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Optimizing Digital Health Informatics Interventions Through Unobtrusive Quantitative Process Evaluations

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Abstract. Health informatics interventions such as clinical decision support (CDS) and audit and feedback (A&F) are variably effective at improving care because the underlying mechanisms through which these interventions bring about change are poorly understood. This limits our possibilities to design better interventions. Process evaluations can be used to improve this understanding by assessing fidelity and quality of implementation, clarifying causal mechanisms, and identifying contextual factors associated with variation in outcomes. Coiera describes the intervention process as a series of stages extending from interactions to outcomes: the "information value chain". However, past process evaluations often did not assess the relationships between those stages. In this paper we argue that the chain can be measured quantitatively and unobtrusively in digital interventions thanks to the availability of electronic data that are a by-product of their use. This provides novel possibilities to study the mechanisms of informatics interventions in detail and inform essential design choices to optimize their efficacy.

Keywords. Medical Audit; Clinical Decision Support Systems; Process Evaluation

1. Introduction

Health informatics interventions such as clinical decision support (CDS) and audit and feedback (A&F) have been moderately successful at ensuring patients receive improved care, but their effectiveness is highly variable [1,2]. CDS provides clinicians with case-specific advice at the point of care (e.g., alerts; reminders) [3], whereas A&F provides population-level performance feedback on quality indicators over a period of time [2]. Reasons for their variable effectiveness are unclear because the mechanisms behind interventions' success or failure are poorly understood [1,4]. This limits our ability to design better interventions [5]. The challenge is therefore to speed up the rate

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with which we increase our understanding of the active ingredients of successful health informatics interventions.

Process evaluations can be used to improve this understanding by means of assessing fidelity and quality of implementation, clarifying causal mechanisms, and identifying contextual factors associated with variation in outcomes [6]. Most process evaluations analyse unstructured data collected through interviews, focus groups, or observations using qualitative research methods, to identify design factors (e.g., feedback frequency; timing of alerts) that are potentially important to ensure success in future interventions. However, both the gathering of these data and the qualitative analysis are often laborious and time-consuming. For instance, Hayward et al. observed a total of 112 general practitioner (GP) consultations to analyse how GPs reacted to medication alerts with multi-channel audio and video recordings [7]. Each recording was fully transcribed and subsequently coded by multiple investigators.

In this paper we argue that we can study the mechanism of digital informatics interventions quantitatively and unobtrusively by harnessing data that are routinely captured as a by-product of using the interventions in real-life. To build our argument, we start from Coiera's information value chain framework that describes informatics intervention as a series of stages extending from interactions to outcomes. Next, we consider digital interventions and explain how each stage in the information value chain can be measured. Finally, we provide a real-life example of a unobtrusive quantitative process evaluation of an electronic A&F intervention. We end with a critical appraisal of this approach and discuss the implications for future research.

2. Conceptual framework

Exploring the mechanism through which interventions bring about change is crucial to understand both how the effects of the specific intervention occurred and how these effects might be replicated by similar future interventions [8]. Coiera [9] describes this mechanism as an information value chain that connects the use of a system to health outcomes (Figure 1). The chain begins with a user interacting with a system, and some of these interactions will provide them with information. Some of this information may cause the user to change their decision, which in turn can change the process of care. Finally, only some process changes affect health outcomes. For example, suppose that a general practitioner prescribing non-selective beta blockers in a patient with asthma is alerted by a CDS system that this may cause exacerbations ("interaction"). When the general practitioner notices the alert ("information received") and decides to cancel the prescription ("decision changed") this will affect the patient's medication regimen ("care process altered") and can ultimately reduce the risk of asthma exacerbations and unscheduled hospital admissions ("outcome changed").

Coiera hypothesises that in general, the number of events decreases along the chain, but their value (or expected utility) will increase. For example, optimizing the interaction with medication alerts is of lesser value than reducing the number of unsafe medication prescriptions, which in turn is of lesser value than reducing the number of adverse outcomes. However, in order to understand whether success in one stage of the value chain will actually translate into good results at the next stage, we need to assess the relationships between events that take place at subsequent stages [9]. For instance, we would be interested in knowing how the type and number of medication alerts influence the probability that clinicians notice them; if and how the fact that they notice

them influences their decision making; how their decision making affects which medications are dispensed by pharmacists; and how many exacerbations and unscheduled hospital admissions are prevented by this.

3. Measurement framework

Most studies evaluating an informatics intervention's effectiveness report change in clinical care processes (stage 4: e.g., medication prescriptions according to guidelines) and/or outcomes (stage 5: e.g., hospital admissions). However, we argue that digital interventions provide opportunities to observe the entire information value chain rather than only its final two stages because they can log everything that happens within the system. More specifically, systems can automatically capture interactions (e.g., logins; mouse gestures; key strokes; page views) which refer to whether, which, and how users interacted with the system's components (stage 1). The systems can also log which and under what circumstances information was displayed (stage 2: e.g., content of a medication alert for specific patients), and record clinical decisions (stage 3: e.g., changes to medication prescriptions). Table 1 shows other examples of measures that can be observed in computerized CDS and A&F systems.

Hence, whereas most informatics interventions studies only investigate the relationship between intervention exposure (i.e., inviting recipients to interact with the intervention) and care processes or outcomes (stage 4 and 5), digital interventions can produce usage logs that allow us to measure the relationships between all other stages in the information value chain, often with high fidelity. Using measurements from all those stages can provide a more comprehensive picture of the intervention process to help explain the observed variability in their effectiveness. In fact, analysing the number and types of events in each stage can discover obstructions in the chain that withhold value from progressing to the subsequent stage, and reveal determinants for a successful progression.

Table 1. Examples events of which their number and type can be measured to evaluate computerized CDS and A&F interventions at different stages of the information value chain; adapted from Coiera [9].

	Interaction	**Information**	**Decision**	**Care process**	**Outcome**
CDS	Alerts generated	Alerts noticed (e.g., alerts clicked on), content of alerts (e.g., critical alerts, alerts concerning specific patient groups), alerts for which users retrieved additional details (e.g., patient details, guideline information)	Alerts dismissed (e.g., clicked on 'close' or 'dismiss'), changes to medication prescriptions or test orders, 'correct' or 'incorrect' decisions	(Unsafe) medications prescribed and dispensed, tests ordered, overtreatments	Morbidity, mortality, and unscheduled hospital admissions, levels of blood pressure, and glucose, etc.
A&F	User logins (frequency, durations)	Content of feedback reports (e.g., indicator scores, benchmark values), indicators for which users retrieved additional details (e.g., charts, definitions, patient lists)	Indicators included in action plan, actions per indicator	Indicators for which actions were completed (e.g., protocol disseminated, support staff appointed)	Performance on indicators

4. Example: quantifying the relationship between information and decisions

In Figure 1 we illustrate our argument with an example of a recent quantitative process evaluation of a computerized A&F intervention [10]. The intervention was aimed at improving the quality of cardiac rehabilitation as measured by a set of process and outcome indicators [11]. Clinical teams received electronic feedback reports every three months through a web-based system [12], on the basis of which they made decisions for quality improvement and created an action plan for change. However, a cluster-randomized trial revealed that receiving the intervention was not associated with improvements on any of the process and outcomes indicators [11]. Analysis of the value chain (Figure 1) revealed a loss of events in its subsequent stages: from the 50 feedback reports in which 614 indicators were flagged as below the benchmark, teams only targeted 379 indicators with an action – 31 of which were completed at study end.

To better understand this, we were interested to know how the information they received (stage 2) influenced quality improvement decisions that were made by the teams (stage 3). We extracted relevant information from the system's relational database and conducted multivariable regression analyses to evaluate factors associated with indicator type (process or outcome), clinical performance (indicator score; whether above or below benchmark), and iteration of the A&F cycle, while adjusting for characteristics of participating teams. Key findings were that, in general, teams more often targeted their actions plans towards indicators for which their performance was poor (odds ratio [OR], 4.2), but still half the indicators with values below the benchmark did not lead to improvement intentions; indicators were often reselected (OR, 10.2) in subsequent iterations because actions had not yet been completed; and some indicators were clearly more often targeted than others, even after adjusting for all possible confounders [10]. This evaluation therefore contributed to knowing that the observed ineffectiveness was in part because the feedback did not lead to teams focusing their quality improvement decisions on low performance areas, and that planned improvement actions were often not completed within the study period.

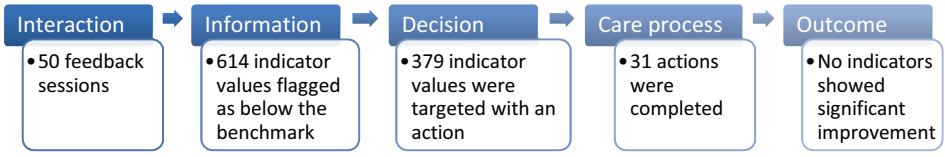

Figure 1. The informatics intervention process as an "information value chain" (from Coiera [9]); displaying the number of events in each stage for a computerized A&F intervention in cardiac rehabilitation [10]. Clinical teams received feedback multiple times on a set of eighteen quality indicators.

5. Discussion

In this paper we described the opportunities for conducting quantitative process evaluations. However, we would like to emphasize that we are not arguing that analysing the information value chain makes qualitative process evaluations obsolete. Whereas a quantitative approach will reveal that certain events occurred (e.g., users declining an alert), a qualitative approach is more suitable to explore reasons for these events occurring (e.g., the alert conflicted with patient preferences). Our vision is that quantitative evaluations may discover gaps in the intervention process which may then

be filled in by qualitative work; making them two complementary approaches to each other.

Even if few events are observed at the final stages of an intervention's value chain, the intervention may still be successful – i.e. when those events have high value [9]. A next step is therefore to calculate the events' expected utility at each stage of the chain.

6. Conclusion

The information value chain framework describes health informatics interventions processes as a series of steps extending from interactions between informatics intervention and user to care outcomes. The chain can be measured quantitatively in digital interventions thanks to the availability of electronic data that are a by-product of using the intervention. To date, this data resource is underutilised when trying to understand how informatics interventions lead to outcomes. Unobtrusive quantitative process evaluations harnessing these "free" usage data provide novel possibilities to study the mechanisms of informatics interventions in detail and optimize their efficacy.

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