



# Multi-method laboratory user evaluation of an actionable clinical performance information system: Implications for usability and patient safety



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## ABSTRACT

**Introduction:** Electronic audit and feedback (e-A&F) systems are used worldwide for care quality improvement. They measure health professionals' performance against clinical guidelines, and some systems suggest improvement actions. However, little is known about optimal interface designs for e-A&F, in particular how to present suggested actions for improvement. We developed a novel theory-informed system for primary care (the Performance Improvement plaN Generator; PINGR) that covers the four principal interface components: clinical performance summaries; patient lists; detailed patient-level information; and suggested actions. As far as we are aware, this is the first report of an e-A&F system with all four interface components.

**Objectives:** (1) Use a combination of quantitative and qualitative methods to evaluate the usability of PINGR with target end-users; (2) refine existing design recommendations for e-A&F systems; (3) determine the implications of these recommendations for patient safety.

**Methods:** We recruited seven primary care physicians to perform seven tasks with PINGR, during which we measured on-screen behaviour and eye movements. Participants subsequently completed usability questionnaires, and were interviewed in-depth. Data were integrated to: gain a more complete understanding of usability issues; enhance and explain each other's findings; and triangulate results to increase validity.

**Results:** Participants committed a median of 10 errors (range 8–21) when using PINGR's interface, and completed a median of five out of seven tasks (range 4–7). Errors violated six usability heuristics: clear response options; perceptual grouping and data relationships; representational formats; unambiguous description; visually distinct screens for confusable items; and workflow integration. Eye movement analysis revealed the integration of components largely supported effective user workflow, although the modular design of clinical performance summaries unnecessarily increased cognitive load. Interviews and questionnaires revealed PINGR is user-friendly, and that improved information prioritisation could further promote useful user action.

**Conclusions:** Comparing our results with the wider usability literature we refine a previously published set of interface design recommendations for e-A&F. The implications for patient safety are significant regarding: user engagement; actionability; and information prioritisation. Our results also support adopting multi-method approaches in usability studies to maximise issue discovery and the credibility of findings.

## 1. Introduction

Quality measurement is central to improvement strategies [1]. It identifies where action is needed and monitors the effects of improvement efforts [1]. In health care, this measurement is usually set in the context of 'audit and feedback' (A&F) or 'clinical performance feedback', where compliance with clinical standards or patient outcomes is the common metric [2]. Clinical performance is primarily fed back as

'quality indicators', 'performance measures', or similar quantities [2]. Electronic audit and feedback (e-A&F) systems communicate this information to health professionals mostly through interactive browser-based portals or desktop applications [3]. They are in use throughout the world, described variously as dashboards, benchmarking tools, scorecards etc [3].

Core to e-A&F systems is the presentation of quality indicators, which may be supplemented by the following components: patient lists;

Abbreviations: A&F, audit and feedback; CDS, clinical decision support; e-A&F, electronic audit and feedback

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detailed patient-level information; and suggested actions [3]. Despite the potential importance of these components for actionable data interpretation [4], relatively little is known about designing usable interfaces for e-A&F to optimise user interaction and reduce errors during decision making [3]. In particular, existing evidence regarding e-A&F usability has been limited to systems without key interface components (e.g. suggested actions), and has largely ignored how interface design can affect user interaction when interpreting clinical performance data [3]. Evidence from the health informatics literature demonstrates that the design of information systems without regard for usability can increase technology-induced errors [5]. In the case of e-A&F systems such errors may have adverse consequences for patient safety by reducing the system's effectiveness to improve health care outcomes [4]. Therefore poorly designed e-A&F interfaces may result in misinterpretation or ignorance of important information, which could ultimately lead to failings in care quality and efficiency (e.g. [6]).

We have previously reported a usability inspection evaluation of an e-A&F system for primary care – the Performance Improvement plan Generator; PINGR [3]. PINGR is currently unique among published e-A&F systems in that it possesses all key interface components: clinical performance summaries (i.e. quality indicators); patient lists; detailed patient-level information; and suggested actions [3]. Its design employs existing evidence and theory regarding effective A&F, and is intended to be generic so it can host quality indicators from a range of clinical areas. Consequently, usability findings from PINGR provide valuable insights into how to best design interfaces for e-A&F systems, and the findings may generalise to other settings such as secondary care. The results of PINGR's usability inspection study enabled us to create a set of generic interface design recommendations for e-A&F systems, covering each of their interface components and how they can be integrated [3]. The study also represented the first step in an iterative approach to optimise PINGR prior to deployment in routine clinical practice [5,7].

The present study extends usability testing to target end-users (primary care clinicians) as planned in PINGR's development framework [5]. We seek to understand how the interface helps or hinders user interaction across a range of information interpretation and decision-making scenarios in clinical quality improvement. To achieve this we used a multi-method study design, collecting and analysing multiple types of qualitative and quantitative data [8]. Multi-method studies have been extensively used in both the natural and social sciences to combine different types of qualitative and quantitative data, such as self-administered questionnaires, semi-structured interviews, and ethnographic observations [9]. Common uses for integrating these different data include but are not limited to: gaining a more comprehensive account of the phenomenon of interest (*completeness*); augmenting or building on each others' results (*enhancement*); explaining findings from another dataset (*explanation*); and corroborating or disconfirming each others' findings in order to increase validity (*triangulation*) [10]. Multi-method approaches are particularly suitable for usability studies in clinical informatics given the increasing complexity of modern information systems [11]. They have been found to more comprehensively uncover usability issues [12], and address different aspects of usability through triangulation and complementarity [13], than either of their constituent methods alone. However, challenges remain with regard to how to most efficiently and effectively synthesise these different data sources [14]. Consequently, the originality of this work lies in studying not only how primary care clinicians interact with e-A&F systems, but also how laboratory-based multi-method usability evaluations may be conducted.

### 1.1. Aim and objectives

The aim was to understand, through usability testing with end-users and theory-based abstraction, how the design of clinical e-A&F interfaces could facilitate improvements in patient safety.

The objectives were to:

1. test the usability of PINGR in terms of efficiency, errors, satisfaction, and utility, using a multi-method approach, combining data from observations of on-screen and visual search behaviour during task performance, post-test user satisfaction questionnaires, and in-depth interviews;
2. use these findings to extend and refine our previous set of interface design recommendations for e-A&F systems [3] in relation to their main interface components (clinical performance summaries; patient lists; detailed patient-level information; and suggested actions), whilst comparing them to the wider usability literature; and
3. determine the implications of these interface design recommendations for patient safety by drawing on evidence regarding clinical audit and feedback implementation.

## 2. Materials and methods

### 2.1. The evaluated system: PINGR

PINGR is an e-A&F system for primary care professionals, developed by the authors (Fig. 1): a primary care physician/informatician (BB), a software engineer/informatician (RW), and a human-computer interaction expert (PB). PINGR is a web-based application that stands alone outside clinical systems. It analyses structured data extracted from electronic health records (EHRs) on a nightly basis against clinical standards and patient outcomes (e.g. from clinical guidelines).

PINGR's present interface design was informed by a usability inspection study [3], and an emerging theoretical causal model of effective audit and feedback [15,16]. The use of theory is recommended in the design of complex interventions in general [7], and of e-A&F tools specifically [17]. Our approach is informed by an ongoing systematic meta-synthesis of qualitative studies [15], and draws on: existing theories (such as Control Theory [18] and Feedback Intervention Theory [19]); intervention description frameworks (e.g. [20]); and organisational implementation models (e.g. [21]). The remainder of this section presents a detailed account of the design and rationale of PINGR's four main interface components.

#### 2.1.1. Clinical performance summaries

The PINGR interface (Fig. 1) employs the overview-preview principle to display information at different levels of detail based on Shneiderman's visual search mantra [22]. Presenting an overview of clinical performance data with details on demand was found to be an important usability feature in e-A&F systems [3]. The overview is provided as performance summaries at the level of the primary care practice/office (Fig. 1; top), where quality indicators are grouped into separate data representation modules for each clinical area. This module oriented design was employed to: enhance information processing, as is usual practice with clinical guidelines [23]; and facilitate user workflow [24]. Within each clinical area, quality indicators are further grouped into common care pathways associated with long-term care: diagnosis, monitoring and control [25], with an additional exclusions pathway to track patients excluded from the quality standards for clinical reasons (e.g. terminal illness). The purpose of the pathway groupings is to create a framework for representing a variety of clinical conditions consistently – as recommended in design best practice for EHRs [26] and clinical decision support (CDS) systems [27].

Currently, PINGR supports four clinical areas: hypertension, asthma, chronic kidney disease, and atrial fibrillation (AF). These clinical areas were chosen because they are:

1. managed mostly in primary care, making them familiar to end-users;
2. common components of multimorbidity – a major quality/safety issue in primary care [28] and core to the challenge of summarising patient information across multiple clinical areas [29], which is

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