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Development and Heuristic-based Usability Evaluation of an E-partograph

Tegegn Kebebaw, Esubalew Alemneh, Muluken Azage, Eyaya Misgan, Dabere Nigatu and Enyew Abat

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Authors list. Affiliation list

***Abstract* - Globally, high number of mothers and infants die every year during childbirth. To reduce this problem WHO recommends use of partograph to monitor the progression of labor. However, the conventional paper-based partograph is usually improperly used or is not used at all. Filling paper partograph and drawing graphs based on measured parameters takes time and it is tiresome and complex. Automating partograph enhances partograph utilization and reduces adverse maternal and fetal outcomes. In this paper, we present the development and usability evaluations made to an electronic partograph (e-partograph). The usability evaluation was done to identify usability problems on the e-partograph and take remedies before putting it in operation. Four usability experts have involved in evaluating the application in each of the three devices (smartphones, tabulates, & desktops) used for testing the application. Most of the usability problems were detected by experts who had used small sized devices. In order to give more attentions on the most serious problems we had conducted severity analysis. The analysis shows that the majority of the usability problems (82.8%) that were detected by smartphone users are ranked minor problems. Because of the size of the screens usability discomforts must have been categorized as usability problems.**

Keywords: Requirement elicitation, responsive design, partograph, Heuristic evaluation, usability problems.

1 INTRODUCTION

Annual maternal and fetal deaths are very high worldwide. According to the WHO, 295,000 mothers died in 2017 [1] and 29 infant deaths per 1000 occurred globally in 2018 due to obstructed and prolonged labour [2]. Even though much progress in maternal and child survival has been made over the past two decades, Sub-Saharan Africa remains the region with the highest maternal mortality and under-five mortality rate [3]. Likewise, the high maternal and neonatal mortalities are persisting problems in Ethiopia [4]. Maternal, perinatal, and neonatal mortality reduction efforts are connected with availability of antenatal care (ANC), skilled childbirth care, and postnatal care (PNC) and new born care packages across life-cycle [5]. Hence, many maternal and fetal mortality can be avoided by complete ANC visit, timely identification and management of labour abnormalities and postnatal care.

In light of this, WHO recommends use of partograph which is a single page paper used to monitor progress of labour. The tool is used to present fetal and maternal welfare graphically and it has proven records in helping to identify obstetric and fetal complications timely [6]. However, utilization of partograph is low in developing countries. It is not initiated at all or at the right time for majority of the labours and those initiated partographs are incomplete, prone to error, and leads to delayed decision [6, 7]. The reasons for poor partograph utilization include lack of pre-printed partograph, workload pressure, insufficient knowledge and unfavorable attitude towards partograph. The other reason for low usage of partograph is complexity and tiresomeness of manually filling out and interpreting partograph [6]. Though WHO comes with different versions of partograph (simple, moderate and detailed) the problem still remains apparent.

Automating partograph has proved evidences in enhancing partograph utilization and in reducing adverse maternal and fetal outcomes [7, 8]. A digital partograph boosts partograph utilization as automation usually increase efficiency and usability, and decrease making error and usage reluctancy by enforcement. Hence, electronic partograph (e-partograph) has to be developed to address paper-based partograph usage challenges and to realize the advantages of digitized partograph.

Development of an e-partograph doesn't suffice for successful utilization of partographs. The tool shall be easy to use by health care providers and it has to be screen compatible with most commonly used devices. Ease of use in this regard describes how easily can a user utilize the application. It is one aspect of a broader term of usability. Usability is a key issue in Human Compute Interaction (HCI) and it measures the quality of a user interface. It is critical in e-health systems where the care providers' ICT skills vary. According to [9] ICT skills and knowledge are one of the factors that hampers the applications of e-health systems. Poor design of e-partograph and size of devices the application is accessed exasperates usability problems.

This paper presents the development of a web-based e-partograph application and heuristic-based usability evaluation made by usability expert. Though there are many digital partographs, none of them are available in the market for free. The application is designed to provide real-time decision support, to improve data entry, and to increase access to information for appropriate decision. The tool is evaluated by experienced usability professionals. The objectives of the usability evaluation are to identify usability problems on e-partograph and take remedies before putting it in operation in real environment, and to compare usability of the application on smartphone, tablet and laptop in order to tweak the application so that its usability on small-size devices ensured. We also aim to compare the severity of the usability problems detected in the devices.

The remaining sections of the paper are organized as follows. In Section 2 we describe related works. The development of the e-partograph is explained in section 3. Section 4 and 5 are dedicated to heuristics evaluation and discussions of the results, respectively. Finally, conclusion drawn and future works are stated, in Section 6.

2 Literature Review

The proper use of the cost-effective paper partograph ameliorates maternal and perinatal morbidity and mortality. It enables to predict deviation of labour progress from normal one at early times and hence helps care providers make decisions before it is too late to act on life threatening complications. However, paper-based partograph is usually inadequately and incorrectly applied. That is, it is not utilized in according to recommended standard of WHO, it is usually filled retrospectively with false data for just record keeping purposes [6], or there is a lack of support from a system [8]. Use of emerging technologies with clinical prompts and remote decision support tool to support electronic recording and provision of appropriate care packages can alleviate the barriers of paper based partograph use [10]. HealthCare practice supported by electronic processes and communication (termed as e-health) has a lot of promises in health sector including efficiency, enhancing quality, empowerment, etc. E-partograph is a childbirth care e-health tool.

Evaluative studies done in resource-constrained settings (in Tanzania and Zanzibar) revealed that the e-partograph tool are feasible and acceptable for skilled birth attendants to support labor management and care [11]. The birth attendants felt the digital partograph improved timeliness of care and supported decision-making. A study in Kenya also reported the effectiveness of the electronic partograph use to improve fetal outcomes and increased use of interventions to maintain normal labor than the paper partograph [8]. According [12], up to 46% obstetric care providers are willing to use mobile-phone for e-partograph in Ethiopia.

Currently, there are enabling factors for developing and applying e-partograph. Number of electronic device users and computer literacy has increased. Moreover, there are also supports and encouragement from governments to exploit the technological progress in health sectors. Hence, the digital partograph should be designed in a such a way that it is easy to use and is accessible in variety of devices. That is the tool should have a decent usability which allows care providers with low Information Technology (IT) skills use it without difficulty.

ISO 9241-11 defines usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. It is imperative to conduct usability testing for application that runs on devices of varied screen sizes [13, 14]. Even though small sized devices have obvious advantages of portability, their size leads to poor usability and efficiency. Applications that run on top of these devices should be tested for their usability and fine-tuned according to the usability problems detected in the evaluation.

We have applied responsive design and a software development methodology that helps to create friendly way of communication between developers and domain experts to extract requirements efficiently. We have applied heuristic based usability testing to evaluate the e-partograph and analyzed the severity of the usability problems detected.

3 Development of E-Partograph

In this section we describe the software development methodology followed to develop the electronic partograph. Fig. 1, shows a snapshoot (from a desktop of the interface that an administrator uses to monitor the partograph uses progresses.

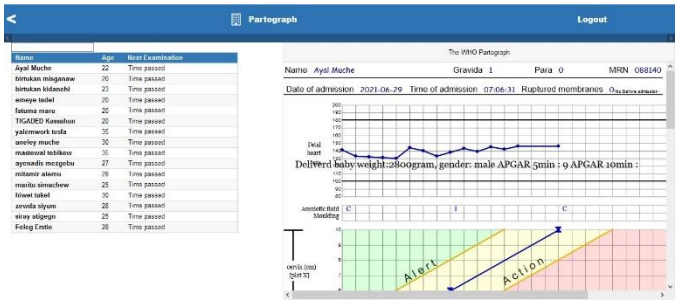


Fig. 1. A snapshot of admin page interface of the partograph progress control

3.1. Requirement Elicitation and Analysis

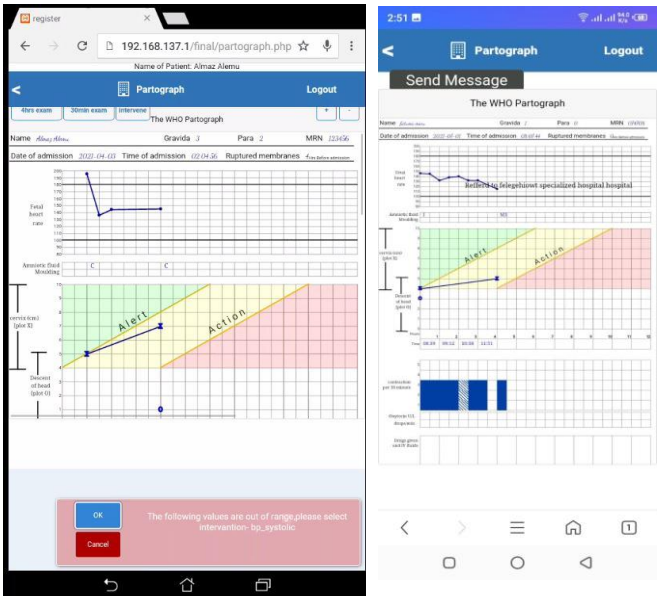
A software development methodology named Enhanced Facilitated Application Specification Techniques (eFAST) [15] has been used to develop the e-Partograph. eFAST is an extension of the traditional Facilitated Application Specification Techniques (FAST). It enables very close and well-disposed way of interaction among teams of clients and developers to find majority of the requirements at the early phase of development more efficiently. The main activities of eFAST are assessment of product needs and justifications, discussion and refinement of pre-defined lists and combining them, preparing detail specifications of each list entry and getting it reviewed by all members of the team and setting of validation criteria. Detail flow of events in eFAST can be viewed from [15].

One of the authors of the paper is selected to facilitate the process. The selecteeh as experience in using partograph and managing meetings, and he is leader of the experts of the health domain who involved in this research. The activities are executed in iteration and domain experts are involved extensively throughout the development process. At the end of each iteration overall draft requirements are written and reviewed. Documents like Intrapartum Care Guidelines [16] of WHO and Ethiopian Emergency Obstetric and Newborn Care (EmONC) Assessment 2016 Final Report [17] are referred to find the requirements. The last set of requirements are used to apply to design and implement the application.

3.2. Responsive Web Design (RWD)

Plethora of electronic devices are owned by individuals and institutions. E-partographs can be accessed by desktops, laptops, tablets, smartphones or others devices. The type of application developed for each device groups have unique features. For instance, tablets and mobile devices, native mobile applications best fit as they help to leverage device features and hardware, have best performance, and are more interactive and intuitive [18, 19]. However, we shouldn’t develop unique application for each gadget in the market. So, we have to develop application that dynamically adapts to different screen resolutions, screen or window sizes, orientations and proportions. We have used responsive design paradigms [20] to develop the web application that can run on multiple devices (desktops, tablets, and phones). Web applications are accessed via the internet from

the server they reside and the applications are developed as collection of web pages using HTML and CSS, with the backend part implemented using scripting languages like PhP, Java, javascript, etc. In RWD the HTML and CSS tags used automatically resize (shrink or enlarge), shuffle or hide graphical user interface (GUI) elements to make its appearance normal and appealing on all devices. The illustration of the responsive design of the e-partograph on a tablet, and a smartphone is shown on Figure 2.



a) b)

Fig. 2. Partograph progress controls on a) Tablet and b) smartphone

4 Heuristic Evaluation

Usability of web-based applications can be evaluated using automated tools, using heuristics, or by end user. In this paper, we present the heuristic-based evaluation conducted to evaluate the e-partograph. Heuristic evaluation is a process where usability experts use rules of thumb to gauge the usability of user interfaces in independent walkthroughs and report issues. The rules of thump which are also called heuristics are usually customizations of well-known usability evaluations heuristics like Nielsen and Molich's rules as they are broad rules. Heuristic based usability evaluation methods (UEM) are easy and quick to conduct methods with minimum cost [21]. In light of this, they are the most widely used UEM and they have proven records in detecting usability problems that has to be fixed to improve user interface [22]. In subsequent subsection we describe evaluation heuristics, tasks used for evaluation, selection of evaluators, briefing of evaluators, severity analysis and the evaluation process.

4.1. Evaluation Heuristics

Heuristics are criteria experts have used to conduct the evaluation. We have established 11 heuristics guidelines which consists of 81 heuristic checklists for this research, Table 1. The heuristic guidelines and checklists are adopted from well-known usability principles of Nelson's rules [23] for eHealth applications [24] and mHealth applications [25].

TABLE 1: USABILITY EVALUATION CHECKLIST

No	Usability Attribute	#Checklist
1	Visibility of System Status	8
2	Match between System and the Real World	8
3	User control and freedom	8
4	Consistency and Standards	12
5	Error Prevention	6
6	Recognition rather than Recall	10
7	Flexibility and Efficiency of use	5
8	Aesthetic and Minimalist Design	8
9	Help and Documentation	5
10	Help Recognize, Diagnose & Recover from Errors	10
11	Privacy	2

4.2. Tasks for Heuristic Evaluators

We have defined 12 tasks that are accessed using two roles (Recorder and Care Provider), Table 2. The tasks describe the defining characteristics of the e-partograph and they cover about 90%of the interface of application. The remaining interfaces are not included in the evaluation as they are used by system administrators who are IT experts.

TABLE 2: TASKS FOR USABILITY EVALUATION

Task ID	**Task**	**Role**
T1	Register a patient	Recorder
T2	Edit/Delete Patient information	Recorder
T3	Assign/Revoke Care Provider for patients	Recorder
T4	View Assigned Patients	Care provider
T5	Initialize Partograph for a patient	Care provider
T6	Record first time Patient Examination data	Care provider
T7	Distinguish delivery care type: basic care and special care	Care provider
T8	Select Intervention to be undertaken	Care provider
T9	View recorded patient information pictorially as partograph table	Care provider
T10	Record 30-minute Examination data	Care provider
T11	View information of mothers who have already delivered	Care provider

4.3. Selection of Evaluator

Participants of the evaluation included both usability experts and domain experts who are classified as 'double experts' as they have experience in evaluating usability of software applications and are actually using paper-based partograph. Four evaluators are selected to evaluate the system in each device. One of the experts in each group is from medical staff while three are usability experts who have 2 to 10 years of experience in mobile and desktop applications user interface development and evaluation, Table 3. Most of the usability experts are currently engaged in software development and except one all of them have minimum qualification of MSc. There is a debate on number of participants for heuristic-based evaluation. According to [26] 4 to 5 participants are sufficient to detect 80% of the usability problems and adding more participants detects fewer unknown problems. The optimal number of participants

based on a cost-benefit analysis proposed in [27] is 3 to 4. One of the researches that has studied usability testing of eHealth applications [28] has found that the average number of participants for heuristic-based evaluation is 3.67.

Evaluators have shown their consent to participate in evaluation after they are briefed the purpose of the evaluation. Their anonymity is kept secret. As a token of appreciation for their time for involving in the usability evaluation, the participants were given ETB 500. The incentives were offered upfront prior to the testing to avoid undue influence [29].

TABLE 3: PARTICIPANTS OF THE EVALUATION

User ID	Device	Experience (Years)	User ID	Device	Experience (Years)
1	Mobile	2	7	Laptop	6
2	Laptop	8	8	Tablet	8
3	Tablet	2	9	Tablet	4
4	Mobile	10	10	Laptop	5
5	Mobile	8	11	Laptop	2
6	Mobile	10	12	Tablet	4

4.4. Briefing the Evaluator

As suggested in [27], before the commencement of testing the e-partograph the participants were briefed. The purpose of the briefing is to help the participants know exactly what they are meant to do and cover during their evaluation. The briefing had two sections: introducing what partograph is and usability testing process. The former briefing was given by senior medical staff who have involved in development of the tool. In the later one the evaluation checklist and the tasks they are going to perform are explained. The briefing session is given to all participants of the evaluation regardless of the device they work on.

4.5. Evaluation Process

In the evaluation process usability experts reviewed the interface of the application and compared it against the evaluation heuristics discussed in section 4.1. They are also told to jot down problems that could not be attributed to any of the evaluation criteria. To make the evaluation independent and unbiased, the evaluation is done alone individually and no communication among evaluator were permitted during evaluation. The participants were given 2 hours for evaluation and they took 54 minutes to 2 hours to complete the evaluation. Authors of this papers observe the evaluation and assisted the users in operating the interface. The evaluators recorded their evaluation and this results in list of potential usability issues.

4.6. Severity Analysis

Severity analysis helps to give attention and allocate resources required to fix the most serious problems without spending time in solving cosmetic problems. Severity analyses also helps to decide whether to release a system or not. After getting usability problems from all testers, we integrated them (after ignoring false positives) to a single list. Then we dispatched the problems to all testers to rank the severity of the problems. The participants are told to rank the severity of the usability problems based on Nielsen's severity rating scale (0 to 4) [30] where 0 means not a usability problem at all, 1 is only cosmetic problem, 2 is minor usability problem, 3 is major usability problem and 4 is usability catastrophe. All 12 evaluators sent back the rated usability problems. Even though the reliability of severity rating estimates is questionable, it is found that as the number of evaluators/raters increase the reliability analysis increases to extent that it is satisfactory for most applications [30].

5 EVALUATION RESULTS AND DISCUSSIONS

In this section we describe the overall usability evaluation result and result of severity analysis.

5.1. Usability Evaluation

Total number of unique problems identified by the evaluators is 33. Most usability problems are detected by users of the three devices while some are uniquely identified in each device. Table 4 shows the total number of errors identified using each evaluation criteria in each of the devices used for evaluation. Majority of the problems, nearly 93.9%, were detected by testers who have evaluated usability of the application on the smartphone. Evaluators who have used tablets and laptops have discovered 75.8% and 60.6% errors respectively. The result is attributed to the difficulty of using small screen devices which compacts user interface controls. Small screens not only negatively influence the usability performance but also, they expose more usability problems despite their proven portability advantages [13, 31].

TABLE 4: USABILITY PROBLEMS DETECTED CORRESPONDING TO THE HEURISTICS USED

No	Usability Attribute	No of problems	Number of problems detected in		
			Smart phone	Tablet	Laptop
1	Visibility of System Status	4	3	3	1
2	Match between System and the Real World	1	1	1	0
3	User control and freedom	1	1	1	1
4	Consistency and Standards	2	2	2	2
5	Error Prevention	3	3	3	3
6	Recognition rather than Recall	3	3	2	2
7	Flexibility and Efficiency of use	2	2	1	2
8	Aesthetic and Minimalist Design	2	2	2	2
9	Help and Documentation	2	2	2	2
10	Help Recognize, Diagnose & Recover from Errors	5	5	3	2
11	Privacy	1	1	1	1
12	Others	7	6	4	2
	Total	33	31	25	20

The data on the table indicates that more has to be done to help users recognize errors and the application prevent errors and recover from errors. Moreover, we have noted that more

work has to be done to enable the system convey its state to users, to increase aesthetics of the application and to include help and documentation facilities. The 10 most frequent errors are shown below on the table 5

TABLE 5: THE 10 MOST FREQUENT ERRORS

Usability Problems	Frequency
Doesn't display a message before taking irreversible actions	11
Some windows do not have title	10
Current status of icons not clearly indicate	9
Page length not controlled	8
Protected or confidential areas can be accessed with certain passwords.	8
Some operator actions do not have system feedback	7
Some error messages hide the field in error	6
Fields in data entry screen and dialogue boxes doesn't contain default values	6
Related and interdependent fields do not appear on the same screen	5
Prompts are not expressed in the affirmative, and do not use the active voice	5

Seven usability problems couldn't be attributed to any of evaluation attributes by are found. This set of problem includes spelling errors, too much free space, no alarm for very high measurement values like temperature, redundant password request and session not managed.

5.2. Severity Analysis

The majority of usability problems (82.8%) that are detected by smartphone users are ranked minor problems. The size of the screen must have played a role to make usability discomforts (that could have been mitigated in larger problems) appear as problems. Larger percentage of usability problems (36.7%) detected in laptops are major problems. From this we can conclude that usability errors detected in using larger screens are real problems by many observations.

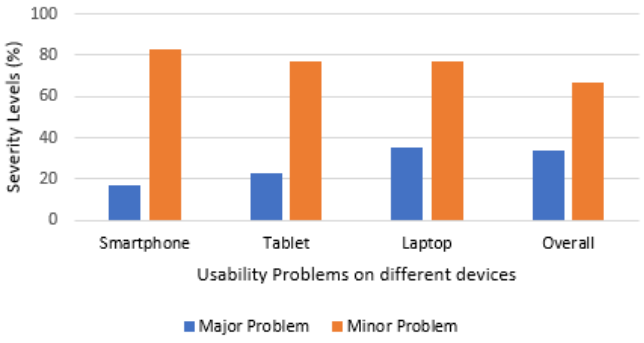


Fig. 3. Severity of the Usability Problems

The top five sever usability problems are shown on Table 6. The inability of the system to give alarms for exceptional reading is ranked first. Domain experts failed to inform the implicit knowledge explicitly as they might have thought that this can't be missed by anybody as it determines life and death of a woman. The other observation tells us that there is no direct correlation between frequency and severity of the problem confirming with other studies [32]. Many of the usability problems which are redundantly detected by evaluators are not among the top usability problems.

TABLE 6: THE TOP FIVE SEVERE USABILITY PROBLEMS

Usability Problem	Average Severity value
No alarms for very high values like temperature	3.6
Invalid field values are not controlled	3.5
Doesn't display a message before taking irreversible actions	3.3
Protected or confidential areas can be accessed with certain passwords.	3.0
Doesn't inform users where they are and how to undo their navigation	2.8

6 CONCLUSION

Extensive application of ICT benefits health sectors in general and continuum of care i.e., the maternal, newborn, and child health in particular significantly. Hence, we have developed an electronic partograph that alleviate some of the challenges of paper-based partograph. The tool helps health care givers to get early warning and to assist them in early decision of transfer/refer, augmentation and termination of labour. The tool is developed with an assumption that it can be utilized in different devices. To detect and correct usability errors we have made usability testing. Those who have used small-sized screens have found majority of the errors. In order to give more attention to disastrous problems severity analysis has been conducted. Errors which are found on devices with larger screens are found to be more severe ones.

We are amending the tool based on the usability problems detected. Moreover, as a future work we plan to conduct further usability tests particularly user testing to identify more usability errors and to sharpen the tool. Usability heuristics cannot detect all usability problems. It has to be accompanied by user testing as studies has shown that the two user interface evaluation techniques (heuristic-based and user testing) recognize unique set of problems. Furthermore, we have a plan to apply the tool on real environment and test the feasibility and acceptability of the tool.

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