Evaluation of an Interactive Surveillance System for Monitoring Acute Bacterial Infections in Nigeria

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Abstract

Objective: The objective of the study is to evaluate the usability of a stand-alone, Internet-enabled interactive surveillance system designed to monitor the burden of invasive bacterial infections among children in Nigeria.

Method: A convenience sample of 10 participants were enrolled in a training session on using the system at a hospital in Nigeria. The participants performed a series of tasks assessing their ability to use the system. System usability was assessed using a System Usability Scale (SUS) questionnaire.

Results: The majority of participants found the system easy to use (90 percent; $n = 9$) and reported confidence in using the system. The average SUS score was 77.8. A total of 30 percent ($n = 3$) of the study participants had exceptional usability scores, 20 percent ($n = 2$) showed acceptable scores, and 10 percent ($n = 1$) had a good score.

Conclusion: Further evaluation of the system will help gauge additional challenges during its long-term utilization. If successful, the system could also be deployed in other resource poor-environments.

Keywords: data capture, data collection, developing countries, research, health records storage

Introduction

The major challenge hindering public health research in Nigeria is the difficulty of obtaining accurate data.[1] Lack of accurate data limits the proper assessment of the magnitude and distribution of disease conditions across various geographic regions.[2] Timely and accurate data are essential to develop evidence-based informed decisions.[3] The lack of reliable data has been attributed to factors including limited financial resources, poor human resource training, and the use of paper-based methods of data collection.[4] The ability to obtain reliable data also largely depends on the mechanism adopted to collect data.[5]

Electronic methods of data collection are frequently utilized in developed countries and have been shown to provide more benefits than paper-based data collection and alleviate most issues associated with paper-based methods. Traditional paper-based methods of data collection have been previously associated with several issues, including error frequency, duplication, and storage costs.[6] Some of the advantages of electronic data collection over paper methods include timeliness, avoidance of record duplication, cost-effectiveness, facilitation of data transmission and synchronization, higher data quality, data completeness, and higher acceptance.[7] Prior studies which examined the use of electronic systems in data collection in comparison to paper-based methods have reported higher patient acceptance and preference among patients in using electronic systems [8,9]. In developing countries, paper-based data collection methods are currently being replaced by electronic means of health research in order to facilitate more effective data collection and storage.[10]Despite these efforts, several impediments in the structure and functioning of the systems in these countries hamper the sustained progress of such activities.[11] These impediments include limited infrastructure and finances, and poor adoption by physicians, which has been attributed to a lack of familiarity with the use of such systems.[12]

The lack of surveillance systems in Nigeria is a major factor that currently hinders the assessment of the disease burden or other health conditions.[13] Health surveillance systems essentially serve as tools for monitoring the incidence of health conditions across geographic boundaries.[14] By doing so, they prompt the discovery of various patterns and relationships that were previously unknown.[15] The data obtained from such systems could serve several purposes, including estimation of the incidence of a disease, visualization of its distribution and spread, hypothesis generation regarding causal factors, implementation of adequate control strategies to foster early detection, and short- and long-term outcome evaluation of the impact of preventive strategies.[16]

An interactive surveillance system was designed and developed for deployment across study sites in several regions of Nigeria to monitor the incidence of acute bacterial infections among children less than five years of age. Children under five years of age in Nigeria have one of the highest burdens of acute respiratory infections, with an estimated carriage of 67.4 percent, compared to 26 percent in adults.[17]About one-fifth of deaths due to acute respiratory infections are found in this segment of the population.[18] Children residing in southwestern states of Nigeria have an estimated occurrence of at least three episodes of such infections annually, with pneumonia being the most prevalent infection.[19]Data regarding the distribution and determinants of acute respiratory infections among Nigerian children are limited, though these diseases have been reported to be more prevalent during the rainy season.[20]

Invasive bacterial infections that are associated with clinical syndromes such as pneumonia, sepsis, and meningitis are the leading causes of mortality and morbidity in several developing countries, with exceptional vulnerability in children aged less than five years.[21, 22] The risk factors associated with these diseases differ depending on populations and geographic regions and have not been well characterized.[23] The lack of sufficient data on the distribution of these diseases may have led to their underestimation.[24] A reliable estimation of the incidence, prevalence, and risk factors associated with this group of diseases is necessary in order to guide effective public health research and implementation of appropriate preventive and therapeutic interventions. A computer-based surveillance system was designed to gather information regarding the risk factors and other variables associated with the incidence of acute respiratory infections across different regions of the country.

Prior to deployment of the surveillance system, usability testing was conducted to evaluate the acceptance of the system among potential users so that any necessary adjustments could be incorporated in a timely manner. Usability is an integral determinant of user satisfaction and utilization of health technologies.[25] Interactivity, which is often hindered by poor usability testing, has been identified as a major issue in the deployment of interventions designed for various patient and clinician groups.[26] This issue is attributed to the fact that the design framework of most electronic systems is essentially "technology driven" rather than "user driven."[27] The incompatibilities that result due to poor consideration of the user's perspectives largely account for the reduced efficiency and utilization of such systems.[28] The design of user-centered systems ultimately depends on the level of integration of user characteristics alongside system requirements.[29] The lack of prioritization of user characteristics will lead to challenges in user satisfaction.[30] The objective of this pilot study is to evaluate the usability of a stand-alone, Internet-enabled interactive surveillance system designed to gather data from various sources for use in monitoring the burden of acute bacterial infections among children in Nigeria.

Conceptual Framework

The study was designed using the combined principles of a human-centered approach and behavioral and information processing. The human-centered approach gives specific considerations to users' knowledge, expertise, and utilization of the interaction techniques to represent tasks performed by the users.[31-35] Processing of different types of information will be affected by the type of visual display that is used to present the information. When the information presented does not match the ultimate needs of the user performing the task, the result is decreased accuracy and increased time required to perform the task.[36] These benefits translate into system- and task-related performance factors. The existing consumer health information platform was modified to meet the needs of the users to gather data related to invasive bacterial infections among children living in diverse settings in Nigeria. The information processing theory facilitates presenting information in small chunks with each screen presenting limited information. The human-centered approach takes into consideration the users, their backgrounds, and the tasks the users need to perform.

Design and Development of an Interactive Surveillance System

A stand-alone, Internet-enabled interactive surveillance system was designed and developed to monitor the burden of invasive bacterial infections among children living in diverse settings of Nigeria. The system will be deployed in three sites, including the University of Abuja teaching hospital in central Nigeria, the Aminu Kano University teaching hospital in northern Nigeria, and University College Hospital in Ibadan (Figure 1).

Software Description

The technology involved in the development of the overall application included PHP version 5.1.2 for user and data management, log-in, and user roles. A MySQL database was utilized to store the data gathered, and jQuery was utilized for generating tabs, toggles, sliders, and all animations in the system. Figures 2 and 3 describe the flow of data for both the Internet-enabled and the stand-alone applications of the system.

Users are required to register themselves (Figure 4) and be approved by the administrator before they can gain access to the system components. Once users are registered, they can use either the Internet-enabled or the stand-alone application to collect data electronically across multiple sites in Nigeria. The users can register new patients into the system or track, and follow patients already registered into the system by clicking on the ‘search button.’ (Figure 5, Figure 6, and Figure 7). Data on various variables are gathered based on the study protocol. A data synchronization capability allows data gathered in the stand-alone system to be remotely uploaded to the centralized database so that data from various sites across Nigeria can be updated and so that the users can download the updated data from the centralized database onto their computers (Figure 3).

Components of the Interactive Surveillance System

The components of the system include the following:

- **User registration:** Initially, users are required to register through the Internet portal and await administrator approval before they are able to use the system (Figure 4). The user registration gathers the username, password, full name, and e-mail address of the user. After registration, the user is able to log into the stand-alone system to collect data in environments with no Internet access.

- **Patient registration:** The user proceeds to register the individual patients. The system utilizes five major patient details to generate a unique identifier for each patient record entered: the patient’s name, date of birth, e-mail address, home address, and phone number (Figure 5).

- **Data entry:** The user enters the patient data corresponding to each of the 36 surveys for acute bacterial infections contained in the system (Figure 8). The user is required to complete each survey with the information obtained while interviewing the patient. The user can also choose to complete the surveys at a later time, and the patient details can be located by searching for existing patient records (Figure 7).

- **Data validation:** Clinical rules are integrated into the system, and if data outside the set threshold are entered into the system, the system generates a flag to reflect that the data value entered is a possible outlier.
- **Data completion:** The user interface displays color codes reflecting which forms have been completed and which forms need to be completed (Figure 6). It also displays a task progression pane reflecting the extent of completion of the form to help both the user and the patient approximate the time that will be needed to complete the forms (Figure 8). Each screen contains limited information to prevent information overload and to ensure that the user interface is easy to use and can help the user complete tasks efficiently and in a timely manner.
- **Data synchronization:** Data synchronization is a bidirectional process that allows data gathered through the stand-alone system to be transmitted to the central server and allows the central server to relay updates back to the stand-alone computers. This process facilitates the systematic synchronization of data across multiple locations that might not always be networked (Figure 9).
- **Tracking patient progress:** This component allows users to monitor the progress of the data gathered on every individual so that data collection is not missed at any of the important time intervals.

Methods

This pilot exploratory study was conducted during July 2013 at University College Hospital in Ibadan, a city in southwestern Nigeria. This hospital was one of the sites that would be utilizing the proposed interactive surveillance system to monitor the incidence of acute bacterial infections among children aged less than five years. Ten study participants from diverse backgrounds were enrolled into this pilot study to assess the usability of the system. These participants were the end users who would be responsible for data collection using the surveillance system. A training module was developed for the study participants to guide them on how to navigate through the system and use its various functions. A training session was conducted by a team of researchers consisting of an epidemiologist, a public health informatics specialist, and an infectious disease pediatrician from the University of Nebraska Medical Center. The participants were provided with information on how to carry out several tasks including (1) registering new users, (2) logging into the system, (3) registering patients, (4) viewing records, (5) navigating through the system, (6) performing data entry, and (7) synchronizing the entered records. After the one-hour training session, the users were asked to complete these seven tasks. Details of the tasks are provided in Table 1.

The System Usability Scale (SUS) was administered to the study participants after the training session to assess their level of comfort or difficulty in performing the stated tasks. The SUS was developed by Brooke in 1986 as a tool for usability testing and has been used extensively in evaluating user acceptance of systems including websites, telephones, and electronic applications.[37] Prior studies have shown that the SUS yields the most reliable results across sample sizes, and provides a good and valid method of assessing interface usability.[38] The optimum number of participants for in-depth interviews typically ranges from 6 to 10 people with similar backgrounds who participate in the interview for one to two hours; however, interview times may vary.[39] Prior literature has suggested that samples of 6 to 10 participants are large enough to gain a variety of perspectives, yet small enough not to become disorderly or fragmented.[40] Vast amounts of usability problems and issues can be identified with only a small number of test subjects, as few as 8 to 10 participants.[41] Usability scores were recorded for the 10 study participants.

Variables Description

Socio demographics: Information regarding the age (years), gender, and level of education of the participants was recorded.

Familiarity with the use of computer systems: Information regarding the ease of use of computers, use of the Internet, and prior use of electronic data capturing systems was recorded.

System Usability Scale (SUS): The SUS assesses the participants' ease of use and satisfaction with the interactive surveillance system. The SUS is a 10-item questionnaire with five response options that range from strong agreement to strong disagreement. Possible scores are 0, 1, 2, 3, or 4 for each question. The questions elucidate the complexity, functioning, ease of use, self-efficacy, and difficulty level associated with operating the system from the user's perspective. To minimize bias based on agreement or disagreement, odd-numbered items of the SUS questionnaire are given more points for strong agreement, and even-numbered items are given more points for strong disagreement. The total score is calculated by adding up the converted responses for each user and multiplying that total by 2.5. This calculation makes the range of possible values 0 to 100 instead of 0 to 40. Prior research has shown that average SUS scores in the 90s are exceptional, scores in the 80s are good, scores in the 70s are acceptable, and scores below 70 indicate some usability concerns.[42]

Statistical Analysis

Descriptive analysis was performed using univariate statistics with means and standard deviations reported for the continuous variable, age. The frequency distribution for the categorical variables, including gender, level of education, familiarity with the use of computer systems, and percentage distributions of the various SUS score categories, were also computed. All the analysis was performed using SAS version 9.1.

Results

Sociodemographic Characteristics

The average age of the study participants was 29.6 years (SD = 2.5) and ranged from 22 to 44 years. More than half of the study participants were male (70 percent; $n = 7$); 80 percent ($n = 8$) of the participants were college graduates and 20 percent ($n = 2$) had a postgraduate study

Familiarity with the Use of Computer Systems

Nine participants (90 percent) reported that they were very familiar with the use of computer systems.

System Usability Scale (SUS) Results

The average SUS score for all the participants was 77.8 with a standard deviation of 15.7. The SUS scores ranged from 60 to 100. Two participants had a score of 100, and these scores were followed by scores of 95 ($n = 1$), 85 ($n = 1$), 70 ($n = 2$), 67.5 ($n = 1$), 65 ($n = 2$), and 60 ($n = 1$). SUS scores were classified into four major categories: exceptional (scores in the 90s or above), good (scores in the 80s), acceptable (scores in the 70s), and minor usability issues (scores below 70) (Figure 10). On the basis of this classification, 30 percent ($n = 3$) of the study participants had exceptional usability scores and 20 percent ($n = 2$) showed acceptable scores, while 10 percent ($n = 1$) had a good score (Figure 10).[43]

Additional analysis was performed to compare the differences in sociodemographic characteristics and familiarity with the use of computers among individuals who found the interactive surveillance system acceptable and those who did not. The results showed that the participants who were above 30 years of age, had a postgraduate study, and were somewhat familiar with prior use of computers had SUS scores that were in the acceptable range (greater than or equal to 70) (Table 3). Individuals younger than 30 years of age were more likely to report minor usability issues (SUS score less than 70) (Table 3).

Discussion

Results of this pilot study reflect high acceptability of the use of electronic data capture systems in Nigeria. Nine participants (90 percent) reported prior familiarity with the use of computers. The majority of the participants found the system easy to use (90 percent, n = 9), and all the participants reported confidence in using the system (100 percent, n = 10). Individuals had limited difficulties in using the system. Only one individual found the system cumbersome to use.

This surveillance system will address several limitations of the traditional paper-based methods of data collection, including record duplication, storage costs, and the difficulty of record retrieval.[44] The synchronization function of the interactive surveillance system limits data duplication. The surveillance system will also facilitate quick and efficient patient record retrieval as compared to time-consuming paper-based methods. Studies that analyzed the cost-effectiveness of electronic data collection methods over paper-based methods showed a 55 percent cost savings for electronic systems.[45] The surveillance system is interactive and easy to use, which may facilitate its adoption among users with limited computer experience. The surveillance system functions as a stand-alone system to enable real-time electronic data collection and stores the data in an encrypted format.

This study has several limitations. First, the study was cross-sectional in design and would need more long-term evaluation to identify the difficulties that the users might encounter during the use of the system. The system would need further evaluation with users having limited or no prior use of computers. To the best of our knowledge, this system is the first electronic disease surveillance system deployed for use in Nigeria on a research platform to monitor the burden of disease. The results of this usability testing showed great prospects for future deployment of the surveillance system across other locations. The high acceptability of the system in the study implies that usability errors, which often hinder adoption of such technology, are negligible in this case.

Electronic data collection systems require constant electricity supply, which is a limiting factor in Nigeria due to poor power generation.[46] However, some other factors that need to be taken into consideration during the deployment of electronic surveillance systems in resource-poor environments include cultural perceptions regarding the use of the system, given the ethnic and cultural diversity of the country. The study participants also expressed concerns regarding the timeliness in completing the patient records given the large volume of patients being seen at the same time.

Conclusion

The current usability study describes the design and development of a stand-alone and Internet-enabled interactive surveillance system that aimed to monitor the burden of acute bacterial infections among children aged less than five years in Nigeria. The study emphasizes the significance of usability evaluation of the health information systems among the actual users so that any challenges identified can be appropriately addressed before the final deployment of the system. Identifying such challenges is key to successful adoption of health technologies, especially in developing countries where users might have limited computer familiarity. Use of electronic data collection can help to improve quality of data collection, which will facilitate informed, evidence-based, and data-driven decision making.

The interactive surveillance system designed for use in data collection will potentially facilitate data completeness, improve data quality, foster timeliness in data entry, and support data validation and rapid synchronization. The successful implementation and utilization of the interactive surveillance system will aid in providing relevant statistics regarding the burden and determinants of acute bacterial infections across various geographical locations in Nigeria. It will also foster the identification of regions where disease is endemic and further guide the development of appropriate intervention strategies and their long-term outcome evaluation. The high usability acceptance of the surveillance system observed in this study will also facilitate its rapid adoption for use in the collection of data on other related health conditions across other Nigerian states and resource-poor countries. A long-term evaluation of the system is ongoing to gauge any challenges that users might encounter during its long-term utilization.

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Notes

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Figure 1

Map of Nigeria Showing the Location of the Study Sites

Zone 3: Northern Nigeria
Study site: Aminu Kano University teaching hospital, Kano state

Zone 2: Central Nigeria
Study site: University of Abuja teaching hospital, Abuja

Zone 1: Southwestern Nigeria
Study site: University College Hospital, Ibadan, where the usability study was conducted

Figure 2

Data Flow for the Internet-enabled Interactive Surveillance System

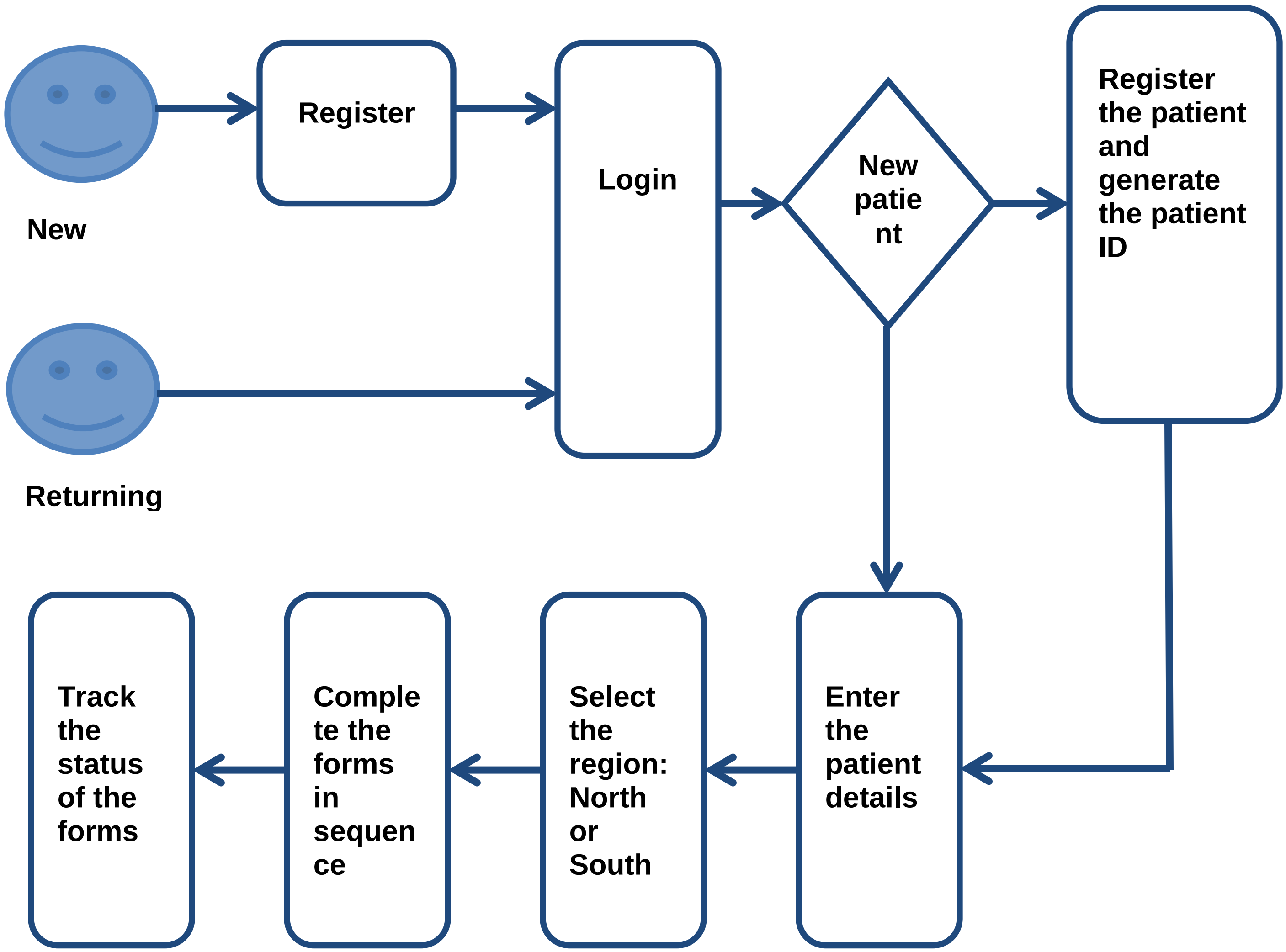

Figure 3

Data Flow for the Stand-alone Desktop-enabled Interactive Surveillance System

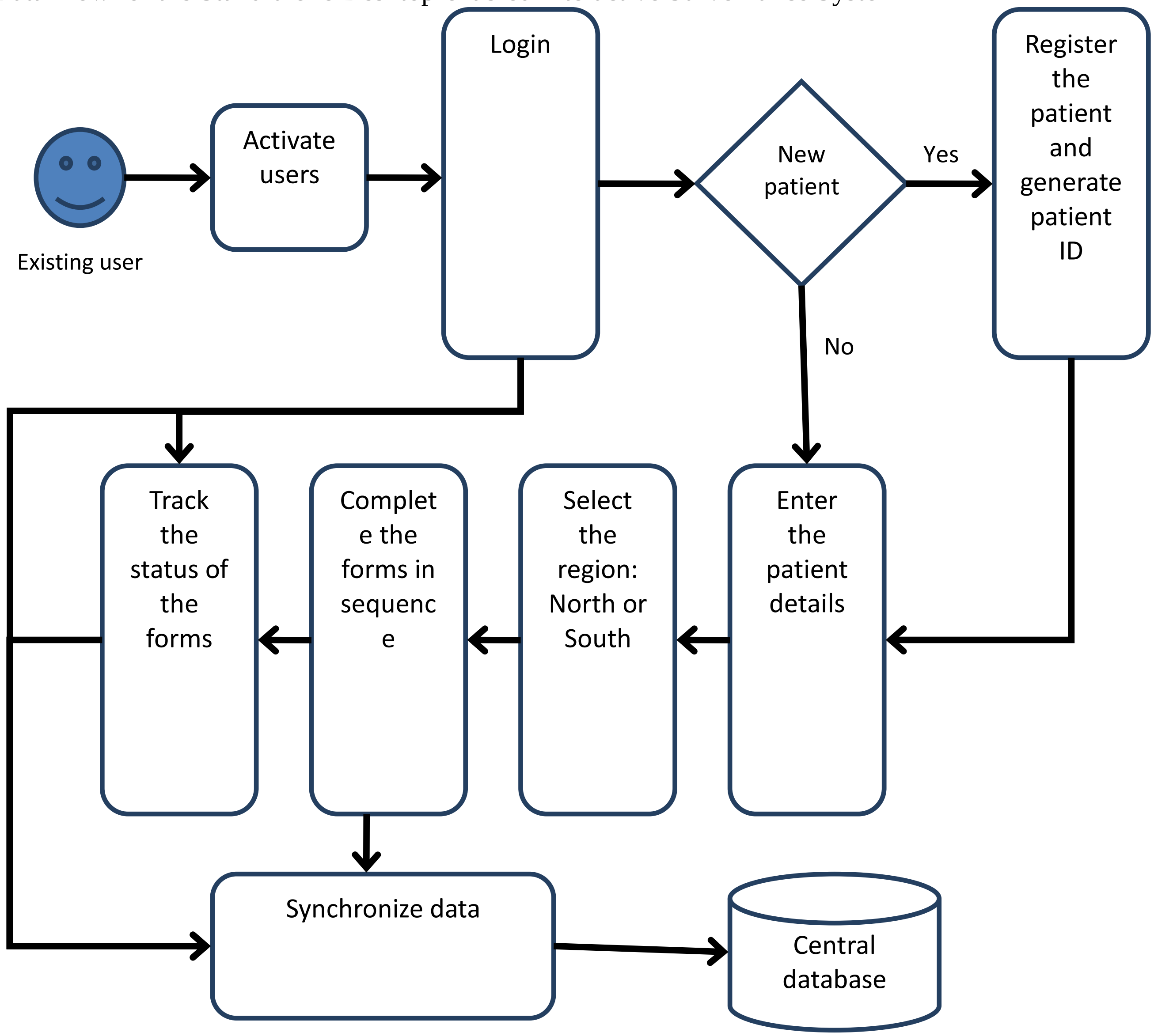

Figure 4

User Registration

Figure 5

Patient Registration

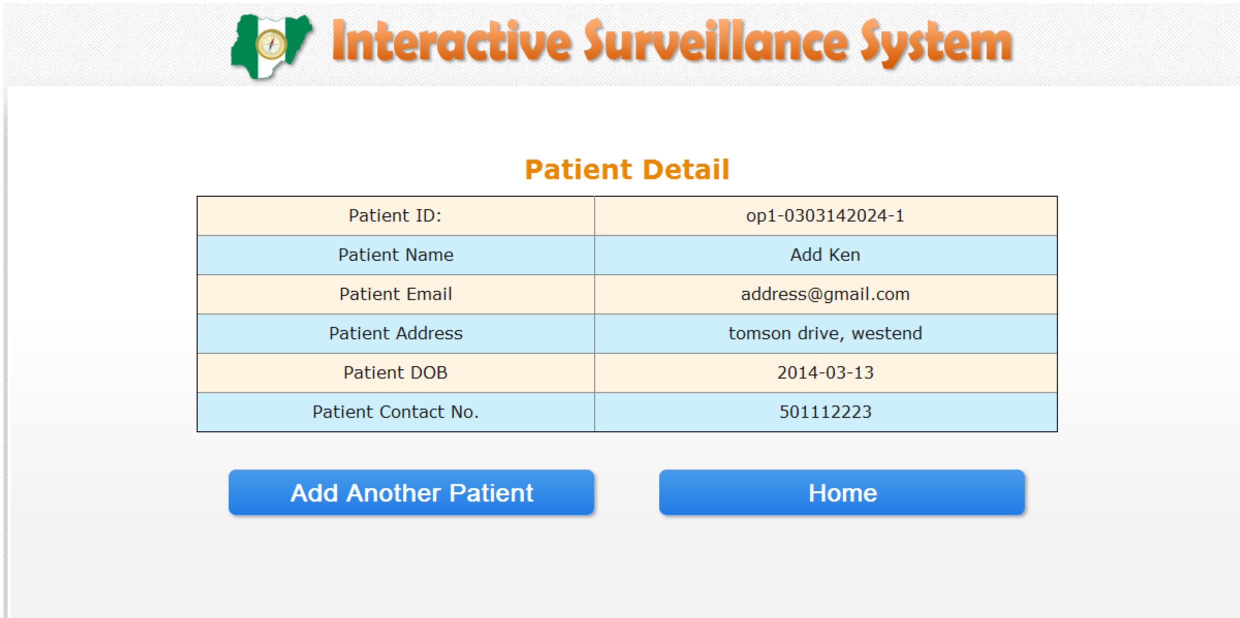

Figure 6

Data Entry Forms (Highlighted)

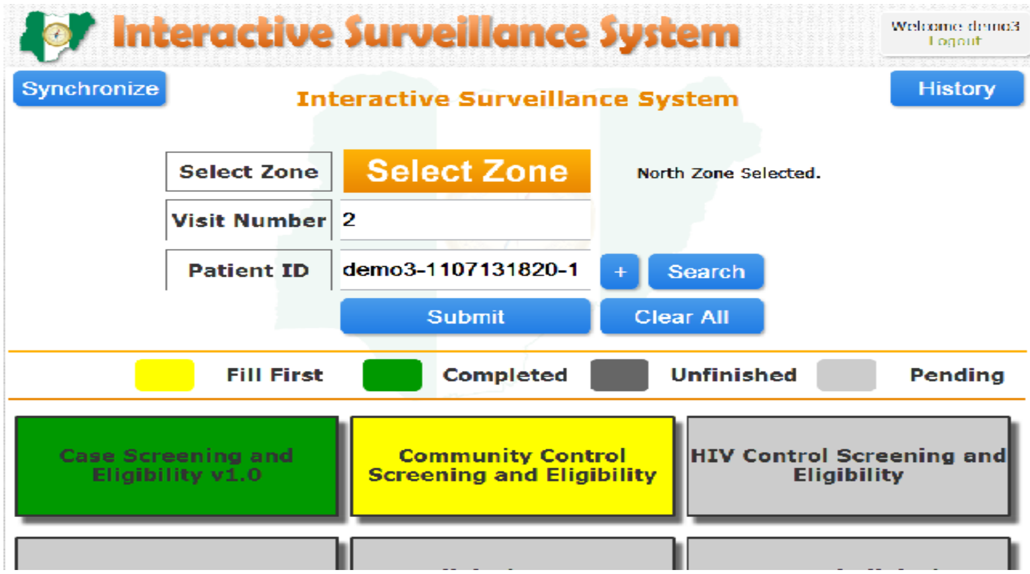

Figure 7

Viewing Existing Patient Records

COPH3-1107131753-3	ABC	DEF	demo@email.com	1
				0
operator3-1107131711-2	Example	kumar	demo@email.com	12345
COPH3-1107132153-3	john	smith		2323
op1-1207132019-4	A	B	ab@email.com	12
op9-1207132029-5	C	D	a@email.com	213123
op6-1207132034-1	G	H	t@tmail.com	1213
op2-1207132050-1	CG	Smith	f@gmail.com	212312
op1-1207132255-1	cynthia	beth	cy@unmc.edu	4234
op7-1207132127-2	ada	k	dat@unmc.edu	3422
op15-1207132144-1	dan	t	c@uuu.edu	32111
cophuser-2907132222-3	jane	smith	email@mail.com	2342
abc-0208132159-4	nancy	smith	email@email.com	2332222
admin-2310130025-5	chioma		ggdfgsdfasd	56353422
op1-0303142024-1	Add	Ken	address@gmail.com	501112223
Patient ID	First Name	Last Name	Email	Phone

Figure 8

Data Entry

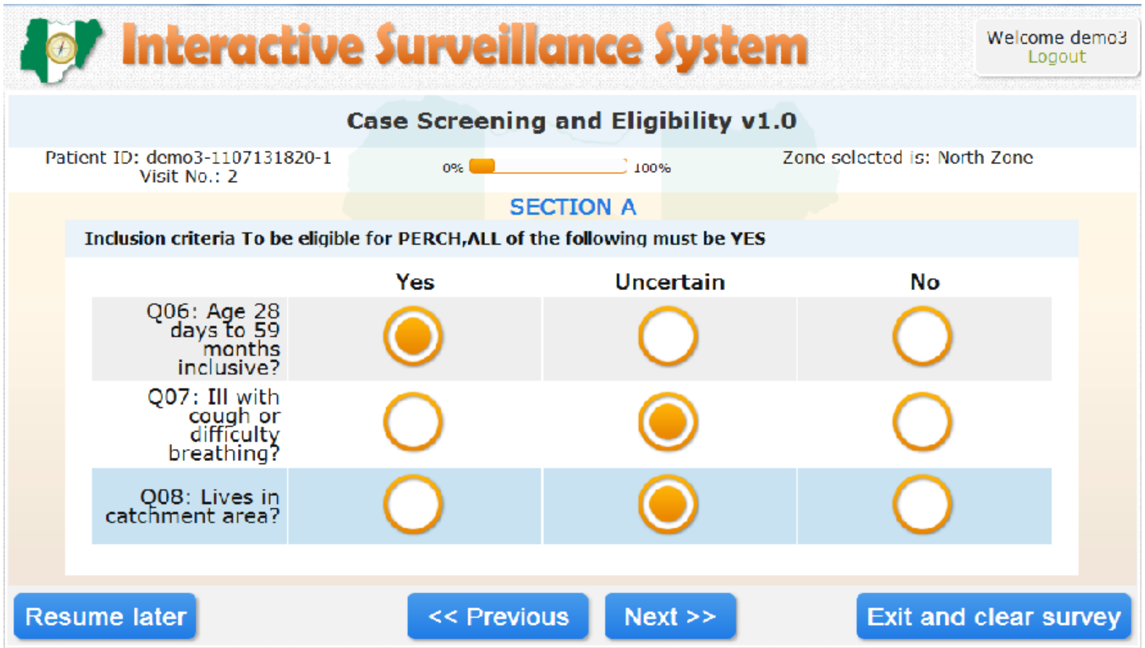

Figure 9

Data Synchronization Process

Figure 10

Percent Distribution of Individuals in the Four System Usability Scale (SUS) Score Categories

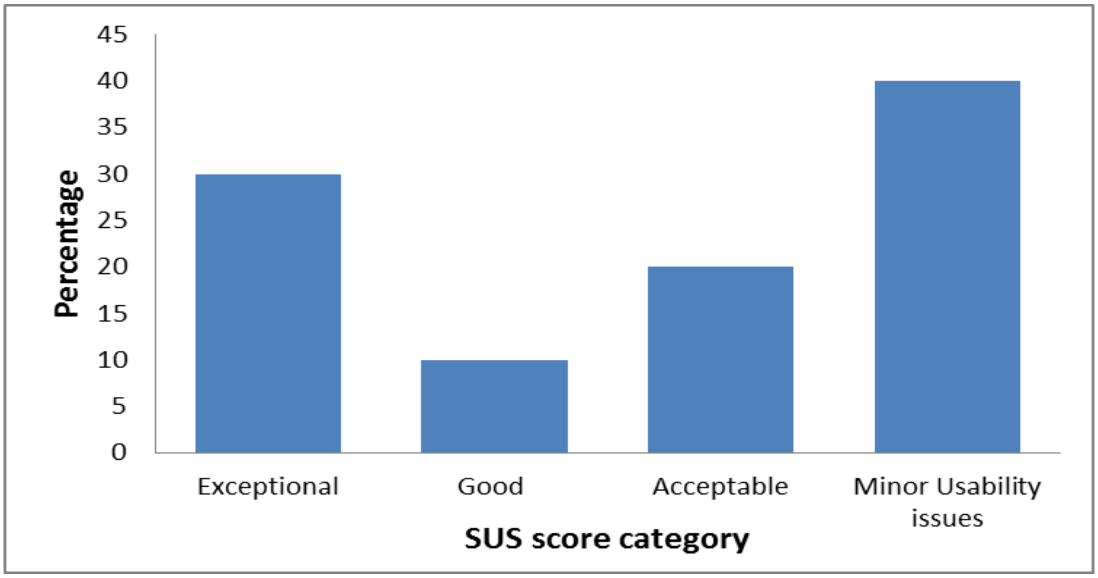

Table 1

Usability Tasks Assigned to Study Participants

Number	**Task**	**Description**
1	Registering new users	The new user is required to enter a username, password, full name, and e-mail address and click on "Register," as shown in Figure 4. Completion of this registration process sends an automated request to the administrator, and the user is expected to wait for approval before proceeding to the next step.
2	Logging into the system	Upon approval by the administrator, the user is able to log into the stand-alone system. Logging into the system requires entering the approved username and password and clicking on "Enter."
3	Registering patients	This is the first step in data collection. The user is expected to enter five major patient details: the patient's name, date of birth, e-mail address, home address, and phone number (Figure 3). These details are utilized by the system in generating a unique identifier for each patient record entered. The user may still proceed with registering a patient in the event that one or more of the required details are missing. However, one or more fields needs to be filled for a patient ID to be generated.
4	Viewing records	This task involves retrieving an existing patient record that was previously incomplete. To do this, the user searches for the record using the "Search" key and identifying the record based on the patient ID number or names displayed in the record list (Figure 7).
5	Navigating through the system	This task involves successively moving through all the steps required to fill a patient record. These steps include registering a new user (task 1 above), logging into the system (task 2), registering patients (task 3), viewing records (task 4), and performing data entry (task 6).
6	Performing data entry	This task involves entering the patient data corresponding to each of the 36 surveys for acute bacterial infections contained in the system (Figure 8). The user is required to complete each survey with the information obtained from interviewing the patient.
7	Synchronizing the entered records	This task involves using the data synchronization feature upon completion of patient records. This function facilitates the transfer of patient data to a central database repository.

Table 2

Frequency Distribution of the Responses to the System Usability Scale (SUS) Variables

Variables	**Frequency of Response Options (%)**				
	1 Strongly Disagree	**2 Disagree**	**3 Neutral**	**4 Agree**	**5 Strongly Agree**
I think I would use the system frequently				60	40
I did not find the system unnecessarily complex	40	40		10	
I thought the system was easy to use		10		40	50
I think that I do not need technical support in using it	50	10	20	20	
I found the functions well integrated		10		40	50
I did not think there was too much inconsistency	40	30	10		20
I imagine most people find it easy to use quickly	10			40	50
I did not find the system very cumbersome to use	40	50		10	
I felt very confident using the system				40	60
I do not need to learn a lot of things before going on with the system	50	20	10	20	

Table 3

Comparison of Variables between Individuals with Acceptable System Usability Scale (SUS) Scores and Individuals with Minor Usability Issues

Variables	Frequency Distribution, % (n)	Acceptable		p-value
		Yes SUS Scores 70 or higher, % (n)	No SUS Score less than 70, % (n)	
Age Group				
Less than 30	50% (5)	17% (1)	100% (4)	0.03
Greater than or Equal to 30	50% (5)	83% (5)		
Gender				
Male	70% (7)	50% (3)	100% (4)	0.20
Female	30% (3)	50% (3)		
Current Education level				
Some College	10% (1)		25% (1)	0.67
College graduate	70% (7)	83% (5)	50% (2)	
Post Graduate study	20% (2)	17% (1)	25% (1)	
Familiarity with use of computers				
Somewhat familiar	10% (1)		25% (1)	0.40
Very familiar	90% (9)	100% (6)	75% (3)	