Published by
NIGERIAN SOCIETY OF PHYSICAL SCIENCES
Available online @ https://asr.nsps.org.ng/index.php/asr

African Scientific Reports 2 (2023) 130

African Scientific Reports

Deploying persuasive technology-based model in the prevention and control of malaria in Nigeria to reduce incidence of deaths

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Abstract

Specifically among pregnant women and young children under the age of five, malaria is one of the major causes of illnesses and fatalities in Nigeria, and in Africa in general. According to recent research, malaria-related deaths (MRDs) have risen even though the government has implemented numerous intervention strategies to combat this deadly among Nigerians. This is a result of people not using such intervention methods to protect themselves. Further research into why people don't comply with intervention systems effectively revealed that the interventions are passive, and sometimes complicated to adopt. Consequently, we established three quantifiable research outcomes that will allow us to assess if persuasive technology is appropriate for eradicating malaria-related deaths. We utilize participatory system design (PSD) and User-Centered methods to collect data from research. The participants provided answers to well-designed questionnaires that were used to gather information to analyze the impact of persuasive technology on the prevention and control of malaria-related deaths. The modeling of the intervention system uses the information gathered from the research survey. The Malaria Prevention and Control Support System (MPCSS), an intervention system, was developed and deployed as part of the research in three phases, and its effectiveness was assessed by an evaluation study. The study revealed that applying the suggested persuading technology-based methodology boosted ownership of mosquito nets, involvement in malaria prevention and control activities, and understanding of the risk of malaria-related mortality.

DOI:10.46481/asr.2023.2.3.130

Keywords: Persuasive technology, Malaria prevention and control support system (MPCSS), Active intervention tool, Mosquitoes, Malaria related deaths (MRDs)

Article History :
Received: 09 June 2023
Received in revised form: 31 July 2023
Accepted for publication: 08 August 2023
Published: 16 December 2023

Communicated by: Tolulope Latunde

1. Introduction

Malaria is one of the leading causes of illness and death, especially among children and pregnant women in Africa and particularly in Nigeria. The third Sustainable Development Goal (SDG) of the United Nations (UN) aims to ensure healthy lifestyles and promote well-being for all people of all ages, and the Target of 3.3 million calls for the eradication of hepatitis, water-borne diseases, and other infectious diseases by 2030. The WHO report of 2020 noted that out of 229 million global malaria cases in 87 malaria-endemic

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countries, Africa region recorded 215 million cases which represented 94% of the overall estimated global cases with Nigeria topping the list of African malaria-endemic countries with an estimated cases of 23% [1, 2].

To curtail the scourge of malaria incidences, the World Health Organization (WHO) recommended that children and pregnant mothers living in malaria-endemic regions must sleep under Mosquito Treated Bed-net (ITN) [3]. The Federal Government of Nigeria launched several malaria intervention programs in response to the WHO's recommendations, including the Roll-Back Malaria (RBM) program, the free distribution of insecticide-treated nets (ITNs), the distribution of free/subsidized Artemisinin Combination Therapy (ACT) drugs, the launch of the Strategic Plan for Nigeria Against Malaria (NMSP), the National Malaria Eradication Programme (NMEP), and the introduction of monthly environmental clean-ups [4].

However, despite these initiatives by the concerned authority, malaria-related deaths (MRDs) have continued to escalate [2].

The escalation was caused by the ineffectiveness of the interventions provided for the eradication of malaria due to their passive nature. Therefore, it is difficult to measure the level of adherence to the interventions by individuals. For instance, if someone is unwell, he follows his medication routine rigorously until the pain subsides. He will either discontinue the medications or begin to miss the scheduled treatment. However, if someone is actively watching him, he will complete the remaining regimen as advised by a healthcare professional.

Moreover, a recent study by Ogbaga & Ugah [5] observed that the difficulty in controlling malaria in Africa is due to constant changes in mosquito genetic makeup, which provides the malaria parasite the ability to fight malaria medications, implying that prevention is much more important than cure since the cure is no longer guaranteed.

Based on these findings, there is a need for the government to incorporate active stimulation, monitoring, and reporting mechanisms into malaria eradication and prevention intervention programs to track their progress and level of acceptance by the intended audience. Furthermore, given that human effort has not delivered the expected results, there is a need for technology adoption to provide a solution to this public health issue.

The most popular technology-based approach to malaria prevention and other behavioral changes is persuasive technology. Persuasive technology (PT) employs appropriate Persuasive Strategies (PS) to stimulate the desired behavior in the target audience, as PT has been used to motivate desirable behaviors in other domains such as health and wellness, sustainable environment, dietary, fitness, etc. [6, 7]. A computer system, device, or program that is specifically created to change the attitudes of an individual or group of individuals in a preset way without coercion or fraud is referred to as persuasive technology [8]. The question of how technology might be adapted to encourage behavior change has piqued the curiosity of researchers and business people [9]. Technology can never be neutral because through 'its consistent use, the user's attitude is influenced incrementally [8].

Several research interventions have been developed using persuasive technologies in different areas of human endeavors. These researches are focused mainly on solving social, economic, health, and educational problems. For instance, Widyasari *et al*. [10] implemented persuasive technology to create more engaging and effective learning experiences for students. This has in turn motivated the interest of researchers to determine how the technology can as well be deployed to personalize learning and provide real-time feedback to students.

The use of persuasive technology to influence social change has also become an important research domain. Gram-Hansen *et al*. [11] in their recent study developed technology to raise awareness on important social issues, encourage people to get involved in their communities, and promote civic engagement within a given environment. As noted by Ogbaga [12] persuasive technology is a proactive technology rather than active because it has the potential of stopping crime before it is committed.

Recent studies have implemented mechanisms to encourage people to eat healthier [13, 14]. The studies designed and implemented a mobile app that provides users with personalized feedback on their eating habits and offers suggestions for healthy recipes and meal plans. In the same vein, some other studies investigated persuasive technology methods to improve students' academic performance [15, 16]. The studies provide students with personalized tutoring and assist them in staying on track with their coursework.

Research has further proved that mobile phone reminders, phone calls, and social media notifications can be used to motivate people to perform expected actions because mobile phone use is very prevalent among low-middle-income communities and any technology implemented through it will undoubtedly enjoy a high level of acceptance, provided it is sufficiently tailored to the target audience usage capacities [2, 6].

The game teaches players how to resist peer pressure (social influence) and steer clear of alcohol consumption, among other health treatments, according to Schinke *et al*. [17]. Personalization was used to make the game character reflect the target audience's age, gender, and demographics. In the game, players see the simulated effects of their alcohol-related choices. To reinforce their behavior, players received rewards. Another research by Ogbaga *et al.* [9] was on determining the factors discouraging people from engaging in malaria preventive behaviors by using/adopting some intervention systems such as sleeping under mosquitoes' nets, fumigating their environments with chemicals, and net-proofing their doors and windows provided by the government. The research observed that lack of tailoring, awareness, users' participation in the programme design, and lack of technology-driven are some of the discouraging factors.

Finally, Thinking Not Drinking is another health intervention system developed by Widyasari *et al*. [10]. It is a persuasive strategy for preventing harmful alcohol use that is based on video games. To encourage behavior change, Thinking Not Drinking uses goal-setting, suggestion, personalization, simulation, incentive, and social comparison. Goal-setting is the first step in every game session. A player must complete skill-specific objectives before moving on. The game instructs players on how to resist peer pressure and

other forms of social influence. However, this study is different from the existing systems on health-based intervention systems because none of the interventions dwelt on malaria control. Secondly, none of the existing malaria control interventions adopted the use of persuasive technology through mobile phone technology which is a common technology among the target audience. Finally, the existing malaria control interventions did not adopt tailoring to suit users' peculiar needs rather, they adopted a one-size-fits-all design. These are the contributions of this work to research.

2. Materials and method

2.1. Research method

The study used several triangulation techniques, often known as methodological approaches. Persuasive System Design (PSD) model, survey, and object-oriented analysis and design methodology are the techniques used. To examine an existing system, identify problem areas, and develop a better system for the future, it was decided to combine these hybridized methodologies. To find out more about the variables influencing healthy behaviors concerning malaria prevention and control, semi-structured survey questions were also used. A few expectant mothers and nursing mothers from three local government regions were identified as the targeted population using a practical sampling technique. Participants were given the study tool both online and offline. The study also asked about the advantages, obstacles, and repercussions of ignoring healthy behaviors, as well as societal and cultural barriers to the adoption of effective malaria prevention and control strategies, as well as fundamental knowledge of mobile technology and its applicability. The sample questions can be found at https://asr.nsps.org.ng/files/supplementary/130.pdf.

2.2. Study setting

Ebonyi State was the site of this study. A state in the South-East of Nigeria, Ebonyi State is made up of 13 local government units (LGAs) that are split into three senatorial zones. The state's three-tiered healthcare delivery structure places primary healthcare at the bottom and secondary and tertiary care above it. In each of these three senatorial zones, there are three towns (Abakaliki, Onueke, and Afikpo). Three inclusion criteria were used to select three local government areas (LGAs) at random from each senatorial zone for the study: proximity to a river, number of malaria-related deaths, and availability of mobile phone network service.

2.3. Study design

This research was conducted in 3 main stages and the methodology adopted at each stage is as follows:

1. Pre-evaluation stage to obtain our measurable outcome: The baseline study was carried out through the administration of questionnaires to the participants. This enabled us to gain insight into the knowledge level of our participants on malaria prevention and control.
2. Development and deployment stage: Findings made from the pre-evaluation stage were used in developing our intervention system. Before developing the intervention system, users were engaged in the design process. This is to avoid a one-size-fits-all design. The intervention was tailored to take care of individual peculiarities in terms of persuasive factors. The intervention system was deployed on the participants for a months.
3. Post-evaluation stage was used to evaluate the performances of the developed intervention system in line with the measurable outcomes of the research. Another questionnaire was developed and administered to the participants after three months of using our intervention system. This enabled us to determine if the intervention system had an impact on the lives of the users.

3. Data collection and analysis

Between August 2021 and September 2022, this study was carried out in a variety of settings, including houses, town squares, schools, and medical facilities. Participants ranged in age from 18 to 69 years old. We outline the participants' demographics in Table 1.

3.1. Analysis of the baseline study questionnaire

After being selected and receiving training, the volunteers were given questionnaires to complete. The survey's questions were divided into seven categories, including demographics, malariology, which measured respondents' knowledge of malaria prevention and control methods, and environmental sustainability, which examined respondents' housing choices and maintenance practices. The next portion, titled "Technology Usage Knowledge," was designed to gauge the participants' familiarity with mobile phone technology. In addition, the motivation/action triggers portion was used to elicit the factors that compel people to act. Rewards and gifts, stroking, personalization, and customization were among the motivating attributes. Finally, we had a section where participants were asked to suggest possible technologies that they believe may be used to modify people's unfavorable attitudes/behavior toward malaria prevention and control.

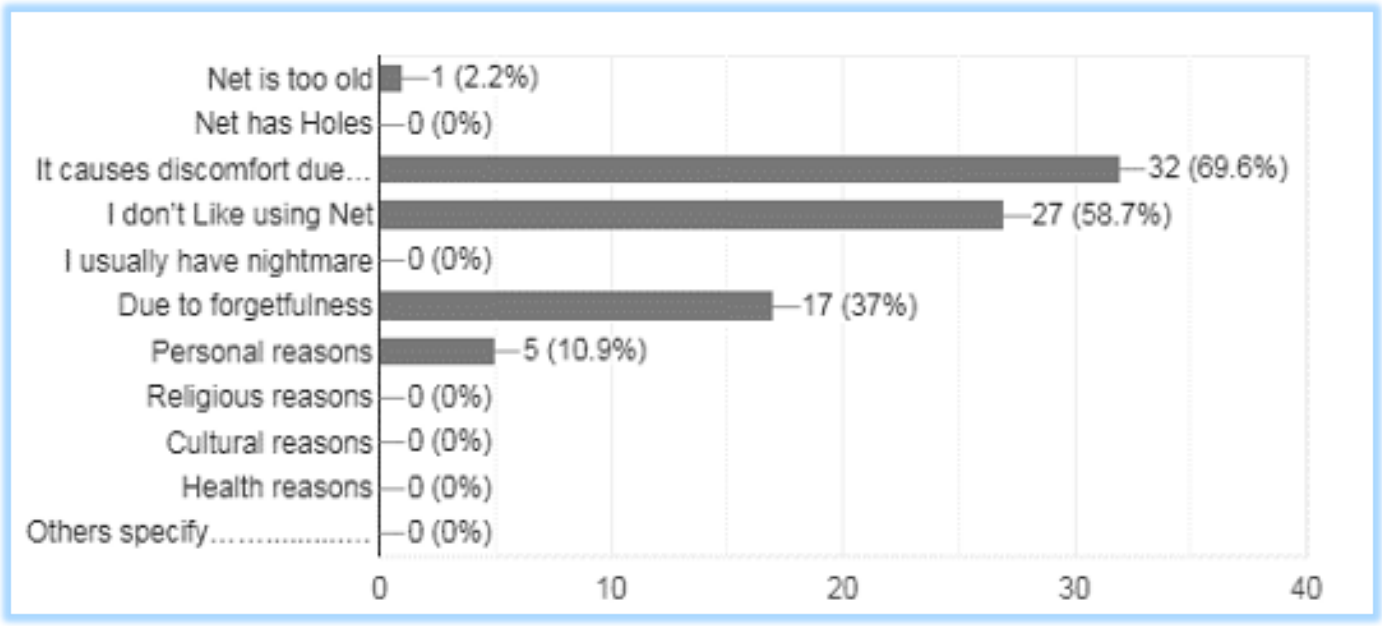

Figure 1. Reasons people avoid using insecticide-treated nets.

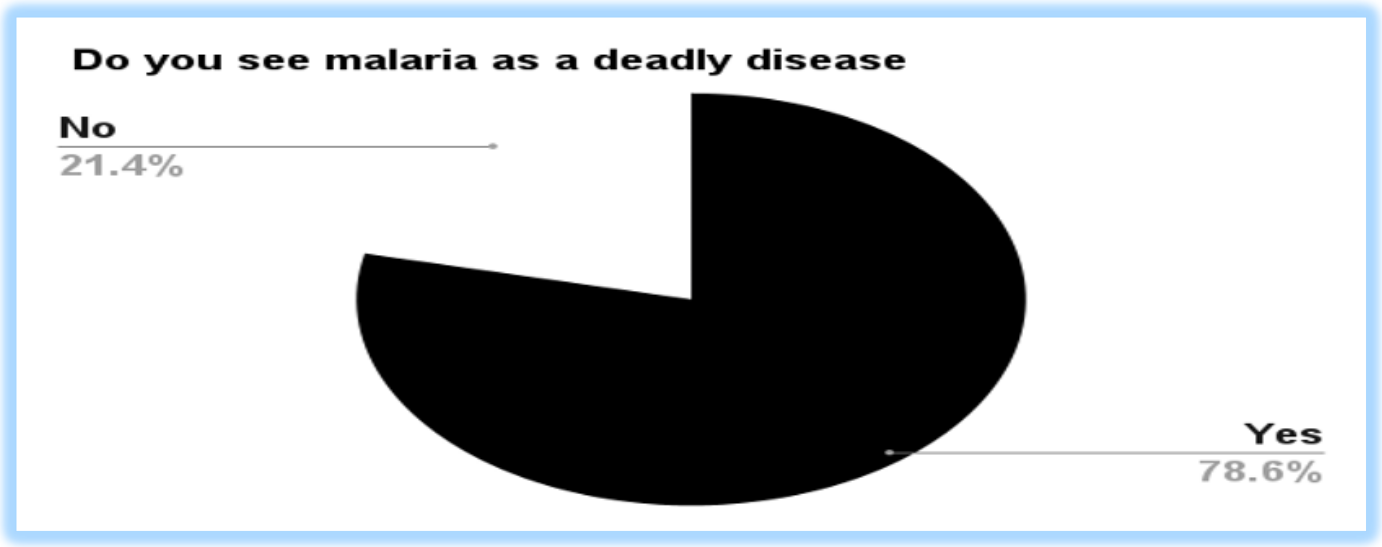

Figure 2. People's perception of malaria.

3.2. Measurable outcomes of the research

1. The study's findings, if put into practice, would boost people's adherence to effective malaria prevention strategies such (as consistently sleeping under an ITN, maintaining a clean environment, use of chemical mosquito repellents such as Sheltox, and net-proofing doors and windows.)
2. The number of persons who become ill from malaria would reduce.
3. Determine whether there is a connection between persuasive technology intervention systems and malaria prevention and control.

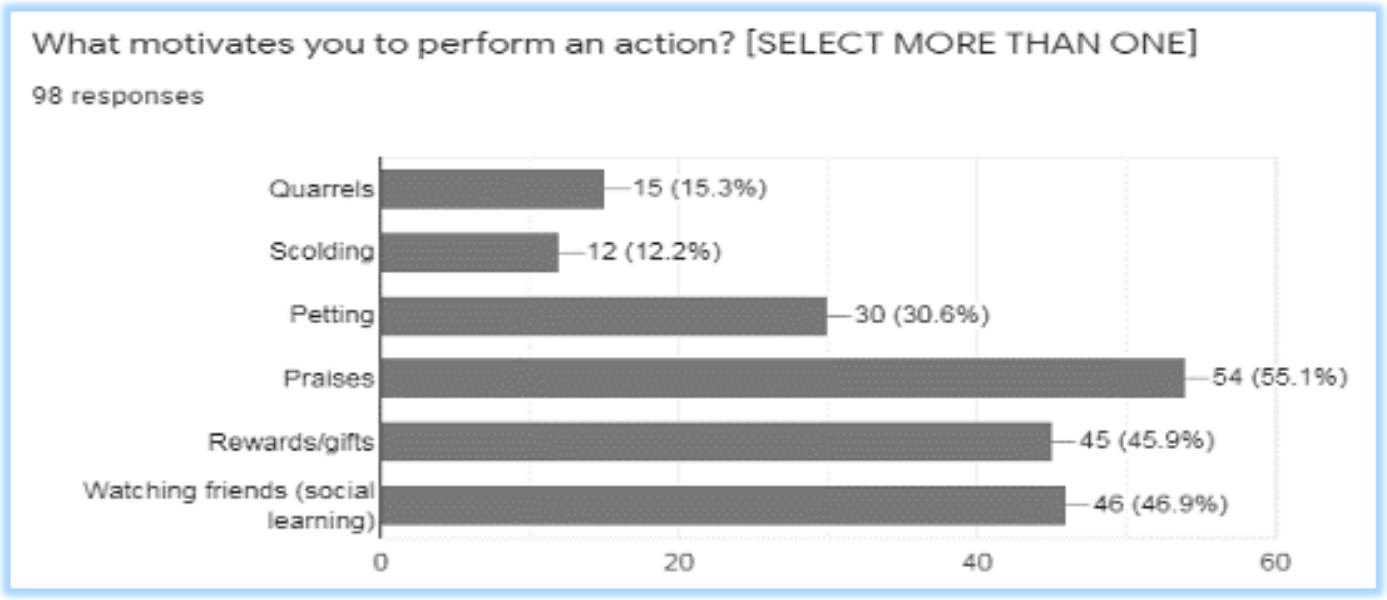

Figure 3. Motivational triggers of the people.

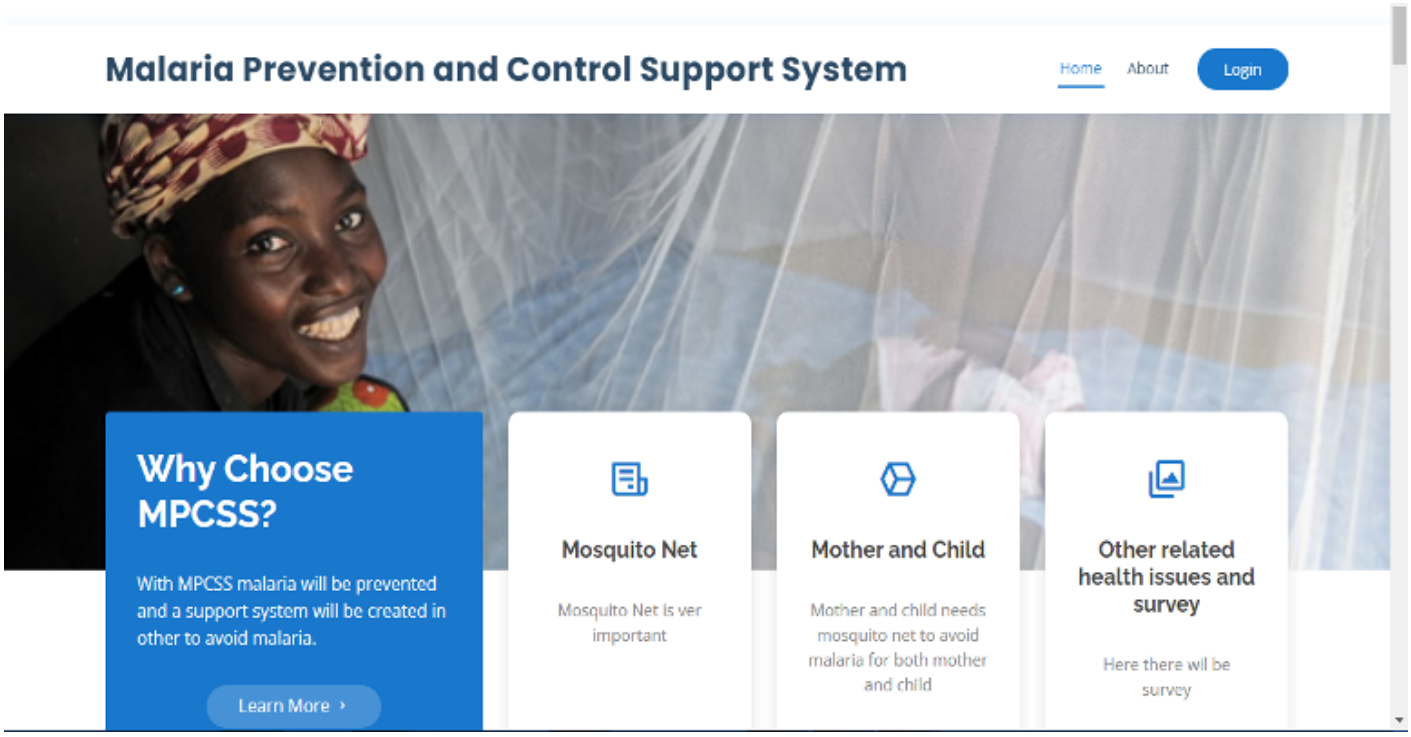

Figure 4. The index page of the MPCSS.

4. Results and discussions

This section discusses the results obtained from the analysis of the survey data collected during the research. Moreover, the section discusses the implications of the research outcomes. The section is subdivided into a baseline study, an evaluation of the proposed persuasive technology-based model, and a discussion of the implications of the results using different measurable outcomes.

Figure 5. Admin panel of the intervention.

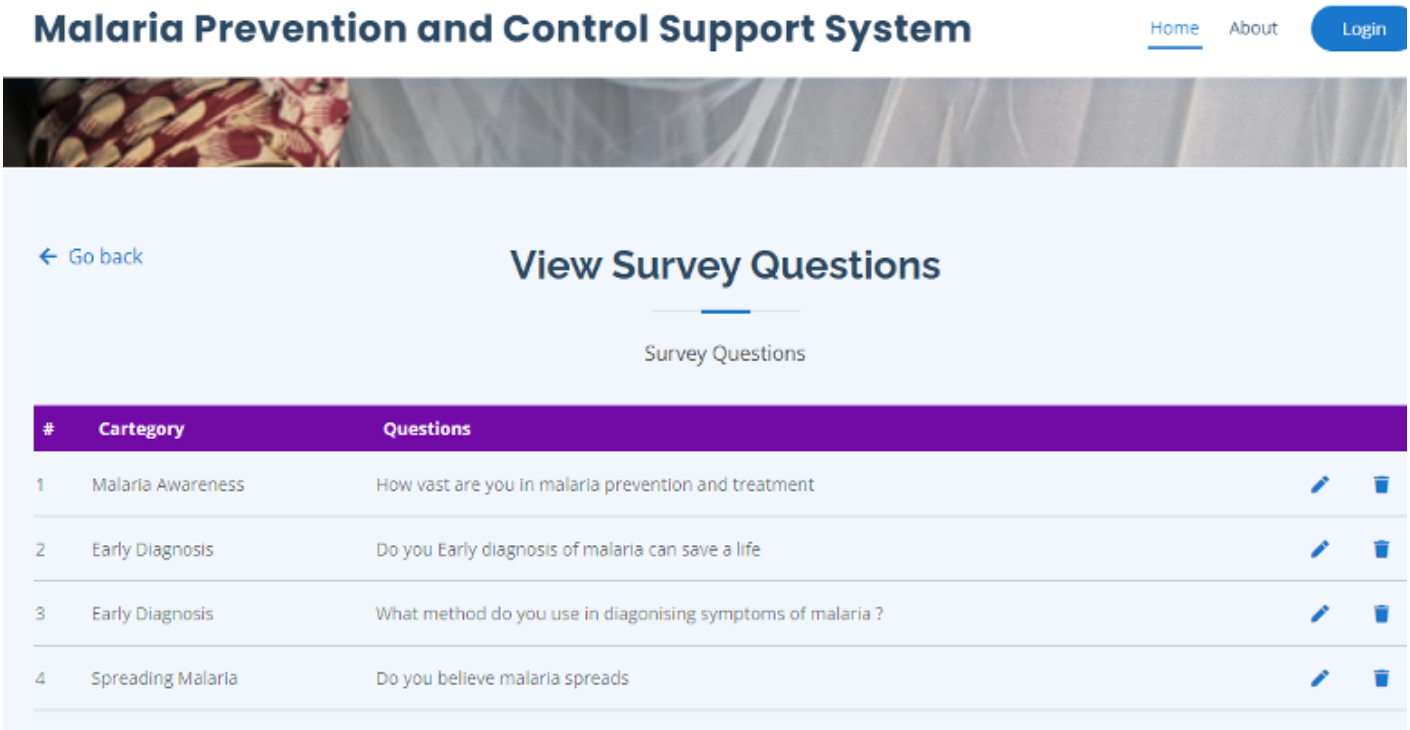

Figure 6. Sample survey question.

4.1. Result of baseline study

This section presents the results of the baseline study. In the baseline study, 98 participants took part in the investigation, however, after the exclusion criteria, the participants were normalized to 76 for parity purposes. The baseline study uncovered that 96.9% of the respondents had been sick with malaria within the time of this research.

1. We also uncovered that 54% of the respondents have ITN and out of the 54%, only 52% of them sleep inside the net.

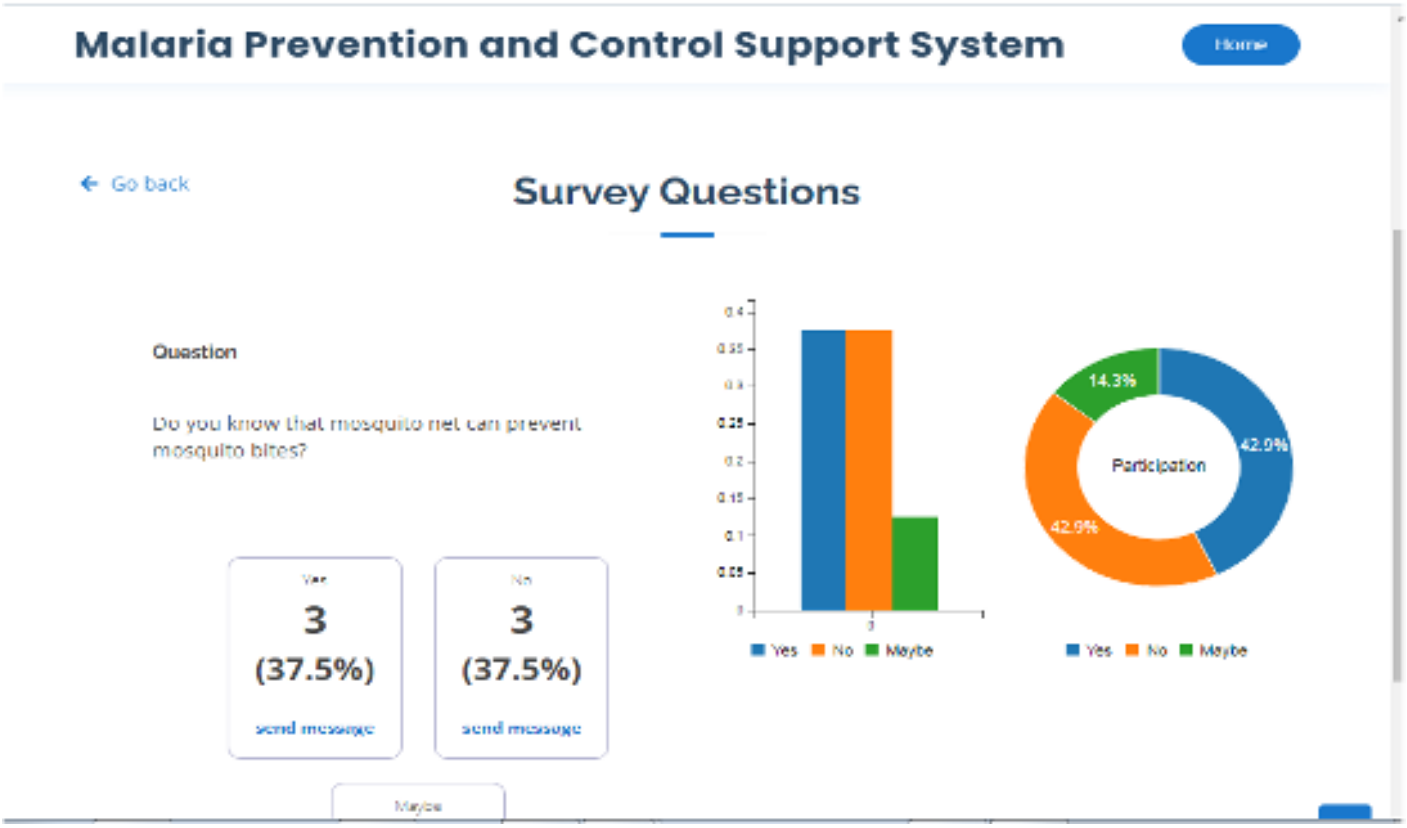

Figure 7. Sample result info-graph of participants' feedback.

Table 1. Participants' demographic detail.

Participants information	Parameters	No. of participants	Total
Pregnancy status			
	Not pregnant	56	97
Age	18-29	40	
	30-40	51	98
Marital Status	Married	80	
	Single	18	
Married with Children	Yes	67	94
	No	27	
Highest Education Level	Primary	0	96
	Secondary	24	
	Tertiary	72	

2. The study also uncovered that 87.5% of the respondents do not have nets on their doors and windows.

Those who do not make use of their ITN have various reasons as presented in Figure 1. The reasons identified for non-adherence to insecticide treatment nets range from forgetfulness, discomfort, and the net being too old to use. Results from the survey showed that discomfort has the highest number of respondents may develop rashes due to the chemical used to treat the net or heat rashes as a result of lack of electricity as experienced daily in Nigeria.

1. Some of the participants believed that malaria is a normal sickness.
2. This opinion was shared by 78.6% of the respondents as depicted in Figure 2.
3. The research was able to ascertain the range of activities that motivate the participants as presented in this chat below with praises and social learning topping as shown in Figure 3. From the survey obtained, praising individuals, and social learning provided needed rewards are the major contributing factors for enabling behavioral changes. Here, 55.1% of the participants noted that showering praises on them enhances their ability to make some behavioral changes as compared to 46.9% of those

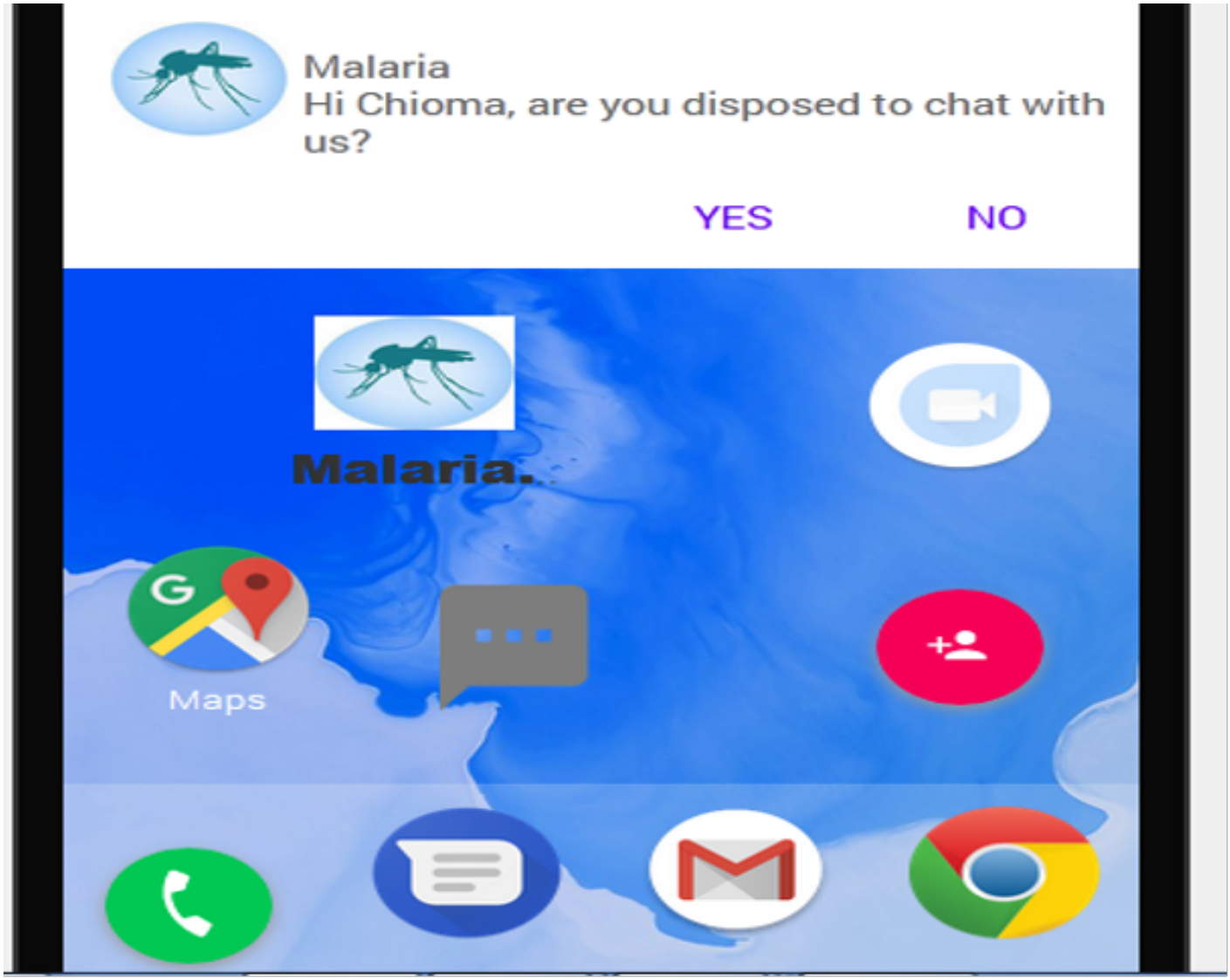

Figure 8. Sample of the persuasive text message received by the participants.

who agreed with social learning and 45.9% who require a reward system. In addition, the results of the analysis showed people hardly make changes to their behavior when scolded.

4.2. Evaluation of the intervention system

Following the baseline, the analytical results were used to inform the design and development of a persuasive technology-based model intervention system termed "*Malaria Prevention and Control Support System*" (MPCSS). The performances of the model were validated with evaluation survey questions, which were distributed across the participating audience recruited during the baseline study. The evaluation was carried out after three months of consistent interactions with the participants. Some specialized message reminders, focused on three major topics: malaria awareness, malaria dangers (severity and susceptibility), and preventative methods. These message reminders were utilized to stimulate/awaken their consciousness to have favorable attitudes regarding malaria prevention practices. A message table was created for this purpose. The assessment of user responses took place in the first week of September 2022. Their responses were examined and compared to the results of the baseline study. Seventy-six (76) participants took part in the evaluation survey. We excluded twenty-two (22) participants from our baseline research respondent database who did not engage in the evaluation. This allowed us to have 76 participants for evaluation analyses. The implemented malaria prevention and control system provided the mechanism to collect data related to Insecticide Treated nets, the effects of malaria on mother and child, and other health-related issues. The system has features that enable researchers and policymakers to automatically collect and analyze survey information related to malaria, the mode of transmission, and various interventions required to minimize its occurrence.

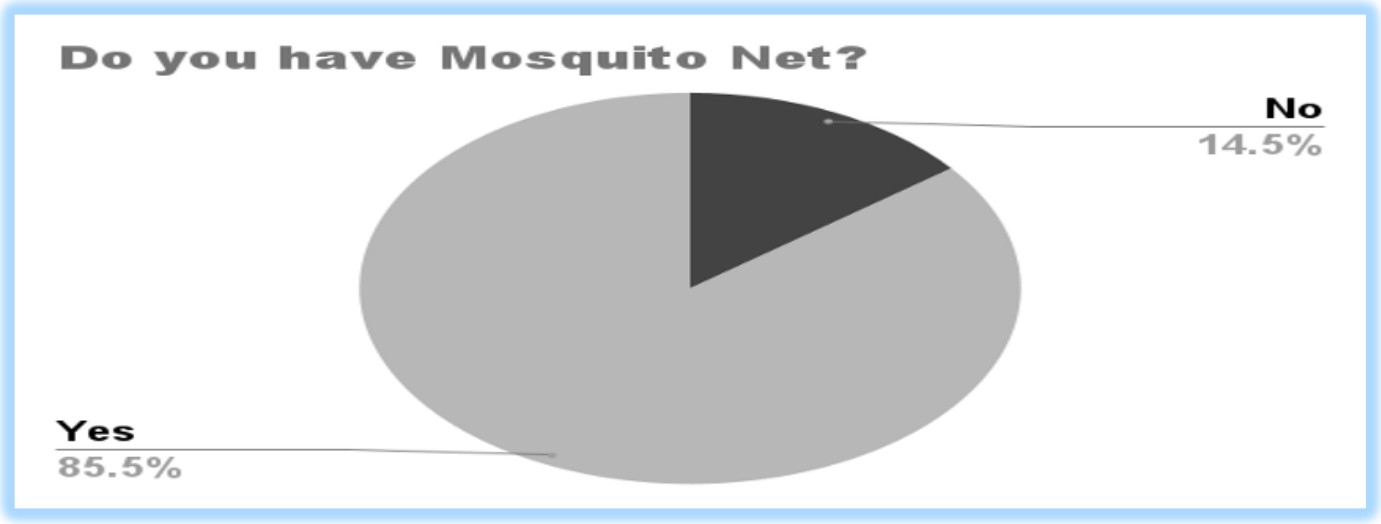

Figure 9. Ownership of mosquitoes' net after deployment of our intervention.

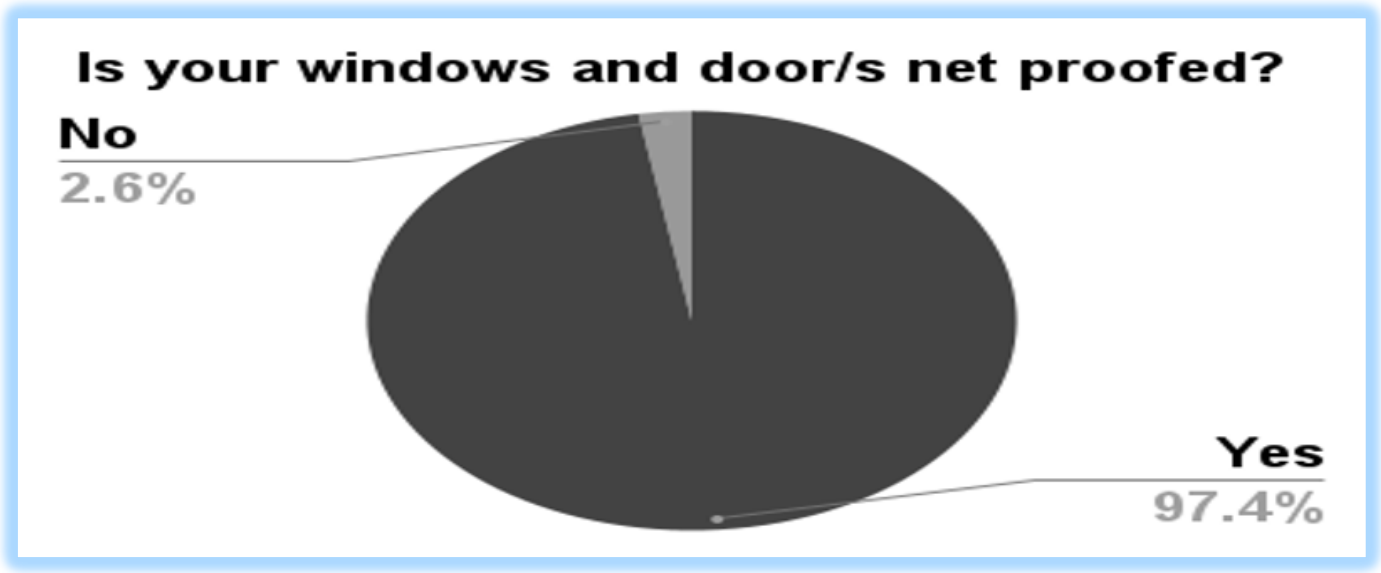

Figure 10. People's perception of malaria after the deployment of our intervention.

Figures 4 and 5 show the home page and system dashboard for system survey collection and analysis. The admin dashboard enables system administrators to perform tasks such as adding sub-admin and managing their login details. In addition, the dashboard enables system administrators to add survey participants and for participants to take survey questions.

he intervention has the following features in the admin panel: survey, analysis, sub-admins, manage sub-admins, add participants, manage participants, and results info-graphs. Figure 6 shows the categories of questions that participants can take during the survey. The survey questions include questions related to malaria awareness, diagnosis, and spreading mechanisms. Moreover, the sample interface for questionnaire analysis is depicted in Figure 7. This interface contains a sample of some of the tailored personalized messages that were sent to the target audience as shown in Figure 8.

After the deployment and analysis of the implemented technology-based intervention strategy, the following results were obtained from participants. The results showed that 68% of the participants fell sick of malaria as against 96.9% that fell sick within the baseline period. The results indicated that the use of persuasive technology greatly increased awareness of the danger of malaria and its mode of transmission. Furthermore, as shown in Figure 9, 85.5% of the participants after the use of persuasive technology adopted the use of insecticide-treated net (ITN) as against 54% recorded in the baseline evaluation results. The increase in the results

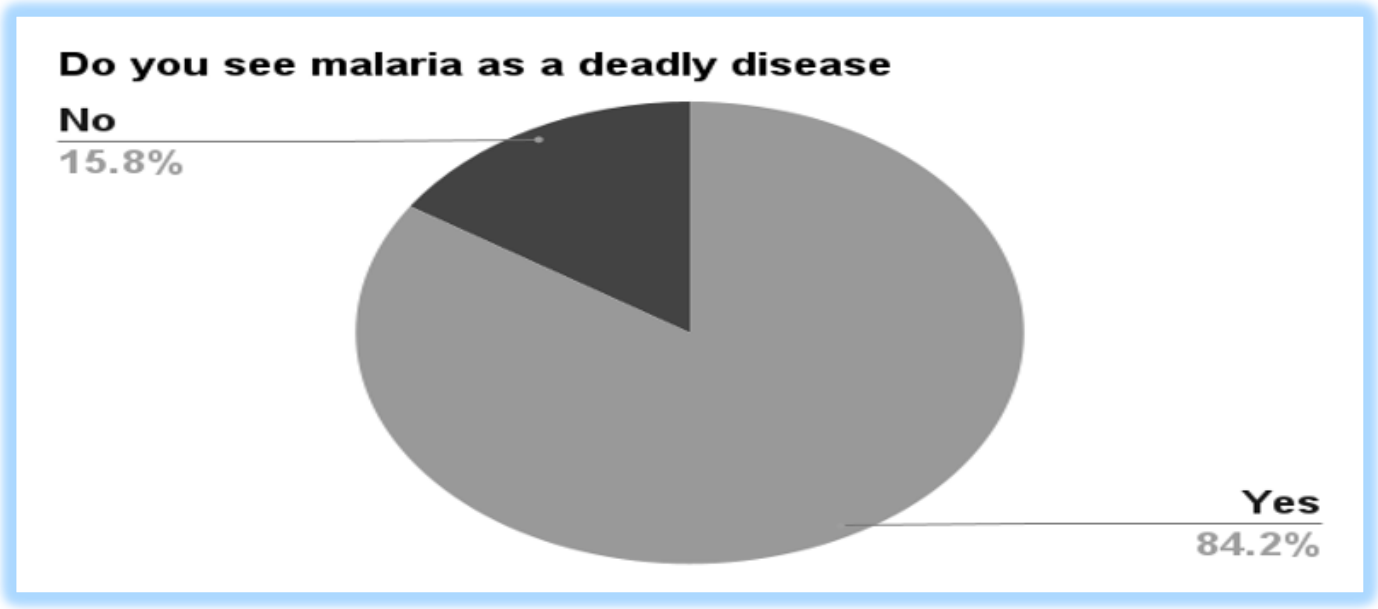

Figure 11. Rate of net-proofing of doors/windows after our intervention deployment.

indicated that the persuasive technology model has the power to appeal to the consciousness of people to use insecticide-treated nets to minimize mosquito bites and the occurrence of related illnesses. The use of the model further increases the awareness of the ownership of insecticide-treated net (ITN) as shown in Figure 9.

In addition, it was found from the participatory survey that the persuasive technology model increases the knowledge of the sample areas on the danger of malaria and its deadly nature as depicted in Figure 10. Hence, 84.2% of the participants now see malaria as a deadly disease and take precautions to minimize exposure as against 78.6% recorded during baseline evaluation. This is an increase of 5.6% (approximately five) participants that adhered to the use of prevention mechanism recommended using persuasive technology. There was a further increase in the number of people that net-proofed their windows during the evaluation. Here, 97.4% net-proofed their doors and windows against 87.5% recorded during the baseline as shown in Figure 11.

During the evaluation, various malaria control behaviors and intervention strategies were adopted. Among the malaria control behaviors modeled in the intervention system included the use of insecticide spray, sleeping under the ITN, net-proofing of doors and windows, closing doors and windows on time, and keeping the environment clean (see the questionnaire, https://asr.nsps.org.ng/files/supplementary/130.pdf). Sleeping under the ITN was mostly influenced with 86.8% followed by keeping the environment clean. Some of these parameters are recorded in Table 2. For each parameters, total of 98 participants completed the questions. While 22 participants data were excluded due to incomplete information, and 79 participants data were evaluated.

4.3. Discussions

A component of our baseline survey was used to identify the factors that discourage individuals from engaging in malaria prevention activities. Factors such as laziness, forgetfulness, loss of interest, etc. were discovered. Due to these constraints, many people found it challenging to adopt free government-provided interventions including insecticide-treated nets (ITN), chemoprevention techniques like burning mosquito coils, and environmental cleanliness. The summary results obtained on the use of the items mentioned above in our baseline study were discussed in the result section.

During our evaluation study, we assessed people's compliance with characteristics such as ITN ownership and use, chemical spray use, and environmental cleanliness. There was an increase in utilization, particularly in the ownership and use of ITN. This is shown in Figure 9 of the evaluation section's results. The idea is that using mobile phone interventions can encourage people to follow malaria prevention and control strategies. Therefore, the first quantifiable result aimed to show that a technology-based intervention approach can boost people's adherence to effective malaria preventative measures like (consistently sleeping under ITN, maintaining a clean environment, and utilizing chemical repellents like Sheltox). We included a portion of our baseline research to determine participant motivation/action triggers. In this section, we attempted to figure out what motivates people to do things even when they do not originally have the desire to do so. People's motivation triggers included quarrels, scolding, petting, praise, rewards/gifts, and watching a friend act (social learning). The results obtained on these triggers can be seen in Figure 3 of the baseline result section.

Table 2. Summary of result.

Participants Information	Parameters	No of Baseline	Total	No of participants evaluated	Total
Pregnancy status	Pregnant	41	97	34	71
	Not pregnant	56		37	
Age	18-29	40	98	30	76
	30-40	51		38	
	Above 40	7		8	
Marital status	Married	80	98	56	76
	Single	18		20	
Married with children	Yes	67	94	58	76
	No	27		18	
Highest level of education	Primary	0	96	2	76
	Secondary	24		27	
	Tertiary	72		47	
Ownership of ITN	Yes	53	98	66	76
	No	45		10	
Rate of Malaria sickness	Rarely	38	96	32	76
	Occasionally	49		36	
	Always	9		8	
Do you see malaria as dangerous?	Yes	77	98	64	76
	No	21		12	

Secondly, we used these action triggers in our persuasion strategies while sending reminders to our participants as depicted in Figure 8. The reminders were tailored to fit within these motivating factors. These reminders were set to be delivered at a time that was convenient for the participants to check their phones. This resulted in a high level of adherence to the reminders. This was reflected in the number of people who were ill with malaria as a result of mosquito bites and their degree of awareness about mosquito management. Thus, our second measurable aim which was to determine whether the use of technology could reduce the number of times people became ill of malaria was achieved.

Additionally, a few questions from our baseline study survey were used to find out how many participants have a mobile phone, what kind of phone it is, what functions they can perform with it, how often it is up and running and offline, how much time they spend using it, and when they are most available to use it. These were done to ensure the participants' full engagement and compliance. The results of these evaluations were used to model the intervention system.

We attempted to determine whether the intervention system had any effect on participant behaviors concerning their perception of malaria through the assessment survey questionnaire. For instance, 20% of participants in the baseline research thought malaria was a common illness and couldn't damage expectant moms or their unborn children. We, therefore, made an effort to verify this perception in the evaluation survey. The proposed intervention system, MPCSS, has impacted this unfavorable attitude of the people, according to the results of the evaluation study, which are shown in Figure 10. The same thing was also done to ascertain the number of them who have net-proofed their doors and windows (see Figure 11).

This alluded to the measurable outcome that sought to prove that there exists a strong relationship between mobile phone-based intervention systems and malaria prevention and control measures.

5. Conclusion

This study set out to develop a persuasive technology-based intervention system for malaria control and prevention. To achieve the stated aim, a baseline study was carried out to ascertain the reason behind the high prevalence of malaria in Nigeria, existing solutions, and people's perceptions about them. The baseline study was carried out using the selected participants recruited for the study. The recruitment was done under convenient sampling techniques since the study was long-term research. The research design was accomplished using a user-centered design approach where our selected participants were in-depth trained for the study. The survey questionnaire was administered to the participants both offline and online while their responses were analyzed. The outcome of their responses animated our system design and implementation.

Additionally, this study primarily focused on pregnant women and mothers of young children under the age of five. This group of persons is chosen because they are the most vulnerable. We do, however, believe that the study's potential for sampling error does not compromise the validity of the findings.

Although this study is limited to pregnant women and within 5 years, the findings may be useful in evaluating other categories of audiences. Future researchers may also adopt other techniques like focus group discussion, interview methods, and quantitative content analysis techniques.

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