



Combining multivariate statistics and the think-aloud protocol to assess Human-Computer Interaction barriers in symptom checkers



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ARTICLE INFO

Article history:

Received 29 January 2017

Revised 28 August 2017

Accepted 4 September 2017

Available online 9 September 2017

Keywords:

Human Computer Interaction

Usability testing

Clinical Decision Support Systems

Symptom checkers

ABSTRACT

Symptom checkers are software tools that allow users to submit a set of symptoms and receive advice related to them in the form of a diagnosis list, health information or triage. The heterogeneity of their potential users and the number of different components in their user interfaces can make testing with end-users unaffordable. We designed and executed a two-phase method to test the respiratory diseases module of the symptom checker Erdusyk. Phase I consisted of an online test with a large sample of users ($n = 53$). In Phase I, users evaluated the system remotely and completed a questionnaire based on the Technology Acceptance Model. Principal Component Analysis was used to correlate each section of the interface with the questionnaire responses, thus identifying which areas of the user interface presented significant contributions to the technology acceptance. In the second phase, the think-aloud procedure was executed with a small number of samples ($n = 15$), focusing on the areas with significant contributions to analyze the reasons for such contributions. Our method was used effectively to optimize the testing of symptom checker user interfaces. The method allowed kept the cost of testing at reasonable levels by restricting the use of the think-aloud procedure while still assuring a high amount of coverage. The main barriers detected in Erdusyk were related to problems understanding time repetition patterns, the selection of levels in scales to record intensities, navigation, the quantification of some symptom attributes, and the characteristics of the symptoms.

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1. Introduction

Consumer-oriented Clinical Decision Support Systems (CDSSs) are software systems that aim to help information consumers making informed decisions about their health [1]. With shared decision making on the agendas of many health organizations [2–4] and an increasing number of patients who are willing to be involved in their own health decisions [5], consumer-oriented CDSSs can be an effective tool to enable patient empowerment, thus allowing patients to become active participants in decisions about their healthcare and, at the same time, allowing them to make sensible use of healthcare resources. Among the different types of existing

consumer-oriented CDSSs [1], symptom checkers allow patients to register a set of symptoms and receive a list of possible diagnoses or advice about what actions might be appropriate to perform (self-triage) [6]. The first symptom checkers were static websites or CD-based applications [7], and they were not widely deployed by health trusts. However, with an increasing pressure on primary care, and studies showing that up to 50% of the visits to a general practitioner's (GP) office were unnecessary [8,9] and up to 70% were minor health incidents [10], consumer CDSSs, and particularly symptom checkers, have caught the attention of health organizations. Nowadays, several health organizations have started using symptom checkers to develop broad diagnostic and self-triage systems to guide each patient to the most appropriate action [11–16]. For example, the symptom checkers offered by the Mayo Clinic [14] and WebMD [16] provide information about the possible diseases linked to the symptoms reported by the

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patient. The British NHS Direct provides a more self-triage oriented service that combines a web application for patients to report symptoms with a call center where nurses provide advice. The appropriate use of symptom checkers can have a significant impact both on patient health and health organizations [6]. Regarding patient health, a symptom checker can help patients to perform self-care, avoiding unnecessary medical attention [8] (e.g. visits can be managed by consulting with a pharmacist) [8], or it can help them to access and process health information rather than search Google, thus avoiding the problems involved in consulting raw information with different quality and technical levels [15,19]. Regarding health organizations, symptom checkers relieve the pressure of unnecessary visits by guiding patients to the appropriate health circuit. For example, in 2011, NHS Direct avoided 1.5 million unnecessary surgery appointments and 0.7 million emergency calls [15,19]. Although more evaluations are needed, recent studies have indicated that investments in web-based symptom checkers already have good outcomes for emergency cases but need improvement in non-emergency and self-care cases [6,20]. This is interesting, since the investment needed to develop them is moderate compared to other health interventions. For example, Elliot et al. reported that the accuracy of web-based symptom checkers and telephone triage lines are comparable [21].

However, when direct human support is not provided by these systems, the appropriate communication of health information by the user is paramount, so the system provides appropriate guidance. This involves a challenge in the design of inquiry methods and user interfaces for symptom checkers since health information usually contains clinical terms, quantitative measures and time patterns [22] that users need to understand to provide accurate communication about their health conditions. In fact, little is known about how patients understand health information [1] or how patients perceive their conditions in contrast to how health professionals characterize and see them [3]. Therefore, assumptions about general user interface design cannot be readily applied and metrics for symptom recording Graphical User Interfaces (GUI) still need to be established. This makes the design and evaluation of each symptom checker's user interface a unique process. That evaluation needs to effectively assess how successful the system is in communicating the clinical concepts that patients must understand to accurately communicate their health information. In fact, there may be many differences among users and many may have problems interpreting their health information considering that only 30–60% of citizens are health literate [23]. How successful that communication is will be the main factor influencing how accurate the system is in providing advice to the patient. Otherwise, even with advanced recommendation algorithms, if poor quality information is provided, the system will end up in a "garbage in, garbage out" situation. In such cases, a consumer CDSS may mislead the user rather than provide support for health related decision-making, driving some of them to increase unnecessary GP visits, or worse, advise others to perform self-care when they may be suffering a life-threatening condition. Therefore, besides measuring design usability flaws, techniques to evaluate Human Computer Interaction (HCI) between users and CDSSs are needed to determine if a cognitive gap exists between the clinical concepts that the GUI exposes and the user's interpretation of the information requested. Only when that gap is minimized will it be effective and safe to deliver a symptom checker.

2. Background

2.1. Context: The symptom checker Erdusyk

Nowadays, most symptom checkers are in their first generation, meaning that they use an algorithm to diagnose or perform triage,

but they still do not use information from external services (such as epidemiological ones) to improve their accuracy [6]. In North Norway, the symptom checker Erdusyk (in English, Are You Ill?) has been running since 2012 [24]. Erdusyk has evolved from this first generation of symptom checkers by introducing algorithms that leverage data provided by the patient (symptoms, demographics, etc.) and data from the incidence of gastrointestinal and respiratory infectious diseases datasets extracted from regional laboratory information systems [25]. By combining both, the system provides users with a list of the probabilities of the diseases that may be affecting them. This way they can access quality information to decide whether it is appropriate to perform self-care or that they need to visit their GP.

Recently, Norway has promoted a national initiative to evaluate openEHR and SNOMED-CT to enable the interoperability of clinical data across electronic health records [26,27,27–29]. As a consequence, the next version of Erdusyk should use Clinical Information Models (CIMs) to structure the information recorded by the patient [30] defined as openEHR archetypes. In addition, the system uses SNOMED-CT as clinical terminology [31].

To adapt Erdusyk to the new national scene and develop it into a second-generation symptom checker that can represent information using archetypes, we have accomplished several tasks. First, we have redefined its architecture to deal with archetypes [32]; second, we have used the national knowledge management center to drive the definition of archetypes for the new Virtual Medical Record (VMR) [31]; and third, we have developed data integration strategies to enable the secondary use of data from the laboratory information system in its inference engine [33]. This study was performed when the combination of different system components was being performed; therefore the interaction with the user had to be evaluated (user-task-system evaluation) [34]. According to the classification proposed by Yen and Bakken, this situates Erdusyk in Stage 3 of the development cycle, where aspects such as perception, acceptance, accuracy, and learnability must be evaluated in a laboratory setting [34]. This evaluation is of paramount importance since it will detect if there are significant usability barriers that will prevent users from using Erdusyk appropriately to record their symptoms. Specifically, this will determine the number of features from archetypes that the user is able to submit and will therefore determine which features from archetypes can be used by the symptom checker's new algorithm. Fig. 1 illustrates the archetype and medical ontology containing the medical concepts that are requested by Erdusyk's user interface, and, on the right side, the cloud representing the cognitive process that users go through in order to understand those medical concepts.

2.2. Usability testing of CDSSs

Usability testing encompasses the evaluation of several dimensions that determine how well a software system can be understood, learned, and used and be attractive to the user [35]. The study of the cognitive process the user goes through when performing a task with the system is covered by the dimension that evaluates how well the system is understood. In symptom checkers, this concerns the identification and understanding of HCI barriers during the symptom recording process. Many techniques, including those performed by both experts and end-users, are available for usability testing in healthcare. Techniques such as cognitive task analysis, heuristic evaluation, and cognitive walk-through involve testing with expert evaluators that examine the system while it performs some tasks to unveil usability problems [36]. Other methods involve end-users to test the system and perform objective and subjective measurements while they are using the system [34]. Examples of objective measurements can be eye-tracking or the time required to finish a task; examples of

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