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Uncovering healthcare practitioners' information processing using the think-aloud method: From paper-based guideline to clinical decision support system

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ABSTRACT

Objective: To investigate whether the use of the think-aloud method with propositional analysis could be helpful in the design of a Clinical Decision Support System (CDSS) providing guideline recommendations about long-term follow-up of childhood cancer survivors.
Materials and methods: The think-aloud method was used to gain insight into healthcare professionals' information processing while reviewing a paper-based guideline. A total of 13 healthcare professionals (6 physicians and 7 physician assistants) prepared 2 fictitious patient consults using the paper-based guideline. Propositional analysis was used to analyze verbal protocols of the think-aloud sessions. A prototype CDSS was developed and a usability study was performed, again with the think-aloud method.
Results: The analysis revealed that the paper-based guideline did not support healthcare practitioners in finding patient-specific recommendations. An information processing model for retrieving recommendations was developed and used as input for the design of a CDSS prototype user interface. Usability analysis of the prototype CDSS showed that the navigational structure of the system fitted well with healthcare practitioners' daily practices.
Conclusions: The think-aloud method combined with propositional analysis of healthcare practitioners' verbal utterances while they processed a paper-based guideline was useful in the design of a usable CDSS providing patient-specific guideline recommendations.

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1. Introduction

Despite evidence that clinical guidelines can improve quality of care, they are currently still underused in practice [1–3]. One of the reasons for this is that guidelines are often communicated through a paper-based format, with limited user friendliness [4]. Clinical reasoning of healthcare professionals is rarely considered in the development of paper-based guidelines. As a result, paper-based guidelines are often insufficiently targeted at their audience, difficult to implement in clinical practice, and eventually evoke reluctance and are therefore disregarded by healthcare practitioners [5].

Computerized Clinical Decision Support Systems (CDSSs) are increasingly acknowledged for their potential to overcome problems with paper-based guidelines [6,7]. Previous research has indeed shown that CDSSs can improve guideline adherence by healthcare practitioners and support healthcare practitioners in effective and efficient medical decision making [7–9]. These potentials of CDSSs yet appear to be only partially achieved as research evidence indicates that certain CDSSs may add extra time and cognitive effort to many routine clinical tasks and healthcare practitioners often object to forced changes in their established working routines [10]. These facts raise concerns that healthcare practitioners' interactions with CDSSs may lead to decreased productivity and an increase in errors [11]. Poor design of a CDSS interface can readily

slow down healthcare practitioners as they may spend more time in searching for relevant information than in reviewing recommendations. Developing CDSS that improve healthcare practitioners' workflow efficiency is thus predicated on a detailed analysis of user requirements and iterative evaluations of CDSS prototypes.

The use of appropriate design strategies and adherence to human-computer interaction principles are critical to the success of Health Information Technology (HIT) systems [10,12]. However, there are still a large number of HIT projects that fail due to the lack of systemic consideration of human and other non-technological issues during the design and implementation process [13]. These failures can be traced back to incomplete requirements, unrealistic expectations and objectives of the system to be implemented. The difficulty to extract implicit and tacit knowledge can be seen as the major cause for incomplete requirements, as in general people lack the ability to express their actual information processing needs [14]. Furthermore, a common problem with software projects is that requirements can change as the project progresses. This may occur because as system prototypes are developed, the future end-users can more clearly see problems with the earlier defined system functionalities and propose necessary addendums and new functionalities not otherwise thought about. Also, future end-users and system engineers often fail to communicate clearly with each other. They come from different worlds and do not understand each other's work domains; the mental models of the system does not match that of its end users. This can lead to confusion and suboptimal system designs. Chances are thus high that the delivered HIT system will not meet the end users' needs.

Human factors engineering offers a broader perspective to the analysis and design of interactive computer systems as it studies phenomena that emerge when humans perform tasks in certain real work settings. It applies knowledge and techniques from cognitive psychology to the design of interactive computer applications [15]. Within healthcare, human factors engineering methods can be applied to explore healthcare practitioners' mental models while processing information and handling complex medical decisions [16]. By capturing and representing these mental models, efforts in designing interactive computer applications can be guided by mapping these models to system design models, thereby supporting the cognitive processing of information when users interact with these applications.

In the Netherlands, the Dutch Childhood Oncology Group Late Effects After Childhood Cancer Collaborative Group (DCOG LATER) developed a guideline for follow-up screening of childhood cancer survivors (CCS) [17]. The goal of the DCOG LATER guideline is to promote uniform and high-quality follow-up care. Unfortunately, about 75% of CCS are confronted with treatment-related health problems (many) years after treatment (called late effects) [18–20]. Early detection and treatment of late effects are important in order to reduce burden of disease in CCS. Therefore, there is a lifelong need for the medical surveillance of CCS.

In this paper, we argue that a method from human factors engineering, based on theories of human information processing could be used for requirements elicitation of the design of a CDSS providing patient-specific guideline recommendations. Based on previous research, there is still disagreement among experts on which methods could best be used for requirements elicitation [21]. We felt that a method from human factors engineering could help in developing a CDSS user interface based on how healthcare practitioners process the information contained in a clinical guideline. A method that is well-suited to analyze mental processes of humans is the think-aloud method. This method requires subjects to verbalize their thoughts while solving a problem or performing a task [22]. The think-aloud method thereby generates direct data on the cognitive processes that take place during human task performance and offers insight into the way that humans solve problems.

Our ultimate aim is to implement the DCOG LATER guideline in a CDSS that offers patient-specific screening recommendations to healthcare practitioners involved in CCS follow-up care. The objectives of this study were: (1) to investigate whether the use of the think-aloud method could be helpful as requirements elicitation technique for designing a CDSS, and (2) to develop a prototype CDSS based on the results of the cognitive analysis. The pivotal investigative questions in this study were: (1) What information do healthcare practitioners review and how do they process this information when they go through a paper-based guideline in preparing for a patient consult? and (2) How can these insights be used in the development of a CDSS user interface that supports efficient review of guideline recommendations in context of their use?

2. Materials and methods

2.1. Research context

As part of regular patient care, all CCS are offered regular follow-up in one of seven long-term follow up clinics, according to the DCOG LATER guideline. All clinics are part of large tertiary hospitals located within main cities in the Netherlands. During a clinic visit, CCS undergo a general medical exam and several additional screening procedures. To prepare a patient visit, historical patient data from a patient's medical record at the DCOG LATER clinic is reviewed to determine the patient-specific screening recommendations. This preparation is either done by the physician ((pediatric) oncologists or internal medicine physicians) performing the screening or by a physician assistant, with the use of the paper-based DCOG LATER guideline. The recommendations in the guideline are organized into 24 organ domains (e.g. heart or kidneys). Each domain specifies recommendations for screening procedures, points of interest for anamnesis and physical examination, advices and lists possible late effects. The recommendations apply to a CCS, when the inclusion criteria of a domain, which are based on the childhood cancer diagnosis and treatment, are met.

2.2. Study population

Six physicians and seven physician assistants participated in this study, all taking responsibility for preparing CCS patient visits. Three male and three female physicians participated, and seven female physician assistants. Their mean age was 44.9 years (range 27–56 years) with a mean of 4.8 years of experience working for the long-term follow-up clinics (range 0.5–15 years). Physicians and physician assistants were recruited through the coordinators of the DCOG LATER long-term follow-up clinics and participated on a voluntary basis. Before the start of the study, all participants signed an informed consent form.

2.3. Research design

Fig. 1 shows the research design of this study. In the first step, we used the think-aloud method in combination with propositional analysis and a semi-structured interview to analyze healthcare practitioners' information processing in the context of using the paper-based guideline. In the second step, the results were used to develop an information processing model which represents the mental model of participants' information retrieval when using the paper-based guideline. This model was then used as input to design specifications of a CDSS user interface. In the third step, the developed prototype CDSS was evaluated, first by conducting the think-aloud method again, then by administering the Questionnaire for User Interface Satisfaction (QUIS) [23], and finally by conducting a semi-structured interview. Efficacy (time