

Improving Form-Based Data Entry with Image Snippets

Nicola Dell*
Computer Science and
Engineering
University of Washington

Nathan Breit†
Computer Science and
Engineering
University of Washington

Jacob O. Wobbrock‡
Information School
DUB Group
University of Washington

Gaetano Borriello§
Computer Science and
Engineering
University of Washington

ABSTRACT

This paper describes *Snippets*, a novel method for improving computerized data entry from paper forms. Using computer vision techniques, *Snippets* segments an image of the form into small snippets that each contain the content for a single form field. Data entry is performed by looking at the snippets on the screen and typing values directly on the same screen. We evaluated *Snippets* through a controlled user study in Seattle, Washington, USA, comparing the performance of *Snippets* on desktop and mobile platforms to the baseline method of reading the form and manually entering the data. Our results show that *Snippets* improved the speed of data entry by an average of 28.3% on the desktop platform and 10.8% on the mobile platform without any detectable loss of accuracy. In addition, findings from a preliminary field study with five participants in Bangalore, India support these empirical results. We conclude that *Snippets* is an efficient and practical method that could be widely used to aid data entry from paper forms.

Keywords: Text entry; data entry; transcription; interaction techniques; paper forms; mobile touchscreen; HCI4D; ICTD.

Index Terms: H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces—Interaction Styles;

1 INTRODUCTION

Since its invention millennia ago, paper has served as one of our primary mediums for data collection [9]. Paper is tangible, portable and does not require batteries. Its inherent physical properties make it easy to use and almost universally accessible. It is a well understood and trusted medium that will continue to be extensively utilized for data collection throughout the world for years to come. Collecting data on paper forms is especially prevalent in developing countries that often lack the technology infrastructure required for collecting data directly in a digital format. Government, social and health organizations therefore routinely rely on large-scale, paper-based data collection to measure their impact and control the quality of the services they provide [19].

However, before the information recorded on paper forms can be easily aggregated, analyzed, searched or shared, it needs to be transcribed into a digital format. Currently, the predominant method for entering data from paper forms into structured digital content is manual data entry. This is a slow and laborious process in which data entry workers read information written on the paper forms and manually type it into a computer. Ideally, this kind of data entry should be performed by expert touch typists who are able to enter the data without looking at the keyboard or the screen. However, if the data to be entered is in a structured or semi-structured format, the typist may be required to look at the screen to navigate to the

appropriate digital data entry box, or use the mouse to select a value from a checklist or drop-down menu. Additionally, if the typist is at a less-than-expert level she must look at the screen to monitor the transcription results and correct errors. Any of these scenarios results in the data entry worker repeatedly switching her focus of attention back and forth between the screen and the form.

Broadly, this work seeks to answer the following research question: *How can we improve the process of transcribing data from paper forms into a usable digital format?* Given the prevalence of paper-based data collection in developing countries, we wanted to design new data entry methods that would be useful in *both* resource-rich and resource-poor settings, and designing for low-resource environments presents a number of interesting additional challenges. For example, many organizations do not have the financial resources required to purchase and maintain enough desktop computers to meet their data entry needs. In addition, there is often a lack of reliable technological infrastructure in these areas, including electricity or Internet connection, which makes it difficult to use desktop computers for data entry. Instead, mobile touchscreen devices are increasingly becoming the computing platform of choice in these settings. Mobile devices are battery-powered and can handle intermittent power. They are also portable and can be used in remote areas. In addition, users with little computer experience find mobile devices easier to use than desktops because of their more intuitive touchscreen interfaces. However, purchasing a mobile touchscreen device for every field worker is still too expensive for many organizations, who continue to use paper forms to collect data in the field, and then transcribe the paper-based data using a smaller number of mobile devices. Unfortunately, most keyboards on mobile devices are too small for touch typing, and reduce the process of entering data to one- or two-finger text entry. In addition, many touchscreen devices make use of soft keyboards displayed on the screen, and the lack of tactile feedback makes it impossible to enter data without looking at the screen [18].

Prior work [1] has explored the potential for data entry from paper forms to be crowdsourced. However, we have identified a number of reasons why organizations in developing countries may find it undesirable to use a crowdsourced solution. First, many organizations do not have a reliable Internet connection or sufficient bandwidth to be able to upload all of their data to the Internet. In addition, they may only need to enter data from a few forms per day, rather than thousands of forms, which might not warrant the overhead required to set up a crowdsourced solution. Furthermore, for a variety of political and security reasons, many organizations would prefer that the data only exists locally within their organization and is not uploaded to the Internet. Many paper-based data collection efforts gather personal health information, which people may be reluctant to provide if they fear that it will be put online for others to see, even anonymously. Finally, employing local data entry workers may be cheaper than outsourcing the data entry, and additionally creates jobs within the local community.

There is thus a need for mobile and desktop based data entry methods that allow data to be entered by local workers within an organization's own infrastructure without requiring access to the Internet. To address this challenge, we developed *Snippets*, a new method that facilitates data entry from images of forms that have

*e-mail: nixdell@cs.washington.edu

†e-mail: nbnate@cs.washington.edu

‡e-mail: wobbrock@uw.edu

§e-mail: gaetano@cs.washington.edu

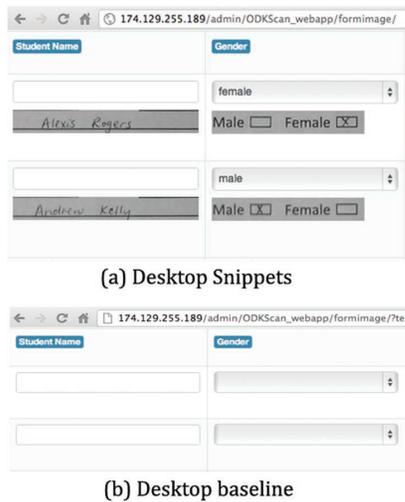


Figure 1: Screenshots of the data entry methods tested on the desktop: (a) Snippets: the form image is segmented into snippets that correspond to individual fields and the snippets for each form are displayed as a row in the table and (b) Baseline: Users look at the paper form and type in the data.

been captured using a cell-phone camera or scanner. Snippets uses computer vision techniques to segment the image into small snippets (see Figures 1a and 2a) that each contain the content for a single field. The snippets are displayed on the screen so that users can simply look at the snippets and type in the data. This approach negates the need for workers to have access to the physical form. Snippets makes data entry more efficient by (1) automatically processing machine-readable data types so that they do not have to be manually entered, and (2) displaying non-machine readable data on the screen for efficient entry, so that users do not have to switch their focus of attention between the paper and the screen or keyboard. In addition, all of the segmentation and processing is performed locally, eliminating the need for an Internet connection.

We evaluated Snippets in a controlled study with 26 participants in Seattle, Washington, USA. Our findings show that Snippets increased the speed of data entry over a baseline method of looking at the form and manually entering data (see Figures 1b and 2b) by an average of 28.3% on the desktop platform, and 10.8% on the mobile platform without any detectable loss of accuracy. Participants' subjective comments support our statistical findings, and show that participants perceived a performance benefit when entering data using Snippets. Finally, data from a preliminary field study with five participants in Bangalore, India shows similar trends to the data from Seattle, providing further evidence for the success of Snippets.

This paper makes two primary contributions to the HCI community: (1) the development of Snippets, a novel method for entering data from paper forms that eliminates the need for workers to switch their focus of attention back and forth between the form and the screen, and (2) an empirical evaluation showing that Snippets significantly increases the speed of data entry over a baseline method in current use on both desktop and mobile platforms. We conclude that Snippets is a simple and practical data entry method that could be widely used to improve data collection from paper forms.

2 RELATED WORK

The long-term coexistence of paper forms and electronic documents has resulted in a plethora of research that examines their interaction. We focus on two areas of related research: bridging the gap between the paper and digital worlds and digitizing paper forms in the developing world.

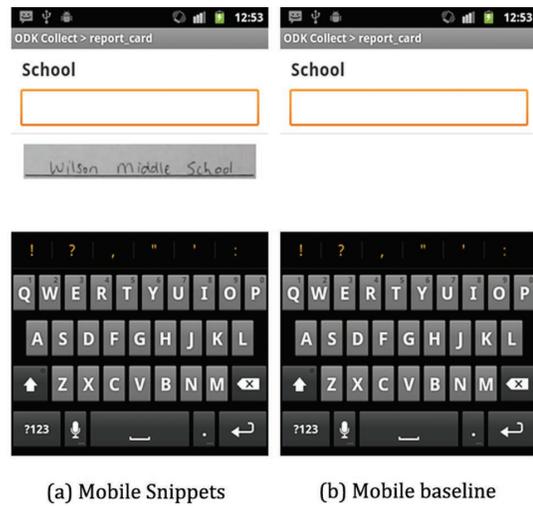


Figure 2: Screenshots of the two data entry methods tested on the mobile platform: (a) Snippets: Image snippets are displayed on the touchscreen with a data entry box and (b) Baseline: Users look at the paper form and type in the data.

2.1 Bridging the Gap between Paper and Digital Worlds

Many systems attempt to bridge the gap between the paper and digital worlds. Some, such as the Digital Desk [22], add digital resources to paper. Others, like Freestyle [10], augment computers with paper affordances. Intelligent Paper [3] uses a code to identify each sheet of paper and a pointer to specify points of interest. Paper Augmented Digital Documents [5] treats the digital and paper worlds as two different ways to interact with data. The Paper PDA [8] allows a paper notebook to be synchronized with electronic information. Xax [9] uses the paper itself as the user interface and encodes the forms with machine-readable registration marks. Optical character recognition (OCR) [14] can recognize printed text but is incapable of accurately processing handwritten data. Optical mark recognition (OMR) [14] can accurately recognize data recorded in multiple-choice or "bubble" format, but handwritten text and numbers need to be entered manually, and the cost of commercial OMR systems prevents them from being a viable option for many organizations in developing countries. Despite the existence of all these systems, the predominant method used to digitize handwritten data from paper forms remains manual data entry, in which workers read information on paper and type it in to a computer.

2.2 Paper Forms in the Developing World

The ubiquitous use of paper forms in the developing world has resulted in a large amount of research that focuses on extracting digital data from paper. Shreddr [1] is one system that has contributed substantially to this design space. Users capture images of forms using a camera or scanner and Shreddr segments the image and assigns the recognition of individual fields into tasks that are performed by people via crowdsourcing. Our data entry methods adapt and build on this research in several ways. First, although Shreddr can handle a wide variety of data types, it does not yet leverage the direct machine readability of some data types, although it does have a method of doing machine learning based on a sample of the crowdsourced answers. In addition, a reliable Internet connection and sufficient bandwidth are required for the effective use of a crowdsourcing platform, which is problematic for many organizations in developing countries, and Shreddr does not provide organizations with the option of distributing the data entry to its own workers. Finally, since crowdsourced workers can step away from the task at any time, it has not been possible for the researchers

to reliably evaluate the time that it takes for workers to transcribe data. By performing our study in a controlled setting, we are able to provide a rigorous quantification of the benefits of displaying data on the screen to facilitate transcription rather than shifting focus of attention between the paper and the screen.

CAM [15] allows a camera-equipped mobile phone to interact with paper forms. The forms contain visual codes that serve as references to assist with data entry. CAM is a powerful tool that can handle a variety of data types, but users are still required to switch their focus of attention between the screen and the form as they transcribe data. Local Ground [21] is a tool that allows people to annotate paper maps using markers and stamps. The maps are scanned and user markings extracted and overlaid on existing online maps to aid local planning decisions. Local Ground allows people to use special stickers or markings to add meaning to some of their annotations, but the system is currently not able to decipher freeform annotations made by users. Finally, Ratan et al. [17] present a financial record management application built on a digital slate device. The solution accepts handwritten input on paper and provides electronic feedback. Unfortunately, although the system showed initial promise, the purchase and maintenance of specialized slate devices hindered its scalability and sustainability.

3 DESIGN CONSIDERATIONS

Traditional data entry requires users to look at the form and find a field to enter, then look at the screen and find the corresponding entry box, and then type in the value. One major disadvantage of this approach is that the user has to switch her *focus of attention* (FOA) back and forth between the paper and the screen or keyboard. The burden of switching FOA and the benefits of reducing the FOA required for a task is a well-studied phenomenon [12]. For example, if the worker is an expert touch typist and is merely copying unstructured text, she may not need to look at the screen or keyboard at all, and can instead remain entirely focused on the paper form. However, if the data to be entered is in a structured or semi-structured format, even touch typists will need to look at the screen to ensure that they are typing data into the correct entry box or selecting the correct value from a list or drop-down menu. This increases the FOA required for the task and will reduce the rate at which data can be entered. Our design attempts to reduce the FOA required for data entry by placing the form content on the screen alongside the appropriate entry box so that users can simply look at the screen and enter data, rather than switch their attention between the form and the screen.

In addition to reducing the FOA required for data entry, we also wanted a design that does not require the user to possess the physical form. During a preliminary study in Mozambique in which health workers used smartphones to enter data from paper forms, it became clear that it would be an advantage if users could perform data entry in a variety of different locations, such as while waiting for the bus or during their daily commute. Our design therefore facilitates data entry from images of forms rather than physical forms.

To ensure that our design is suitable for both resource-rich and resource-poor settings, we interviewed people from organizations that conduct large-scale data entry, including the Akshara Foundation [20], the Mozambique Health Ministry [13] and PATH Seattle [16]. One common theme that emerged during these interviews was the need for *both* desktop and mobile entry methods. We also learned that it would be best if the same (or similar) methods could be applied on both platforms to minimize training. This led to the idea of using image snippets that could easily be displayed on both the large screens of desktop computers and the small screens of mobile devices. On the mobile platform, prior research on digital data collection showed that displaying one field per screen was best [7]. In contrast, the larger screen space available on the desktop makes it more efficient to display many snippets at the same time.

Many of the forms used by organizations for data collection contain a mixture of data types, including handwritten text, numbers, checkboxes, multiple choice answers, and tallies in “bubble” format. While some of these data types, like handwritten text, require a person to manually transcribe the data, others, like checkboxes or bubbles, can be interpreted by a computer. Snippets takes advantage of this machine-readability and uses software we designed called Open Data Kit (ODK) Scan [2] to automatically interpret these data types so that they do not have to be manually transcribed.

4 SNIPPETS

Snippets makes the entry of data from paper forms more efficient by segmenting an image of the form into individual fields that are displayed on the screen for easy entry. Prior to data entry, the image of the paper form is processed by our software and data types that are machine-readable are automatically interpreted. We will now discuss each of these steps in greater detail.

4.1 Processing an Image of the Paper Form

ODK Scan [2] is software capable of automatically reading and interpreting machine-readable data types like bubbles and checkboxes. ODK Scan uses a lightweight form description language to facilitate the processing of existing paper forms without the need to redesign or add coded marks to the forms. To add a form to the system, a user creates a form description file that specifies the size, location and data type of each field to be processed. The system uses this file to automatically interpret machine-readable data.

In a prior paper [2], we described the design and initial smartphone implementation of the ODK Scan algorithms and showed that the software was capable of processing multiple choice and “bubble” fields with over 99% accuracy. However, we did not consider the design of user interfaces or methods to aid the entry of non-machine readable data, and we did not provide a way for users to check and correct the processed results. We also only implemented the algorithms on a smartphone, and did not consider data entry on desktop computers.

Therefore, this paper focuses on the design of desktop *and* mobile user interfaces and methods that help *people* to transcribe data from paper forms. The results of the algorithms described in [2] serve as one input to these new data entry methods. The other main input, which we created solely for this paper, consists of image “snippets”. Snippets are small fragments of the original form image that correspond to individual form fields, and it is these snippets that our Snippets technique provides to users for transcription. In addition, since the ODK Scan algorithms occasionally make classification errors, Snippets affords users the opportunity to check and possibly correct the results of the automated scanning.

4.2 Data Entry from Image Snippets

Snippets improves data entry by eliminating the need for users to refer to the physical form. Instead, an image of the form is captured and segmented into image snippets, with each snippet containing the portion of the image that corresponds to a single field. Each snippet is displayed on the screen with a data entry box so that users can simply look at the snippet and type in the value. An additional benefit of our approach is that it makes it clear how users should progress with data entry by guiding them from snippet to snippet. This reduces the likelihood that users will accidentally skip fields. Snippets also incorporates the output of the ODK Scan software, which consists of processed data values for fields that are machine-readable (bubble and checkbox fields). Snippets uses these values to pre-populate the entry boxes that correspond to these fields. This allows users to quickly check the results of the automated processing and, if necessary, correct any errors.

For this paper, we implemented two versions of Snippets: a desktop version, shown in Figure 1a, that runs within our custom-built

web application, and a mobile version, shown in Figure 2a, that runs on Android devices. In the desktop version, all of the snippets for the whole form are displayed simultaneously on the screen in a table. Multiple forms can be displayed at the same time, with the snippets for each form represented as a row in the table. Users can enter data horizontally or vertically, and columns of fields that have already been entered can be hidden by clicking on the column heading. In addition, users are able to save partially entered forms so that the transcription can be completed at a later time.

We implemented the mobile version of Snippets using the Android-based data collection tool ODK Collect [7] that we modified and extended to include the display of the image snippets. The small screen size of many mobile devices makes it impractical to display all of the image snippets for a whole form on one screen. Instead, as shown in Figure 2a, we display each image snippet individually on the screen along with the corresponding data entry box. Users type in the data value using the standard android touchscreen keyboard, and then use the swipe gesture to progress to the next snippet. As with the desktop version, users are able to save partially entered forms and return to them at a later time.

5 LESSONS FROM A FAILED DESIGN

In an effort to fully explore the design space, we tested several other designs that warrant mention. One of these designs, an Interactive Form, emerged out of a concern that breaking up the form into smaller pieces may result in a loss of context that might make accurate data entry difficult. We therefore wanted to try at least one design that preserved the overall context of the form. As shown in Figure 3, instead of segmenting the image into snippets, the Interactive Form design keeps the form image intact and transforms it into an interactive surface. Clicking on a field brings up a dialog box that displays a snippet containing the selected field along with an entry box for transcription. When the user finishes transcribing or checking this field and returns to the form image, the colored outline of the field that has just been transcribed changes from orange to green. In addition, entered values are overlaid in blue text close to the location of the corresponding fields. These overlays allow users to check values without having to click on every field.

We ultimately discarded the Interactive Form for several reasons. First, initial tests showed that the additional step of bringing up a dialog box to facilitate entry took almost as long as manual data entry, but entering data directly on to the form image without using dialog boxes proved to be confusing for users. In addition, the order in which users should enter form fields was unclear, which resulted in users accidentally skipping some fields. It was also unclear which fields had been automatically processed by the system and which fields required manual data entry, and it was difficult for users to check the results of the automated processing since the feedback provided by the system somewhat obscured the underlying markings. Finally, we wanted to ensure that our methods would work on both mobile and desktop platforms, but found that displaying and interacting with an image of the whole form was cumbersome using the small screens on mobile devices. Fortunately, Snippets avoids all of these problems, whose importance was highlighted by the failed Interactive Form design.

6 LABORATORY EVALUATION

We evaluated Snippets through a controlled user study. We wanted to see if the new technique would improve the rate and accuracy at which people enter data compared to the traditional method of reading a paper form and typing into the device. Since we wanted to evaluate entry on both a desktop computer and a mobile touchscreen device, we conducted two studies: one in which participants entered data into a desktop computer, and another in which participants entered data using a touchscreen smartphone. We chose not to compare the user experience and performance of the desktop

Subject	A	B	C	D	F
Writing	0	0	0	0	0
Reading	0	0	0	0	0
Mathematics	0	0	0	0	0
Science	0	0	0	0	0

Figure 3: Failed Interactive Form design: Individual form fields are outlined in orange, the results of scanning are colored pink and green, and entered data values are shown in blue text. Clicking on a form field opens a dialog box that facilitates entry of the data.

and mobile platforms since these platforms target different usage scenarios, and most organizations only use mobile phones for data entry if using a desktop platform is inappropriate or impossible.

6.1 Participants

Our study took place in Seattle, Washington, USA. We recruited 26 participants (13 female) ranging in age from 18 to 49 years ($M = 27.0$, $SD = 5.9$). All participants had over 10 years experience with computers and self-rated as intermediate to expert computer users. None of the participants were professional data entry workers or typists. Ten participants were near-expert touchscreen users with approximately three years of touchscreen use. Five participants did not own a touchscreen device and had little experience with them.

6.2 Apparatus

For the desktop study, participants entered data using our custom web application running in the Chrome browser on a Dell desktop computer with a 2.5 GHz processor and 2 GB of memory. A 17" monitor, standard optical mouse, and keyboard were connected to the computer, and the application recorded all of the user's screen interactions and timing information. For the mobile study, participants entered data using an HTC Nexus One Android smartphone with 512 MB memory and a 1 GHz processor. The phone had a 3.7 inch capacitive touchscreen. Participants entered data using the ODK Collect software [7] that we modified considerably to include the display of image snippets. In addition, we recorded all the touch and keyboard events and timing data.

We created a report card to use for the forms in the study (see Figure 4). The form contained 15 fields: 3 text, 3 number, one checkbox, 4 multiple-choice and 4 tally fields. We created enough test forms so that no participant would enter data from the same form more than once, and filled the forms with realistic, fictitious values. Since we wanted to use the same forms for the laboratory study in Seattle, Washington, USA and the field study in Bangalore, India (described below), half the forms contained common American names, and the other half common Indian names. All the forms were filled in English, since the data entry workers in India spoke English. An image of each form was captured using a 5 mega-pixel smartphone camera and processed using our software.

6.3 Procedure

The experimental procedure was designed to fit into a single 60-minute session. Each session began with an introduction to the data entry platforms and techniques, and a description of the tasks that

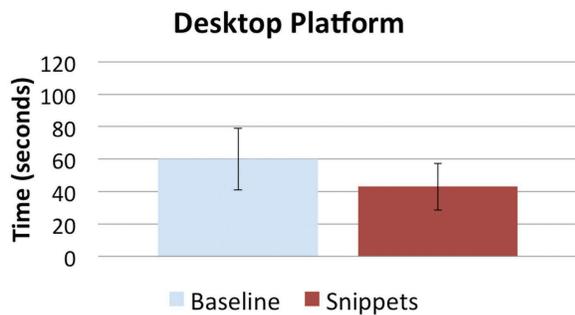


Figure 5: Average time taken to complete data entry for one paper form in the desktop study. Lower is better. Error bars show ± 1 SD.

test was run. The test was also nonsignificant for *Entry Method* on *Errors* ($Z = 0.29, n.s.$). Taken together, these results indicate that there was no detectable difference in accuracy between the two methods on either the desktop or mobile platform.

7.3 Subjective Responses

The NASA task load index (TLX) questionnaire [6] was completed by participants after each data entry method, allowing for 1-20 ratings on six scales: mental demand, physical demand, temporal demand, perceived performance, perceived effort, and perceived frustration. Except for perceived performance, which ranges from “perfect” (1) to “failure” (20), all scales range from “very low” (1) to “very high” (20). Lower is therefore better on all scales.

Results for the desktop entry methods are shown in Figure 7. Nonparametric Wilcoxon signed-rank tests were conducted on the desktop ratings with significant outcomes in favor of Snippets on *all* scales: mental demand ($Z = -2.74, p = .006$), physical demand ($Z = -3.09, p = .002$), temporal demand ($Z = -2.45, p = .014$), perceived performance ($Z = -2.97, p = .003$), perceived effort ($Z = -3.67, p < .0001$), and perceived frustration ($Z = -3.22, p = .001$). These findings show that participants perceived a substantial performance benefit of Snippets over the baseline.

NASA TLX results for the two mobile entry methods are shown in Figure 8. Nonparametric Wilcoxon signed-rank tests were conducted on these ratings with a significant outcome only for mental demand, with Snippets being significantly less mentally demanding than the baseline method ($Z = 2.49, p < .02$). However, there were trend-level results in favor of Snippets over the baseline method for temporal demand ($Z = 1.69, p = .092$), perceived performance ($Z = 1.85, p = .065$), and perceived frustration ($Z = 1.86, p = .063$), providing further evidence for the success of Snippets.

7.4 Interpretation of Results

Our goal was to develop methods that improve the entry of data from paper forms. Snippets improves the speed of the entire data entry process over the baseline method by an average of 28.3% on the desktop platform and 10.8% on the mobile platform without any detectable loss of accuracy. Since entering data with Snippets still requires participants to read and type in many of the data values, a large proportion of the time savings is likely due to improving the users’ focus of attention. Snippets eliminates the need for users to look at the form to find the next item of data and then find the entry box on the screen before typing in the value. Thus, it is likely that Snippets moves us closer to the lower bound on data entry time.

However, since our Snippets method incorporates the output of the ODK Scan software, it is impossible to tell what proportion of the speed-up is due to displaying image snippets on the screen and what proportion is due to the pre-populated values computed by ODK Scan. Since we asked participants to check the pre-processed

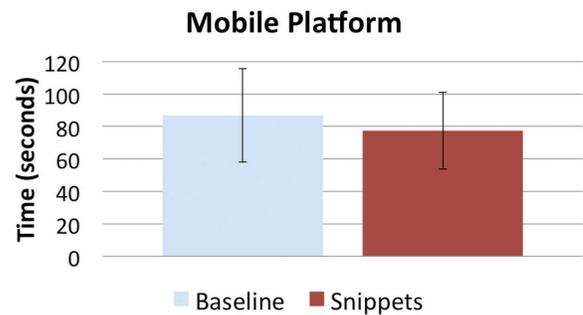


Figure 6: Average time taken to complete data entry for one paper form in the mobile study. Lower is better. Error bars show ± 1 SD.

values from ODK Scan and correct any mistakes, we are confident that participants at least read and interpreted all of the form fields even if they did not manually enter values that had been processed correctly. An interesting area of future research would be to perform a study to tease apart the relative performance benefits afforded by the image snippets versus the ODK Scan software.

It is also interesting that we did *not* see any substantial differences in the accuracy of data entry between the baseline method and Snippets on either the desktop or the mobile platforms. Data entry tasks typically result in a speed-accuracy tradeoff, in which an improvement in the speed of data entry comes at the cost of decreased accuracy. It is therefore highly encouraging that the improvement in speed that we saw with Snippets did not detectably affect the accuracy of data entry. Instead, both methods exhibited similar errors rates. Observation of the data entry process revealed that although we made an effort to ensure that the handwriting on the test forms was clearly readable, a large proportion of errors resulted from participants being unable to correctly interpret the handwriting. For example, participants often purposely typed the letter ‘v’ when the handwritten letter was actually ‘u’. Since participants were reading the same handwritten values on both the paper form and the image snippet, these kinds of errors were equally likely to occur with both methods. Unfortunately for data entry workers, accurately transcribing human handwriting remains an inherently difficult task.

The NASA TLX questionnaires for the desktop platform show that participants rated Snippets as being significantly better than the baseline method on *all* six scales tested: mental demand, physical demand, temporal demand, perceived performance, perceived effort, and perceived frustration. These results clearly show that participants perceived the performance benefit of Snippets and preferred it over the baseline method. Participants’ subjective comments overwhelmingly support this preference. Participant 7 told us, “My favorite technique was [Snippets]. I felt the fastest with this technique and it was also easy to check that my responses were correct, since the images were right next to the entry fields.” In addition, several participants liked being able to transcribe the data by column, rather than by row. Participant 4 said, “The best entry technique was [Snippets]; I was able to enter the same column for all four forms, then move to the next column for all four forms, minimizing the amount of mental context-switching to process each particular column.” When combined with our statistical results, these findings suggest that Snippets is a simple, practical technique that improves the process of entering data from paper forms.

On the mobile platform, Snippets improved the speed of data entry by an average of 10.8% over the baseline. This is substantially less of an improvement than we saw with the desktop, which could be explained by a number of reasons. First, since participants held the device in their hands, they were able to position the device relatively close to the paper form for the baseline method, which decreased the amount of head and eye movement required

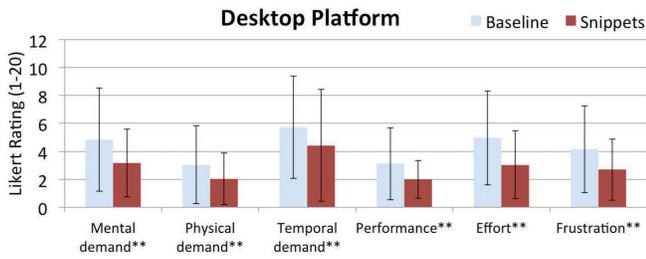


Figure 7: Results of the NASA Task Load Index survey for the desktop study. Lower is better on all scales. Error bars show ± 1 SD. ** indicates $p < .05$; * indicates $p < .01$.

to switch focus of attention between the device and the paper. In addition, for both Snippets and the baseline, it was generally more difficult for participants to type using the small, soft mobile keyboard than the desktop keyboard. Participant 4 commented, “*The worst entry techniques were the two on the phone; I’m an experienced mobile touchscreen user, but it’s still a pain to enter any non-trivial amount of data using just my two thumbs.*” The general difficulty that participants had with data entry on the mobile device suggests that organizations who choose to use mobile devices for data collection should try to minimize the amount of text that must be typed. This could be achieved by auto-filling fields with likely responses, providing pre-programmed options that can be chosen with a single touch, and maximizing the use of drop-down menus.

However, although participants found data entry on the mobile platform to be generally slow and laborious, the results of the NASA TLX surveys show a trend in favor of Snippets, and participants’ subjective comments support this trend. Participant 21 told us, “*I [preferred] the phone with Snippets over the [baseline] due to having the form data right on the screen. This was especially useful for data entry that was largely just confirming that the system had already made the correct selection.*” Again, when combined with our statistical results, these findings suggest that Snippets could aid the process of entering data on mobile devices.

8 FIELD EVALUATION IN BANGALORE, INDIA

Our primary research objective is to develop data entry techniques that will be useful in both developed and developing world scenarios. As such, we felt that it was important to collect preliminary data from a low-resource setting. Thus, in addition to the laboratory evaluation in Seattle, we also performed a small field evaluation at the data entry offices of the Akshara Foundation in Bangalore, India [20]. At this stage, the field evaluation was intended to be an additional data gathering exercise rather than a formal, quantitative evaluation. The Akshara Foundation is a Bangalore-based NGO that is working to universalize equitable access to quality preschool and elementary education for all children in India. The Foundation relies on large scale paper-based data collection to measure its impact and control the quality of the services it provides. At the beginning, middle, and end of each school term, teachers and evaluators administer academic assessments to over 200,000 students, and record the performance of each student on a paper form. The hundreds of thousands of paper forms are collected and transported back to the Akshara offices in Bangalore where they are manually entered twice by different people to avoid errors. To perform the data entry, Akshara employs a number of full time workers who spend their entire day entering data from paper into computers.

8.1 Participants

We recruited five data entry workers (all female) ranging in age from 22 to 40 years ($M = 28.0$, $SD = 2.6$). Four participants had about 3 years of computer experience, and the fifth had about a year of computer experience. None of the participants owned a

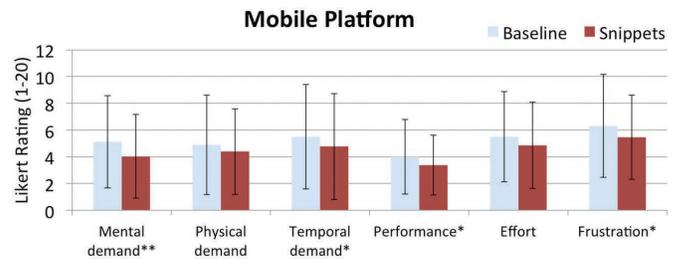


Figure 8: Results of the NASA Task Load Index survey for the mobile study. Lower is better on all scales. Error bars show ± 1 SD. ** indicates $p < .05$; * indicates $p < .01$.

touchscreen device, and all self-rated as beginner touchscreen users. Three participants said this was their first time using a touchscreen.

8.2 Apparatus and Procedure

The field evaluation took place in the data entry offices of the Akshara Foundation in Bangalore, India. Participants experienced the same procedure as those in Seattle, completing the practice session and the data entry of four paper forms (trials) for each technique using a desktop and an HTC Nexus One touchscreen device. The forms used were the same as those in the Seattle study, and participants in India entered the same amount of data per method as the participants in Seattle. In addition, participants again completed a NASA TLX questionnaire after each entry method.

8.3 Results

Due to the relatively small number of participants in the field study, we do not have sufficient data for statistical significance. Instead, we report descriptive statistics and qualitative data in an effort to characterize our users’ experiences. For speed, Snippets took the lowest average time on the desktop, averaging 80.9 seconds ($SD = 20.0$) to transcribe a form compared to 84.9 seconds ($SD = 18.8$) with the baseline method. Snippets also took the lowest average time on the mobile platform, averaging 110.8 seconds ($SD = 23.2$) compared to 155.3 seconds ($SD = 46.4$) with the baseline method. For accuracy, Snippets resulted in the fewest errors on the desktop, averaging 0.80 ($SD = 0.89$) incorrect fields per form, while the baseline method averaged 0.95 ($SD = 0.82$) incorrect fields per form. On the mobile platform, Snippets also resulted in the fewest errors, averaging 1.05 ($SD = 0.82$) incorrect fields per form, while the baseline averaged 1.20 ($SD = 0.89$) incorrect fields per form.

As with the laboratory study, the NASA TLX questionnaire was given to participants after each method. On average, the NASA TLX ratings for Snippets were all lower than the baseline method, indicating that participants seemed to perceive a performance benefit with Snippets. Participant comments overwhelmingly support this perception. Participant 31 told us, “*Entering data from the [paper form] is more difficult, the scanned image [snippets] and especially the fields where I can select the answer, like the [multiple choice] marks or [bubble] tallies, make it easier to enter data.*” These comments highlight the relative success of Snippets and suggest that it could improve data entry in the developing world.

However, participants generally struggled to use the small, soft keyboard on the mobile device. Participant 29 said, “*The typing is hard because the keyboard is very tiny,*” while Participant 31 told us, “*It is quite stressful to do data entry on the phone because I have to continuously bend my head to look at the screen and [navigate] back and forth when I make a mistake.*” These findings mirror our observations in Seattle, and suggest that using mobile devices for large-scale data entry presents challenges that make them inferior to desktops, and we recommend that organizations only use mobile devices for large-scale data entry if a desktop solution is infeasible.

9 DISCUSSION AND FUTURE WORK

We observed a number of interesting differences between the participants in India and the participants in Seattle. First, data entry workers at the Akshara Foundation currently enter data from paper forms directly into Excel spreadsheets, and are thus familiar with moving to the next field on the screen using the arrow keys on the keyboard. In contrast, the participants in Seattle were familiar with using the tab key to navigate their way around the screen. Since our interfaces supported the use of the tab key but not the arrow keys, the Seattle participants may have been at an advantage. In addition, the Indian participants were generally more cautious with the data entry than the Seattle participants, and took time to check the values that they entered. This is probably due to the fact that they have been trained to recognize the importance of accurate data entry. Furthermore, rather than just entering whatever values had been recorded on the form, the Indian participants thought about whether these values made sense. For example, participant 28 asked us, “*This name could be a girl’s name, but the form says that it is a boy. Should I correct the gender to female?*” She recognized that whoever filled out the form may also have made mistakes, and that she could correct some of these mistakes at data entry.

For many of the Indian participants, data entry from paper forms has been their primary interaction with computers, and they were visibly more comfortable when they had the physical paper form to refer to. Participant 30 commented, “*I am familiar with the [paper form] so it was easy, but the scanned [snippets] were as easy even though it was my first time using it. If I used the scanned [snippets] for some time then I think it would be faster than the [paper form].*” Furthermore, when entering data for the baseline method, the majority of Indian participants kept one finger physically on the paper form so as to be able to easily remember which form field to enter next. Additional observation of the current data entry process at Akshara revealed that this appears to be standard practice for these workers. By keeping one finger on the paper, participants were only able to type using one hand (and in several cases, only one finger), and were unfamiliar with how to type using two hands. This unfamiliarity may have affected the speed at which data was entered for Snippets, which could explain why we saw less of an improvement with Snippets on the desktop in India than in Seattle. We would expect that as these workers become familiar with typing using two hands, their rate of data entry will likely increase.

There is still work to be done to ensure that Snippets is appropriate and usable in both resource-rich and resource-poor environments. Primarily, we need to deploy Snippets with an organization that performs large-scale data entry. We plan to run a trial in which half of the organization’s data entry workers use Snippets, while the other half continue to use whatever data entry tools the organization currently employs. Such a trial would provide us with valuable data to quantify the performance of Snippets “in the wild.”

10 CONCLUSION

Paper forms are utilized extensively throughout the world for large scale data collection. In particular, government, social and health organizations working in developing countries rely heavily on paper forms to collect information from the communities in which they work. Digitizing, aggregating and sharing this information is crucial to help these organizations provide services to low-resource populations. However, manually transcribing the data collected on paper forms into a digital format is a slow and laborious process. To address this problem, we developed Snippets, a novel data entry method that improves data entry by (1) automatically processing machine-readable data types so that they do not have to be manually entered, and (2) displaying non-machine readable data on the screen to eliminate the need for users to refer to the physical paper form. Findings from an empirical study with 26 participants in Seattle, Washington, USA show that Snippets increases the speed of

data entry over the baseline method of reading the paper form and manually entering the data by an average of 28.3% on the desktop platform and 10.8% on the mobile platform without any detectable loss of accuracy. Findings from a preliminary field study with five participants in Bangalore, India support these empirical results. We conclude that Snippets is a simple and efficient technique that could be widely used to improve data entry from paper forms.

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