia, this methodology saved time. Specifically, in 2009, only 39 households were surveyed over 10 days (with no spatial data collected). By comparison, 170 households were visited over 4.5 days using the tablets. In addition, there was no time needed for data entry because data collected were digital. By comparison, the 2009 survey required 6 hours of data entry for every 10 households. In addition, prefield time was saved that would have been needed for photocopying surveys and parking them.

TABLE 2 Benefits of this methodology

Benefit	Description	Future Recommendation
Reduced data collection time	As compared with similar survey conducted in 2009, time was reduced by more than half.	Ensure that the survey is well prepared and enumerators are properly trained. Pretest the survey and set all logistical issues in advance.
Devices easy to carry and handle	The tablets were easily managed.	Choice of enumerators matters, prior experience counts. Ensure that the devices are well protected.
Multiple use of devices	Various data could be collected at once.	With proper choice of devices and organization of the survey, several data sets may be collected at the same time.
Easy and fast data sharing	Device inbuilt functions Wi-Fi, Bluetooth, and USB made data sharing easy.	When choosing devices to use, consider how you would wish to share or transfer the data collected.
Novelty of the technology	The tablets drew the interest of the enumerators and respondents.	The beauty of the technology may be a motivation for positive participation in the survey.

6.2 | Devices were easy to handle and carry

The tablets were easy to carry and manage in field conditions, compared with the traditional paper surveys that would require enumerators to carry (and maintain the integrity of) several bundles. They also could store several files at once. The tablets also had a very durable cover to protect them from water and other physical damage. No tablets were damaged during field data collection. Enumerators with no prior experience (before training) easily grasped touch screen data entry process and spatial data collection.

6.3 | Multiple ways of data collection

Using tablets enabled enumerators to multitask; for instance, they were able to conduct surveys, take photographs, record voices, and collect spatial information at the same time. The ability to collect numerous types of data on one device, from surveys to images and to spatial or audio data is a major advantage and facilitates mixed methods research. Typically, enumerators would have required several devices including a camera, a GPS receiver, and paper surveys. This enabled them to work more efficiently and comfortably.

6.4 | Easy and fast data sharing

The tablet had variety of inbuilt functions to share data like Bluetooth, USB, and Wi-Fi. It was very easy to share data not only among the enumerators but also with colleagues in MSU (aside from the Collector sync challenge noted above). With Wi-Fi, the team could communicate with colleagues in MSU to troubleshoot some of problems that occurred in the field and needed immediate attention through email and messaging.

6.5 | Novelty of technology

The enumerators were the finalist student teachers majoring in Geography at DUCE. They had previously completed an introductory course in Geographic Information Systems. However, they had never had an opportunity to apply these skills in the field. Being introduced to the use of tablets and having opportunity to work with them drew a great interest in the technology and, therefore, in collecting the data. They learnt very quickly and performed the work enthusiastically; they were surprised by the amount of data they could collect and a number of surveys they completed in a day. The power of the technology bound the team together, ie, MSU and Tanzania; problems were solved right on time, and that made the work easy. Respondents were also very interested with the tablets and wanted to know how they worked. In many households visited, the respondents also requested the enumerators to take them photographs, and they were very happy to see their electronic photos. Many villagers who were not in the sample wanted to be involved in the survey so that they can also taste the beauty of this technology.

7 | CONCLUSION

This work examined how effective tablets computers are in data collection for both spatial and social surveys in a rural setting in Tanzania. In this survey, particularly, tablets were mainly used for data collection, and they have proved to be very instrumental, economical, and efficient way of data collection. The multifunctionality of the tablets, ease of sharing the information collected, and the time saved in conducting surveys make the device most convenient tool for surveys and spatial data collection in tandem. There are also several challenges that may, in part, depend on the exact device and apps used for data collection. Among the major challenges of using the device in rural setting is lack of reliable electricity to

recharge the devices. In most of the rural areas in poor countries, there is no electricity; this is one of the main constrain of using the device especially if the survey requires long period of time. It is important to consider having alternative means of charging the devices like using solar power or extending battery life. Designing a device that keeps power over a long period of time or power banks that can recharge the devices over a week, for instance, may help researchers to make effective use of the tablets. Design devices that require less time to charge and save power for longer time use. It is also important to carry survey hard copies for backup, ordinary GPS, and camera to ensure the data collection continue just in case there are any technical issues with the device or if it stops working in the field. Still, the benefits accrued from using these devices largely outweigh the challenges, but researchers should take great care and precautions to avoid disappointments that they may face in the field.

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CONFLICT OF INTERESTS

The authors declared no potential conflict of interests with respect to the research, authorship, and/or publication of this article.

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